Clive Davis from the European Test & Measurement Centre of Yokogawa describes a measurement system for real-time calculations of power and efficiency in power electronics devices, and gives some examples

REAL-TIME MATHS FUNCTIONS ENHANCE WAVEFORM RECORDING

Increased emphasis on energy efficiency and a rapid expansion of the power electronics sector in recent years have placed the spotlight on the need for accurate and meaningful measurements for these applications. Engineers in these sectors now need to evaluate their prototypes in real time to optimise their efficiency. As such their measuring instruments need not only to measure voltages and currents but also provide calculated values of derived parameters, such as power and efficiency, based on recorded data.

CRITICAL MEASUREMENT FACTORS

In recent years, energy conservation has been a hot topic, and manufacturers of electric appliances and industrial equipment are under constant pressure to improve the energy efficiency of their products. For example, power devices used in inverters are required to feature faster operation and higher voltages for improving efficiency. Similarly, the increased use of electronics in cars requires multiple CPUs to provide more precise control and functional enhancement. All these applications involve large numbers of different signals – both digital and analogue – that require monitoring and measuring.

Most measuring instruments record voltage, current and other values of the target devices. However, the evaluation of operating efficiency involves other parameters including power, along with inputs from sensors measuring physical quantities such as torque and speed of revolution. This means that the original data recorded by the measuring instrument has to be processed to produce a derived value – for example, watts or voltamperes from basic current and voltage values.

The electric output of the sensor does not always vary in a linear manner with the physical quantity, so a lineariser or similar device may have to be installed between the sensor and the measuring instrument. The physical quantity measured in this manner is an instantaneous value, so calculations such as time-series integration are required to derive the amount of mechanical work – a key measure of efficiency. In other words, simple measurement is not sufficient to evaluate the energy-saving efficiency of a device; the collected data from a variety of sources must be processed.

Conventionally, the data collected by a measuring instrument is transmitted to a PC for linearisation and processing to obtain derived values such as electric power and power efficiency. One disadvantage of this approach is that these processes are carried out in batches, which can cause a bottleneck. The ideal situation is to have a measuring instrument that can perform both measurement and data processing and can provide meaningful results immediately at the measurement site.

Figure 1: The Yokogawa DL850 ScopeCorder waveform recording instrument

This combination of features is now a reality with the addition of real-time mathematics capabilities to the multi-channel high-speed waveform recording instrument shown in Figure 1.

GOOD COMBINATION OF FEATURES

The Yokogawa DL850 ScopeCorder is a waveform measuring and recording instrument with eight slots for input modules. Depending on the target devices, any of 17 modules can be selected and combined to directly connect various sensors and measure physical quantities.

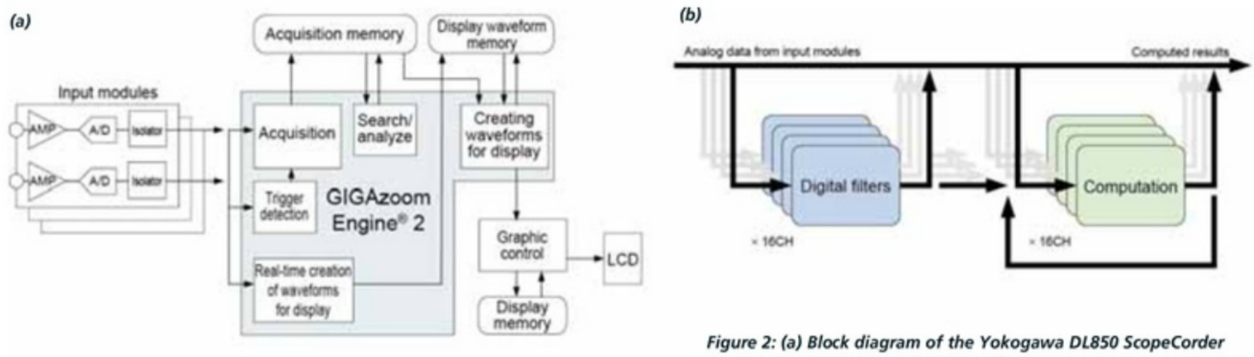
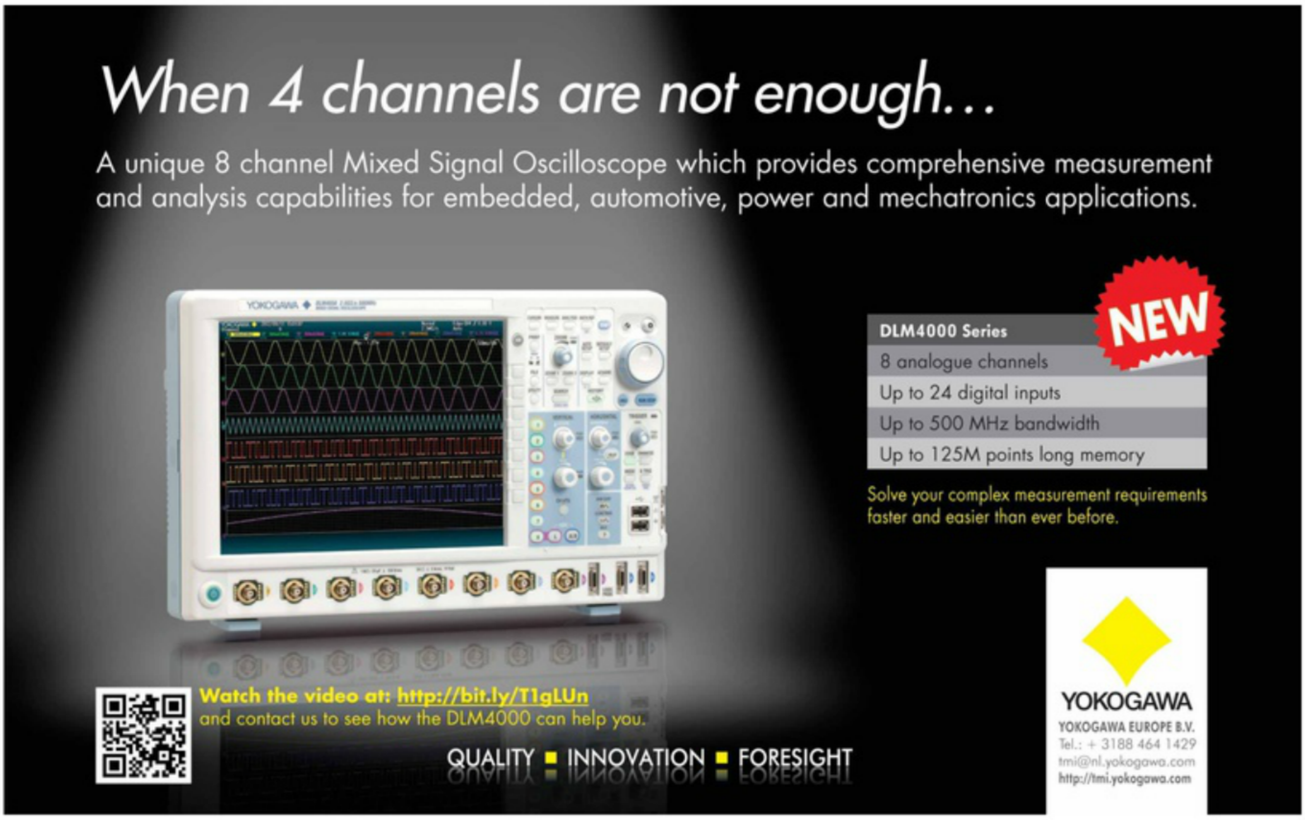


Figure 2: (a) Block diagram of the Yokogawa DL850 ScopeCorder (b) Structure of real-time mathematics unit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Basic performance covers a sampling rate of up to 100MS/s (megasamples per second) and includes a memory capacity of up to 2 gigapoints. When equipped with a high-speed 100MS/s 12-bit isolation module, the instrument can measure the output voltage of an inverter safely and accurately in a broad bandwidth of 20MHz and high dielectric strength voltage of 1000V. With a 16-channel voltage input module, it can measure the voltage of up to 128 channels. In this way, a single instrument can perform multi-channel high-speed sampling alongside long-term measurement.

Figure 2a shows a block diagram of the instrument. Input data is digitised at the A/D converter of each input module and sent to the

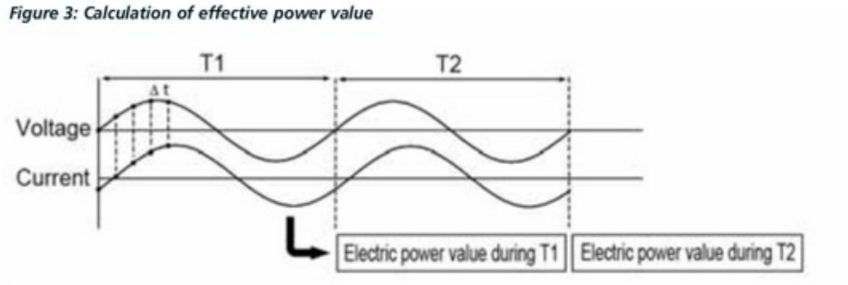
> **"The electric output of the sensor does not always vary in a linear manner with the physical quantity, so a lineariser or similar device may have to be installed between the sensor and the measuring instrument"**

acquisition memory via a digital signal processing system known as GIGAzoom Engine 2. On receiving the data, the system determines if there is any trigger and stores only a required portion before and after the trigger in the acquisition memory.

The processing circuitry also includes a section that can draw waveforms of the data in the acquisition memory at high speed. This function allows the instrument to quickly display waveforms of all the data, even with a large memory capacity of 2 gigapoints.

The real-time maths function is provided between the input module and the GIGAzoom Engine 2. It is selectable for each channel, irrespective of whether the data from each input

Figure 3: Calculation of effective power value



module will be stored in the acquisition memory as it is, or after processing at the function. When all the data paths are assigned to the real-time maths function, data from up to 16 channels can be processed simultaneously.

The features of the real-time math function in this system are as follows: Data is processed before storing it in the acquisition memory, so the processing time is not restricted by the acquisition memory capacity. The data can be successively processed at any time. Data is processed before the trigger detection circuit and the trigger is detected by using the computed result. The acquisition of data is based on the computed result, so it can be stored efficiently. Routing it enables simultaneous acquisition of the data before and after the calculation. The processed data can be routed to a channel in which no input module is present and then recorded.

THE MATHS UNIT'S STRUCTURE

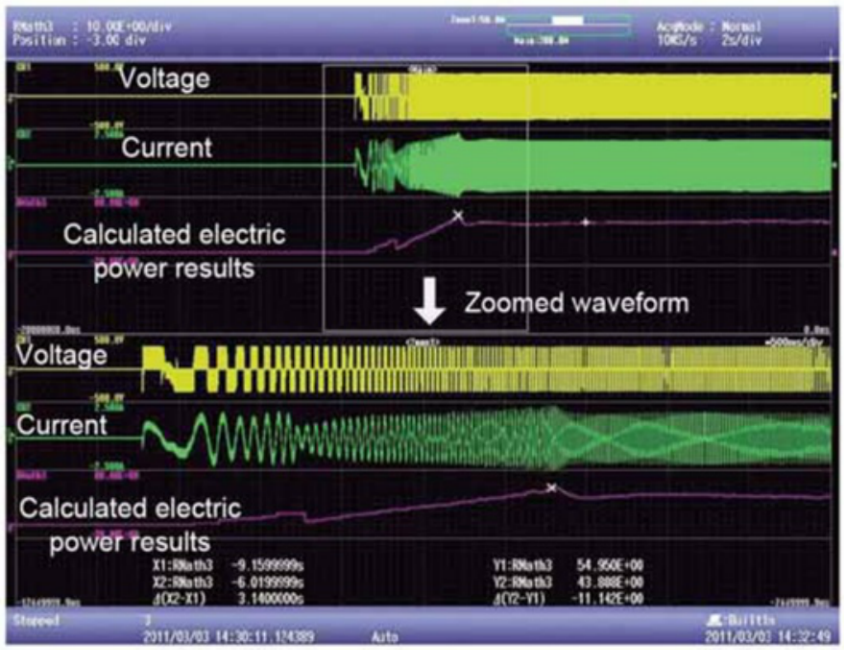
The real-time maths unit is configured by using a dedicated hardware mathematics circuit for high-speed processing; see its block diagram in Figure 2b. It mainly consists of two components: the digital filter unit and the calculation unit. Each section can operate independently, and each can perform processing for 16 channels simultaneously.

Filters in the digital filter unit can be selected from low-pass, high-pass and band-pass filters of a finite impulse response (FIR) or infinite impulse response (IIR) type, or Gaussian and moving average filters. Processing time of the digital filter is up to 1MS/s in 16 channels at the same time.

At the calculation unit, a processing method can be set for each channel and is performed by using one of 28 built-in computing functions. These include fundamental functions such as the four arithmetic operations, square root and logarithm, and applied functions such as electric power calculation and electrical angle calculation. The desired results can then be acquired simply by selecting the appropriate computing functions without the need for complicated settings.

Table 1 lists the computing functions. The results of the real-time calculation can be used in other calculations and, thus, complicated

Figure 4: Example of measuring start-up of a motor



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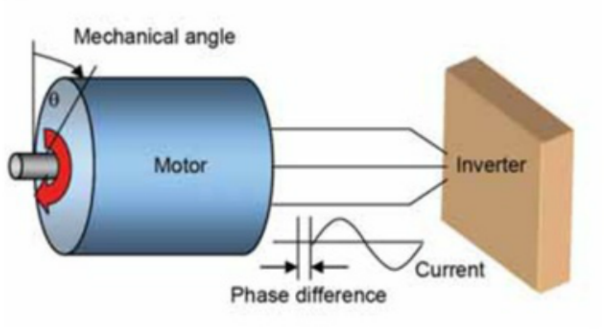

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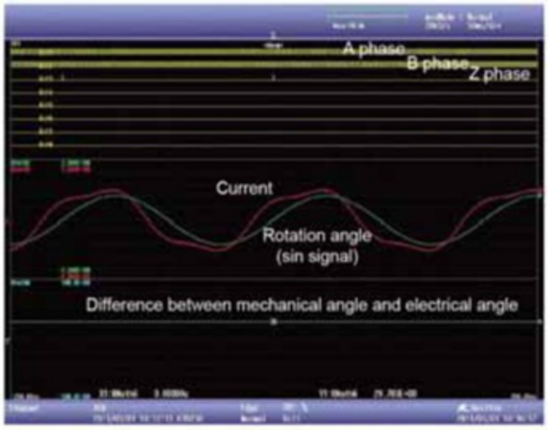


Figure 5: (a) Set-up for measuring electrical angle
(b) Screen display of electrical angle measurements

calculation is possible by combining multiple computing functions.

Calculations are implemented in hardware, so high-speed calculations of up to 10MS/s are possible in 16 channels at the same time.

APPLICATION EXAMPLES

Characteristic applied functions are provided for various applications. Some measurement examples using these functions are described here.

Measuring transient power

With the power function, transient effective power for every cycle can be measured. The power function integrates instantaneous power values for one cycle, which are a product of voltage and current, to calculate an effective power value for this cycle. The calculation is repeated and the result is updated every cycle.

Take as an example the voltage and current waveforms shown in Figure 3. During period T1, which spans from a negative-to-positive zero crossing-point of the voltage signal to the next point, the product of voltage and current at every sampling period is integrated. The time of T1 is measured automatically and, at the end of it, the integrated result is divided by T1 and updated as the electric power value. The same process is repeated in period T2 and, at the end of this period, the electric power value is updated again.

This electric power calculation is performed for every waveform cycle, so the changes in electric power can be precisely recorded, even when the waveform cycle-time fluctuates. For example, the waveform cycle-time transiently fluctuates during the start-up of a motor, and the instrument with this function can follow changes in the waveform cycle-time and record the electric power value in real time for every waveform cycle. With the high-speed calculation of 10MS/s, the instrument can catch all data and calculate the electric power value of a pulse-width modulation (PWM) waveform from devices such as inverters.

Figure 4 shows an example of electric power measurement at the start-up of a motor.

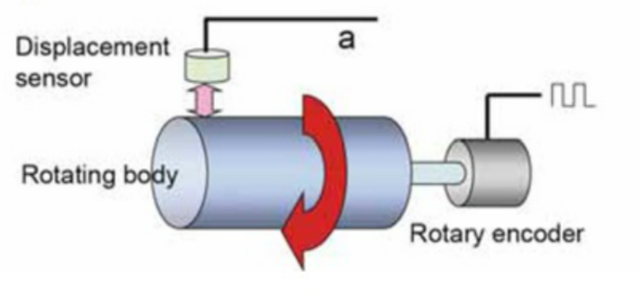
Measurement of the electrical angle of motors

To achieve energy savings when operating motors, inverters and vector control methods are widely used. Torque characteristics of motors depend on the phase difference between the mechanical angle of a motor (absolute angle of the motor rotating shaft) and the electrical angle of an exciting current. Therefore, measuring the electrical angle corresponding to the mechanical angle is important for understanding motor characteristics (Figure 5a). For this purpose, the waveform recorder provides an electrical angle function for calculating the phase difference by using the mechanical angle, a signal obtained from a rotary encoder on the motor's rotating shaft. The electrical angle function then performs a discrete Fourier transform.

The fundamental frequency of an exciting current waveform is the same as that of motor rotation. The rotation angle of the motor is measured for every sampling period, the cosine and sine values of the angle are calculated, and the products of the current value at that time and the cosine and sine values are accumulated for one cycle of the motor rotation. As the fundamental frequency is that of the motor rotation, a phase difference between the mechanical angle of the motor and the electrical angle of the exciting current is just the argument of the discrete Fourier transform equation.

This calculation is performed focusing on the fundamental frequency only on the basis of the principle of discrete Fourier transform. Therefore, the electrical angle of the fundamental frequency component can be calculated for every cycle and recorded in real time, even when the current waveforms are distorted. Figure 5b shows an example of measuring electrical angle in distorted current waveforms.

(a)



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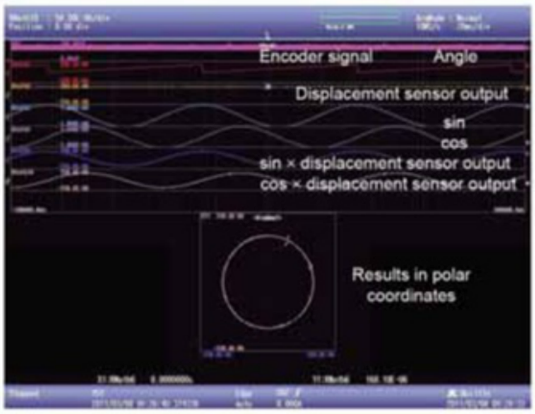
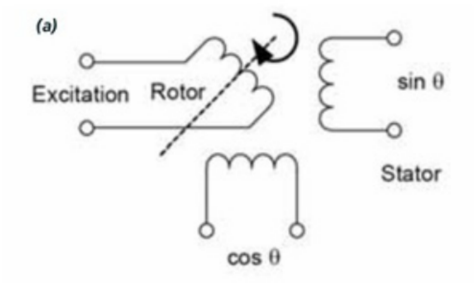


Figure 6: (a) Set-up for measurement of rotation wobble
(b) Screen display for measurement of rotation wobble

(a)



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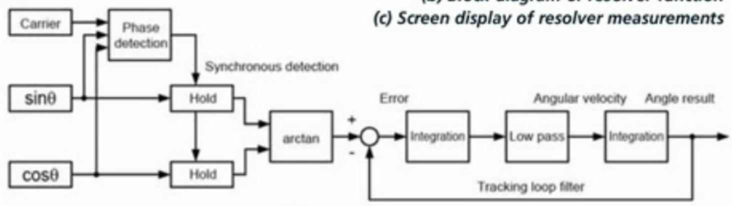

Figure 7: (a) Resolver structure
(b) Block diagram of resolver function
(c) Screen display of resolver measurements

(c)

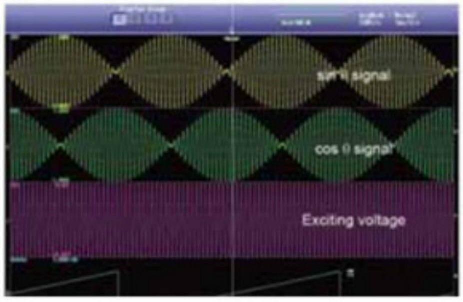

Table 1: List of computing functions

Computing functions	Description
Four fundamental arithmetic operations	S1 \$ S2 (\$: select from among +, −, *, /)
Four arithmetic operations with coefficients	(a * S1) \$ (b * S2) + c (\$: select from among +, −, *, /)
Integration	Integrate every sampling data
Differentiation	Differentiate sampling data with the fifth-order Lagrange differential equation
Angle and displacement	Convert the A-phase, B-phase, and Z-phase signals of the encoder into angle and displacement
DA conversion	Convert digital data into analog quantity
Fourth-order polynomial (Poly)	$a * S1^4 + b * S1^3 + c * S1^2 + d * S1 + e$
Root mean square (Rms)	$\sqrt{(\sum S1^2 / n)}$ (n is the number of data between negative-to-positive zero crossing points)
Effective power (Power)	$1 / T * \int (S1 * S2)\, dt$ (T is the time between negative-to-positive zero crossing points)
Reactive power (Reactive Power)	Calculate reactive power by the following equation $\sqrt{([\text{apparent power}]^2 - [\text{effective power}]^2)}$
Power integration (Power Integ)	$\int (S1 * S2)\, dt$
Logarithm 1 (Log1)	a * log(S1 / S2)
Logarithm 2 (Log2)	a * log(S1)
Square root 1 (Sqrt1)	$\sqrt{(S1^2 \$ S2^2)}$ (\$: select from among +, −)
Square root 2 (Sqrt2)	$\sqrt{(S1)}$
Cos	a * cos(angle) (An encoder signal is converted into an angle)
Sin	a * sin(angle) (An encoder signal is converted into an angle)
Atan	atan(S1 / S2)
Knock Filter	Elimination filter forcing signals lower than the setting value to 0
Electrical angle	Calculate phase difference between the specified data with discrete Fourier transform
Polynomial addition and subtraction	a * (\$ S1 \$ S2 \$ S3 \$ S4) (\$: select from among +, −)
Event counting	Count the number of negative-to-positive zero crossing points
Cycle time	Signal cycle time between negative-to-positive zero crossing points
Frequency	Signal frequency between negative-to-positive zero crossing points
Resolver	Convert signals from a resolver sensor into angle
IIR filter	Selectable from infinite impulse response (IIR)-type low pass, high pass, or band pass filters.
Pwm	Integrate pulse widths of pulse width modulation (PWM) waveform during a cycle time to convert into a sinusoidal wave
CAN ID	Analyze signals of CAN bus and detect a specific ID

* S1, S2, S3, and S4: Select data of measurement channels or computed results.

* a, b, c, d, and e: Arbitrary constants

Displaying the measurement results of a rotating body in polar coordinates

The real-time maths function enables measurement results of a rotating body to be displayed in polar co-ordinates in real time: for example when measuring the wobble of a rotating body as shown in Figure 6a.

The behaviour of a rotating body can be displayed in polar co-ordinates in real time by using the angle function to calculate the angle value based on the output of the rotary encoder, calculating sine and cosine values based on this value and using the x-y display function to display each value on the co-ordinates.

Figure 6b shows a measurement example of the rotary displacement. The behaviour of the rotating body can be easily understood from the display on the polar co-ordinates which depends on the rotation angle.

MEASUREMENT WITH THE RESOLVER ANGLE SENSOR

In recent years, resolvers have often been used for detecting motor angles in hybrid cars and other vehicles, as they offer excellent environmental resistance in automotive applications. As shown in Figure 7a, the resolver sensor detects sinusoidal exciting voltage applied to exciting coils, mounted on the rotor by using the two orthogonal sensing coils and outputting two signals (sin θ and cos θ) corresponding to the angle θ of the rotor. Exciting voltage is superimposed on the sin θ and cos θ signals, so this carrier component is removed and the angle calculation is performed. The resolver function automatically detects sin θ and cos θ signals synchronising with the resolver exciting voltage, samples them and calculates angle values.

The resolver function has a built-in tracking loop filter as shown in Figure 7b. Even when some sampling data of sin θ and cos θ signals are missing, they can be interpolated.

Figure 7c shows a measurement example using this function. As seen, the computed angle data is not affected by synchronous detection, and highly accurate results can be obtained without discontinuity. ●

OPTIMISING AUTOMATED TEST SYSTEMS WITH NI PXI PROGRAMMABLE POWER SUPPLIES

National Instruments has announced its newest general-purpose programmable power supplies, which offer the highest power density available in PXI and form the foundation of automated test systems. The NI PXIe-4112 and NI PXIe-4113 modules provide high power density that saves rack space while simplifying design by eliminating the need to mix multiple instrumentation form-factors. When programmed with NI LabVIEW software and paired with a range of PXI hardware instrumentation, the new power supplies can help engineers create a complete, customised test solution.

The new programmable power supplies are ideal for a range of applications from aerospace and defence to automotive and component test. These modules feature two 60W power supply channels in a single PXI Express slot. The NI PXIe-4112 power supply features 60V at 1A per channel and the NI PXIe-4113 power supply offers 10V at 6A per channel. The two channels can be combined to create a single 120W channel.

www.ni.com/powersupplies

YOKOGAWA ENHANCES DLM4000 8-CHANNEL MIXED-SIGNAL OSCILLOSCOPE

A number of new enhancements have been introduced to the Yokogawa DLM4000 Series of 8-channel mixed-signal oscilloscopes. These include the L16 option, which adds 16 extra channels of logic, plus upgraded firmware for power measurements and serial-bus testing.

Launched in October 2012, the new Yokogawa DLM4000 is the industry's first mixed-signal oscilloscope to feature eight channels. Combining the large screen and 8-channel capability of Yokogawa's earlier 8-channel DL7480 oscilloscope with the mixed-signal technology of the company's pioneering DLM2000 Series, the instrument is ideally suited to test and debugging applications in the embedded systems, power electronics, mechatronics and automotive sectors.

The eight channels on the original instrument could be allocated as eight analogue channels or seven analogue channels plus one 8-bit digital input. The new L16 option adds 16 more channels of logic to give seven channels of analogue plus a 24-bit digital input, allowing more detailed analysis of embedded electronics and serial-bus-based systems.

www.tmi.yokogawa.com

SPIRENT LAUNCHES PERFORMANCE MEASUREMENT SYSTEM FOR HD VOICE AND VOICE OVER LTE

Spirent Communications launched its Nomad HD call and voice measurement system. As VoLTE deployments ramp up and early device support for the technology varies in implementation and performance, Nomad HD provides critical voice quality analysis for HD voice and VoLTE services on any device, across any network.

As the first measurement system of its kind, Nomad HD provides a comprehensive package for HD voice quality measurements and call performance testing to support the evolution of voice services. It incorporates Perceptual Objective Listening Quality Assessment (POLQA), a next generation voice testing methodology standardized by the ITU. Using the POLQA algorithm for HD Voice and VoLTE voice quality measurement allows for actionable comparison between legacy circuit-switched and packet-switched voice from the same service provider, across networks and technologies. Nomad HD makes available to the industry a much-needed capability to simultaneously measure VoLTE voice quality, delay and call performance objectively under real-world conditions in both lab and field environments.

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TEST AND VERIFICATION SOLUTIONS LAUNCHES BIGGER LIBRARY OF VERIFICATION IP

Test and Verification Solutions (TVS) has expanded its asureVIP library of verification IP to cover protocols in MIPI, memories, Universal Serial IO and communication as well as a bespoke VIP development service.

The TVS VIP offers many advantages to the user such as access to the source code, flexible licensing agreements and protocol compliance test suites. The latter enables the engineer to more quickly demonstrate that their design complies with the standard.

TVS

The tests are mapped to the protocol specification so that the user can quickly see the intention of the test. Additionally, the asureVIP library contains traffic generators that allow the chip integrator to quickly generate traffic across the interface. Synthesisable drivers and C interfaces allow the VIP to be used in emulation using SCEMI.

The UVM compliant asureVIP is written in native System Verilog so that debug becomes much easier, given that the user has access to the code.

www.testandverification.com

AEROFLEX LAUNCHES FIFTH GENERATION MODULAR WIRELESS TEST SYSTEM

Aeroflex launched a new generation of wide-bandwidth RF signal generators and analyzers in PXI format with class-leading performance, enabling a high performance, flexible and cost-effective solution for RF component and wireless device testing to the latest standards, including WLAN 802.11ac.

The PXI 3050A low-noise RF signal generator and the PXI 3320 arbitrary waveform generator (AWG) are used together to provide a fully configurable RF signal generator with wide bandwidth vector modulation, low phase noise, and fast frequency and level settling.

The signal generator is available in two frequency range options, from 100kHz to either 3GHz or 6GHz, and with a choice of +10dBm or +20dBm output power. A 200MHz modulated RF bandwidth with low residual error vector magnitude (EVM) of less than 0.5% makes it the ideal choice for wideband standards using high order 256 QAM modulation, such as 802.11ac.

Excellent linearity (ACLR) of greater than 70dB 3GPP TM1 makes 3050A ideal for use in test solutions for power amplifiers and repeaters.

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