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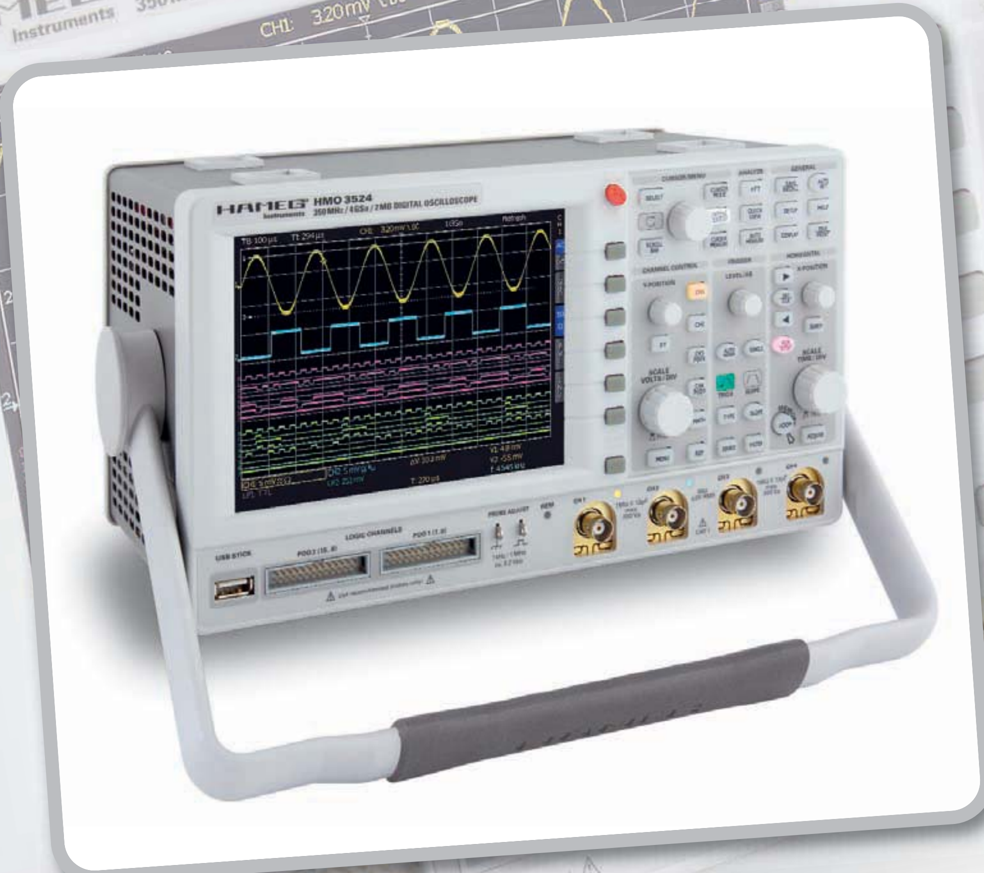


- T&M REPORT:
- EFFICIENT METHOD FOR OFFLINE ANALYSIS
- OPTICAL MEASUREMENTS
- CREATING A LOSSLESS AMP – PART 2
- HARNESSING COMPUTER VISION FOR EFFICIENT TRAFFIC CONTROL

ANALOGUE MEETS DIGITAL

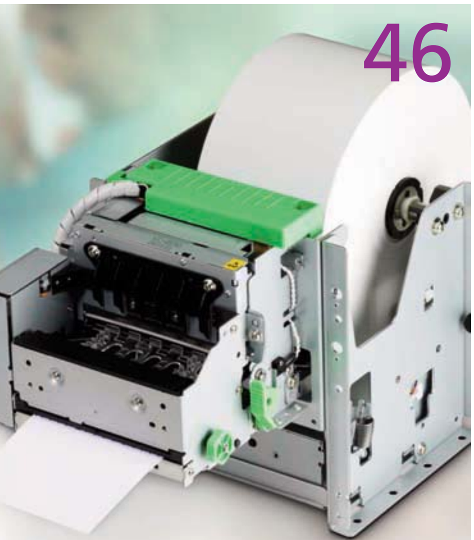
NEW HAMEG FAMILY OF 350MHZ DSO/MSO OSCILLOSCOPES

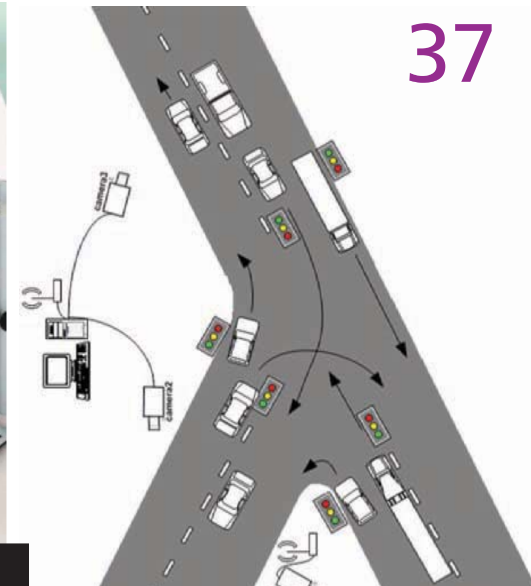
TECHNOLOGY
GERMANY COMMITS TO AN INTELLIGENT TRANSPORT NETWORK

NANO KTN
LAB-ON-A-PILL MAKES A PROMISING DEBUT

DAQ BOARD
PART 3 OF THE SPECIAL DATA ACQUISITION BOARD PROJECT

ALSO IN THIS ISSUE: THE TROUBLE WITH RF • TIPS 'N' TRICKS • PRODUCTS





REGULARS

Find about Hameg's new 350MHz DSO/MSO on **Page 10**

FEATURES

ELECTRONICS WORLD

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It's Time For Cool Heads and Firm Action

Dear Readers,

It was only a couple of issues ago when I wrote about the 2009 industry health-check. We are nearing the end of the first quarter of 2009 and do we have any greater visibility? Some would say yes, and it is not all necessarily doom and gloom for the future.

In fact, some industry analysts believe we will see the first improved conditions in the industry as soon as the second half of 2009.

It was only three or so months ago when many said that visibility was too low to state with any certainty the future of the industry over the coming year and beyond.

As we all know, many firms did batten their hatches, and either slashed their workforce or turned a five-working day into a four-working day to cut down on costs, as well as reduced production.

As Malcolm Penn, chairman and CEO of industry analyst house Future Horizons says: "It is, of course, impossible to predict when the green shoots of recovery will start to appear, but they eventually will – possibly as soon as the second half of 2009."

"We expect the first half of 2009 to be bad, down 8.7% on the second half of 2008 offset by a recovery starting Q3-09, with the full year's market down 28% on 2009. 2010 should then see a strong market rebound, driven by seasonality and the green shoots of a recovering world economy."

Penn's advice to businesses now is to focus on innovation and technology. He says: "The only way forward and out of the crisis is to get back to what the industry does best: inventing its way out of a recession and into growth. Right now the industry is flying blind in a storm, but indecisiveness is not the way forward. Technology and innovation will again drive the recovery process, and they will have to as it will be some time before banks start to lend freely again."

There's a recorded slowing trend in decline of semiconductors sales worldwide, which suggests that the market collapse triggered in the fourth quarter of 2008 may be starting to reach a bottom.

Equally, inventory levels have dropped to a low and there are some signs that forward visibility is improving there too. Japanese companies, where the recession has been lasting for over 10 years now, are also reporting low inventories, and potential production comebacks.

So, in the words of Malcolm Penn: "There will be blood on the road ahead in 2009", but the most important thing is to "keep a cool head and [prepare for a] firm action".

Editor
Svetlana Josifovska

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GERMANY'S COMMITMENT TO AN INTELLIGENT TRANSPORT NETWORK IS FURTHER CEMENTED WITH FUNDING

Germany's Ministry of Economic Affairs and Technology is confirming its commitment to the development of an intelligent transport network by funding the research initiative "*Traffic Management 2010*". The inititative consist of many projects but its ultimate focus is to promote the efficient use of the existing infrastructure, service-orientated offerings for the public transport sector and the development of affordable procedures for recording traffic flows in Germany.

One of the projects is the €18m research initiative called AKTIV (the German acronym stands for "*Adaptive and Cooperative Technologies for Intelligent Transport*"), where a comprehensive network of gantries will convey traffic messages to passing vehicles, which will be processed by an on-board driver assistance system. Each gantry will also collect data from the vehicles.

Data over short distances will be transmitted via the WLAN standard, complementing the already established communication channels such as DAB and UMTS. In the AKTIV project the information is processed by a central data-hub. The idea is to provide motorists with clear and standardized information on the gantry displays and on their sat-nav screens.

Another project goes under the acronym of COOPERS, which stands for "*Cooperative Systems for Intelligent Road Safety*". This €9m collaborative venture involves 37 companies, research establishments and universities from 15 EU countries, including the Fraunhofer Institute for Computer Architecture and Software Engineering (FIRST) in Berlin. Here too data is gathered from the road network and it will be merged with data collected from vehicles to produce a clear picture of the traffic situation. These so-called "floating car data" make it possible to introduce services that no current navigation device can offer – such as localized warnings of road works, accidents or cars driving in the wrong direction, as well as weather condition updates such as unexpected black ice.

All this requires a technological architecture that is capable of analyzing data from a range of different sources, assessing it appropriately and transmitting it over the mobile phone network – across national frontiers.

Among the other interesting projects are truck navigation software which aims to help heavy goods vehicles to combat traffic and avoid danger spots; and autonomous driving project that involves an array of 'stereo' cameras, radar sensors and GPS units to enable stress-free driving.

■ A new initiative targeting complex embedded systems and software development and funded under the European Union's 7th Framework Programme entitled INTERESTED (INTERoperable Embedded Systems Tool chain for Enhanced rapid Design, prototyping and code generation) has been announced last month.
INTERESTED aims to create the first-ever Europe-wide, integrated and open reference tool chain, covering the full spectrum of embedded systems and software development. The results should be a reference tool chain that is highly dependable, safe and efficient, while helping to reduce the cost of deployment and maintenance by 50%. Delivery of the complete, integrated reference tool chain is expected by the end of 2010.

■ Rambus, the supplier of IP in high-speed memory architectures, announced its new initiative focusing on high-bandwidth, low-power memory technologies called the Mobile Memory Initiative. The target is to achieve data rates of 4.3Gbps at best-in-class power efficiency.

"As consumer expectations grow for more media-rich applications on their mobile devices, new memory solutions will be needed to keep pace with the rapidly increasing bandwidth requirements," said Martin Scott, senior vice president of Research and Technology Development at Rambus. "With the breakthrough technologies developed through the Mobile Memory Initiative, we'll enable a broad range of advanced mobile applications that will enrich the lives of consumers worldwide."

LEDs will replace energy-efficient bulbs, thanks to a Cambridge research project

University of Cambridge researchers have developed bulbs made of cheap, white light-emitting diodes (LEDs) that produce bright light with very little electricity. The new bulbs are said to be 12 times more efficient than conventional tungsten bulbs and three times more efficient than the unpopular fluorescent low-energy versions.

The project was funded by the Engineering and Physical Sciences Research Council (EPSRC). Typically, white LEDs are made of gallium nitride and grown on sapphire wafers, a method used since the 1990s, but which adds to their manufacturing cost. However, the University of Cambridge scientists replaced the growth wafers with silicon, achieving a 50% improvement in cost and efficiency.

A GaN LED can burn for 100,000 hours and therefore, on average, only needs replacing after 60 years. Additionally, unlike currently available energy-saving bulbs, GaN LEDs do not contain mercury, eliminating the environmental problems posed by their disposal. GaN LEDs also have the advantage of turning on instantly and being dimmable.

Professor Colin Humphreys led the team that developed the low-cost white LED bulbs
[Photo credit: EPSRC]

"We are very close to achieving highly efficient, low-cost white LEDs; this could well be the holy grail in terms of providing our lighting needs for the future," said Professor Colin Humphreys, the head of the centre that helps grow the LEDs. "It is our belief they will render current energy-efficiency bulbs redundant."

RFMD has now been appointed as the manufacturer of the prototypes. The first bulbs are expected to be commercially available in two years' time.

CONVERGENCE OF THE NANOTECHNOLOGIES

BY MIKE FISHER

The Nanotechnology Knowledge Transfer Network (NanoKTN), one of the UK's primary knowledge-based networks for Micro and Nano-technologies, was set up by the Technology Strategy Board to promote and facilitate knowledge exchange, support the growth of UK capabilities, raise awareness of nanotechnology and provide thought leadership and input to the UK policy and strategy.

The NanoKTN's activities are built around focus groups which identify the gaps in the supply chain, as well as identifying the UK's potential in innovation. This information is reported back to the Technology Strategy Board to input into their UK Nanotechnology Strategy and also provides leverage for channeling government funds into specific areas of need.

For further information on the NanoKTN and its activities visit www.nanoktn.com

Lab-on-a-pill device for remote measurement of physiological conditions in the gut

[Courtesy of the Royal Society of Chemistry]

ON THE 11TH February 2009, the NanoKTN organised the Nano4Life Conference to explore the opportunities that nanotechnology holds for the life science industry. The aim was to look at current research trends and match these with the needs of industry, healthcare providers and patients.

Numerous studies have predicted that nanotechnology offers solutions to current issues in healthcare and that it is the wave of the future that will create the next opportunities for investment growth. How, when and where this will happen is, as always, difficult to foresee. The Nano4Life conference did however look at the future by examining current trajectories of research and comparing these with the drivers within industry.

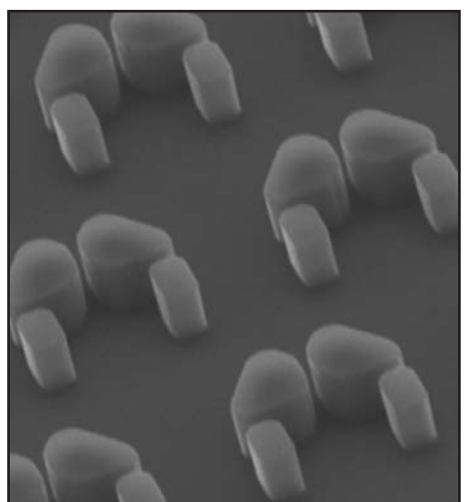
Nano4Life examined four technology areas of bionano and nanomedicine, two of which are relevant to the electronics industry: medical imaging and diagnostics.

Medical imaging systems are now being developed with extremely high resolution. These systems are being used in two ways – diagnosis of diseases such as cancer and neurological disorders and, secondly, in the drug development process. Current technologies are capable of creating images of where in the body drugs are localising. A drug may have high potency in vitro, but if it becomes localised in an area away from the disease site when placed in the body, its efficacy is dramatically diminished and side effects can occur.

Imaging systems can be used to track radioactive-labelled drugs and identify exactly where they are absorbed and distributed in real time, producing three-dimensional pictures of drug localisation in the body. This is being widely adopted in aiding early go/no-go decisions in product development.

The production of medical imaging equipment, such as Magnetic Resonance Imaging (MRI) and Positron emission tomography (PET) scanners, tends to be dominated by the larger players, such as GE Healthcare, Siemens and Philips, due to the high capital cost of these pieces of equipment.

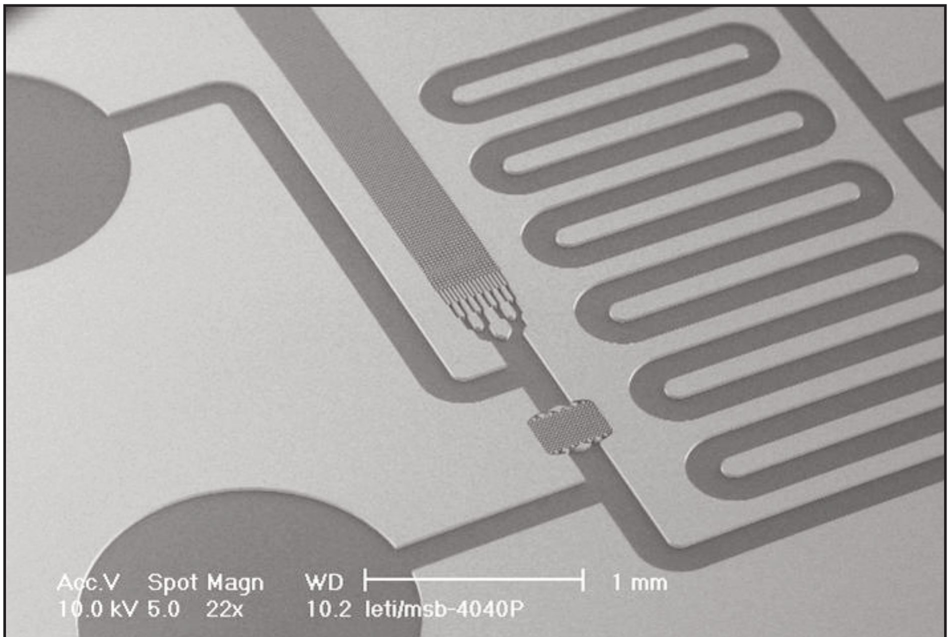
With regards to diagnostics, the drive is



Cell capture device for cell sorting

[Courtesy of Professor Jon Cooper, University of Glasgow]

AND THE LIFE SCIENCES



Microfluidics channel in silicon [Courtesy of Professor Jon Cooper, University of Glasgow]

to reduce size and cost of equipment to make sensors available at point of care. In many cases, providing a diagnosis whilst the patient is with the doctor can ensure the right treatment is received early, avoiding complications caused by delays. Micro and nano diagnostic devices can also provide closed-loop systems, which continuously monitor patients and immediately respond to changes in physiological conditions. This is particularly important in Intensive Care Units (ICU) where simple parameters such as oxygen levels, can be critical. It is also important in ensuring drug concentrations are within the therapeutic range.

There is a significant number of small companies developing these 'lab-on-a-chip' technologies, due to the amount of research funding available and the relative ease (when compared to pharmaceuticals), of regulatory approval. The issue here is that not all will, or can make it to the market, and it is envisioned that the successful products will be those that can provide an all in one solution for primary care use. This will require integration of multiple systems, or the production of a standardised platform technology that will be adopted by healthcare systems generally.

Lab-on-a-pill device
[Courtesy of Professor Jon Cooper, University of Glasgow]

A second application of diagnostics examined during Nano4Life was that of lab-on-a-pill. Similar to the lab-on-a-chip system, this device, which is still at the research stage, is designed to be swallowed and then wirelessly reports physiological conditions as it passes through the digestive tract. With this system power supply is key – the 'pill' in question must have enough power to run for 24 hours, transmit wirelessly through human tissue and also perform diagnostic tests.

The Nano4Life conference was finally summarised and assessed from the clinical perspective. Whilst all these products are obviously novel and include the latest technologies, one must not forget that there must be an unmet medical need addressed by the solution offered and also that patients, doctors and healthcare payers will want to use and purchase the product.

For example, for bespoke therapies offered by tissue engineering, the question of health technology assessment and value for money will appear – would these products be approved by the National Institute for Health and Clinical Excellence (NICE)? Companies must ensure that these stakeholders see a demand and there is a market for the product before they invest such large sums into product development.

The Nano4Life conference covered significant ground and it is hoped that many of the issues and opportunities covered in the bionano and nanomedicine area will enable companies and entrepreneurs to be successful in generating the next wave of medical products, through the use of nanotechnology.

Mike Fisher is the Theme Manager for Bionano and Nanomedicine at the NanoKTN.
The Nanotechnology Knowledge Transfer Network (NanoKTN) is one of the UK's primary knowledge-based networks for Micro and Nanotechnologies.
www.nanoktn.com

ANALOGUE MEETS DIGITAL

HAMEG Instruments introduces new family of 350MHz DSO/MSO oscilloscopes

Featuring 4 GSa/s and 2 MByte of memory per channel, the brand new HMO series of 350MHz DSOs can easily be up-graded to MSO functionality with up to 16 active logic channels by simply plugging in an optional logic probe.

The steadily increasing requirements, calling for more bandwidth, sampling rate and storage depth, are predetermined by the latest designs to be developed in record time. Complex bus systems and high clock rates put great demands on the measurement equipment. Signal slopes to be characterized demand sufficient margins in bandwidth and sampling rate.

More and more designs, e.g. embedded systems, contain analogue as well as digital signals, and raise the demand for MSOs (Mixed Signal Oscilloscopes). Countless designs use serial or parallel bus systems (SPI, UART, SSP, I²C, I²S, JTAG, 8 Bit, 16 Bit etc.). Taking additional control signals into account (e.g. CS, RD, WR etc.), often only MSOs are considered when it comes to purchase of new oscilloscopes. Mere DSOs with up to 4 analogue channels simply can't meet the requirements. Recognising this trend, HAMEG introduces its new family of DSO/MSO scopes in the 350 MHz / 4 GSa/s class. Each logic channel provides a memory depth of 2 Meg sampling points, acquired with low capacity active logic probes (100 kOhm II 4 pF) with up to 1 GSa/s.

Simplicity

The operational concept of the new HMO family perfectly reflects the proven HAMEG philosophy for user interfaces: frequently used functions as RUN/STOP, SINGLE, NORM-Trigger, SLOPE or SOURCE are directly accessible via dedicated buttons - no need to dig in deep menus (figure 1). Meaningful illuminated keys clearly indicate the current state of the instrument. The adjustment of many settings, e.g. logic trigger or measurement functions, are graphically supported. If assistance is needed, pressing a help button provides for detailed explanations in several languages.

Inside the HMO - inner values

Besides the real time sampling rate of 4 GSa/s, the oscilloscopes capture periodic signals in random mode at a sampling rate of up to 50 GSa/s. The low noise flash A/D converters establish a new reference in its class, enabling a clear examination of fine signal details - even at the 1 mV/Div setting. To account for DC coupled signals, each channel is provided with an individual selectable DC offset. Numerous auto measurement functions, including a 6 digit hardware counter as well as comfortable cursor measurement functions, meet even the most ad-vanced requirements. The HMO series features an electronically realised persistence which can also be found in some competitor scopes. HAMEG extended this functionality and added an inverse luminosity to emphasize seldom occurring signal details.

***Figure 1:** Frequently used functions are directly accessible via dedicated buttons*

FFT

Many products on the market provide access to the FFT function only through the mathematics menu. The HMO series is equipped with a dedicated button to start FFT: The frequency domain main pane shows the signal spectrum together with typical measurement functions. A small time domain pane is shown in parallel to indicate the amplitude and the currently selected sampling interval. In FFT context the Autoset button provides for a signal based adjustment of amplitude and frequency resolution.

X-Y-Z operation

The X-Y-(Z) operation can also be directly accessed via a dedicated key, so no entering of display menus is necessary. The X-Y-(Z) curves (see figure 2) are displayed in a square main pane, whereas the X, Y and Z signals are shown in additional small preview panes as curves in the time domain. On closer examination of figure 2, the persistence of X and Y signals can be seen in the Lissajous diagram. Controlling the Z channel (e.g. CH 3) provides for an additional luminosity modulation as used e.g. in constellation diagrams. Of course, cursor measure-ments are also available in X Y Z mode of operation.

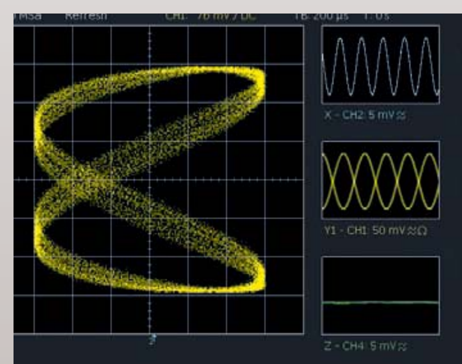


***Figure 2:** Persistence as a function of writing speed can be seen in the Lissajous curves. Luminance modulation via Z channel is set up to 100%*

Dr. Ing. Peter Reichert is head of R&D oscilloscopes at HAMEG Instruments GmbH.

Navigation features for time domain display

The memory depth of 2 MPts per channel, an outstanding feature in this price range, together with the MemoryZoom function, enables users to benefit from a horizontal magnification of 100,000:1. This aids users in cutting down times for diagnosis of complex faults, where the cause often is far away from the trigger point. The VGA resolution (640x480) of the 6.5" TFT display enables a horizontal signal presenta-tion in 12 Divs. Using the MemoryZoom mode, users benefit from a split screen representation. Above the main zoom pane a small survey pane will display the complete signal. Due to the large memory depth the selection of the proper zoom position via rotary knob can be a really tiring job. Therefore, configurable navigation buttons close to the rotary knob will considerably ease operations. Users can choose to move screenwise, go to the trigger point, jump to the start/end point, set/reset position markers or simply scroll along.

QuickView

Pressing the QuickView button will display and permanently refresh all internally available readings for a selected signal such as Max, Min, Vpeak, RMS, Mean, tr, tf or f. So users can forget about the widely known table or list

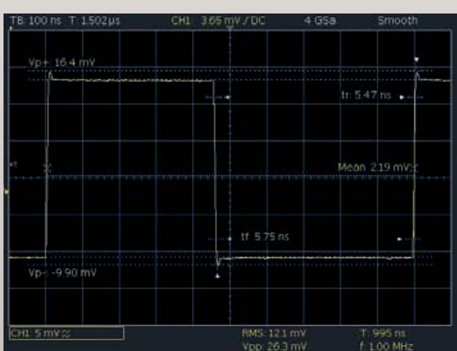


***Figure 3:** QuickView provides for permanently refreshed display of all internally available readings*

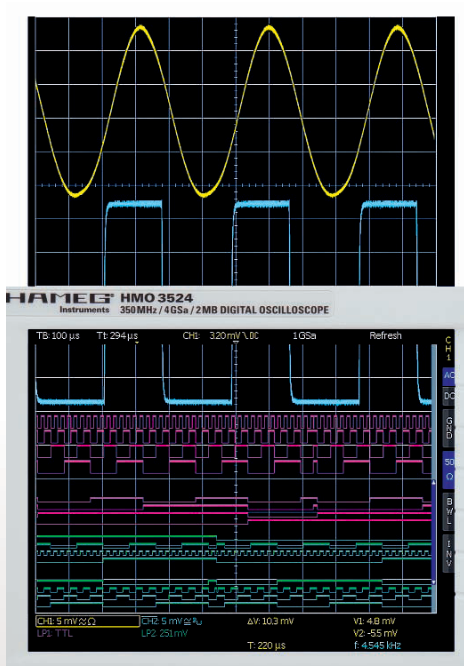


***Figure 4:** VirtualScreen enables the extension of the signal display beyond the classical 8 Div range in vertical direction*

representations found in many competitor scopes. The newly introduced HMO series, assisted by auxiliary lines and markers in the display, writes the read out values close to the signal curve. The clarity of the display is remarkably enhanced - no need to consult the manual.

Display and connectivity

There are several scopes out in the market which rely on QVGA (320x240) or WQVGA (480x234) displays. Taking into account that readout values and soft keys eat up some pixels, there is very little left to represent 4 analogue signal curves and up to 16 logic channels. Investing in a 640x480 VGA TFT display, the HMO series delivers pin sharp pictures. Using VirtualScreen, the well known 8 Div display for analogue signals can be extended to 10 Divs. Alternatively a full screen representation of 16 logic channels is possible (figure 4). The DVI

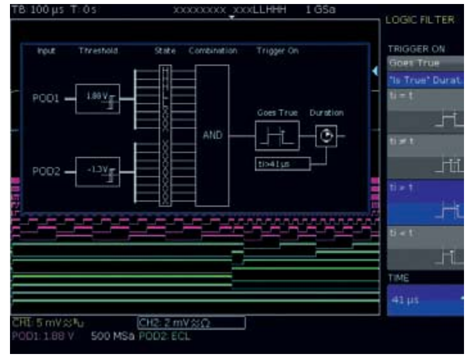


***Figure 5:** Graphically supported entry of logic trigger conditions*

output can be used for an external TFT monitor to support 19" rack mount applications. For presentation purposes a projector can be connected. 3 USB interfaces are provided for mass memory, printer and remote control. Optionally a IEEE-488 (HO740) or a Ethernet/USB (HO730) plug-in with integrated web server can be added.

Setup of tricky trigger criteria

In addition to standard trigger criteria such as Slope, Line and Video, the HMO series provides Pulse width and B trigger (two stage trig-ger) with event or time delayed final trigger with separate selection of slope or level as trigger condition. Besides capturing the analogue curve shapes of critical signals like "chip select" or "read/write", the two-channel HMO3522 and the four channel HMO3524 are capa-ble of recording up to 16 additional digital signals with 1 GSa/s and 2 MPts using the active logic probe. By logically combining up to 16 logic channels, it's easy to set up trigger conditions to drill down to fault conditions of interest (figure 5).

Conclusion

Launching the HMO series of 350 MHz TFT DSO/MSO with 4 GSa/s and 2 MByte memory per channel, HAMEG introduces a series of state of the art digital scopes that even meet the constraints of limited budgets. Due to their stackability on other HAMEG instruments, they take up only very little footprint. The HMO series is priced starting at 3,100 € and is available from March 2009. Please find more details at http://www.hameg.com/HMO3524.

FAULT REPORT: The power LED is flashing on and off

Myk Dormer

I WAS RECENTLY presented with a rather interesting fault report. A customer installing a newly delivered – actually a prototype – wireless control link was unable to get it working. He'd gone through the usual troubleshooting processes (to make sure the radio channel and address programming matches up, check external connections, confirm the aerials are fitted correctly) and had got as far as a phone call to technical support to see if there were any set-up 'small-print' details they had missed.

During the call he innocently reported that the transmitter 'power' LED was flashing and asked what operating mode this was indicating?

Unfortunately, and quite unlike the case of sophisticated 'programmable' indicator lights on much consumer equipment, the power LED on this unit just indicates power on. It is simply wired (with its current limiting resistor) across the raw supply input.

"MORE INSIDIOUSLY, DESIGNS WITH BARELY ADEQUATE ISOLATION, OR POOR SHIELDING, CAN EXHIBIT THIS FAULT UNDER SOME CONDITIONS OF AERIAL MISMATCH, BUT THEN OBSTINATELY REFUSE TO SHOW IT WHEN OPERATING INTO A 50-OHM LOAD, ON THE TEST BENCH"

The application of an oscilloscope across the power supply input terminals revealed a somewhat distorted squarewave, with a frequency equal to the flashing. An immediate cure was to replace the power supply.

So why is this elementary story of an easily diagnosed problem of interest? There are two points here worth discussing:

1. The fault itself manifested because of a specific characteristic of the transmitter.

The radio module used in this system was a multi-channel synthesized design. The carrier frequency signal in such a unit is produced by a voltage-controlled oscillator, which is phase-locked to a stable, fixed reference. However, during the time taken for the PLL to come into lock, and also in the event of a fault in the PLL or reference circuitry, the VCO output is not on the correct frequency. Therefore, unless the loop is solidly in lock, the buffer and power amplifiers must be inhibited and no RF energy can be allowed at the output.

It is actually a requirement of the EN300-220 specification and numerous other, similar, requirements worldwide that specific circuitry is provided to detect out-of-lock conditions and shut down the transmitter.

In this case, that circuitry contributed to the symptoms of the problem thus:

The power supply connected was defective, having an excessive output resistance.

On first connecting the transmitter, only the power on LED draws current.

Activating the transmitter powered up the synthesizer sections (also drawing an insignificant current), which initially locked up normally.

Then the power amplifiers turned on. The greatly increased current markedly reduced the power supply terminal voltage, enough to disrupt the operation of the PLL, which lost lock.

The out-of-lock detect circuitry then shut down the power amplifiers.

Relieved of the load, the power supply voltage recovered, the transmitter circuitry returned to normal operation, the PLL re-acquired lock and the whole process began again.

The result was a 'relaxation' oscillation, at a frequency determined by loop lock-up and out-of-lock detector reaction time.

In general, this class of transmitter misbehaviour (manifesting as a low frequency amplitude oscillation sometimes called 'motorboating') is not uncommon in synthesized designs. If there is insufficient isolation between the power amplifier and the VCO stages, then it can occur as a design fault (as the impedance change as the PA turns on is enough to unlock the PLL).

More insidiously, designs with barely adequate isolation, or poor shielding, can exhibit this fault under some conditions of aerial mismatch, but then obstinately refuse to show it when operating into a 50-ohm load, on the test bench.

More commonly, as in this case, it will be a result of a power supply problem. High internal resistance, inadequate current capacity (initiating regulator 'foldback' limiting) or insufficient supply voltage can all be causes. Occasionally, a much slower oscillation is seen, as the power supply enters thermal shutdown and recovery under an excess load.

2. Diagnosis of the fault was complicated by a misunderstanding of the unit operation:

Indicator LEDs in other apparatus are frequently under firmware control and are used to provide extra information to the user. It was a reasonable, although incorrect, assumption that this flashing LED was indicating a fault condition in the equipment, rather than a fault in the power supply, as was finally found to be the case.

Some useful troubleshooting pointers arise from this:

- Always make sure the support circuits (power supplies, aerials, baseband and interface signals) are functional, and confirm that any setup or programming has been properly executed, before assuming the radio hardware has failed.
- Understanding the internal operation of a module can greatly assist in diagnosing awkward faults, although this information is frequently only available from the manufacturer (so contacting their technical support or engineering departments can be well worth while).
- Never assume anything on the basis that 'everything just works that way'. Even if something is true in 90% of cases, that still leaves 10% waiting to ambush you.

Good luck!

Myk Dormer is Senior RF Design Engineer at Radiometrix Ltd
www.radiometrix.com

PC-based Oscilloscope Analysis

ENGINEERS have long relied on oscilloscopes to test and debug their designs. When viewing target signals the engineer requires exclusive use of an oscilloscope, which means that it is then unavailable to other users. This can be problematic when equipment is shared between team members.

For local and geographically dispersed teams, one team member often makes the oscilloscope measurements and an image of the screen is then sent to other team members for analysis. Whilst this allows the measured results to be seen by other team members, in practice it is of limited use. The images produced do not allow the engineers to see what happened before and after the time captured on the screen image. More detailed analysis is hampered by the fact that the information shared is simply a screen image without any of the underlying data.

New PC-based analysis tools allow oscilloscope data to be more efficiently shared by all team members and allow more extensive analysis of saved data away from the instrument. Offline PC analysis provides engineers with a powerful user interface to analyze data on their PC, while allowing others on the team to use the oscilloscope for additional measurements. This increases team and equipment productivity and maximizes the use of limited equipment resources.

Sharing Data for Analysis

There has always been a need to share data between engineers and scientists working on design verification and debug. The first method of data sharing was simply verbal. Then came manual, handwritten documentation, the printing out of data or even using photographic techniques to capture the screen. From photography to printing to floppy disks to advanced computer networking, file sharing has continued to evolve. The ability to share gives the design team a powerful tool that can enable it to be more productive and efficient. However, engineers are often frustrated by the inability to analyze previously acquired data from test equipment in a way that might unveil the bug in the design or allow other engineers to verify the data.

Offline PC analysis provides a solution to this. It gives engineers a powerful user interface to analyze data on their PC. Solutions such as the B4610A Data Import Tool from Agilent Technologies allow the acquisition of raw measurement data from an oscilloscope or other test instrument and the viewing and analysis of this on an offline PC.

Viewing and Analyzing Data

The intuitive interface of the B4610A provides instant insights into the system's operation and enables the rapid identification of design problems. The system provides an efficient option for data storage, data retrieval and data sharing among team members. The entire team, whether local or geographically dispersed, can view and analyze the same data offline on their PCs.

The analysis can be done individually, irrespective of time zones, or viewed collaboratively via web-based meeting tools. The ability to view and analyze the entire captured data offline on a PC increases the team's productivity and the test equipment utilization. In a situation where the cause of the problem in the device under test it is not clear the user can perform multiple analysis scenarios without having to re-acquire data.

In the example of **Figure 1** the user needs to measure the time between the rising edge of the D0 digital signal and the falling edge of the D1 digital signal to ensure the timing of the device is correct. To do this the user assigns markers to the display that allow greater insight to the possible timing problems on the signal. The time-correlated global markers allow a symptom on one bus to be

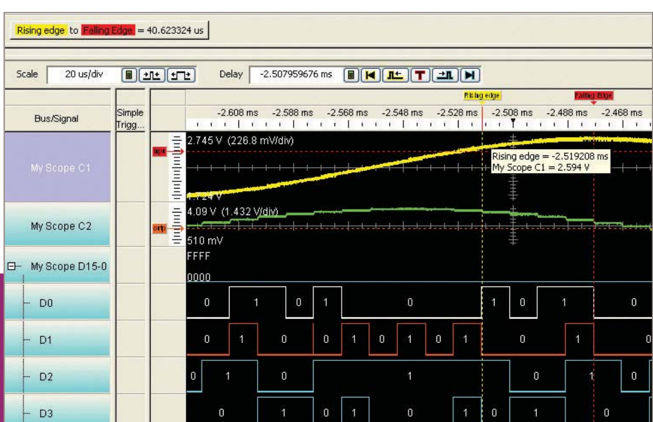


***Figure 1:** The markers are placed on the rising edge and the falling edge of the signals and they have been renamed for better analysis*

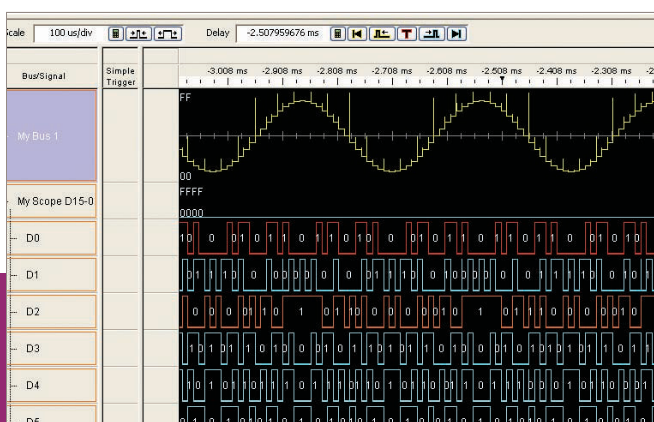


***Figure 2:** Chart mode shows the graphical representation of digitized signals from an A/D converter*

Maryjane Hayes Business Development Engineer at Agilent Technologies offers an insight into how to make the most efficient use of T&M equipment with PC-based offline analysis tools

tracked to its cause on another bus.

Flexibility in how the data is displayed can aid in verifying that the design is working as expected. A special mode that allows the user to view bus data values as a chart instead of the conventional bus shape provides a quick visual verification. The example of **Figure 2** shows this chart mode. In this example by charting bus values over time the digitized signals to and from A/D converters can be graphically validated.

Search and Filtering of Data Reduces Debug Time

Faster debug analysis of the acquired data can be achieving by using a filter tool to display only the transactions that of most interest and relevance. The filter tool allows the user to focus just on the information he or she needs, for example, by filtering out data such as idle states from deep, complex acquisition traces.

In the example of **Figure 3**, the engineer only wants to analyze the memory reads and writes. By using a filter tool, the user can specify what signals to display by selecting specific parameters, as well as choosing different display colours for each transaction. This enables the user to quickly isolate and view the different transactions of interest within the trace.

By using a search tool, complex patterns can be specified to find elusive events or timing violations in the data record. With the ability to add many levels to the search criteria and to set each bit of the digital record to specific values, it is possible to find the precise point of the device failure. Since it is feasible that these searches could become very complex, it is of great value to be able to save and recall the parameters of the search for use in subsequent data captures.

In the example of **Figure 4**, the engineer needed to implement a very complex search in order to find a design violation in the Device Under Test.

Here to Share

In today's test and measurement engineering world, there is always a need to share data. Many engineers are working on designs with members from other teams, whether it is a test team, a manufacturing team or a customer that is integrating the device into a final product. These teams can be local or geographically dispersed. Oscilloscopes are used to debug, test and validate many engineering designs.

With such a broad base of users, it becomes necessary to be able to view, analyze and share data offline on a PC as all members of the team do not all have access to the instrument performing the debug. With PC-based offline analysis tools, the process of data sharing and analysis can now be faster and more efficient. The ability to send the full data record to team members in the same building, or even other parts of the world makes PC-based offline analysis a much needed tool for more extensive analysis of saved data away from the oscilloscope.

With limited budgets on projects, there is not always enough test equipment to go around. PC-based offline analysis solves this problem by allowing the team more efficient use of the oscilloscope as the entire data record to be analyzed offline and thus making the instrument available for additional data captures. ■

Agilent Technologies offers PC-based data import and offline analysis for Oscilloscopes and Logic Analyzers with the B4610A Data Import Tool. For more information visit **www.agilent.com/find/infiniivisionoffline**

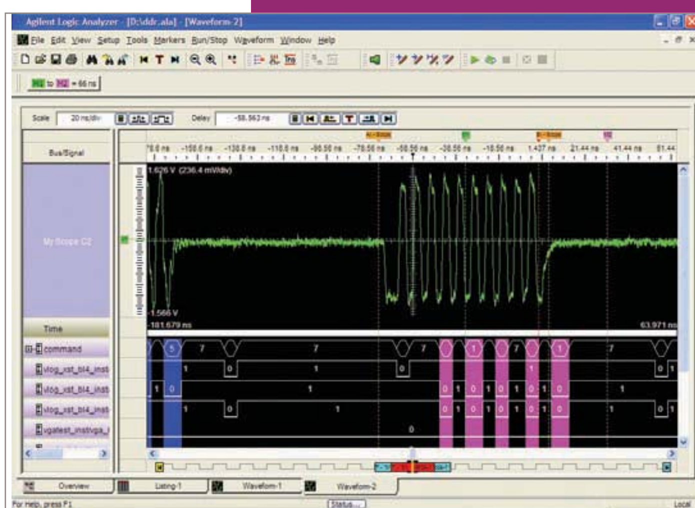


Figure 3: *Separating memory reads and writes with the filter tool*

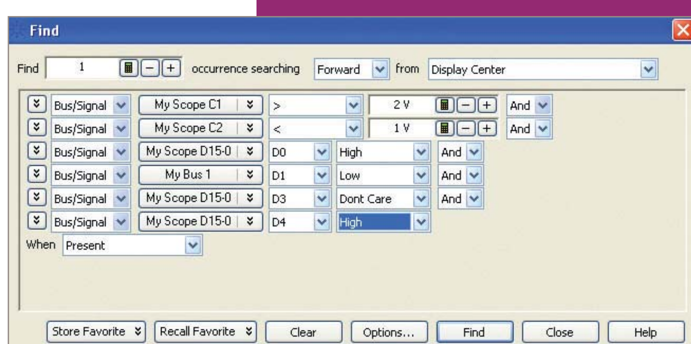


Figure 4: *Complex search parameters can be saved and recalled for later use*

Optical Modulation Methods for High-Speed Networks and the Consequences for Test Equipment

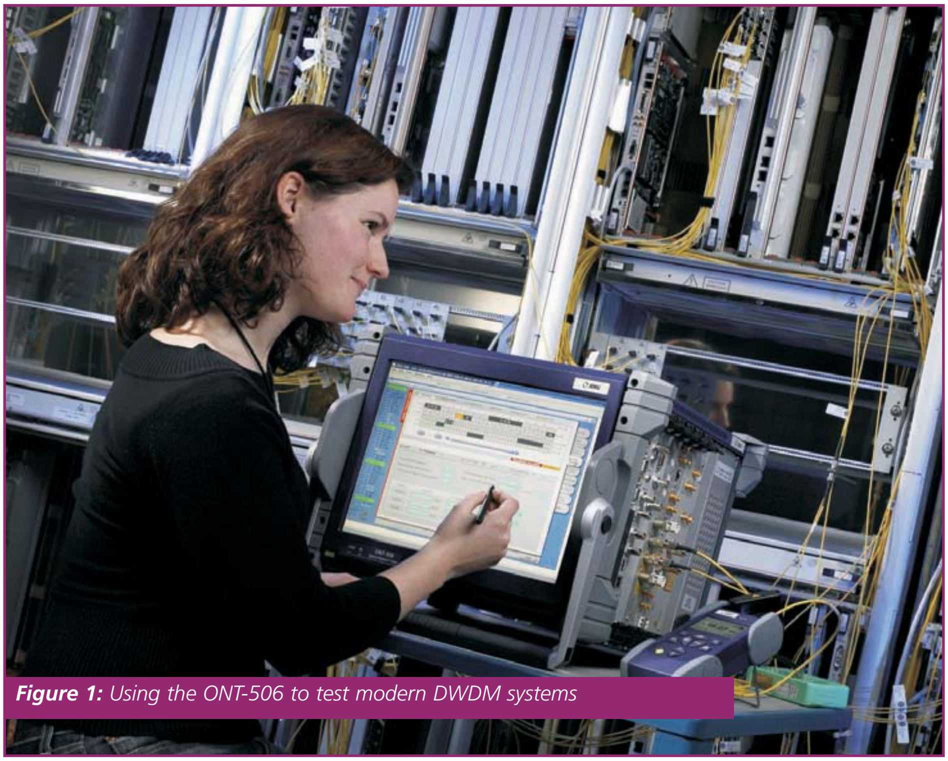


***Figure 1:** Using the ONT-506 to test modern DWDM systems*

A RANGE of newly developed fundamental communications technologies must be employed in order to reliably transmit signals of 40/43 Gbit/s and even 100Gbit/s in the near future using telecommunications networks. One of these technologies involves the use of higher-level modulation methods on the optical side, similar to those which have been used for many years successfully on the electrical side in xDSL broadband access technology, for example.

A lot of new abbreviations for optical modulation methods have sprung up with the introduction of 40/43 Gbit/s communications technology. Until now, just one modulation method was used for transmission rates of up to 10Gbit/s, namely on-off keying or OOK for short. Put simply, this means that the laser light used for transmission was either on or off depending on the logical state 1 or 0 respectively of the data signal. This is the simplest form of amplitude modulation.

Additional external modulation is used at 10Gbit/s. The laser itself is switched to give a continuous light output and the coding is achieved by means of a subsequent modulator.

The Need for Certain Methods

So, why are higher-level modulation methods with their attendant complexity needed at 40/43 Gbit/s?

There are many reasons for this. Every method of modulation broadens the width of the laser spectrum. At 10Gbit/s this means that about 80pm bandwidth is needed for OOK. If the transmission rate is quadrupled to 40Gbit/s, the necessary bandwidth also quadruples, i.e. to around 320pm. The greater bandwidth results in a linear increase in the noise power level in the communications channel. A fourfold increase in the noise power level corresponds to 6dB and would result in a decrease in the minimum sensitivity of the system by this same factor. This results in a much shorter transmission range at 40Gbit/s

	ODB/ PSPT	NRZ-DPSK	NRZ-ADPSK	RZ-ADPSK	RZ-DQPSK	PM-QPSK
OSNR sensitivity at BER = 2x10-3 [dB]	17.5	12.5	13	12.5	13.5	12.5
Nominal range using EDFA (1)	700	1600	1600	2200	1400	1700
Filter tolerant, suitable for 50 GHz channel spacing	yes	affects range	yes	yes	yes	yes
PMD tolerance without compensation (ps)	2.5	3	3.5	3.5	6	10
Sensitivity to non-linear distortion	no	no	no	no	yes	yes
Complexity / Cost	low	low	low	medium	high	high

(1) 100km range (23 dB attenuation), EDFA noise figure = 6 dB, 100 GHz spacing

***Table 1:** Comparison of optical modulation methods for 40Gbit/s*

Peter Winterling, Senior Solution Specialist for Optical Transport at JDSU examines why the use of higher-level modulation methods on the optical side are necessary and the consequences of this for the measuring equipment needed

ONT-506 for R&D and TS-30 for production: 40/43 Gbit/s with DQPSK modulation

and, as a consequence, in the need for more regenerators.

Increasing the laser power in sufficient measure to compensate for the missing balance in the system compared to 10Gbit/s is not possible. Nonlinear effects in the glass fiber, such as four-wave mixing (FWM), self-phase modulation (SPM) and cross-phase modulation (XPM) would also adversely affect the transmission quality to a significant degree. Higher-level modulation methods reduce the modulation bandwidth and, thus, provide a way out of this dilemma.

One absolute necessity is the need to integrate the 40/43 Gbit/s systems into the existing DWDM infrastructure. The bandwidth required by OOK or optical dual binary (ODB) modulation only allows a best case channel spacing of 100GHz (= approx 0.8nm) in a DWDM system. Systems with a channel spacing of 50GHz (= approx 0.4nm) have long been implemented in order to optimize the number of communications channels in the DWDM system.

For both technologies to be integrated into a single DWDM system, the multiplexers/demultiplexers (MUX/DEMUX) would have to be reconfigured back to a channel spacing of 100GHz and the corresponding channel bandwidths, or hybrid MUX/ DEMUX would have to be installed. Both these solutions are far from ideal, since they either result in a reduction in the number of communications channels or the loss of flexibility in the configuration of the DWDM system. Here, too, the answer is to use higher-level modulation methods that reduce the required bandwidth.

Quality of Transmission

As well as other factors, the transmission quality of a communications path also depends on polarization mode dispersion (PMD) and chromatic dispersion (CD). CD depends on the fiber and can be compensated for relatively simply by switching in dispersion-compensating fibers.

However, this once again degrades the loss budget. This is within acceptable limits for realizing the usual range distances in 10Gbit/s systems. But this is not the case with 40Gbit/s, where the system budget is already reduced anyway. For this reason, other compensation methods must be used, subject to the additional requirement for exact compensation at all wavelengths of a DWDM system because the maximum acceptable value for CD is a factor of 16 lower than that for 10Gbit/s.

The maximum acceptable PMD value for 40Gbit/s is reduced by a factor of four. The PMD value is largely affected by external influences on the fiber, such as temperature and mechanical stress, and is also dependent on the quality of manufacture of the fiber itself. A requirement for any new modulation method would be a corresponding tolerance to PMD and CD.

When you take a look at the data sheets issued by systems manufacturers or in other technical publications, it is easy to be confused by the number of abbreviations used for new modulation methods. How do these methods differ and which of them are really suitable for future transmission speeds? Unfortunately, there is no easy answer to that either. Apart from the technical requirements, such as:

- significant improvement in minimum OSNR by reducing the signal bandwidth;
- compatibility with the 50GHz ITU-T

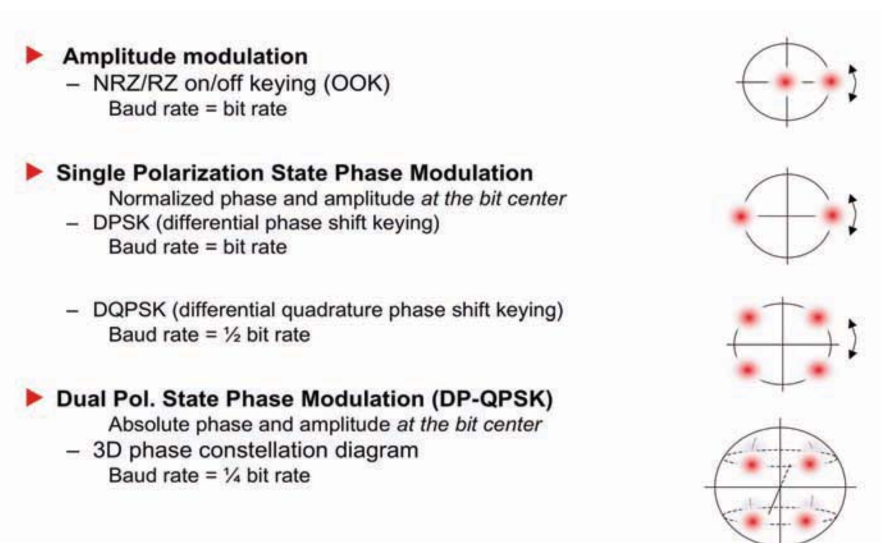


Figure 2: *Modulation types and their constellation in the system of coordinates*

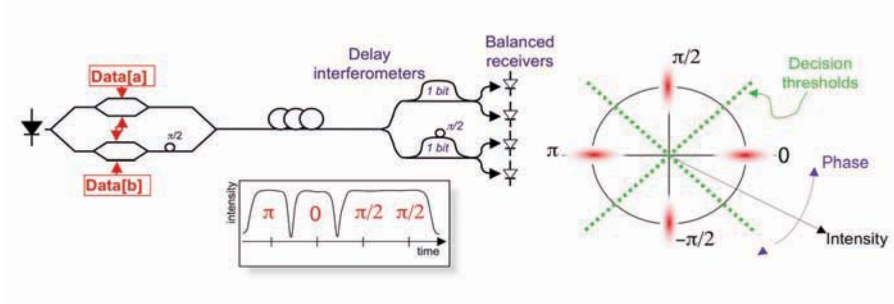


***Figure 3:** DQPSK – Differential Quadrature Phase Shift Keying / Differential Detection*

channel spacing or at least with a spacing of 100GHz;

- coexistence with 10Gbit/s systems;
- transmission in networks that use ROADMs;
- scalable for 100Gbit/s; and
- the degree of technical difficulty and, hence, the economic viability also have to be taken into account.

Modulation Methods

The modulation methods can be basically divided into different categories (**Figure 2**).

OOK amplitude modulation and ODB optical dual binary modulation can only be used in a very restricted sense for 40/43 Gbit/s for the reasons described above.

Higher-level phase modulation methods represent the next category. Differential phase shift keying (DPSK) improves the system balance by means of a much reduced OSNR limit value. In all the other aspects mentioned, this modulation method has similar characteristics to OOK. This modulation method can, therefore, only be used for DWDM systems with 100GHz channel spacing because of the bandwidth it requires. It can only be employed with restrictions in ROADM-based networks.

Reconfigurable optical add/drop multiplexers allow routing of individual wavelengths in a DWDM system at network nodes. The basic components of a ROADM are multiplexers and demultiplexers with wavelength-selective filter characteristics and a switch matrix. The cascading of bandpass filters unavoidably leads to a narrowing of the communications channel pass band, with the resultant truncation of the DPSK modulated signal. Adaptive DPSK takes account of these restrictions and results in clear improvements when used in complex network structures.

Improvements in all areas are brought about by modulation methods in the next category, that of quadrature phase shift keying QPSK (**Figure 3**). Return to zero differential QPSK (RZ-DQPSK) has been around for some time now. The RZ coding requires slightly higher complexity on the modulation side compared with the more usual non return to zero (NRZ) coding, but it considerably reduces the susceptibility to PMD and nonlinear effects.

QPSK modulated signals use four possible positions in the constellation diagram. Each phase state now encodes two bits. The baud rate (symbol rate) is therefore halved, so the bandwidth requirement is also halved.

Use in systems with 50GHz channel spacing and in ROADM-based networks is assured, with a simultaneous improvement in susceptibility to PMD. The technical complexity required in the realization of this modulation method is admittedly greater. Figure 3 shows the principle of modulation and demodulation of a QPSK signal and outlines the technical outlay on the optical side.

Systems using polarization mode (PM) QPSK modulation methods have been tried out recently. This opens the way towards a coherent system of transmission and detection. Although this is by far the most complex method, the advantages are significant.

Using a total of eight positions in what is now a three-dimensional constellation diagram, the baud rate is thus reduced by a factor of four. Each state encodes four bits. This makes the method ideally suited for 100Gbit/s, and the bandwidth requirement is within a range that would fit within existing DWDM structures.

An additional forward error correction (FEC) is applied to 100Gbit/s signals, so the actual transmission rate is more likely to be around 112Gbit/s. The symbol rate using PM-QPSK modulation would be in the range of 28GBaud, which requires a bandwidth of about 40GHz. **Table 1** compares the characteristics of the different modulation methods.

Implementation

Implementation of higher-level modulation methods for optical communications is still in the early stages. It is to be expected that further innovations will be triggered by the next level in the transmission rate hierarchy.

In order to be as widely useful as possible, the measurement equipment would have to include facilities for testing the complete range of modulation methods. It is true that there will always be standardized interfaces on the client side of the network; these are 40Gbit/s in SDH and 43Gbit/s in OTN according to ITU-T Recommendation G.709 for the 40G hierarchy.

However, there is an increase in the diversity of non-standardized solutions on the line side. Not only do the optical parameters vary, but manufacturer-specific coding is being used more and more frequently for FEC. Use of through-mode in an analyzer for insertion into the communications path has, so far, been an important approach: it is important to check that the payload signal is correctly mapped into the communications frame on the line side, that the FEC is generated correctly and that alarms are consistent. Or that the correct signaling procedure is followed in the receiver when an error message is received, and that error-free reception is possible in the presence of clock offsets or jittered signals. It is now the time to decide quickly on using just a few modulation methods, otherwise the cost of investment in measuring equipment will rise to astronomical levels.

In contrast to the wide variety in electrical multiplexers for 10Gbit/s, optical modulation methods each require a corresponding optical transponder. The cost of these transponders largely determines the price of the test equipment. The greater the diversity, the less likely it is that investment will be made in a tester for a particular optical interface. This will mean that important tests will be omitted from systems using the latest technology.

Access to the line side is probably the easiest route for network operators who in any case have had to keep up with a diversity of systems manufacturers over the years. The most important tests on installed communications systems are end-to-end measurements. Fully developed test equipment for such measurements is available for 40/43 Gbit/s.

Measuring Equipment for 40/43 Gbit/s

JDSU is one of the leading manufacturers of 40/43 Gbit/s measuring equipment. As the first on the market, it now has three different platform solutions available for R&D, production and onsite measurements. The JDSU ONT-503 is the "little brother" of the ONT-506 (large picture) and offers the greatest depth of testing for R&D, although the inclusion of jitter is only possible with the ONT-506.

JDSU rounds out its 40/43 G portfolio The JDSU TestPoint TP-30 is designed for use in production, while the JDSU MTS-8000 is the ideal platform for all interfaces encountered in onsite applications.

All three solutions can be expanded with modules to provide all other interfaces for SDH, OTN and Ethernet from STM-1 through to STM-256, GE and 10 GE as well as Fiber Channel.

Interfaces for higher-level modulation methods are now available for the ONT-506 and TS-30 for 40/43 Gbit/s, and ODU multiplexers are available for OTN. ■

Lossless Feedback Amplifiers

Chris Trask goes into the theory, practice and advanced techniques of creating lossless feedback amplifiers. The first part to this article was published in our last issue of Electronics World. If you missed it, you can order your digital copy by

IT WAS MENTIONED earlier (**Part 1** of this article is in the March issue of *Electronics World*) that the collector load resistance R_C is a significant factor in establishing the high frequency cutoff of the lossless feedback amplifier. From the earlier discussion related to Equation 12, it is obvious that there is little that can be done to substantially improve the high frequency performance by way of altering the various capacitances. Also, reducing R_C outright requires that the turns ratio of the feedback transformer be reduced, which will result in a potentially unacceptable reduction of the amplifier gain.

An alternative is to provide some form of current gain within the amplifier. This can be done easily by adding an autotransformer to the input of the RF amplifier transistor. Such a method is shown in **Figure 13**, where a tap has been added to the primary side of a passive augmentation transformer, resulting in what is called compound passive augmentation. Here, the common-base amplifier has a current gain of K+1 and the secondary side of the transformer performs in the same manner as with simple passive augmentation, with the turns ratio L remaining arbitrary.

The implementation of compound passive augmentation in a lossless feedback amplifier is illustrated in the schematic of **Figure 14**. The voltage gain of the amplifier is still equal to M, as before, and the gain remains as follows:

$$G = 20 \log M \qquad (17)$$

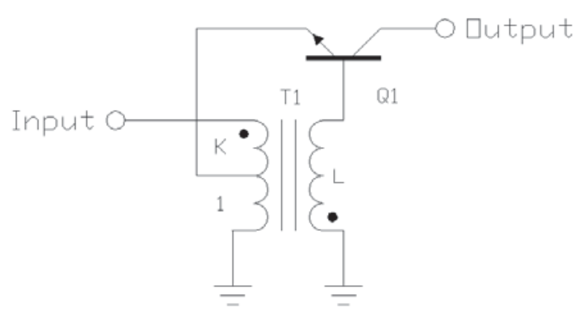


Figure 13: *Common base amplifier with compound passive augmentation*

K	N	M	Rc Ohms	Gain dB
1	1	3	100	9.54
1	7	5	300	13.98
2	1	4	83	12.04
2	3	5	133	13.98
2	9	7	267	16.90
3	1	5	75	13.98
3	5	7	150	16.90
3	11	9	250	19.08

Table 2: *Compound lossless feedback amplifier transformer ratios*

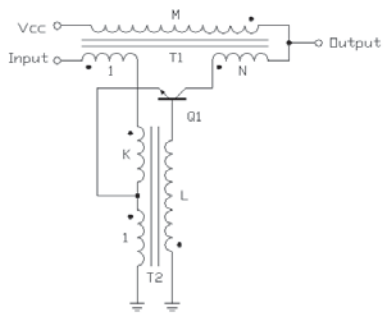


Figure 14: *Lossless feedback amplifier with compound passive augmentation*

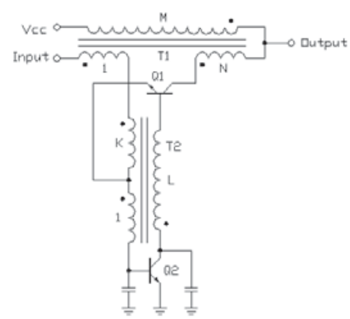


Figure 15: *Lossless feedback amplifier with compound tandem augmentation*

– Part 2

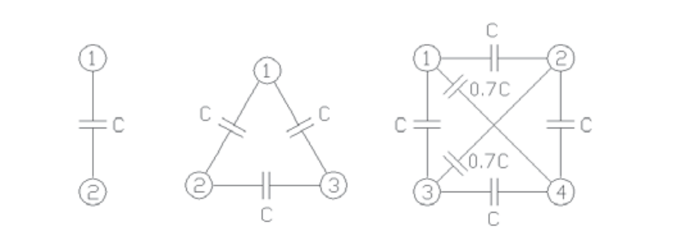


Figure 16: *Bifilar, trifilar and quadrifilar interwire capacitances*

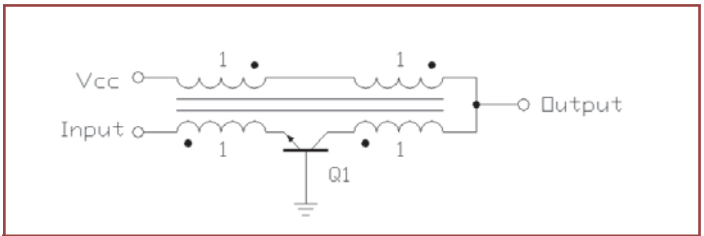


Figure 17: *6dB lossless feedback amplifier with transformer partitioning*

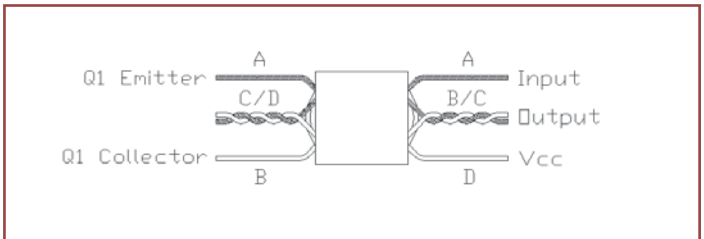


Figure 18: *Feedback transformer construction for 6dB amplifier of Figure 17*

Now, the input resistance has become

$$R_{IN} = R_L \frac{(K+1)(M+N)+1}{M^2} \qquad \textbf{(18)}$$

For an amplifier whose input impedance is equal to the load impedance, the turns ratios of M and N are related by:

$$N = \frac{M^2 - 1}{K+1} - M \qquad \textbf{(19)}$$

and the collector load resistance now becomes:

$$R_C = R_L \frac{M+N}{K+1} \qquad \textbf{(20)}$$

which shows that by compound passive augmentation can substantially reduce R_C with little if any added circuit complexity. Note here that **Equations 18**, **19** and **20** may be used in place of the earlier **Equations 8**, **9** and **10** by simply setting K to zero. **Table 2** lists a number of combinations that can be realized to provide a significant increase in amplifier gain while retaining or even improving the high cutoff frequency by way of a reduction in R_C.

Tandem augmentation may also be applied to the compound augmented lossless feedback amplifier of **Figure 14**, as illustrated in the schematic of **Figure 15**. Amplifiers such as this provide superb dynamic range.

Transformer Partitioning

As was mentioned earlier, the overall performance of lossless feedback amplifiers is less dependent on the transistor and more dependent upon the transformer, especially on the coupling coefficient between the various windings. In the overall concept of constructing wideband transformers with wire, those that are constructed using monofilar (single wire) windings have the least degree of coupling, whereas those that employ bifilar (two wire) and trifilar (three wire) windings enjoy the highest degree of coupling. Quadrifilar (four wire) and higher windings suffer from unequal degrees of coupling between the various wires.

As shown in **Figure 16**, the interwinding capacitances for trifilar windings are uniform between all three wires, just as with bifilar windings. However, for quadrifilar windings the capacitances between the diagonally opposite wires are less than that for the immediately adjacent wires, so that the coupling coefficient between all four wires is not equal.

This creates a considerable dilemma when the designer is faced with transformers which have dissimilar turns ratios. As anyone who has ever built a 4:1 impedance ratio transformer can attest, you can get far better performance with a single trifilar winding, connecting two of the wires in series, than you can by way of a pair of monofilar windings.

Unfortunately, the windings ratios of the transformers for lossless feedback amplifiers are not so convenient, as the listings in Tables 1 and 2 indicate. However, by partitioning the feedback and augmentation transformers into a pair of bifilar and/or trifilar windings on a single core, practical designs can be achieved that provide the desired high degree of coupling.

Consider, for example, the 6dB amplifier of Table 1 (see last issue of *Electronics World*), where the feedback transformer has a turns ratio of 1:1:2. By partitioning the winding having two turns into a pair of windings having 1 turn each, the earlier schematic of Figure 2

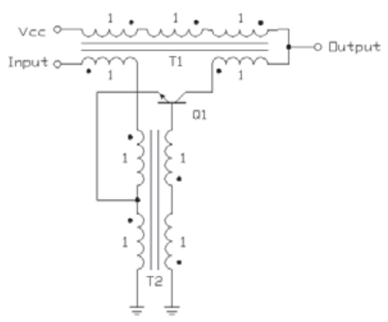


Figure 19: *9.5dB lossless feedback amplifier with compound passive augmentation and transformer partitioning*

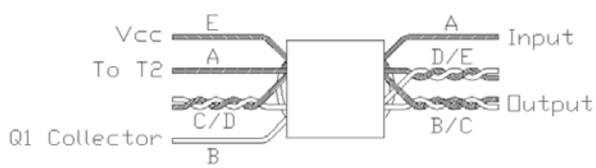


Figure 20: *Feedback transformer construction for 9.5dB amplifier of Figure 19*

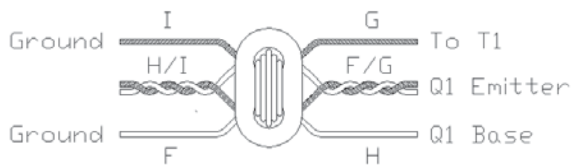


Figure 21: *Augmentation transformer construction for 9.5dB amplifier of Figure 19*

(see last issue of *Electronics World*) now becomes that of **Figure 17**, where the feedback transformer now has four windings, each having an identical ratio of one, and which can now be realized by way of a pair of identical bifilar windings on a single core.

The four windings of Figure 17 are labelled as A, B, C and D, as an aid in discussing the physical construction of the transformer. Since all of the windings are placed on a single core, they may be combined in bifilar pairs in any manner. However, the overall performance will benefit greatly from having the input winding A twisted together with one of the C or D windings, and the collector winding B twisted with the other.

In **Figure 18**, the four windings are combined in pairs of A/C and B/D and constructed on a binocular core (also known as a balun or multi-aperture core), as this arrangement results in a minimum of lead length in making connections to the transistor, the input and output, and the winding interconnections. This is an important consideration with regard to minimizing parasitic series inductance and shunt capacitance in the physical design.

As a result of improved coupling, an amplifier having transformers constructed in this manner can have an improvement in IMD products of 10dB or more over a similar amplifier where the transformer is constructed using monofilar windings, and the construction of the improved transformer only requires that one addition pair of wires be interconnected, which is an insignificant labour burden.

Construction of a Transformer

The construction of the augmentation transformer can also benefit from partitioning. Referring for the moment to Table 2, an amplifier having 9.54dB of gain employing compound passive augmentation would require a feedback transformer having a turns ratio of 1:1:3 and an augmentation transformer having a turns ratio of 1:1:L, where the ratio L is once again arbitrary. Referring to **Figure 19**, the feedback transformer is now partitioned so as to make use of bifilar and trifilar windings of the same ratio, as well as an augmentation transformer employing a pair of bifilar windings also having the same ratio, resulting in an L winding ratio of 2, which could be increased further to as much as 4 by using a combination of bifilar and trifilar windings.

As with the previous 6dB amplifier of Figure 17, the feedback transformer (T1) windings of the 9.5dB amplifier of Figure 19 have been labelled as A, B, C, D and E, all having a winding ratio of one, and the augmentation transformer (T2) windings, also having a winding ratio of one, have been similarly labelled as F, G, H, and I as an aid to discussion.

The construction of the feedback transformer T1 is shown in **Figure 20**. Here, the transformer is constructed on a binocular core with a trifilar group consisting of windings A, C and E, together with a bifilar pair consisting of windings B and D. The interconnections are again consistent with the intent of minimizing the lead lengths to the transistor, the input and output, the augmentation transformer T2, and the winding interconnections.

The construction of the augmentation transformer T2 is shown in **Figure 21**. Here, the transformer has been constructed on a binocular core with all of the free wire ends exiting from the far end of the core with the four windings combined in bifilar pairs of F/H and G/I in order to minimize the lead lengths to the transistor and the feedback transformer T1, as was done with the feedback transformers of both this and the previous example.

The concept of alternating from one group of twisted wires (either bifilar or trifilar) to the other, as one proceeds from the Vcc terminal to the input terminal of the feedback transformer T1, results in designs that have consistently short lead lengths. The same is true when proceeding from the grounded ends of the primary and secondary sides of the augmentation transformer T2.

This technique may be further extended by using bifilar and trifilar windings of different ratios. For instance, from Table 2 we see that a 14dB amplifier may be realized using a feedback transformer ratio of 1:3:5 and an augmentation transformer ratio of 1:2:L, with L again being arbitrary.

In the schematic of **Figure 22**, this amplifier is realized using a feedback transformer having a trifilar winding of one turn and a bifilar winding of three turns, while the augmentation transformer is realized with two bifilar windings having a ratio of 1:2, which sets L to a convenient ratio of 3 and which can be further increased to as much as 6 by making both windings in trifilar form. For this amplifier, the transformer construction is the same as shown in Figure 20 (feedback transformer) and Figure 21 (augmentation transformer), except that the windings ratios are now 1:3 and 1:2, respectively.

There are numerous combinations that can be brought to bear to realize this design concept. Experience shows that it works best when the input winding and the N winding are part of separate bifilar or trifilar windings that each include at least one portion of the M winding, to ensure that the currents in the three windings be in the proper ratios. As a general design methodology, the two twisted wire groups (either bifilar or trifilar) that comprise the feedback transformer have a ratio of 1:N, where N is obtained from **Equation 9** or **Equation 19**. The number of wires in the two groups is adjusted so as to arrive at the required M turns that determine the amplifier gain of **Equation 8** or **Equation 17**.

This methodology is equally applicable to the design of the augmentation transformer, where the two twisted wire groups (again either bifilar or trifilar) have a ratio of 1:K. As a matter of convenience, the augmentation transformer may be constructed using two bifilar pairs, which will result in an L ratio of K+1, and if trifilar wires are used the L ratio can be increased to 2K+2. **Table 3** lists feedback and augmentation transformer ratios for amplifiers suitable for transformer partitioning.

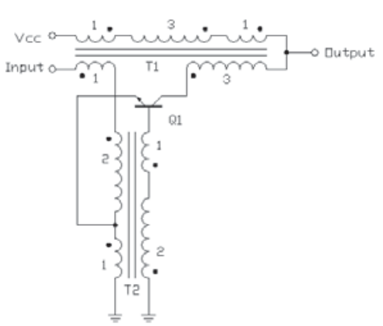


Figure 22: *Augmented 14dB lossless feedback amplifier with compound passive augmentation and transformer partitioning*

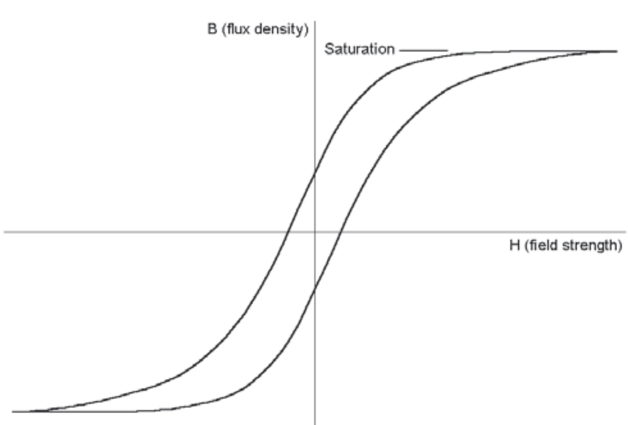


Figure 23: *Typical hysteresis curve*

Transformer Construction Details

The bandwidth of the amplifier is dependent upon a number of factors that are directly related to the feedback transformer beyond those that were discussed earlier, where **Equation 12** showed that the high frequency cutoff is determined by the collector load resistance R_C along with the transistor and transformer output winding capacitances. These factors normally dominate the high frequency cutoff, but at higher frequencies an excessive amount of wire (resulting in high leakage inductances) and induced transformer core losses may become significant factors.

On the other hand, an insufficient amount of wire or a transformer core that has low permeability may hamper the low frequency performance. These factors, along with the selection of the transistor(s) must all be brought into consideration in order that the amplifier meets the desired bandwidth goals.

The transformer can also play a significant role in the IMD performance of the amplifier. As shown in **Figure 23**, the ferromagnetic properties of the core material are not necessarily linear. A transformer core of insufficient size may result in the signal flux encroaching on the saturation region of the hysteresis curve. In addition, bias current passing through the windings will result in a bias flux that will cause the quiescent operating point of the core to be displaced from zero, which will result in the signal flux saturating prematurely.

The transformer will also add noise to the amplifier due to bulk and skin effect losses in the wires, induced losses from the core material conductivity and magnetic skin effect, which are primarily thermal noise, as well as 1/f noise due to Barkhausen effect in the core material, which is dependent upon the amount of bias flux in the core.

Needless to say, there are many factors regarding the design and construction of the transformer(s) that are instrumental in the overall bandwidth, IMD and NF performance of the amplifier, which include but are not limited to, the amount of wire in the windings (low and high cutoff frequencies), the degree of coupling between the

K	N	M	Rc Ohms	Gain dB
	1	2	150	6.02
1	1	3	100	9.54
2	1	4	83	12.04
2	3	5	133	13.98
3	5	7	150	16.90

Table 3: *Lossless feedback amplifier transformer ratios suitable for transformer partitioning*

high cutoff frequencies), the degree of coupling between the windings themselves (losses, low frequency cutoff), core size (low frequency cutoff, saturation, and IMD products), core material permeability (low frequency cutoff), core material losses (high frequency cutoff) and bias flux (early saturation, IMD products, noise).

A number of these amplifiers have been constructed and tested, and with common parts such as a 2N2222 for the RF amplifier transistor Q1 and an MPSA14 Darlington pair for the augmentation transistor Q2, a bandwidth of over two decades, an OIP3 of +45dBm, and a NF approaching 1dB is easily achieved.

Lossless Feedback Amplifiers with Transmission Line Transformers

There are circumstances in the design of lossless feedback amplifiers in which the usage of wideband transformers made with wires begins to compromise the performance. These situations exist where the leakage inductance, inter- and intrawinding capacitances and losses interfere with realizing the desired high frequency cutoff. This is especially the case when designing power amplifiers where the parasitics of the transistors themselves, combined with those of the transformers, occasionally result in an unstable or potentially unstable operation.

For some transformer ratios, lossless feedback amplifiers may be realized by making use of transmission line transformers (TLTs), which are made of short sections of transmission line, usually in the form of coaxial cable, which is what will be considered in the furtherance of this discussion. In such designs, it is necessary to recognize that the current of the inner surface of the outer conductor is equal in magnitude and opposite in phase to that of the inner conductor. Also, the upper frequency limit of such transformers is generally considered to be the point at which the section of transmission line is one eighth of a wavelength.

The low cutoff frequency is determined primarily by the value of the magnetization inductance, which is a function of the outer surface of the outer conductor and which is influenced by any magnetic material (either ferrite or powdered iron), through which the coaxial cable is inserted. A general rule of thumb, though not entirely accurate, is that the electrical length of the transformer is increased by a factor equal to the square root of the relative permeability (μ_r) of the magnetic material.

As a design example, consider the partitioned 6dB amplifier of Figure 17. Here, the feedback transformer consists of two equal 1:1 sections, each of which has equal and opposite signal currents in the two winding pairs. To realize this amplifier in TLT form requires two equal sections of coaxial cable, the schematic of which is shown in **Figure 24**. By way of current mapping, the first TLT section receives the input signal v_{in} which conducts a signal current *i* to the emitter of the transistor. This induces an equal and opposite signal current *i* in the second conductor of the first TLT section that is conducted to the output. The transistor collector produces a signal current *I* which is conducted to the second TLT section. These last two currents are summed at the output, resulting in an output current of 2*i*. The collector signal current passing through the second TLT section

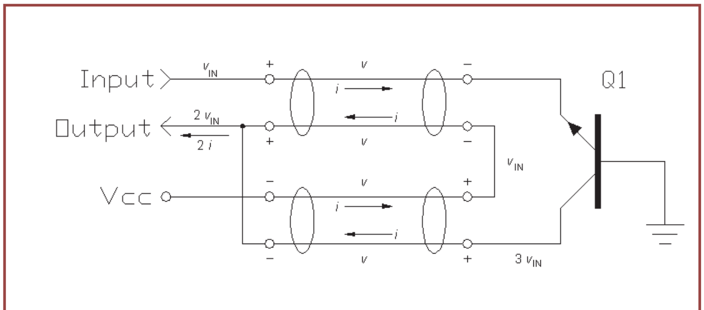


Figure 24: *6dB lossless feedback amplifier using transmission line transformers*

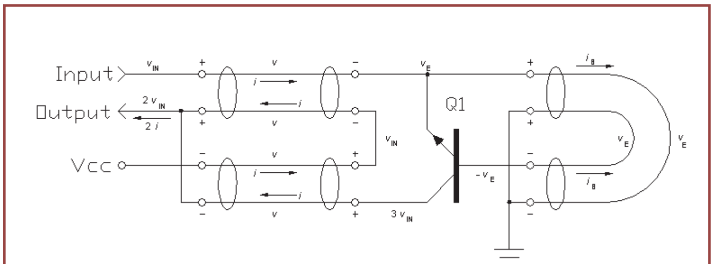


Figure 25: *Passively augmented 6dB lossless feedback amplifier using transmission line transformers*

induces and equal and opposite signal current in the second conductor of the second TLT section, which is equal to the signal current of the second conductor of the first TLT section, thus completing the M portion of the feedback transformer.

Similarly, the voltage mapping of Figure 24 shows that the output voltage is twice that of the input voltage. Thus, the amplifier has 6dB of power gain. In addition, the collector voltage is three times that of the input voltage, the exact same as when using wire-wound wideband transformers.

The augmentation transformer may also be realized by way of TLTs. **Figure 25** illustrates the addition of 1:1 passive augmentation to the amplifier of Figure 24. The signal voltage applied to the transistor base is equal and opposite to the emitter signal voltage, and the input signal current is equal and opposite to that of the base signal current, thus forming a 1:1 inverting transformer as required for realizing passive augmentation.

By using TLTs in the lossless feedback topology, stable linear power amplifiers having bandwidths of over two decades are easily produced.

Closing Remarks

The techniques described herein extend the Norton patent into a strongly enhanced and optimized design in which NF, IMD, gain and high frequency performance can be improved without compromising power efficiency and circuit complexity, objectives which were difficult to achieve with earlier designs. Furthermore, these techniques demonstrate that such amplifiers can be built with commonly obtainable parts, making the improved performance economically attractive. It is hoped that others will be encouraged to extend or develop new technologies in this important area of LNA design. ■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Associate Professor **Dr Murat Uzam** from Nigde University in Turkey presents a series of articles on a project that focuses on a microcontroller-based PLC. This is the sixth article of the series describing the first set of timer macros

PLC with PIC16F648A Micro

THE PULSE timer can be used to generate output pulses of a given time duration. The symbol and timing diagram of the pulse timer (TP) are both shown in **Figure 1**. As the input signal IN goes true (ON – 1), the output Q follows and remains true (ON – 1), for the pulse duration as specified by the preset time input PT.

While the pulse output Q is true (ON – 1), the elapsed time ET is increased. On the termination of the pulse, the elapsed time ET is reset. The output Q will remain true (ON – 1) until the pulse time has elapsed, irrespective of the state of the input signal IN. Extended pulse timer (TEP) differs from the pulse timer in one point that with every state-change of the input signal from 0 to 1 the elapsed time is re-started from the beginning and, thus, extending the pulse duration with another PT.

The symbol and timing diagram of the extended pulse timer (TEP) are both shown in **Figure 2**, from where the difference from the pulse timer (TP) can easily be seen. In UZAM_PLC, only the extended pulse timer (TEP) is implemented. The following section explains the implementation of eight of 8-bit extended pulse timers (TEP) for UZAM_PLC.

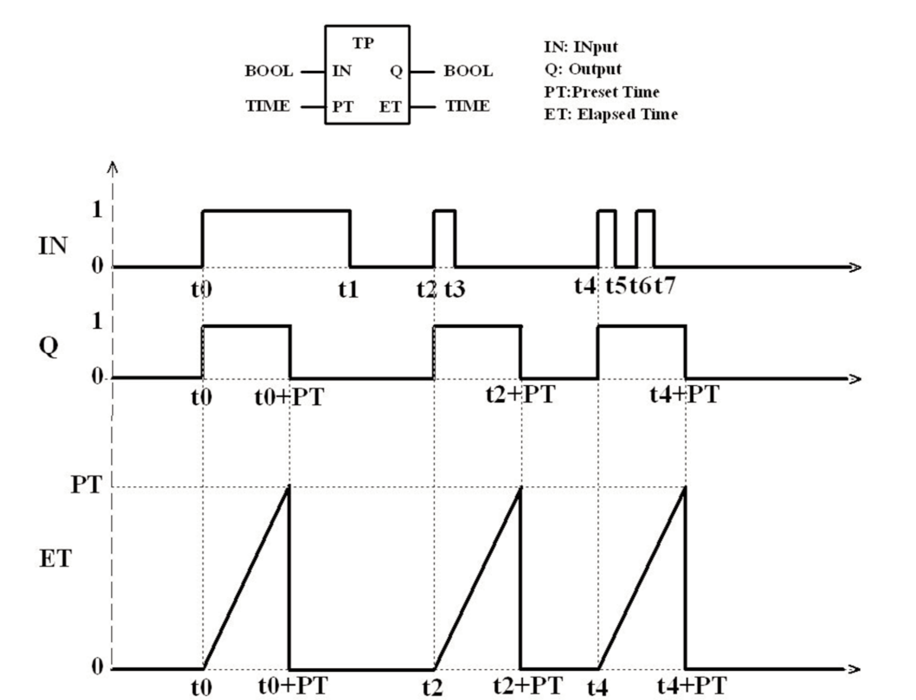


***Figure 1:** The symbol and timing diagram of the pulse timer (TP)*

Macro "TEP_8" (8-bit Extended Pulse Timer)

The macro "TEP_8" defines 8 extended pulse timers selected with the num = 0, 1…7. **Table 1** shows the macro "TEP_8" and its symbol.

IN (input signal), Q (output signal = timer status bit) and CLK {free-running timing signals – ticks: T00(0.512ms)…T15(16777 .216ms)} are all defined as Boolean variables. The time constant "tcnst" is an integer constant (here for 8-bit resolution it is chosen any number in the range 1-255) and is used to define preset time PT, which is obtained by the formula: PT = tcnst × CLK, where CLK should be used as the period of the free-running timing signals – ticks.

The extended pulse timer outputs are represented by the status bits: TEP8_Q,num (num = 0, 1…7), namely TEP8_Q0, TEP8_Q1…TEP8_Q7, as shown in Figure 2a. A Boolean variable, namely TEP8_RED1,num (num = 0, 1…7), is used as a rising edge detector for identifying the rising edges of the chosen CLK. Similarly, another Boolean variable, namely TEP8_RED2,num (num = 0, 1…7), is used as a rising edge detector for identifying the rising edges of the input signal IN, taken into the macro by means of W. An 8-bit integer variable TEP8+num (num = 0, 1…7) is used to count the rising edges of the CLK. The count value of TEP8+num (num = 0, 1…7) defines the elapsed time ET as follows: ET = CLK × count value of TEP8+num (either of 0, 1…7).

Let us now briefly consider how the macro "TEP_8" works. First of all, preset time PT is defined by means of a reference timing signal "CLK = t_reg,t_bit" and a time constant "tcnst". If the rising edge of the input signal IN is detected, by means of TEP8_RED2,num, then the output signal TEP8_Q,num (num = 0, 1…7) is forced to be true (ON – 1), and at the same time the

controller – Part 6

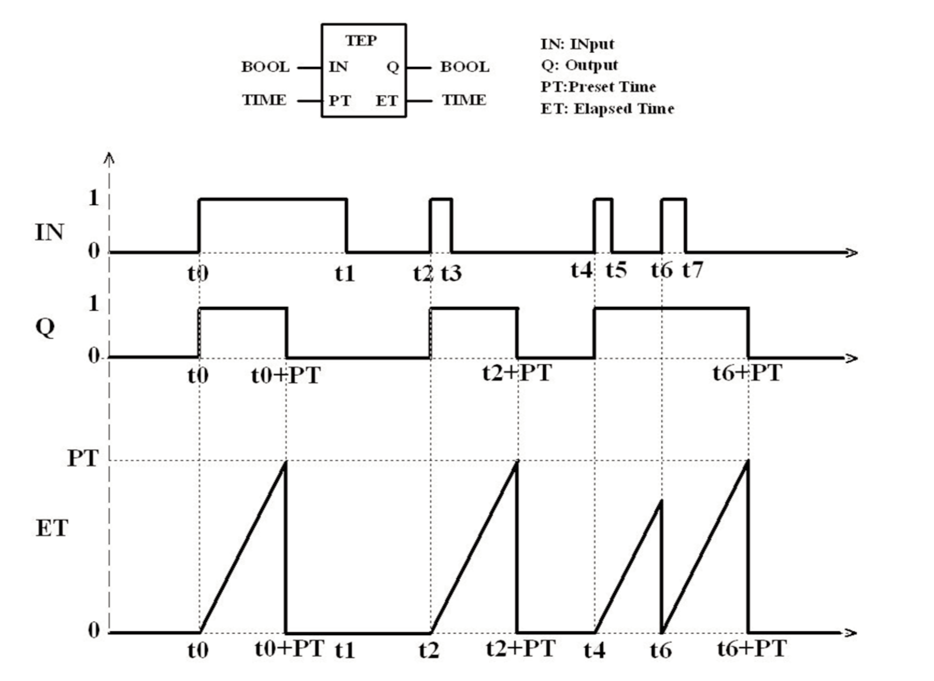


Figure 2: *The symbol and timing diagram of the extended pulse timer (TEP)*

counter TEP8+num (num = 0, 1…7) is cleared. After the output becomes true, i.e. TEP8_Q,num = 1, the related counter "TEP8+num" is incremented by one with each "rising edge" of the reference timing signal "CLK = t_reg,t_bit" detected by means of TEP8_RED1,num. When the count value of "TEP8+num" is equal to the number "tcnst", then state-change from 1 to 0 is issued for the output signal (timer status bit) TEP8_Q,num (num = 0, 1…7). In this macro a previously defined 8-bit variable "Temp_1" is also utilized.

Oscillator Timer (TOS)

The oscillator timer can be used to generate pulse trains with given durations for true (ON) and false (OFF) times. Therefore, the oscillator timer can be used in PWM (Pulse Width Modulation) applications.

The symbol and timing diagram of the oscillator timer (TOS) are both shown in **Figure 3**. PT0 (respectively PT1) defines the false (OFF) time {respectively true (ON) time} of the pulse. As the input signal IN goes and remains true (ON – 1), the OFF timing function is started and, therefore, the elapsed time ET0 is increased. When the elapsed time ET0 reaches the time specified by the preset time input PT0, the output Q goes true (ON – 1) and ET0 is cleared. At the same time, as long as the input signal IN remains true (ON – 1), the ON timing function is started and, therefore, the elapsed time ET1 is increased. When the elapsed time ET1 reaches the time specified by the preset time input PT1, the output Q goes false (OFF – 1) and ET1 is cleared. Then it is time for next operation for OFF and ON times.

This operation will carry on as long as the input signal IN remains true (ON – 1), generating the pulse trains based on PT0 and PT1. If the input signal IN goes and remains false (OFF – 0), then the output Q is forced to be false (OFF – 0). The following section explains the implementation of eight of 8-bit oscillator timers (TOS) for UZAM_PLC.

Macro "TOS_8" (8-bit Oscillator Timer)

The macro "TOS_8" defines 8 oscillator timers selected with the num = 0, 1…7. **Table 2** shows the macro "TOS_8" and its symbol. IN (input signal), Q (output signal = timer status bit) and CLK {free-running timing signals – ticks: T00(0.512ms)…T15 (16777.216ms)} are all defined as Boolean variables.

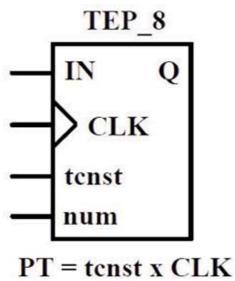
The time constant "tcnst0" is an integer constant (here for 8-bit resolution it is chosen any number in the range 1-255) and is used to define preset time PT0, which is obtained by the formula: PT0 = tcnst0 × CLK, where CLK should be used as the period of the free-running timing signals – ticks. The time constant "tcnst1" is an integer constant (here for 8-bit resolution it is chosen any number in the range 1-255) and is used to define preset time PT1, which is obtained by the formula: PT1 = tcnst1 × CLK, where CLK should be used as the period of the free-running timing signals – ticks.

The oscillator timer outputs are represented by the status bits: TOS8_Q,num

Macro

```
;--------- macro: TEP_8 -----------
TEP_8 macro    num,t_reg,t_bit,tcnst
      local    L0,L1,L2,L3
      movwf    Temp_1
      btfss    Temp_1,0
      bsf      TEP8_RED2,num
      btfss    Temp_1,0
      goto     L3
      btfss    TEP8_RED2,num
      goto     L3
      bsf      TEP8_Q,num
      bcf      TEP8_RED2,num
      clrf     TEP8+num
L3    btfsc    TEP8_Q,num
      goto     L2
      btfss    Temp_1,0
      goto     L1
L2    btfss    t_reg,t_bit
      bsf      TEP8_RED1,num
      btfss    t_reg,t_bit
      goto     L1
      btfss    TEP8_RED1,num
      goto     L1
      bcf      TEP8_RED1,num
      incf     TEP8+num,f
      movfw    TEP8+num
      xorlw    tcnst
      skpz
      goto     L1
      bcf      TEP8_Q,num
L1    btfsc    TEP8_Q,num
      goto     L0
      clrf     TEP8+num
L0
      endm
;----------------------------------
```

Symbol



num = 0, 1, …, 7

IN = 0, 1

CLK (t_reg,t_bit) = T00(0.512 ms), …, T15(16777.216 ms)

tcnst (8bit) = 1, 2, ..., 255

Q = TEP8_Q,num (num = 0, 1, …, 7)

Table 1: *The macro "TEP_8" and its symbol*

(num = 0, 1…7), namely TOS8_Q0, TOS8_Q1…TOS8_Q7, as shown in Figure 2a. We use a Boolean variable, namely TOS8_RED,num (num = 0, 1…7), as a rising edge detector for identifying the rising edges of the chosen CLK.

An 8-bit integer variable TOS8+num (num = 0, 1…7) is used to count the rising edges of the CLK. Note that we use the same counter TOS8+num (num = 0, 1…7) to obtain the time delays for both OFF and ON times, as these durations are mutually exclusive. The count value of TOS8+num (num = 0, 1…7) defines the elapsed time ET0 or ET1 as follows: ET(0 or 1) = CLK × count value of TOS8+num (either of 0, 1…7).

Let us now briefly consider how the macro "TOS_8" works. First of all, preset time PT0 (respectively PT1), is defined by means of a reference timing signal "CLK = t_reg,t_bit" and a time constant "tcnst0" (respectively "tcnst1"). If the input signal IN, taken into the macro by means of W, is false (OFF – 0), then the output signal TOS8_Q,num (num = 0, 1…7) is forced to be false (OFF – 0) and the counter TOS8+num (num = 0, 1…7) is loaded with "00h".

If the input signal IN is true (ON – 1) and the output signal Q, i.e. the status bit TON8_Q,num (num = 0, 1…7) is false (OFF – 0), then with each "rising edge" of the reference timing signal "CLK = t_reg,t_bit" the related counter "TON8+num" is incremented by one. In this case, when the count value of "TON8+num" is equal to the number "tcnst0", then "TON8+num" is cleared and a state-change from 0 to 1 is issued for the output signal (timer status bit) TON8_Q,num (num = 0, 1…7). If both the input signal IN is and the output signal Q, i.e. the status bit TON8_Q,num (num = 0, 1…7), are true (ON – 1), then with each "rising edge" of the reference timing signal "CLK = t_reg,t_bit" the related counter "TON8+num" is incremented by one.

In this case, when the count value of "TON8+num" is equal to the number

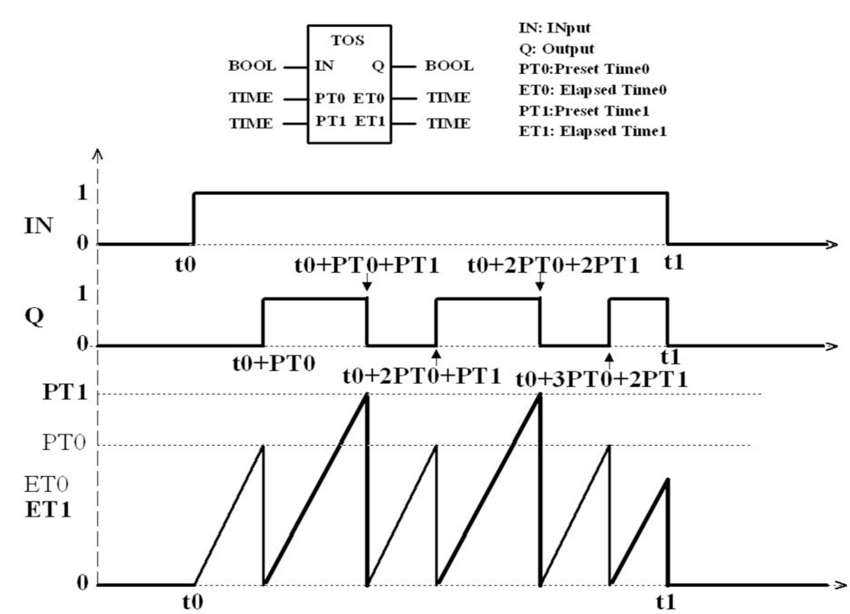


Figure 3: *The symbol and timing diagram of the oscillator timer (TOS)*

"tcnst1", then "TON8+num" is cleared and a state-change from 1 to 0 is issued for the output signal (timer status bit) TON8_Q,num (num = 0, 1 …7). This process will continue as long as the input signal IN remains true (ON – 1). In this macro a previously defined 8-bit variable "Temp_1" is also utilized.

Timer Macros Example

Let's consider an example, namely UZAM_plc_8i8o_ex11.asm, to show the usage of timer macros. In order to test this example please download the related files from http://host.nigde.edu.tr/muzam/ and then open the program UZAM_plc_8i8o_ex11.asm by MPLAB IDE and compile it.

Following that, by using the PIC programmer software, take the compiled file "UZAM_PLC_8i8o_ex11.hex" and by your PIC programmer hardware send it to the program memory of PIC16F648A microcontroller within the UZAM_PLC. After loading the "UZAM_PLC_8i8o_ex11.hex", switch the 4PDT in "RUN" and the power switch in "ON" position.

Finally, you are ready to test the example program. To check the correctness of the program you are referred to the related information for the each timer function provided above.

The example program, "UZAM_plc_8i8o_ex11.asm" is shown in **Figure 4**. It shows the usage of all timer macros described here.

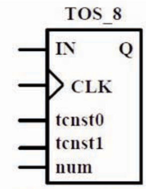
The schematic and ladder diagrams of the user program of "UZAM_plc_8i8o_ex11.asm" shown in Figure 4 are depicted in **Figures 5a** and **5b** respectively.

In the first two rungs, an on-delay timer "TON_8" is implemented as follows: the input signal IN is taken from I0.0. num = 0 and therefore we choose the first on-delay timer, whose timer status bit (or output Q) is TON8_Q0. The preset time PT = tcnst × CLK = 50 × 65.536ms (T07) = 3276.8ms = 3.2768s. As can be seen from the second rung, the timer status bit TON8_Q0 is sent

Macro

```
;--------- macro: TOS_8 --------------------
TOS_8 macro    num,t_reg,t_bit,tcnst0,tcnst1
      local    L1,L2,L3
      movwf    Temp_1
      btfsc    Temp_1,0
      goto     L3
      movlw    00h
      movwf    TOS8+num
      bcf      TOS8_Q,num
      goto     L1
L3    btfss    t_reg,t_bit
      bsf      TOS8_RED,num
      btfss    t_reg,t_bit
      goto     L1
      btfss    TOS8_RED,num
      goto     L1
      bcf      TOS8_RED,num
      incf     TOS8+num,f
      btfsc    TOS8_Q,num
      goto     L2
      movfw    TOS8+num
      xorlw    tcnst0
      skpz
      goto     L1
      bsf      TOS8_Q,num
      movlw    00h
      movwf    TOS8+num
      goto     L1
L2    movfw    TOS8+num
      xorlw    tcnst1
      skpz
      goto     L1
      bcf      TOS8_Q,num
      movlw    00h
      movwf    TOS8+num
L1
      endm
;---------------------------------------
```

Symbol



PT0 = tcnst0 x CLK
PT1 = tcnst1 x CLK

IN = 0, 1

CLK (t_reg,t_bit) = T00(0.512 ms), …, T15(16777.216 ms)

tcnst0 (8bit) = 1, 2, ..., 255

tcnst1 (8bit) = 1, 2, ..., 255

num = 0, 1, …, 7

Q = TOS8_Q,num (num = 0, 1, …, 7)

Table 2: *The macro "TOS_8" and its symbol*

```
;
      #include <cntct_mcr_def.inc>  ;Contact & Relay based macros
      #include <tmr_mcr_def.inc>    ;Timer macros
;
main
      initialize
      init_tmrs
scan

      get_inputs
;--------------- user program starts here -----------------------
      ld          I0.0              ;rung 1
      TON_8       0,T07,.50

      ld          TON8_Q0           ;rung 2
      out         Q0.0

      ld          I0.2              ;rung 3
      TOF_8       2,T07,.50

      ld          TOF8_Q2           ;rung 4
      out         Q0.2

      ld          I0.4              ;rung 5
      TEP_8       4,T07,.50

      ld          TEP8_Q4           ;rung 6
      out         Q0.4

      ld          I0.6              ;rung 7
      TOS_8       6,T07,.50,.50

      ld          TOS8_Q6           ;rung 8
      out         Q0.6

      ld          I0.7              ;rung 9
      TOS_8       1,T07,.30,.10

      ld          TOS8_Q1           ;rung 10
      out         Q0.7
;--------------- user program ends here --------------------------
      send_outputs

      goto  scan
      end                           ;directive 'end of program'
```

Figure 4: *The user program of UZAM_plc_8i8o_ex11.asm*

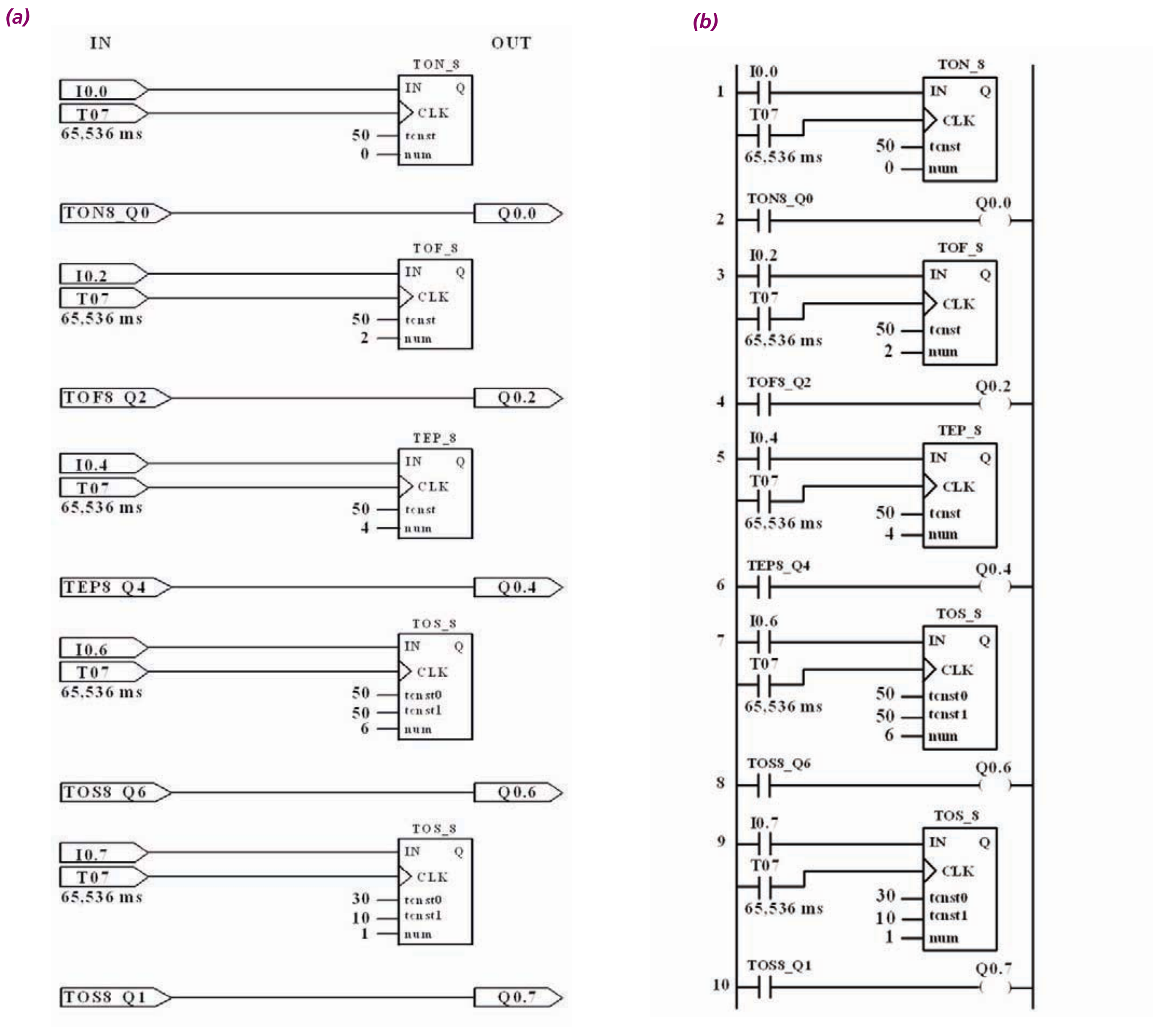


Figure 5:* *(a) *Schematic diagram and* ***(b)*** *Ladder diagram for the user program of UZAM_plc_8i8o_ex11.asm*

to output Q0.0.

In the rungs 3 and 4, an off-delay timer "TOF_8" is implemented as follows: the input signal IN is taken from I0.2. num = 2 and therefore we choose the third off-delay timer, whose timer status bit (or output Q) is TOF8_Q2. The preset time PT = tcnst × CLK = 50 × 65.536ms (T07) = 3276.8ms = 3.2768s. As can be seen from the rung 4, the timer status bit TOF8_Q2 is sent to output Q0.2.

In the rungs 5 and 6, an extended pulse timer "TEP_8" is implemented as follows: the input signal IN is taken from I0.4. num = 4 and therefore we choose the fifth extended pulse timer, whose timer status bit (or output Q) is TEP8_Q4. The preset time PT = tcnst × CLK = 50 × 65.536ms (T07) = 3276.8ms = 3.2768s. As can be seen from the rung 6, the timer status bit TEP8_Q4 is sent to output Q0.4.

In the rungs 7 and 8, an oscillator timer "TOS_8" is implemented as follows: the input signal IN is taken from I0.6. num = 6 and therefore we choose the seventh oscillator timer, whose timer status bit (or output Q) is TOS8_Q6. The preset time PT0 = tcnst0 × CLK = 50 × 65.536ms (T07) = 3276.8ms = 3.2768s. The preset time PT1 = tcnst1 × CLK = 50 × 65.536ms (T07) = 3276.8ms = 3.2768s.

In this set-up, the pulse trains we will obtain has a 50% duty cycle with the time period of T = 100 × 65.536ms = 6.5536s. As can be seen from the rung 8, the timer status bit TOS8_Q6 is sent to output Q0.6.

In the rungs 9 and 10, another oscillator timer "TOS_8" is implemented as follows: the input signal IN is taken from I0.7. num = 1 and therefore we choose the second oscillator timer, whose timer status bit (or output Q) is TOS8_Q1. The preset time PT0 = tcnst0 × CLK = 30 × 65.536ms (T07) = 1966.08ms = 1.96608s. The preset time PT1 = tcnst1 × CLK = 10 × 65.536ms (T07) = 655.36ms = 0.65536s. In this set-up, the pulse trains we will obtain has a 33.34% duty cycle with the time period of T = 40 × 65.536ms = 2.62144s. As can be seen from the rung 10, the timer status bit TOS8_Q1 is sent to output Q0.7. ■

WIN AN LED-DRIVING CONSTANT CURRENT DEMO BOARD!

Electronics World is offering its readers the chance to win a new demonstration board for LED applications from V•I Chip, Inc., a subsidiary of Vicor Corporation. The constant current PRM™ regulator board demonstrates the precisely regulated current output of the high-power density V•I Chip PRM. These devices deliver 99.7% across the load range, meeting the demands of direct-drive multi-LED applications where the intensity and brightness are controlled by regulating the current through the LEDs. The board can be used as a standalone non-isolated source to provide adjustable current up to 240 W (5 A at 48 V), or combined with V•I Chip VTM™ transformers to provide an adjustable isolated current up to 100 A. Paired PRM+VTM modules use less than 1 W for every 1,000 Lumens generated by the LEDs, enabling high-efficiency applications. This is a perfect complement to using BCM™ bus converters with low-voltage driver ICs for lower power applications such as LED TV backlighting.

The V•I Chip regulator board has Kelvin connections for measuring the efficiency of the V•I Chip components, independent of load connect losses, whilst oscilloscope probe jacks are available for measuring output voltage, including output voltage ripple. The board has fused PRM inputs and provision for mounting an optional V•I Chip pushpin heat sink, as well as system enable and disable.

To enter the prize draw send an email to surope@vicorpower.com, with the subject 'LED Competition' with a description of an application that could make use of the V•I Chip PRM driving LEDs. Your description should be less than 50 words. The winner will be both innovative and make best use of the benefits of the PRM. All entries must be received by April 30th 2009 and the winners name will be published in a subsequent issue of Electronics World.

To enter the prize draw send an email to:

europe@vicorpower.com

with the subject 'LED Competition' with a description of an application that could make use of the V•I Chip PRM driving LEDs. Your description should be less than 50 words. The winner will be both innovative and make best use of the benefits of the PRM. All entries must be received by April 30th 2009 and the winners name will be published in a subsequent issue of Electronics World.

ELECTRONICS WORLD & LANTRONIX COMPETITION OFFER

Lantronix (www.lantronix.com) is a global leader in secure communication technologies that simplify remote access, management, and control of virtually any electronic device regardless of location. Lantronix innovative solutions enable businesses to make better decisions, based on real-time information and are utilised in almost every vertical market including: security, building and industrial automation, medical/healthcare, IT/data center, government, transportation, pro AV/signage, retail, power and utilities.

In conjunction with Electronics World, Lantronix is offering readers a chance to win one of the SecureLinx Spider™ next generation KVM-over-IP kits, worth over £300. The kit provides secure KVM (keyboard, video, mouse) server management over an IP network. Unlike any other product on the market, Spider offers a flexible, scalable and affordable CAT5-based remote access KVM solution in a cable friendly, compact "zero-U" footprint package. Connected directly to the server, Spider guarantees non-blocked access from any web browser, anywhere, at any time! More cost-effective than traditional KVM, it provides one of the lowest "cost-per-remote-user" server management solutions available. Furthermore no client software or external power supply is required.

For a chance to win a copy of **Lantronix SecureLinx Spider kit**, please answer the following question: **WHAT DOES KVM STAND FOR?** Please send you response to:

lantronix.competition@livewirepr.com

with the following information: Name • E-mail • Job title (student if applicable) • Company/Educational institution • Address (Work or Home to be specified) • Tel No.

Please mark the subject heading as "Electronics World competition entry"

WAVERUNNER XI-A OSCILLOSCOPE SERIES

New Architecture Maximizes Speed, Performance, and Analysis Capabilities for 400 MHz – 2 GHz Oscilloscopes

LeCroy Corporation today announced the launch of the new line of WaveRunner Xi-A Oscilloscopes. Leveraging the innovations and industrial design developed for the recently launched WavePro 7 Zi and WaveMaster 8 Zi oscilloscopes, the WaveRunner Xi-A series of oscilloscopes deliver speed, performance, and analysis capabilities beyond anything in the 400 MHz to 2 GHz bandwidth range.

The WaveRunner Xi-A incorporates new X-StreamTM II hardware architecture to increase acquisition and display speed, TriggerScanTM rare event capture technology to improve debug and analysis, a new Spectrum Analyzer option to effectively debug in the frequency domain, and new connectivity and control options with LXI (LAN eXtension for Instrumentation) for automated test systems. The striking black and silver industrial design incorporates a large, bright display and a space-efficient footprint, and is available on all models which range from 400 MHz to 2 GHz, with 10 GS/s sample rate (400 MHz model WR 44(M)Xi-A 5 GS/s) and 25 Mpts memory.

The LeCroy WaveRunner Xi-A is the latest generation of the popular WaveRunner Xi oscilloscope platform, the most capable instrument available in its class. The combination of WaveRunner Xi power and flexibility with new architecture advances first tested and validated in LeCroy's revolutionary Zi oscilloscopes provides the WaveRunner Xi-A with the fastest acquisition and most responsive front panel in its class. The PC system in the WaveRunner Xi-A boasts a new motherboard, augmented with an Intel® Core™2 Duo processor, faster RAM, and a faster hard drive. This results in a 40-70% speed improvement over competitive units in deep memory analysis, and serial data decoding. The software improvements also incorporate key elements of X-Stream II architecture, providing preview and abort capabilities that permit the user instant control of the oscilloscope without any hold-off or delay.

Fast Throughput with X-Stream II Streaming Architecture

Designed for long memory operation and responsiveness, X-Stream II technology enables high throughput of data. This architecture uses variable waveform segment lengths to improve CPU cache memory efficiency resulting in faster processing compared to other oscilloscopes. This eliminates the trade-offs between long memory length and quick processing.

TriggerScan Accumulates More Anomalies/Second

TriggerScan rare event capture technology detects and captures more anomalies per second. TriggerScan uses high-speed hardware to detect undesired behaviors, then captures and displays them in a persistence mode for additional analysis of glitches, runts, and timing anomalies. A built in trainer identifies normal signal behavior and then constructs a large set of rare event trigger setups that target abnormal behavior. TriggerScan captures only the signals of interest and provides answers in minutes instead of hours.

Spectrum Analyzer Option Offers Debug in the Frequency Domain

The WaveRunner Xi-A Spectrum Analyzer option allows customers to effectively debug in the frequency domain. The option provides common controls of a spectrum analyzer, allowing a user to navigate a signal by specifying center frequency, span and resolution bandwidth. The Spectrum Analyzer option provides an additional feature to annotate peaks which is not available in spectrum analyzers. This feature allows the user to highlight a user-selectable number of peaks and illustrates the frequency and gain at the specific peaks, significantly reducing debug time.

LXI Compliance Enhances Connectivity

LXI is based on the open standard LAN (Ethernet) for system interdevice communication, and has been widely accepted in the test and measurement industry. LXI leverages the mature and robust LAN standard by offering a low cost solution that that is backward compatible and supported by all computer platforms. It also allows for automatic discovery, addressing, asset and network management, permitting engineers to build powerful, web enabled test systems in less time.

Full Set of Analysis Tools Includes Low-Speed Serial Data Trigger and Decode

In addition, all WaveRunner Xi-A models are compatible with LeCroy's optional low-speed serial triggering and decode packages to help engineers quickly analyze I2C, SPI, UART, RS-232, CAN, LIN and FlexRay protocols through the use of easy to read transparent overlays, search/zoom capabilities, and tabular displays. A full set of analysis tools, including WaveScanTM, an advanced search & analysis feature; WaveStreamTM, a fast viewing mode; and LabNotebook™, a unique tool for documentation and report generation combine high performance and ease of use with the best tools for understanding and validating a design. The Xi-A oscilloscopes are also hot-plug ready for LeCroy's 36-channel Mixed Signal Oscilloscope.

LECROY EUROPE:
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WaveRunner MXi-A Models Provide Complete Debug Solution

The WaveRunner MXi-A models (400 MHz – 2 GHz) go one step further and ship standard with a variety of analysis tools and application programs, such as Tracks, Histograms, long memory FFTs, user-defined functions, jitter and timing analysis, and are also compatible with mixed signal options, power device analysis, and a host of other applications. The WaveRunner MXi series goes beyond debug and validation to help engineers understand the root causes of complex problems.

Special DATA Acquisition Board

Maurizio Di Paolo Emilio presents a series of articles on a data acqusition (DAQ) board project for the management of environmental sensors and a high-speed data acquisition system. This article is the third in the series, focusing on the wireless and GSM aspects of the project.

THE DAQ board is composed of various slots for the upgrade. It can work on a VME bus but also by means of USB, GSM, wireless and Ethernet connection. It is composed of the following parts: GPS, analogue-to-digital converter, FPGA, serial port and a scaler.

In this article we will analyze the wireless and the GSM connections used with the DAQ board.

GSM Communications

GSM's air interface is based on narrowband TDMA technology, where available frequency bands are divided into time slots, with each user having access to one time slot at regular intervals.

GSM offers a variety of data services. GSM users can send and receive data, at rates up to 9600bps, to users on POTS (Plain Old Telephone Service), ISDN, Packet Switched Public Data Networks and Circuit Switched Public Data Networks, using a variety of access methods and protocols, such as X.25 or X.32.

The European version of GSM operates at the 900MHz frequency (and now at the newer 1800MHz frequency). Since the North American version of GSM operates at the 1900MHz frequency, the phones are not interoperable, but the SIMs are. Dual-band 900-1800 and 900-1900 phones are already released and in production.

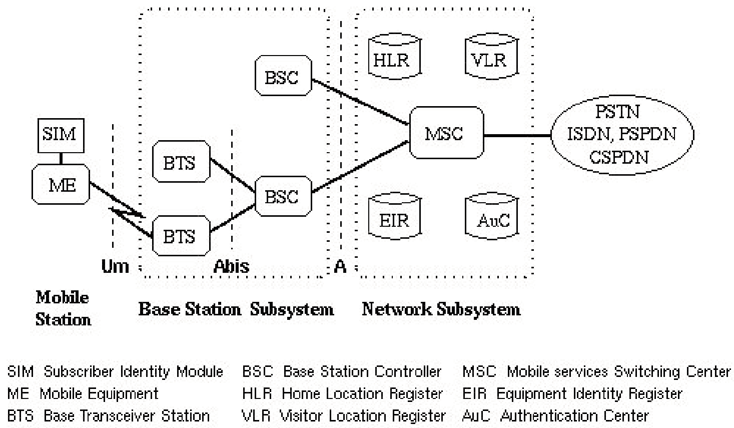


***Figure 1:** GSM network*

A GSM network consists of mobile stations talking to the base transceiver station, on the Um interface. Many BTS are connected to a BSC via the Abis interface and the BSC connect to the MSC (the core switching network) via the A interface (**Figure 1**).

GSM has used a variety of voice codecs to squeeze 3.1kHz audio into between 5.6 and 13kbit/s. Originally, two codecs, named after the types of data channel they were allocated, were used, called Half Rate (5.6kbit/s) and Full Rate (13kbit/s). These used a system based upon linear predictive coding (LPC). In addition to being efficient with bit rates, these codecs also made it easier to identify more important parts of the audio, allowing the air interface layer to prioritize and better protect these parts of the signal.

GSM was further enhanced in 1997 with the Enhanced Full Rate (EFR) codec, a 12.2kbit/s codec that uses a full rate channel. Finally, with the development

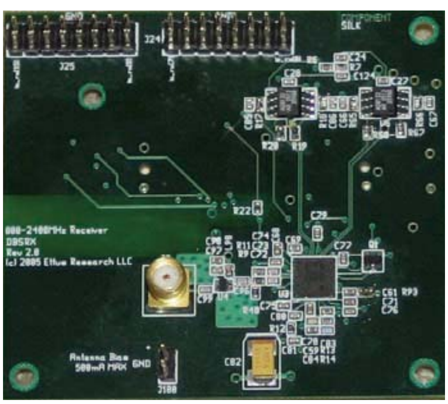


***Figure 2:** GSM board*

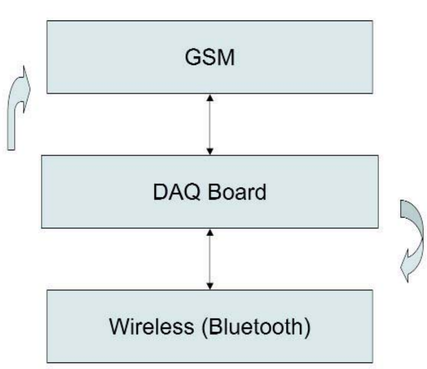


***Figure 3:** GSM and wireless*

PART 3

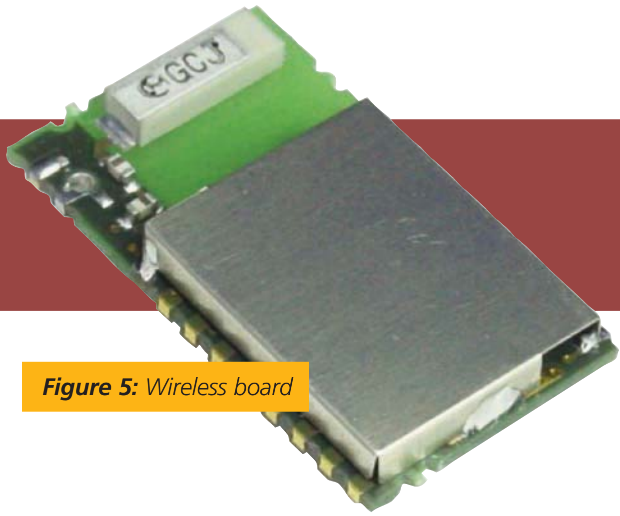


Figure 5: *Wireless board*

of UMTS, EFR was refactored into a variable-rate codec called AMR-Narrowband, which is high quality and robust against interference when used on full rate channels, and less robust but still relatively high quality when used in good radio conditions on half-rate channels.

For receiving GSM signals (**Figure 8**) it is advisable to choose DBSRX daughterboard (see **Figures 2** and **3**) and also plug it into one slot. It is a receiver only board but it covers the 800MHz–2.4GHz band, which is enough to receive most GSM signals used worldwide. This daughterboard along with, for example 900MHz to 2.6GHz PCB antenna, can be chosen by developers as a set of tools for further research and experiments.

The DBSRX frequency range covers many bands of interest, including all GPS and Galileo bands, the 902-928MHz ISM band, cellular and PCS, the Hydrogen and Hydroxyl radio astronomy bands, DECT and many more. The DBSRX is MIMO capable and can power an active antenna via the coax.

Wireless Communications

Wireless communication is the transfer of information over a distance without the use of electrical conductors or "wires". The distances involved may be short (a few meters as in television remote control) or long (thousands or millions of kilometers for radio communication). When the context is clear, the term is often shortened to "wireless". Wireless communication is generally considered to be a branch of telecommunications.

The BlueNiceCom IV module (BNCIV, **Figures 4** and **5**) is a completely integrated Bluetooth solution, containing Bluetooth radio (LMX9830), antenna and a fully implemented software protocol stack. The module provides reliable Bluetooth data communication links as well as audio communication links. Thus the module supports audio gateway applications (e.g. headset or handsfree).

The module features point-to-point and point-to-multipoint link management supporting data rates up to 704kbps. The internal memory supports up to seven active Bluetooth ACL links (data) and one SCO link (AUDIO). BlueNiceCom IV is supplied with an onboard chip antenna.

The BlueNiceCom IV module enables OEMs and designers to easily add wireless Bluetooth communication to their products without the need for RF and antenna design expertise.

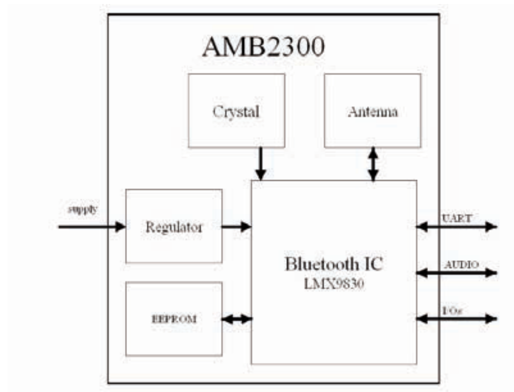


Figure 4: *Wireless board (block diagram)*

The firmware supplied within this module offers a complete Bluetooth (v2.0) stack including the following profiles:

- SPP (Serial Port Profile)
- GAP (Generic Access Profile)
- SDAP (Service Discovery Access Profile).

In combination with a host, BlueNiceCom IV additionally supports amongst others the following profiles:

- DUN (Dial up Networking Profile)
- FAX (Facsimile Profile)
- FTP (File Transfer Profile)
- HSP (Headset Profile)

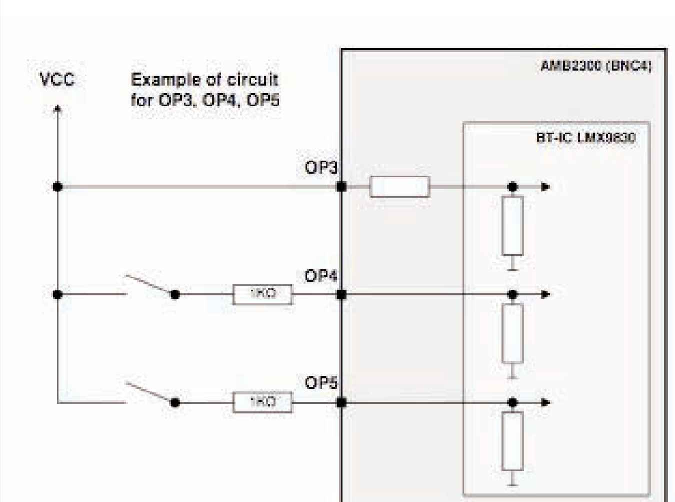


Figure 6: *Example of a circuit*

Pin name	Typ[1]	Notice
GND	I	Ground
OP3	I	At start up configuration of the UART-data rate, otherwise internal use
PG7	I/O	GPIO (default setting as output, display a data exchange)
SCLK	I/O	Audio PCM Interface Clock
SFS	I/O	Audio PCM Interface Frame Synchronization
SRD	I	Audio PCM Interface Receive Data Input
STD	O	Audio PCM Interface Transmit Data Output
OP5	I	Configuration UART-data rate at Start up
OP4	I I/O	Configuration UART-data rate at Start up, otherwise GPIO
RESETBB#	I	Reset, internal Pull up, active low
CTS#_BT	I	Host Serial Port Clear To Send, active low [2] - see footnote 2
RTS#_BT	O	Host Serial Port Request To Send, active low [3] - see footnote 3
TX_BT	O	Host Serial Port Transmit Data
RX_BT	I	Host Serial Port Receive Data
PG6	I/O	GPIO (default setting as output, display a link connection)
NC	I	Not connected, no ground
Vcc	I	Power consumption, 2.9V to 3.6V
Antenna	O	Connection for external antenna[4] - see footnote 4
GND	O	

***Figure 7:** Datasheet*

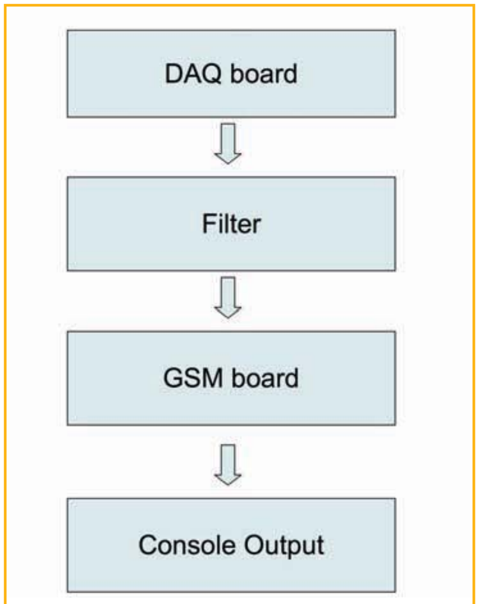


***Figure 8:** GSM processing signal*

- HFP (Handsfree Profile)
- OPP (Object Push Profile)
- SYNC (Synchronisation Profile)
- BIP (Basic Imaging Profile)
- BPP (Basic Printing Profile).

Depending on the respective application, BlueNiceCom IV can either be linked to a processor via serial UART-interface or directly to a terminal device. Configuration of the module is being effected through a host processor. Depending on the application and pre-parameterization, BlueNiceCom IV can either be operated as 'master' module or as standalone 'slave' module. The module supports automatic 'slave' operation eliminating the need for an external control unit.

The technical specifications are:

- Voltage supply 2.9 to 3.6V;
- Current consumption typical 65mA;
- RF output typical 0dBm (Class 2);
- Rx sensitivity typical -80dBm;
- Data rate UART 2.4 to 921.6kbit/s;
- Operating temperature -20°C to 70°C;
- Integrated chip antenna;
- Connection of an external antenna is also possible;
- Dimensions are 27.5 x 16.0 x 3.5mm;
- Bluetooth-PIN 0000;
- Miscellaneous: All further technical data according to the LMX9830 module from National Semiconductor.

Bluetooth Communication

Bluetooth is a wireless protocol for exchanging data over short distances from fixed and mobile devices, creating personal area networks (PANs). It was originally conceived as a wireless alternative to RS232 data cables. It can connect several devices, overcoming problems of synchronization.

It is a free technology and it is provided by the mobile phone operators who are having the capability of GSM and CDMA technologies.

Bluetooth uses radio waves frequency as a medium and is suitable for the 1, 10 and 100 meters distance. Every Bluetooth-enabled device, such as mobile phones, laptops, digital cameras, video games consoles, have built-in microchip. There are about more than 1800 members of the Bluetooth consortium from all over the world. Every GSM and CDMA mobile operator must provide the features of the Bluetooth technology to its users. Like the Bluetooth, Wi-Fi uses the same frequency but the power consumption of the Wi-Fi is high so it produces more powerful signals.

Bluetooth uses radio waves that operate at 2.4GHz bands. The personal computers must have built-in dongle in them to use the Bluetooth technology. Bluetooth is also used to transfer the files from the mobile phones or PDA devices to the computers. Also, you can transfer files and information between people with Bluetooth devices. Microsoft Windows XP with the service pack 2 has the built-in support for the Bluetooth technology. Bluetooth defines the wireless standards to maintain the secure data communication.

Bluetooth technology also provides support for VOIP (Voice Over IP). The Bluetooth headset provides the wireless extension to the Bluetooth device. A typical Bluetooth device consist of RS transceiver, protocol stacks and basebands and it does not require to install the additional drivers to use the Bluetooth technology and it can connect all the office peripheral such as computer with printer, computer with scanner and computer with laptop.

Among the other advantages of the Bluetooth technology is the automatic synchronization of the desktops, mobile phones and other Bluetooth held devices. Another popular use of the Bluetooth is in the automotive sector. The most commonly Bluetooth held devices are mobile phones, personal computers, laptops, headsets, access points, car kits, speaker phone, streaming video, MP3 players, SIM cards, Push-2-talk, PDA and digital cameras. ■

The series continues in the next issue of Electronics World magazine. If you missed your last copy you can order your digital version of that issue on line at
www.electronicsworld.co.uk

Dynamic traffic lights control system using computer vision

Huseyin Kusetogulları and **Emre Gokus** from the Eastern Mediterranean University in Turkey and **Turgay Celik** from Nanyang Technological University in Singapore propose a novel dynamic traffic lights control system that uses computer vision that is automatic with almost no human interaction required

IN THIS ARTICLE, we propose a novel method to make the flow of traffic faster. Image processing techniques are used to control the delay of traffic lights according to the number of vehicles in a lane where traffic lights are located. The system uses a single video acquision device for each lane and a single central computer that controls the traffic lights.

A traffic surveillance camera system is used in various applications for protection of the public and private areas, measuring data and obtaining information for statistical analysis. Furthermore, the system is used to make the flow of traffic faster.

In a complex traffic surveillance and control scenario, traffic density can be measured from video data to control a number of subsequent traffic lights at different crossings. In recent years, image processing techniques have been applied to the field of traffic research for queue detection, incident detection, vehicle classification, vehicle counting and estimating the speed of cars for security and safety reasons.

Early designs included the vehicle speed measurement sensors such, as magnetic loop detector and radar, which are more reliable in detecting and counting vehicles, however, they are also avoided because of the destruction caused on the asphalt during installation, as well as due the interruption of the traffic.

In this article, image processing is used to count the number of vehicles in each lane. The number of detected vehicles is used to adapt time delays for traffic lights. Most of the time, even there are no cars waiting in other lanes, you still have to wait for a green light in your own lane, which wastes time and fuel. We use image processing to check the existence of vehicles in other lanes and this information is then used for controlling the traffic lights to avoid unnecessary waiting.

The proposed system uses 'background subtraction' to find the difference image between the current frame and the registered background. Adaptive tresholding is applied to convert the difference image to a binary image. After the binary image is determined vehicles are detected. Each detected vehicle is classified into one of two types: light vehicles, i.e. a car, motorbike etc, and large vehicles, such as a truck, lorry, juggernaut etc. The reason behind this classification is to make our system behave more realistically.

Each vehicle needs a certain time interval to pass through a traffic light. On average, light vehicles make their actions within 3 seconds and large vehicles make it within 5 seconds. So the number of vehicles with average action times gives the time interval that each traffic light should use. For instance, if there are two vehicles in the lane and one of them is a lorry and the other a car, then the duration of green light for this lane will be 8 seconds.

Proposed System Configuration

The configuration of the system is shown in **Figure 1**. Cameras are positioned along the lanes for a wider view. Acquired images are

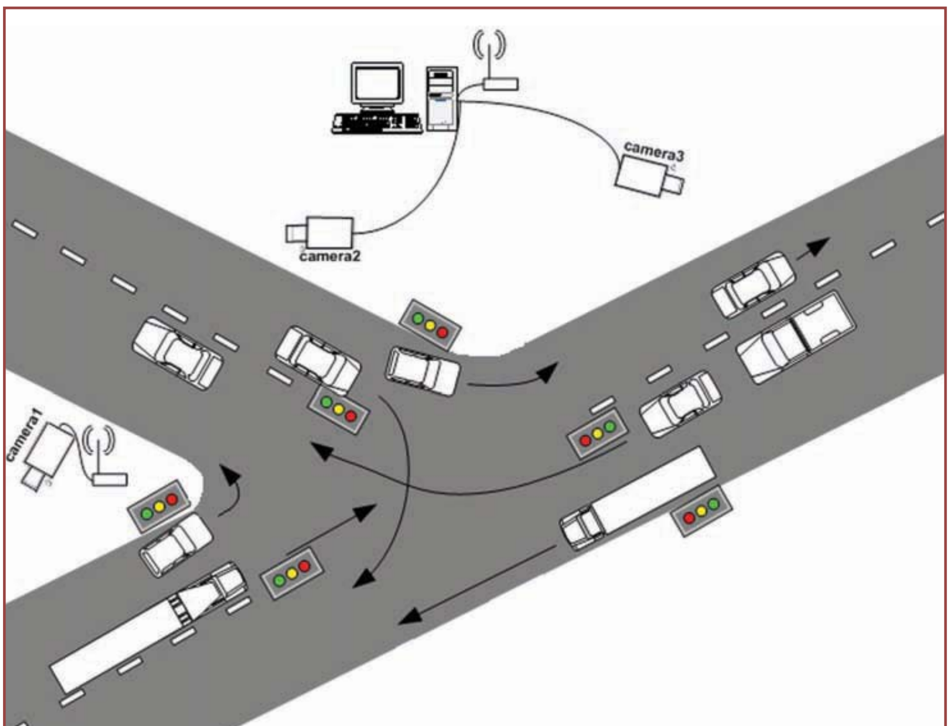


Figure 1: *System configuration*

processed by a central computer that controls the traffic lights via a radio frequency (RF) link.

The background image is subtracted from the current frame to detect the moving object. Several methods already exist to update the background image.

An image of an empty road, called the background image, is used from a reference frame. Vehicle detection using image processing is based on the comparison between a current picture-frame with the background image; this is known as 'background subtraction'. Consequently, each frame is subtracted from the reference frame to determine the difference frame, which is then converted into a binary form by using the adaptive thresholding method. The background image is adaptively updated by the system in order to combat changes in daylight and other conditions that may cause false detection.

The proposed system uses a number of image processing techniques including RGB to greyscale conversion, image subtraction and thresholding. After the conversion to greyscale, the current frame is subtracted from the background frame, which is formulated as follows:

$$I_d = I_c - I_r \quad (1)$$

where I_c is current frame and I_r is the background image. The subtraction gives the difference frame I_d. Thresholding is applied to the difference image. This process generates a binary image I_r for further processing. The threshold value τ is obtained statistically and is given in **Equation 2**:

$$I_\tau(x,y) = \begin{cases} 255, & \text{if } I_d(x,y) \geq \tau \\ 0, & \text{otherwise} \end{cases} \quad (2)$$

$$\tau = \mu + \sigma$$

***Figure 2: (a)** current frame, **(b)** background image, **(c)** resulting difference image, **(d)** binary image obtained by thresholding the difference frame*

Figure 3: *The start positions of vehicles;* ***(a)*** *a light vehicle;* ***(b)*** *safe position for a light vehicle;* ***(c)*** *start position of a large vehicle;* ***(d)*** *safe position for a large vehicle*

where μ and σ are mean and standard deviation of the difference image formulated in Equation 1, and τ are the coordinates of the spatial location.

Figure 2 illustrates the process of background subtraction and converting the difference image into a binary image. Figure 2a shows the current frame and 2b the registered background image. The difference between the two is shown in Figure 2c, with the binary version in Figure 2d. It is very clear that vehicles have been detected.

After creating the binary image, the next stage will be detecting the moving vehicles. For this purpose, we apply 'connected component labelling', where the aim is to group all the pixels with a single label, with respect to their connectivity. For instance in Figure 2, there are five different groups of pixels. In order to remove effects of noisy measurements, a number of pixels in each group are compared with a predefined threshold and the groups with a number of pixels less than the predefined threshold are not accepted as moving vehicles. In our system 40 is used for threshold and this value is determined statistically.

In order to determine how much time each moving vehicle needs to be in a 'safe' position where each car has already passed through the junction with the traffic lights, we do a set of tests. We used recorded video sequences and manually determined how much time each type of vehicle needed to be in a safe position. A test area where video sequences are recorded is shown in **Figure 3**.

Each picture shows a snapshot from a three-lane junction controlled by traffic lights and under different conditions. In order to determine how much time is required for light vehicles to be in safe position, we manually labelled two times: the time when the vehicle is near the traffic lights (starting point in Figure 3a) and the time when the vehicle is at the safe position (end point in Figure 3b). The difference between them gives the time interval for each vehicle to be in the safe position.

A similar action is performed for the large vehicles. This is demonstrated in Figures 3c and 3d.

Dynamic Traffic Lights Adaptation Algorithm

The overall algorithm to determine dynamic green-light duration for each lane is given as a flowchart in **Figure 4**. The first step of the algorithm is the generation of a background image. The background image is generated when there are no moving objects in the observed scene.

The next stage is the subtraction of the current frame from background image. The resultant data is converted into binary image by using adaptive threshold defined in Equation 1. After the binary image is prepared, the background image is updated with pixel values where there is no moving object, in another words if the binary value of the difference image is 0 then the background image at the corresponding pixel value is updated with the data coming from the acquisition device, and vice versa. This way, an adaptive background model is kept in the memory so that the change in lighting conditions does not affect the overall performance of the system.

The connected component labelling algorithm is applied to the binary difference image to detect any moving objects. Sometimes, due to the noisy data acquisition, the resultant binary difference image consists of regions where even if there hasn't been a change, it shows that a moving object has been detected. In order to combat this effect, each moving object is tested against a constant threshold, and objects with a number of pixels less than 40 are seen as false alarm and are not taken into consideration.

Each moving region with a number of pixels greater than 40 is classified into two categories: light or large vehicles. The total time delay that will be applied to the corresponding lane's traffic lights is increased by 5 for large vehicles and by 3 for light vehicles. This process is repeated for each detected moving-region. This renders the total delay that will be used to apply a green light at the corresponding traffic lights.

After waiting for the other lanes to be processed, this course is repeated again. Here the advantage is that if there is no waiting car in any of the other lanes, then the corresponding process finishes immediately.

Testing Proposed System

The performance of the proposed algorithm depends mainly on the detection and correct classification of the detected vehicles. For this purpose we have performed a series of tests.

We recorded 10 video sequences, under different conditions, for the junction shown in Figure 3. Each recorded video is 10 minutes long with 30 frames per second (fps). For each video we manually count the number of light and large vehicles. Then the proposed algorithm is applied to count and classify the detected objects automatically.

The number of vehicles that were and were not detected is shown in **Table 1**. It is clear that our proposed system makes a correct detection and classification with 99.62%, with an overall miss rate of 0.38%. This rate is satisfactory enough to realise proposed algorithm in real-time.

	# OF DETECTED	# OF NOT DETECTED	TOTAL
SMALL SIZE OF VEHICLES	3230	10	3240
LARGE SIZE OF VEHICLES	137	3	140
TOTAL	3367	13	3380

Table 1: *The number of detected and not detected vehicles for one lane*

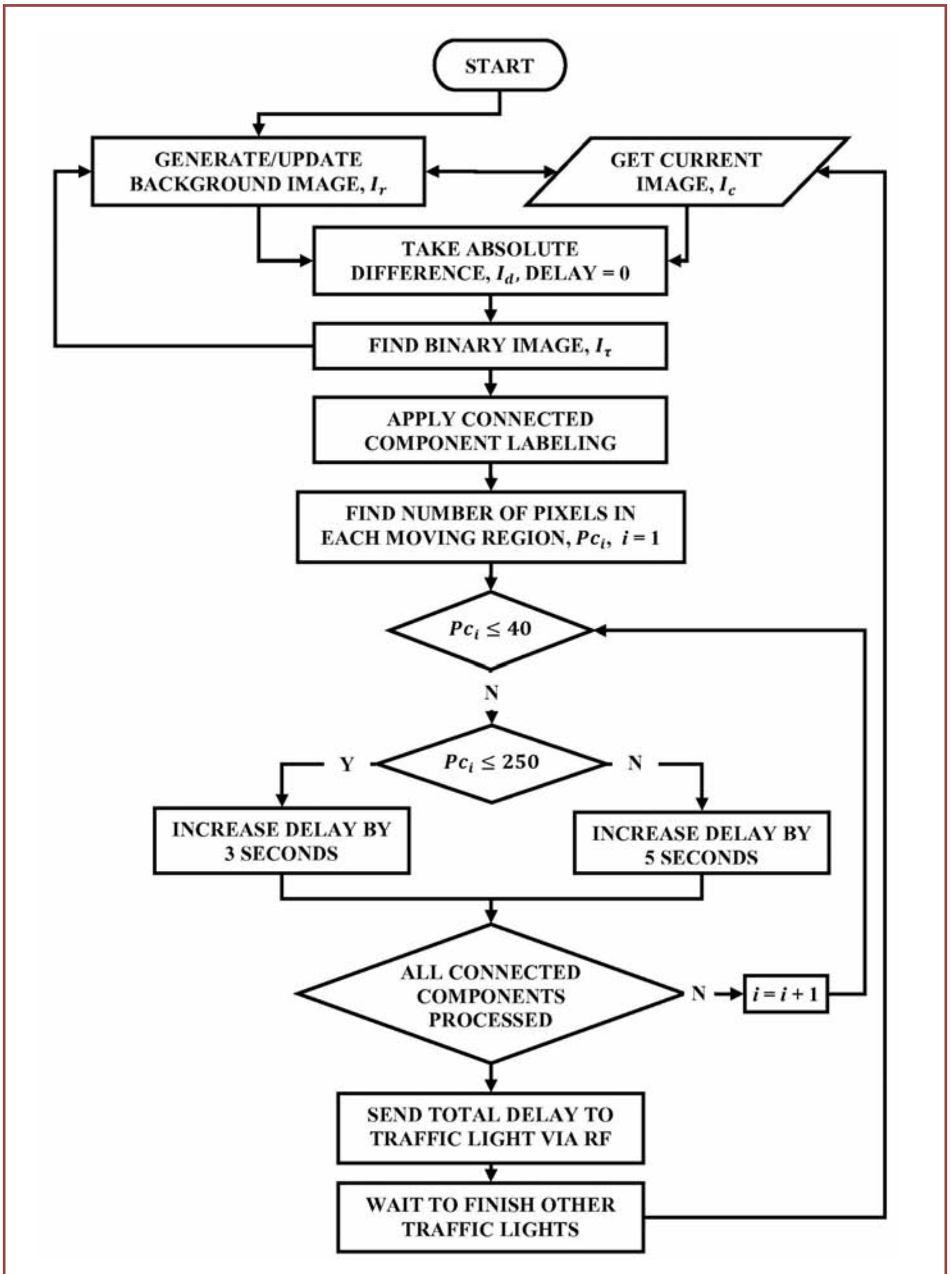


Figure 4: *Flowchart of the system*

Automatic System

In this paper we present a dynamic traffic lights control system using computer vision. The system is completely automatic with almost no human interaction required. The system brings a solution to consuming time and energy caused by waiting at traffic lights. Traffic lights are adapted dynamically with respect to the number of vehicles waiting in lanes. If there are no waiting vehicles in any other lanes, the system will grant a green light to the vehicle in the lane where it has been detected. ■

DESIGN OF A VOLTAGE-CONTROLLED, HIGH-CURRENT SOURCE WITH BIPOLAR OUTPUT

A VOLTAGE-CONTROLLED, high-current source with bipolar output is introduced in this article. Using a simple operational amplifier system to produce a voltage and current output, this source can provide 25V, 0-2A adjustable constant current. Experiment results show that this constant current source has characteristics of high load stability and lower ripple.

Voltage-controlled current source is widely used in the electronic equipment, which need higher load stability. The traditional current sources include parameter constant current source which uses diode, triode, integrated voltage source as regulator; series feedback regulation type current source, switching constant current source and so on. Parameter current source has a low current output range and a low current stability. Serial feedback current source also has a small current output and a low efficiency. Switching current source not only has a complicated circuit and a large amount of components but also has higher ripple and poor reliability. Considering the former disadvantages, this design adopts the ordinary operational amplifier combined with a triode to produce a current and voltage output. This circuit can precisely provide a high current and voltage output; moreover, it is simple with low cost.

Circuit Design

Figure 1 is the principle diagram of this circuit. The external controlling voltage signal is input to the constant current module consisted of operational amplifiers. The current output passes through a voltage expansion module and a current expansion module to provide constant current to the load.

The output current is sampled by sampling resistance. The obtained sampling signals are fed back to the constant current module through a voltage feedback module. The power module supplies power to the voltage module and the current module.

Figure 2 is the circuit of constant current module consisting of operational amplifiers and the voltage-feedback module. The sampling feedback signal from the current output is first dealt with by the voltage divider, and then it passes through the follower and reverser, which consist of operational amplifiers. Finally, this signal is sent to the reverse end of the reverse-phase adder U4 and added by the voltage controlling signals. The output voltage of the operational amplifier V3 is:

$$V3 = -(Vi - V2/m) \quad (1)$$

where

$$m = 1 + R22/R23 \quad (2)$$

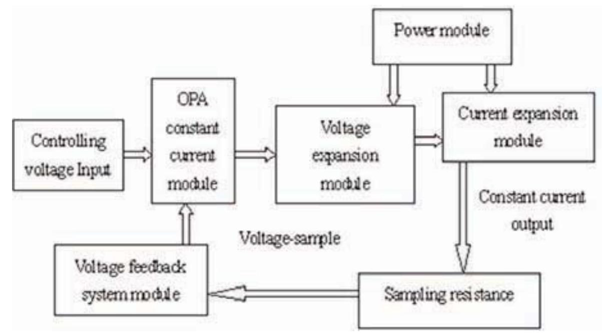


Figure 1: *Principle diagram of the circuit*

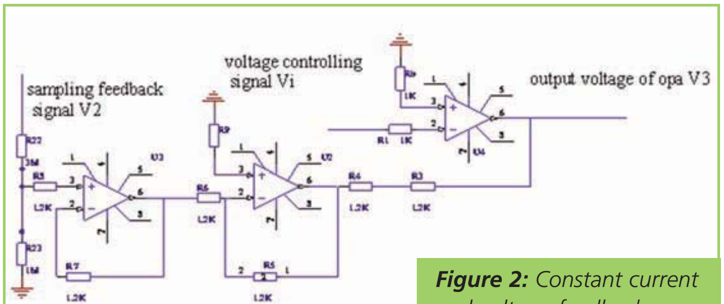


Figure 2: *Constant current and voltage-feedback module*

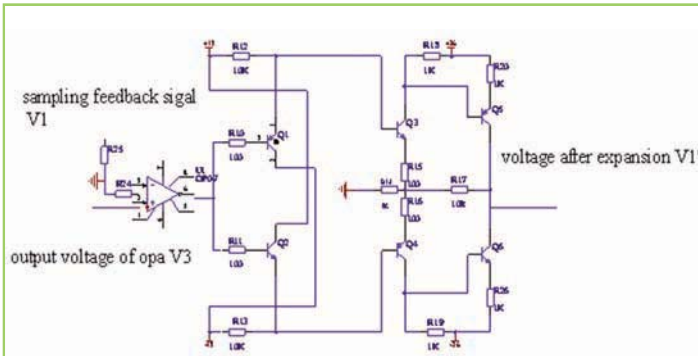


Figure 3: *Voltage expansion module*

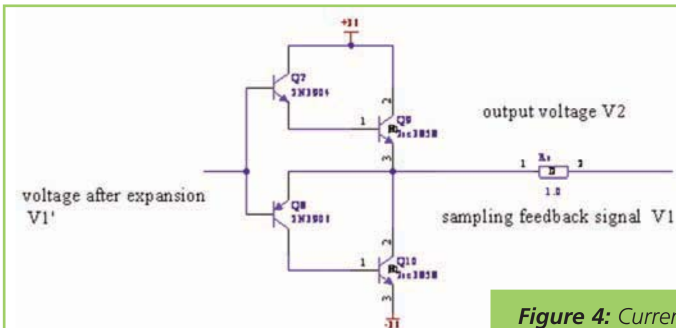


Figure 4: *Current expansion module*

Figure 3 is the circuit diagram of the voltage expansion module. The differential amplifier constructed by the operational amplifier compares the output voltage after the voltage divider and the sampling signal from the constant current system. This differential signal forms the final output voltage. A pair of mated triodes is used in this system to obtain a bipolar output. The open-loop gain of this system is only determined by the ratio of R17 and R14. But after the voltage is divided and fed back by R25 and R14, this system is like an amplifier, whose gain is determined by R25 and R24.

Figure 4 is the circuit diagram of the current expansion module. A simple common method of totem-pole current expansion is applied. The selection of the power-triode and the thermal sink assures the power output. Thus, the output voltage after current expansion and voltage expansion is:

$$V1 = nV3 \quad (3)$$

where

$$n = 1 + R25/R24 \quad (4)$$

RS is sampling resistor. In the circuit of constant current source, precision of the sampling resistor directly affects the stability of the current output. In this experiment, 2Ω, 10W precision metal film resistor with temperature-drift less than 5ppm/°C is used as the sampling resistor. After voltage-sampling at the two ends of the sampling resistor respectively, the current (I) passing through the sampling resistor is:

$$I = (V2-V1)/2 \quad (5)$$

According to the above circuit analysis Equations 1 and 3, we can get**:**

$$V2/n - V1/m = Vi \quad (6)$$

Adjust the resistance of R22, R33, R24 and R25 to make m = n = l. In this experiment l is equal to 4, so the output current is:

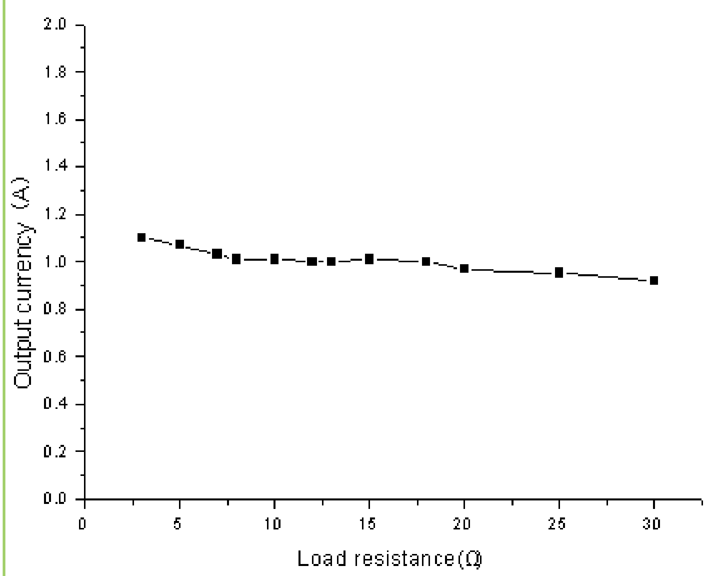


Figure 5: *Experimental result of load stability*

$$I = 4V1/2 \quad (7)$$

Equation 7 shows that the current passing through sampling resistance is only related to the input controlling voltage.

Experimental Results

In this experiment, a normal voltage source is used as input controlling signal and a high-power variable resistance of 50Ω is used as the simulative load. The output current ripple of this constant current source is 0.8%. The main ripple comes from the stability of the controlling signal.

Higher output precision can be obtained if the high precision voltage signal is used. **Figure 5** is the curve of load stability. The current begins to attenuate if the load resistance is more than 30Ω because the power supply is only 36V.

Hongzhi Jia, Boshi Jiang and Qianqian Li
University of Shanghai for Science and Technology
China

TIP 1: REDUCING OUTPUT-DELAY OF MODERN RS-485 TRANSCEIVERS FOR BUS VOLTAGES GREATER THAN V_{CC}

By Thomas Kugelstadt, Senior Applications Manager, Texas Instruments

HIGH-SPEED data links using RS-485 typically require fast bus access times, that is, transmit data must occur on the A and B bus lines almost instantly after activating the driver via the driver enable terminal, DE. While older transceivers maintain a short delay between output data and enable signal, many modern designs, using sophisticated output stages for minimum reverse leakage current, can cause extended delays when the bus voltage potential exceeds the supply voltage. This paper describes the problems caused by an extended output delay, its root cause and the solution to circumvent the conditions that lead to the problem in the first place.

Problem

When switching from passive (tristate) into active mode, modern RS-485 transceivers can present a non-specified, long delay between the output voltage, V_{OD}, and the driver enable signal, DE, if the common-mode voltage, V_{CM} exceeds the transceiver supply, V_{CC}. This delay elongates significantly with rising values of V_{CM} and can lead to data loss in time-critical applications.

The timing diagram in **Figure 1** shows a delay of several hundreds of nanoseconds between the differential output voltage, V_{OD}, and the driver enable signal DE when V_{CM} (5.4V) is higher then V_{CC} (5.0V). In comparison to the above, output delays reduce to well below 100ns when V_{CM} is equal to or below V_{CC}.

Root Cause

The root cause lies in the biasing requirements of the device enhanced output structure during tristate (**Figure 2**). The output stage comprises a network of PMOS transistors that:

- provide a large differential output signal at low supply;
- sense whether the line voltages (V_A, V_B) exceed the transceiver supply;
- minimize leakage current if V_A, $V_B > V_{CC}$.

The biasing sequence involves the charging and discharging of the gate capacitances of the internal PMOS FETs and, in particular, the large gate-capacitance of the large output drive PMOS-transistors.

In active mode, the output PMOS transistors are biased for forward conduction, thus driving the transmission line with low output impedance, which assures that the line voltages are below V_{CC}.

In disabled mode, however, the tristated, high-impedance outputs receive the full common-mode voltage, V_{CM} at their terminals. When Q3 detects that the common-mode voltage is higher than the supply voltage ($V_{CM} > V_{CC}$), the biasing network (dotted block), biases Q2 such, that it conducts the output pin voltage to the gate of Q1 to prevent it from reverse conduction.

Because the gate charges of the PMOS FETs drastically increase for common-mode voltages higher than V_{CC}, the charge and discharge time constants become significantly longer. Thus, when enabling the transceiver, the output stage's re-biasing into forward conduction leads to the aforementioned long delay.

Solution

To minimize the delay keep the line voltage below the transceiver supply during tristate by connecting pull-down resistor, RPD, from each signal line to driver ground. As shown in **Figure 3**, these resistors build a voltage divider with the transceiver input impedances that attenuates the common-mode voltage below the supply level.

The RPD value is calculated via

$$R_{PD} < \frac{R_{INEQ}}{V_{CM}/V_{CC} - 1}$$

with R_{INEQ} being the equivalent input resistance of all transceivers connected to the bus. While it is possible to increase the divider ratio for higher common-mode voltages, care must be taken that the parallel value of R_{PD} and R_{INEQ} is higher than the specified maximum common-mode loading of 375Ω:

$$\frac{R_{PD} \cdot R_{INEQ}}{R_{PD} + R_{INEQ}} \geq 375\Omega$$

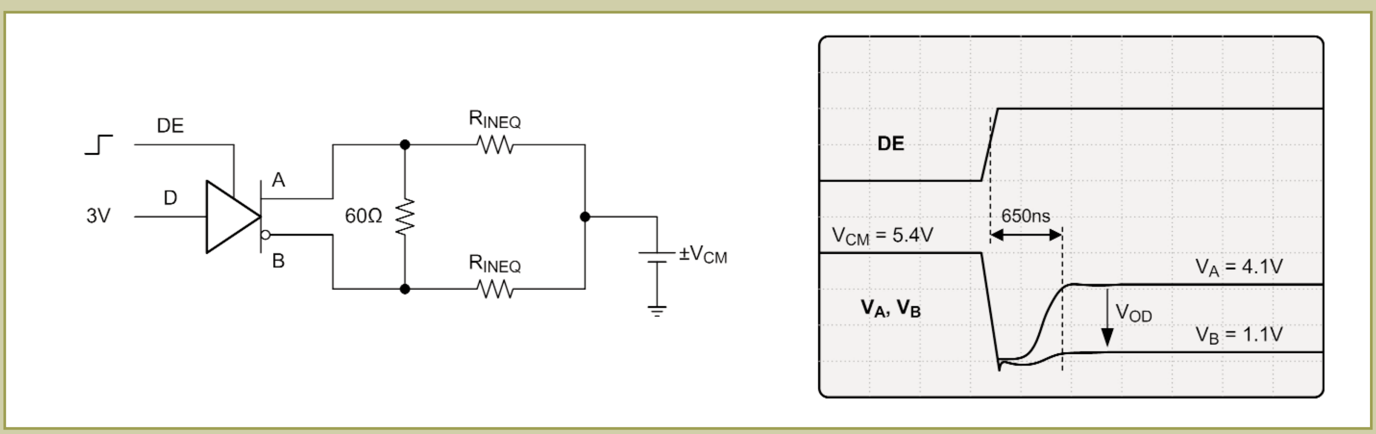


Figure 1: *VOD-to-DE delay due to VCM > VCC*

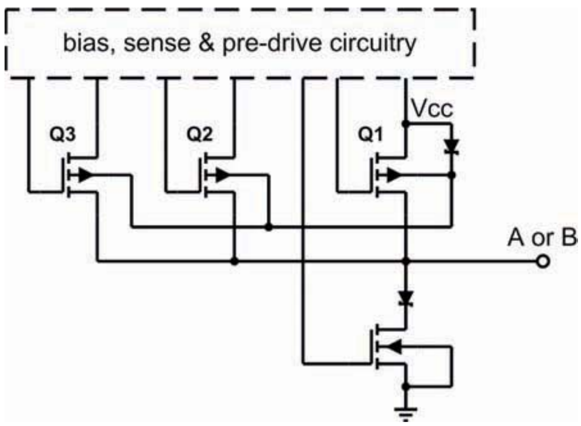


Figure 2: *Transceiver PMOS output structure*

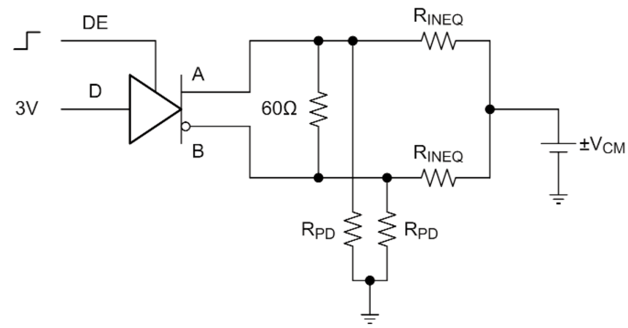


Figure 3: *Pull-down resistors at A and B attenuate VCM below VCC*

MINIATURE CRYSTALS OFFER HIGH STABILITY AND LOW AGEING

IQD Frequency Products has launched a new range of low-cost miniature quartz crystals for use as timing sources in consumer electronics and computing applications. The new CFPX-181 series is available in a range of fundamental frequencies from 16MHz to 50MHz.

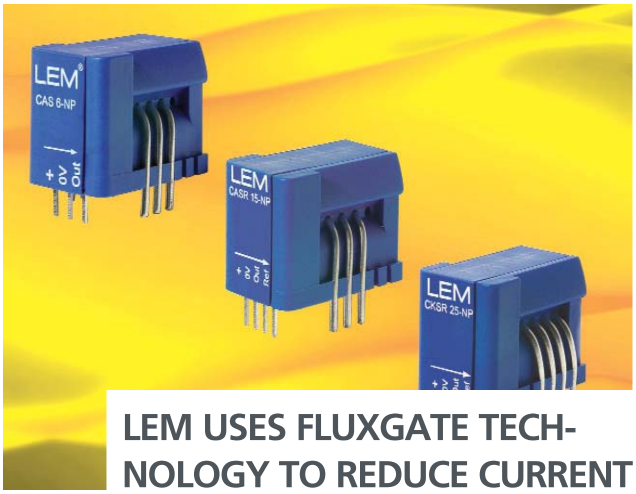
Housed in a hermetically sealed, four-pad ceramic SMD package measuring just 2.5 x 2.1mm, the CFPX-181 series is suitable for use in set-top boxes and personal video recorders (PVRs), games consoles, smart-card readers and a wide variety of computer peripherals and IT equipment with tight space and cost limitations.

For accurate performance at high data transfer rates, the CFPX-181 can be specified to stabilities as good as 10ppm over an operating temperature range from –10° to +60°C. Crystal ageing properties are also excellent at just 1ppm per year (maximum, at +25°C).

Consumer and ICT devices are being made continually smaller and lower in price, but still have to cope with ever increasing data rates. The company says the CFPX-181 is the perfect timing source to use in such applications, for systems with oscillator circuitry already embedded into a chipset: a miniscule crystal with cutting-edge performance and stability.

CFPX-181 crystals can be delivered in both bulk-pack and tape-and-reel formats.

www.iqdfrequencyproducts.com



LEM USES FLUXGATE TECHNOLOGY TO REDUCE CURRENT TRANSDUCER SIZE BY 30%

LEM has introduced several ranges of PCB-mounted current transducers housed in a package 30% smaller than the company's LTS devices. The CAS, CASR and CKSR family of transducers are intended for AC and DC isolated current measurement from 6-50A_{RMS} nominal, up to three times the nominal values for the peak measurement and up to 300kHz (±3dB).

All the models (6A_{RMS}, 15A_{RMS}, 25A_{RMS} and 50A_{RMS}) are housed in the same compact package and can be set up on PCB according to the needs for different ranges from 1.5-50A_{RMS} respectively.

The new transducers have been specially designed to respond to the technology advances in drives and inverters, which require better performance in areas such as common-mode influence, thermal drifts (offset and gain; max thermal offset drift for the models with reference access: 7 to 30 ppm/K according to the models), response time (less than 0.3 microseconds), levels of insulation and size.

To obtain this performance the Closed Loop Fluxgate technology has been used. This enables LEM to combine high accuracy and attractive price without compromising any of the advantages of the LTS family, such as size, dynamic performance and wide measuring range.

www.lem.com

ONE OF THE LOWEST VOLTAGE EEPROM DEVICES AROUND IS NOW LAUNCHED

Microchip has announced a series of I2C EEPROM devices with the lowest operating voltage available on the market. The 24VLXX series of devices has an operating voltage down to 1.5V for both read and write operations, with a very low operating current of less than 400μA.

These 1kbit and 2kbit EEPROM devices are the first to support two different write-protect features; the 24VL014, 24VL024 and 24VL025 can be ordered with a full-array write protect. The 24VL014H and 24VL024H devices support a half-array write protect.

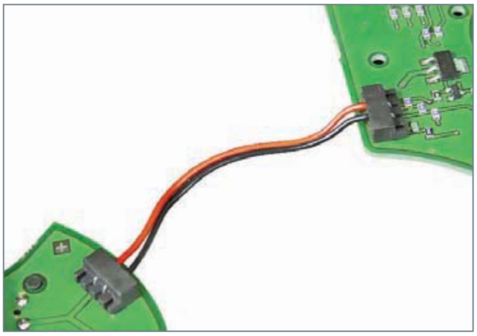
With an operating frequency of 100kHz at 1.5V, the new EEPROMs can operate in portable and handheld applications with very low voltages, thus reducing power consumption and extending the useful life of the battery.

The new 24VLXX devices provide another option for designers looking to maximize battery life in their applications.

The very low voltage EEPROM devices are supported by the MPLAB Starter Kit (part number DV243003 at $79.98). The kit includes the MPLAB Starter Kit for serial memory products board, a serial EEPROM starter pack, a USB cable and a CD containing the MPLAB IDE, Total Endurance software model and a serial EEPROM interface tool.

www.microchip.com

NEW PCB INTERCONNECTS SET TO BENEFIT MANY ELECTRONIC APPLICATIONS



Inconnect Ltd, the specialist cable harness manufacturer based in Lincoln, has teamed up with Hylec-APL, which specializes in the bulk supply of electrical and electronic components, to jointly promote the range of PCB interconnects manufactured by the German company Provertha GmbH.

One in the range, the 'Wire Clip', simplifies the termination of cable to PCB boards; its small size and low profile are ideal for designs where space is at a premium. The vertical or horizontal mount connectors stand just 4.5mm above the board. The design of the connector is ideal for those applications where vibration may be an issue and it can be manually or flow soldered.

The special feature of the Wire Clip is that the wire's ends, having been terminated, form the contacts thus eliminating the need for standard terminations and, therefore, offers significant cost savings over conventional methods.

Terminations are on a standard 2.54mm pitch, with 2, 4, and 6 pole options as standard and they are suitable for wires between AWG18-AWG26.

The Wire Clip will be of benefit in many industries, its application being particularly appropriate for the test instrumentation and the aeronautical, automotive and marine markets.

www.inconnect.uk.net

SUPERFAST, COMPACT KIOSK PRINTER – THE STAR MICRONICS TUP500 SERIES

DED has introduced its Star Micronics TUP500 Series. Based on the tried and tested TUP900 model, known worldwide for providing effective printing solutions in a host of applications, the TUP500 brings new features along with versatility to the kiosk printing marketplace.

Demonstrating the ultimate in flexibility, the TUP500 prints thermal receipts, tickets, barcodes and labels at the superfast speed of up to 220mm per second with the standard 15cm paper roll. The compact TUP500 offers an easy 'lift and tilt' mechanism for hassle-free paper loading of paper stock from 45-82.5mm wide and media of up to 0.15mm thick.

Offering a versatile, open frame kiosk printing solution, the TUP500 features removable metal sides as standard so that the paper spindle holders or control panel can be relocated to meet the most demanding of kiosk layouts.

Options on the TUP500 include a flashing paper exit guide/snout and a 25cm paper roll holder for horizontal or vertical use (maximum capacity of 18cm in vertical role).

The TUP500 has drivers for Windows 2000 and XP, Ethernet, USB, parallel and serial interface options and is compatible with OPOS, Java-POS, Linux, ESC/POS and Microsoft Windows with WHQL certification.

www.ded.co.uk

TREND COMMUNICATIONS LAUNCHES SIX NEW FIBRE OPTIC TESTERS

With increasing customer demands for test products, in a rapidly expanding sector of optical fibre-based telecommunications, Trend Communications is excited to announce the introduction of a new range of six fibre optic testers to complement its existing product line.

The new products include optical power meters, attenuators and multimeters which are simpler and far lower in cost than the premium versions hitherto supplied, new laser sources, fibre identifiers and fault locators, and a PON power meter.

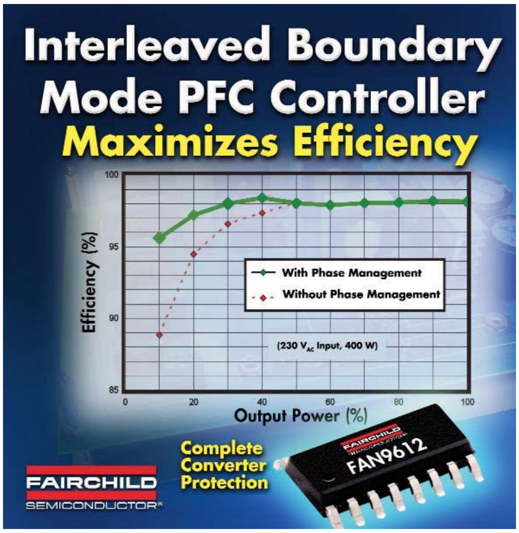
The fibre identifier is an essential installation and maintenance tool used to identify power and traffic direction in jacketed or bare fibre without service interruption. The clamp design allows the tester to detect light in the fibre without damage or disconnection and with low bending loss.

The visual fault locator is used for the location of faults in single-mode and multi-mode fibres using light in the visible spectrum to reveal bad connections, fibre breaks and excessive bending in jacketed or bare fibre.

The optical light sources are simple to use transmitters that can be used in conjunction with other types of test equipment. There are three types in the range.

www.trendcomms.com

INTERLEAVED BOUNDARY-MODE PFC CONTROLLER FOR HIGH EFFICIENCY IN GREEN POWER SUPPLIES



Fairchild Semiconductor brings power supply designers a boundary-conduction mode (BCM) interleaving power factor correction (PFC) controller that provides over 96% power conversion efficiency for AC-DC power supplies. Applications include power supplies for digital TVs, desktop and entry-level server computers, front-end telecom systems and industrial power systems rated from 100W to 1000W.

Historically, the higher-efficiency and lower-cost BCM PFC converters are limited to about 300W of maximum power level. Interleaving extends the power range of BCM control while ripple current cancellation minimizes high peak currents. By interleaving and keeping two power stages at precisely 180 degrees out of phase timing under all operating conditions, the FAN9612 lowers conduction losses. These energy-conservation benefits are integral in helping customers meet the latest Energy Star and Climate Savers Computing Initiative requirements.

By the interleaving of the power trains, the FAN9612 is also able to reduce the input filter size and reduce board space by as much as 10%, compared to alternative solutions.

The FAN9612 incorporates many features including automatic phase disable to operate with only one channel under light-load conditions; a low start-up and operating current; and valley switching technology that minimizes losses at MOSFET turn-on.

www.fairchildsemi.com

ALPHA LAUNCHES ADVANCED TELECORE XL-806 PB-FREE CORED WIRE

Alpha, Cookson Electronics has launched Alpha Telecore XL-806, a new Pb-free cored solder wire featuring the latest technological innovations that deliver world class soldering performance and reliability.

The company claims that users will experience its fast wetting and significantly lower spattering performance versus the previous generation of competitive cored wire products. Alpha Telecore XL-806's unique formulation allows it to withstand the higher temperatures required for Pb-free component attach and rework while offering overall superior functionality.

Alpha Telecore is also highly reliable. It will be available in SAC305, SACX0307 and SACX0807 alloys with both 2.2% and 3.3% flux loading, in order to meet the widest range of customer requirements.

Alpha Telecore XL-806 Pb-free cored wire is classified as J-STD-004 ROM1 (for Halide content) and it passes all reliability testing for the ROL1 classification, including testing for ROL1 Copper Mirror, Copper Corrosion, SIR and EMC 'uncleaned' for the ROL1 classification. It also passes the HP ECM test and SIR based on the IPC J-STD, JIS and Bellcore tests.

www.alpha.cooksonelectronics.com

YOKOGAWA OFFERS TOTAL PACKAGE FOR AUTOMOTIVE BUS TESTING

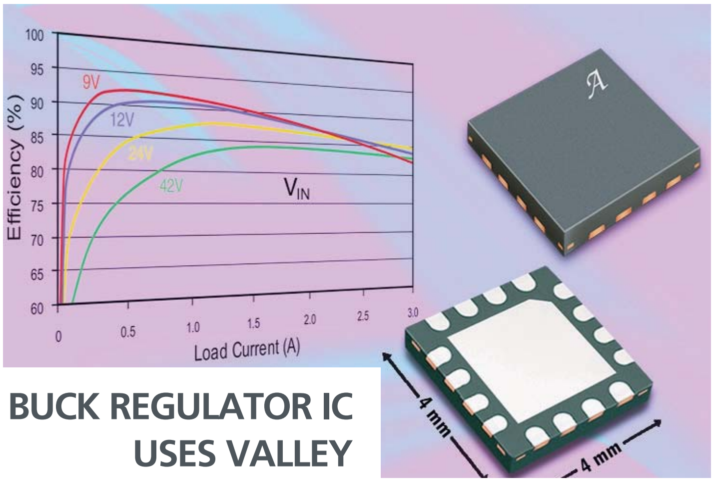
With the launch of the new DLM2000 mixed-signal oscilloscope (MSO), Yokogawa Europe is now able to offer a complete package of test & measurement solutions for analysing the serial bus systems that are increasingly being used in the automotive sector.

The DLM2000, which includes dedicated trigger functions for CAN, LIN, UART, I2C and SPI serial bus patterns, is complemented by Yokogawa's established SB5000 vehicle serial bus analyser, which offers the ability to debug and analyse the Flexray high-speed vehicle bus with associated physical-layer testing.

The DLM2000 series is a new family of MSOs that represent a major step forward in terms of price/performance specification and ease of use. With up to 500MHz bandwidth and 2.5GS/s sampling speed, the new oscilloscopes have the longest memory (up to 125M points) and fastest update rate (up to 450,000 waveforms per second) in this class of instrument. In addition, the combination of flexible analogue and digital inputs, plus a large-screen display in a compact ergonomically styled body, makes the instruments exceptionally easy to use.

In addition to the key performance specifications, the DLM2000 series also offers histogram and trending functions, up to 20,000 history memories, digital filtering, zoom windows and user-defined mathematics.

www.yokogawa.com



BUCK REGULATOR IC USES VALLEY CURRENT-MODE CONTROL TO ACHIEVE HIGH SWITCHING FREQUENCY

The new A4403 from Allegro MicroSystems Europe is a 3A buck regulator IC which uses a valley current-mode control scheme to offer very low switch-on times, making it ideal for applications that require high switching frequencies combined with high input voltages and low output voltages.

The high step-down ratio made possible by an 'on' time of less than 50ns permits a wide output voltage range from 0.8V to 15V at 3A from an input supply voltage range from 9V to 46V. Standby current is less than 100 microampere.

The device's capability for high switching frequencies (up to 2MHz) leads to the use of smaller and lower-value ancillary components such as inductors and capacitors, while the high level of integration means that a minimal number of external components are needed. As a result, the A4403 provides a compact, flexible and cost-effective solution for office automation, industrial and consumer applications.

Optimal drive circuits are utilized to minimize switching losses, and the switching frequency is maintained constant as the input voltage modulates the 'on' time. This feed-forward control ensures excellent line correction. An external resistor pulled up to the input supply programs the 'on' time.

www.allegromicro.com

CONGA-ARKIT: A REFERENCE PLATFORM FOR AUTOMATION

congatec AG presents the conga-ARkit, a complete solution package for the implementation of PLC functions.

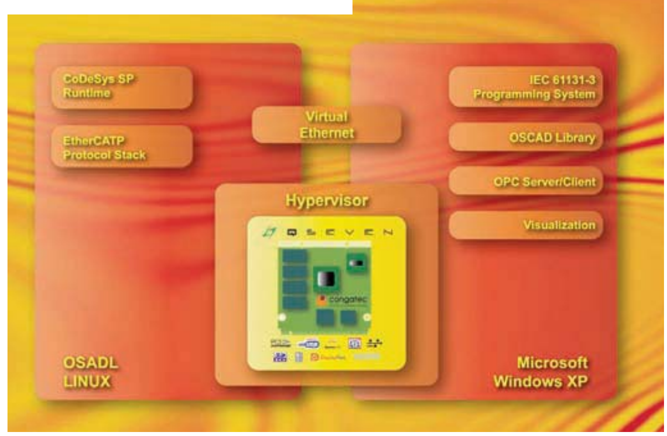
This comprehensive package was developed in conjunction with 3S-Smart Software Solutions GmbH, Real-Time Systems GmbH and OSCAT ('Open Source Community for Automation Technology'). It addresses PLC manufacturers and companies that intend to integrate PLC functionality in their applications.

The conga-QA, a Qseven Computer-On-Module with the Intel Atom Processor Z530, was chosen as the hardware basis. Due to its compact dimensions of just 7x7cm², this module can be easily integrated via top-hat rail housing. Additionally, it provides capable, future-oriented interfaces and can simultaneously run two separate operating systems thanks to hyper-threading and virtualization support. This makes the well-priced conga-QA the ideal platform for the majority of control and visualization tasks.

The kit includes a suitable evaluation carrier board to facilitate the use of the Qseven module. This provides access to all Qseven interfaces through standard connectors. Manufacturer-specific I/O components can then be flexibly configured and controlled via Ethernet/Ethercat or another suitable field bus.

The software package, which has been compiled on an entirely application-orientated basis, comes pre-installed on a bootable USB stick.

www.congatec.com



HIGHEST CURRENT RATINGS AVAILABLE IN THE 1206 FORM-FACTOR, AT TYCO

Tyco Electronics introduced recently a new line of fast-acting, high-current chip fuses. The surface mount chip fuse offers strong arc suppression characteristics and some of the highest current ratings available in the industry-standard 1206 form-factor. It helps provide overcurrent protection on power supplies, servers, communications equipment, voltage regulator modules and other space-constrained applications.

Key device parameters for the high-current fuse include rated current values up to 20A with voltage ratings up to 24VDC, operating temperature range of -55°C to +125°C, 100A interrupt rating at rated voltage and halogen-free and RoHS compliant packaging.

The fuse's monolithic, multilayer design enhances high temperature performance and contributes to the high inrush current withstanding capability.

The new high-current chip fuse complements and expands Tyco Electronics's line of overcurrent protection devices. The small form-factor device promises to help designers optimise board space requirements in high-current, high-temperature applications.

www.tyco.com

NEW TROGAMID LIQUID LEVEL SWITCHES FEATURE VERY HIGH CHEMICAL RESISTANCE

Sensortechnics introduces the new OLT liquid level switches for cost-effective optical point level detection. These sensors feature very high chemical resistance due to their Trogamid miniature plastic housings making them suitable for a wide range of medical and industrial OEM applications.

The OLT series can be used with many liquids which are not compatible with conventional polysulphone housings such as fuel, halogenated hydrocarbons (e.g. chloroform), methanol, acetone and ethyl acetate. Furthermore, Trogamid can also be used in direct contact with food and drinking water.

The optical OLT switches use solid state technology with no moving parts to measure accurately and reliably the presence or absence of liquid in tanks, reservoirs and pipes. The product range includes basic devices with analogue phototransistor outputs, switches with microprocessor compatible TTL signals, or high power devices with transistor outputs for switching currents up to 500mA. With their miniature threaded housings the OLT sensors are easy to install and consume little space. Additionally, Sensortechnics can easily modify or customise these products to fit special customer requirements.

www.sensortechnics.com/olt

LITRE METER OFFERS DIGMESA FLOW METERS FOR UK INDUSTRIAL APPLICATIONS

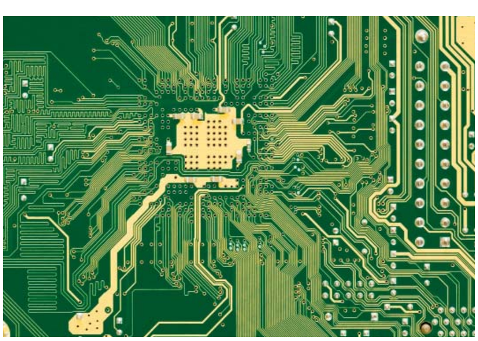
UK flowmeter specialist Litre Meter has introduced a range of industrial flowmeters from Swiss manufacturer Digmesa.

The devices are employed in a wide range of industrial and process applications worldwide – from measuring highly aggressive etching fluids used in the manufacture of electronic chips through to dispensing detergent concentrates and disinfectants in industrial washing systems. Litre Meter is now able to supply the full Digmesa range to UK customers.

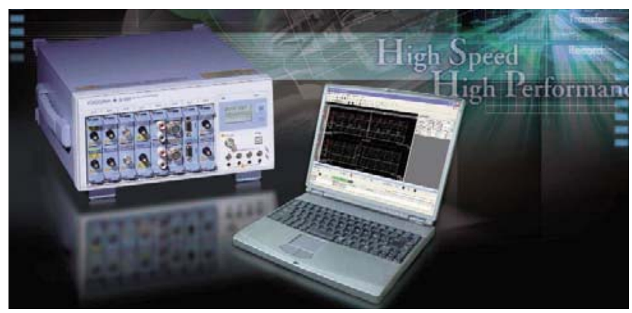
The meters offer a measuring accuracy of ±0.25%, even in long term operation and across a temperature range from -10°C to +120°C. The design is based on detection of electronic pulses generated by an impeller turned by the fluid flow. Different materials, bearings and electrical properties can be supplied to meet the needs of different applications, including variants that can be used to automatically switch off pumps or other processing equipment if flows fall below specified levels.

The Digmesa product line complements the range of flowmeters built by Litre Meter in its own premises in Buckingham. The company offers a broad range of metering technologies suitable for virtually every liquid, gas or steam measurement application and has particular expertise in measuring low flow rates.

www.litremeter.com



SOFTWARE ADDS NEW FUNCTIONALITY TO PC-BASED DATA-ACQUISITION SYSTEM



New acquisition and utility software has been introduced to add additional functionality and ease of use to the Yokogawa SL1000 PC-based data-acquisition system.

Extra functionality provided by the software includes the ability to link and synchronize multiple SL1000 units, new triggering and display capabilities, support for the Windows Vista operating system, waveform interpolation and CSV file conversion. In addition, improved user friendliness is provided by a number of enhancements to the set-up, display and measurement operations.

The most significant feature of the new software is the ability to interconnect and synchronize up to eight SL1000 units, allowing simultaneous measurements on up to 128 channels. In such a configuration, one unit is allocated as the master for controlling functions such as start/stop, triggering and alarms.

The software also includes file transfer functions and other utilities which ease the handling and merging of measurement files from multiple synchronised units.

The software also enhances the user friendliness of the SL1000 by providing improved features such as scaling, icons, trigger adjustment, measurement settings and display modes.

www.yokogawa.com

SMALLER, LIGHTER CIRCULAR CONNECTORS FROM ITT INTERCONNECT SOLUTIONS

Industry-leading connector manufacturer ITT Interconnect Solutions has shrunk the size and reduced the weight of its circular interconnection components, while still maintaining their high levels of reliability and performance in tough environments. The new, compact Trinity MKJ connectors are better prepared to deal with the demands of high-end system designs, such as those used in medical, military, space and industrial scenarios.

Employing a choice of three different coupling methodologies (bayonet, threaded, or breakaway), this component portfolio offers a fully optimized mix of functionality and flexibility. Though scaled down, components in the Trinity series do not come up short. They meet the highest of specs in terms of long-term reliability and operating performance despite their reduced proportions, and have been engineered to ITT's most stringent quality standards.

Jam nut, square flange and in-line versions are available. Master and secondary keys allow multiple clocking positions to be utilized.

The connectors are targeted at military hardware, medical equipment, industrial instrumentation, and avionics applications. These include soldiers' helmets/backpacks, aircraft pilots' headsets, missiles, un-manned surveillance aircraft, satellites, and patient monitoring instruments.

www.ittcannon.com

NEW SIZE COMMERCIAL MIL-C CONNECTORS FROM HARWIN

High-reliability interconnect company Harwin has announced a new size within its commercial Mil-C-5015 connector range, plus the availability of end caps and rubber bushing attachments to suit the entire product family.

The new size 12S Mil-C-5015 connector increases design flexibility and adds to Harwin's existing 10SL and 14S sized parts. Devices can be terminated as cable connectors, straight plug or panel mount products. Applications for this product family include mass transit, robotics, machine tools, welding equipment, extension leads, power cords and industrial and agricultural vehicles, plus COTS applications where Mil C qualification is not mandatory.

End caps come available in two different versions. One style has an inner thread, while the other has an exterior thread, so it is possible to either screw the cap into or onto the connector. The rubber bushings enable IP 67 sealing to be achieved protecting the connector from water dust and chemical ingress. End caps are manufactured from an aluminium alloy and are fully ROHS-compliant and competitively priced.

www.harwin.co.uk