Aiming for New Growth in the 21st Century

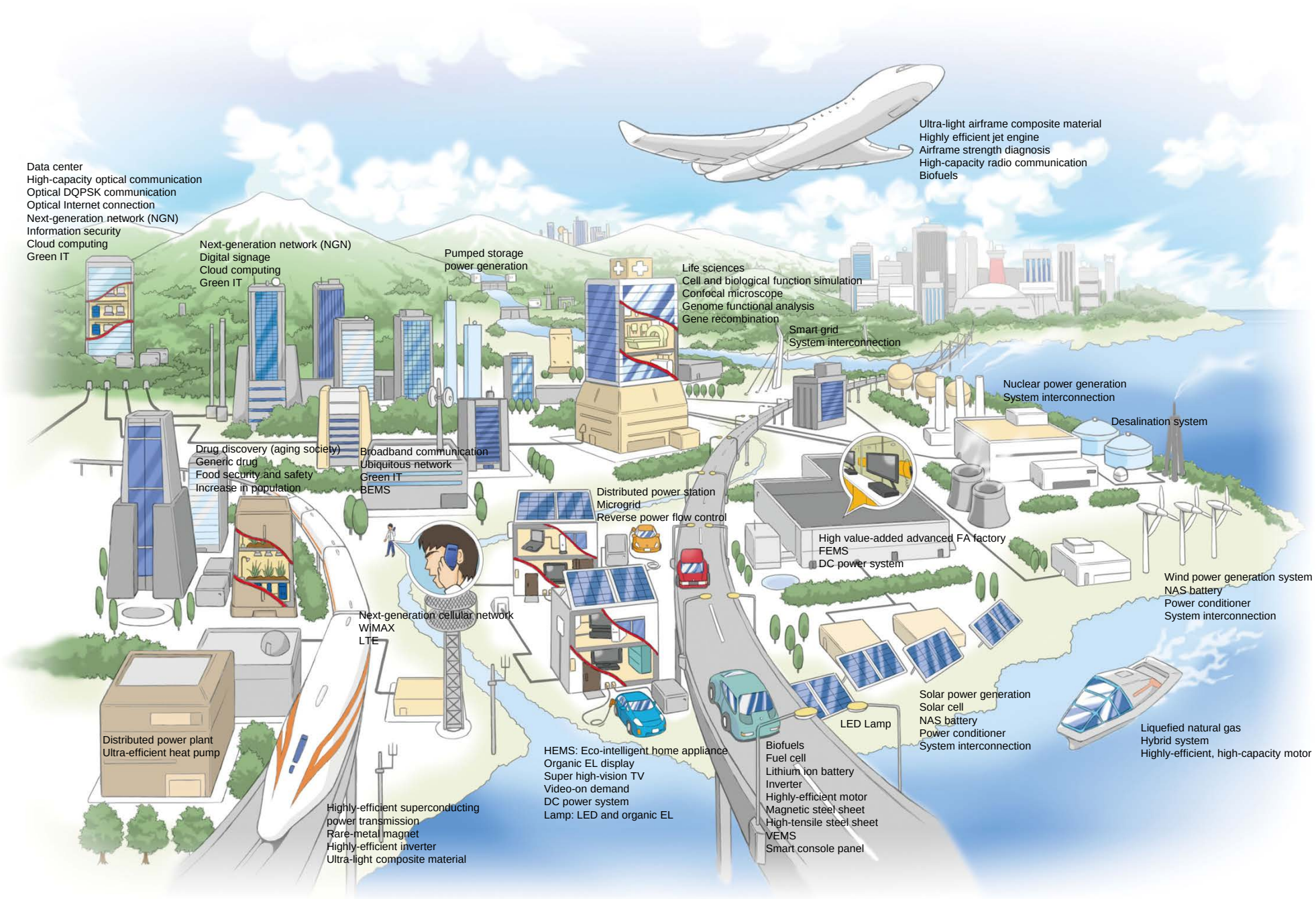
The Limits to Growth was published by the Club of Rome in 1972. I was shocked by the content of the book and had a vague unspeakable anxiety about the coming 21st century in my high school days. I think the situation today marks the start of an era for human beings to challenge the future by seeking harmony with the global environment in which humans are beginning to live with limited resources, breaking today's economic deadlock, making a sustainable, high-quality, prosperous life a reality, and accomplishing further development and growth.

I believe measurement technology, which represents a history of challenges to make invisible quantities visible, is one of the fundamental tools for scientific, industrial, and social infrastructures. It is this visualization technology that promoted efforts to standardize invisible quantities and make waste visible, that advanced today's science and technology, and that helped industrial society become more efficient.

Today in the 21st century, the industrial and social structures are rapidly changing driven by the factors: energy conservation, pursuit of a low carbon society, resource conservation and recycling, food safety, progress of medical care, and promotion of the conservation of the environment in which human beings live on this planet. In an era of transformation like this, measurement technology, which is the origin for visualization, is required for further advancement by combining the conventional measurement notion with the leading-edge information processing and control technologies in an extremely wide range of areas, including resources and energy, advanced factory automation (FA) enabling value-added manufacturing, social infrastructure focusing on the well-being of citizens, life sciences, fundamental science, and materials science that progress every day.

Yokogawa's Measurement Business Headquarters will make its best efforts to advance and upgrade the measurement technology to make invisible quantities visible by integrating the information processing and the advanced control technologies with the aim of enabling the next development and growth, and meeting the requirements for the 21st century.

Akira Miura, Vice President
Measurement Business Headquarters
Yokogawa Electric Corporation



<Table of Contents>

Corporate profile

Founded in 1915, Yokogawa Electric Corporation has devoted the past 90 plus years to the measurement, control, and information technologies, and provides leading-edge products and services to industry. The high added value created by the excellent technology has contributed to industry and to the well being of society. Yokogawa will continue to take on new challenges with the aim of growing in a healthy and profitable manner.

Corporate Philosophy

As a company, Yokogawa's goal is to contribute to society through broad-ranging activities in the areas of measurement, control, and information.

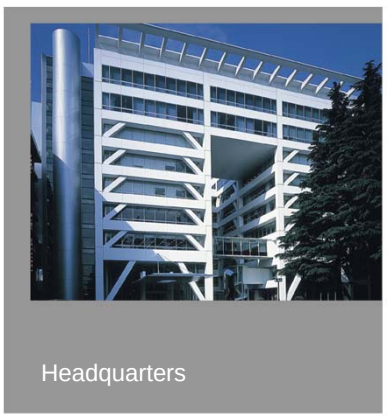
Individually, Yokogawa aims to combine good citizenship with the courage to innovate.

Overall Vision

The Yokogawa Group will work together with its customers to create value in the fields of industrial and social systems. Thus, the Group aims to contribute toward not only preserving the global environment in the 21st century and realizing resource recycling in society, but also realizing a thriving global society.

To achieve these objectives:

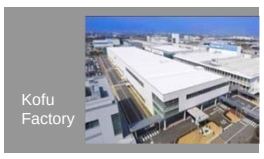
- The Yokogawa Group will become a service company that helps customers improve their managerial efficiency, in accordance with the Enterprise Technology Solutions (ETS) concept.
- The Yokogawa Group improve its quality of management quality so the Group can gain the trust of customers and heighten their impression of the Group.
- The Yokogawa Group will perform sound and profitable management to increase shareholder value.
- All members of the Yokogawa Group will share the same corporate vision and each individual will act autonomously and increase his or her individual worth in order to realize a value-creating company.
- The Company and employees will work together to create affluence.


Headquarters


Komine Factory


Kanazawa Factory


Sagamihara Factory


Kofu Factory

R&D

The Yokogawa Group recognizes that the development of new technologies is one of its most important challenges. We seek to develop technologies for the core business domains of test and measurement , industrial automation and control, and information systems.

- Always thinking 10 – 20 years ahead, we determine what technologies Yokogawa should focus on and select research themes accordingly.
- We conduct research & development, centering on the following three sectors: field-ubiquitous computing technologies; microtechnologies, and photonics technologies.
- Yokogawa's Corporate Research & Development Headquarters is responsible for the research and incubation of common basic technologies that will become tomorrow's leading-edge technology.


CENTUM VP
Integrated Production Control System


DMAG AXF
Magnetic Flowmeter

STARDOM
Network-based Production System

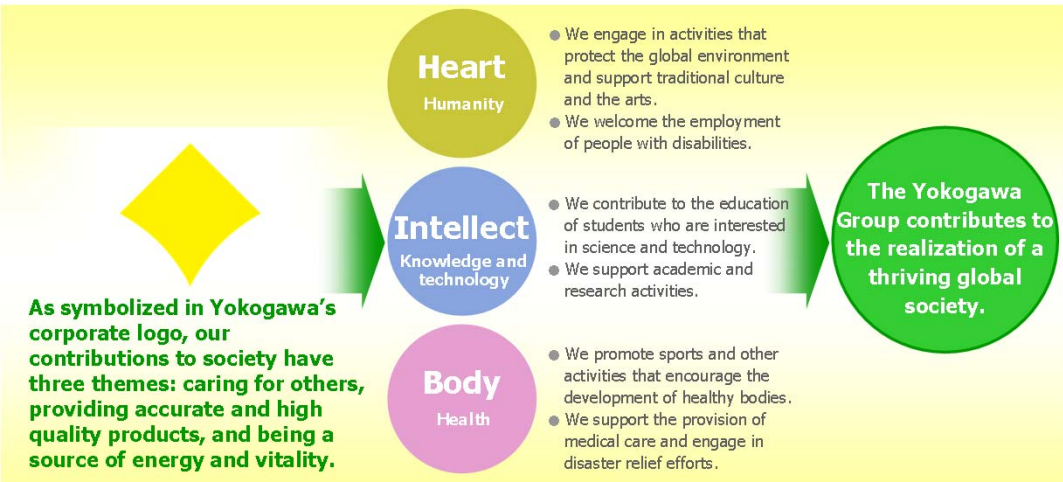

MT6121
Memory Test System


DX Advanced
Data Acquisition Station


WT3000
Precision Power Analyzer

CSR Activities

Based on our corporate philosophy, Yokogawa contributes to local communities and society as a whole under the three themes of heart (humanity), intellect (knowledge and technology), and body (health).



Measurement Business

Yokogawa Supports the Social Infrastructure for the 21 Century in the Areas of Information and Communication, Resources and Energy, and Life Sciences. Thus Contributing to the Sustainable Development of Human Beings

Next Generation Network (NGN), Cloud Computing, Data Center, High-Capacity Optical & Broadband Communications, Ubiquitous Network,
Optical DQPSK/DPSK Communications,
Software-Defined Ratio,
Communication,
High-Vision TV,
Picture, 3D Display,
Display, Digital Signage,
MRAM, NAND Flash,

Information & Communication

Optical & Wireless Communications
Computer & Semiconductor
Video, Music & Communications
Home Appliances
Security, Ubiquitous

Optical Interconnection
Next-Generation Mobile Phone
LTE, Spread Spectrum
On-Demand Video, Super High-Definition Motion
Organic EL Display, LCD
CPU, Nano-CMOS, DRAM
FPGA, Photonic IC

Lithium Ion Battery
Fuel Cell
High-Tensile Steel Sheet
High Damping Steel
Magnetic Steel Sheet
Rare-Earth Magnet
Alternative Energy
Solar Cell
Solar Generation
Wind Generation
Geothermal Generation
Nuclear Generation
Hydrogen Energy
Coal Liquefaction
Oil Sand
Desalination Plant
Liquefied Natural Gas
Highly Efficient Superconducting Power Transmission
Highly Efficient Heat Pump

Advanced Control Algorithm,
Artificial Intelligence & Robotics,
On-Demand Energy
International Logistics,
Global ERP, SAP

Resources & Energy

Oil, Gas, Rare Metal, Iron & Steel, Paper & Pulp, Water, Sunlight, Wind Power, Rechargeable Battery, Fuel Cell, Automotive, Railway, Aerospace

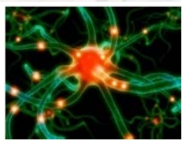
Organic Energy,
Bioenergy,
Nanotechnology
Bioethanol
Biosensor
Biodevice
Bio-Nano-Machine

Medical Network, Organic Electronics, Genetic Recombination & Engineering, Biometric Authentication, Biological Measurement, Advanced Diagnosis, Advanced Medical Equipment

Life Sciences

iPS Cell, Brain Neuroscience,
Clone, Genetic Therapy,
Virus, Drug Discovery,
Nursing Care,
Telemedicine, Food Security & safety

Confocal Microscope
(Real-time Observation of Living Cells)
Cell & Biological Function Simulation
Genome Function Analysis
Human Genome & Post-Genome
Brain Science (MEG)
Clone & ES Cell
Drug Discovery (Aging Society)
Generic Drug
Immunity & Allergy
Food Security & Safety
DNA Traceability
Residual Pesticide Testing
Generic Recombination
Population Growth
Increase in Food Production
Major Grain Companies
Industrialization of Agriculture
Methane Producer
Biofuel (Closed Carbon Dioxide Cycle)



Base Technologies for the Future: Materials Science, Mechatronics, Electronics, Molecular Bioengineering + Measurement Technology, Information Processing Technology, and Control Technology

■ Yokogawa's Measurement Technology Helps Conserve Energy and Recycle Low Carbon Resources in Society

Electric Vehicle

Backbone Base Station

Yokogawa's world class measurement technology contributes to the following: conserving energy of home electronic appliances, including refrigerators, air-conditioners, and television sets, which consume the majority of power at home; decreasing the use of oil through the popularization of electric vehicles and efficiency improvement; and conserving energy through the enhancement of communication using ultra-high-speed, optical communication networks.

DLM 2000 Digital Oscilloscope

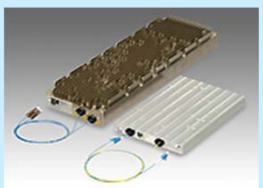
WT3000 Precision Power Analyzer

AQ6370 Optical Spectrum Analyzer

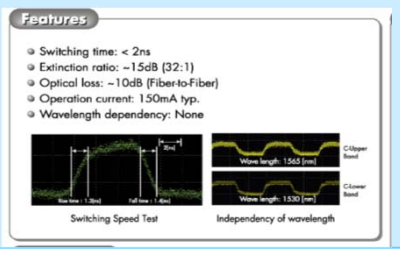
AQ7275 Optical Time Domain Reflectometer

■ Toward Realizing Ultra-High-Speed Photonics Networks that Support Optical Communications Infrastructure

By using advanced compound semiconductor technology, Yokogawa has commercialized the 40G RZ-DQPSK Transponder based on the modulation format, which is intended to be sold in markets for backbone optical communications such as next-generation networks (NGNs) and is already seeing increased sales. Yokogawa also will develop the second generation of transponders that will be smaller in size and consume less power, as well as develop and commercialize leading-edge devices and subsystems, including optical switching devices and optical packet transceivers with the aim of helping realize ultra-fast photonic networks.

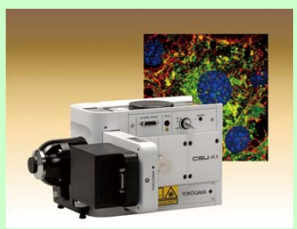


40G RZ-DQPSK Transponder



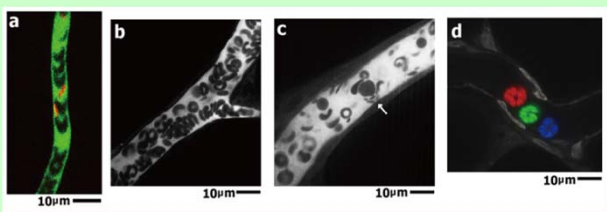
Packet Network Core Technology

■ In Vivo Cellular Imaging Technique Helps Solve More of the Mysteries of Life Sciences



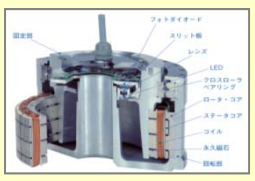
CSU-X1 Confocal Microscope Unit

Yokogawa's CSU-X1 Confocal Microscope was used to develop an imaging technique to visualize individual cells in order to understand dynamic changes in vivo, such as cell kinetics, blood flow, and vascular function.
The left most image below shows a capillary blood flow in the adipose tissue of a normal animal (an ob/ob mouse). The dynamics of blood cells (red indicates a platelet) that flow in the blood vessel are expressed clearly.



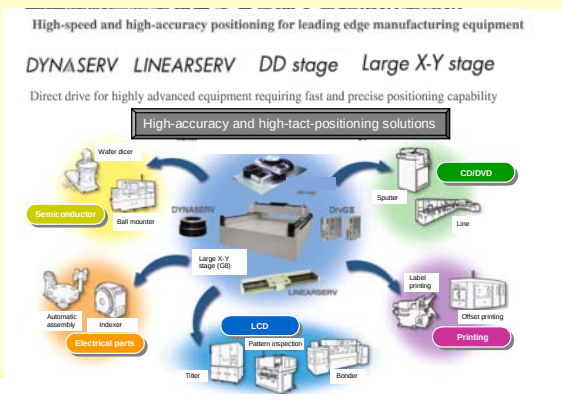
Data: Satoshi Nishimura, Department of Cardiovascular Medicine at University of Tokyo

■ Yokogawa's High Precision Positioning Technology is Used in State-of-the-Art, Advanced Factory Automation Industry



Direct Drive Motor DYNASERV

Yokogawa helps the advanced factory automation industry increase speed, become more precise, make equipment more compact, become more clean, and improve development efficiency in the areas of solar cell and LCD manufacturing, semiconductor (chip on glass), or 3-dimensional packaging.



<Optical & Electronic Test and Measurement Business>

Yokogawa Contributes to Solving Problems to Conserve Energy and Protect the Environment for a Sustainable Society in the Future

From the foundation of the company through to today, test and measurement has been a main business area for Yokogawa, which started its business with instruments to measure basic electrical quantities such as voltage, current, and resistance. Yokogawa offers a variety of measuring instruments, including electro-magnetic oscillographs, high-frequency measuring instruments for communication applications, measuring instruments for aerospace applications and instruments to measure flow rate, temperature, voltage and so on. Yokogawa has contributed to industrial development during a period of rapid economic growth in Japan.
Today, Yokogawa targets the booming mechatronics and energy market, which is a result of increasing use of automotive electronics and a growing demand of cheaper and environmentally friendly sources of energy. In addition Yokogawa also has its eyes set on the communications and network markets, which is expanding due to the full-scale construction of next-generation optical communication networks.
Amid a global growing awareness and importance to reduce CO_2 emissions and protect the environment, Solar Power Generation market is expanding rapidly. The automotive industry is developing hybrid and electric vehicles much faster than ever. For electric vehicles, fuel consumption is determined by the power consumption of the motor replacing the engine, so the most important challenge for car designers is to find a solution to reduce the power consumption. Thanks to its world's highest accuracy for measurement in this area, Yokogawa's power analyzer is widely used as a tool to help design vehicles that consume less energy.
To evaluate the mechanical operations of robots, motors, or the likes, Yokogawa offers waveform measuring instruments, such as Oscilloscopes with large built-in memory, capable of verifying operation over (remove – for) a long period of time. The Scope Corder series offers simultaneous measurements with multiple items, such as temperature, distortion and acceleration, on multiple channels.
Today, optical communication networks are being constructed all around the world to facilitate the distribution of motion pictures such as TV programs and movies. For the communication and network market, Yokogawa offers Optical Time Domain Reflectometers (OTDRs) and Optical Spectrum Analyzers (OSAs) to ensure the optical fibers are installed without a disconnections and other problems.
In this way, Yokogawa takes advantage of its leading-edge test and measurement technology to provide solutions to conserve energy and protect the environment for the optical communications industry.
・Support design to conserve the energy of electronic and mechatronic equipment.
・Help improve development efficiency and enhance production.
・Help install expanding optical communication equipment.

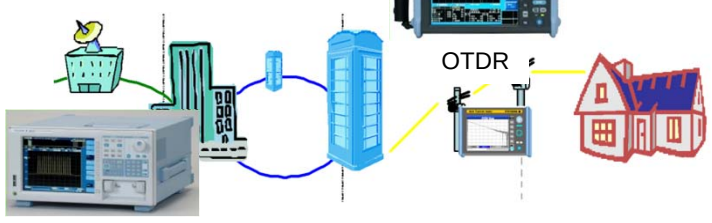

Power Analyzer


Mixed Signal Oscilloscope


Scope Corder


Source Measure Unit


OTDR


Optical Spectrum Analyzer

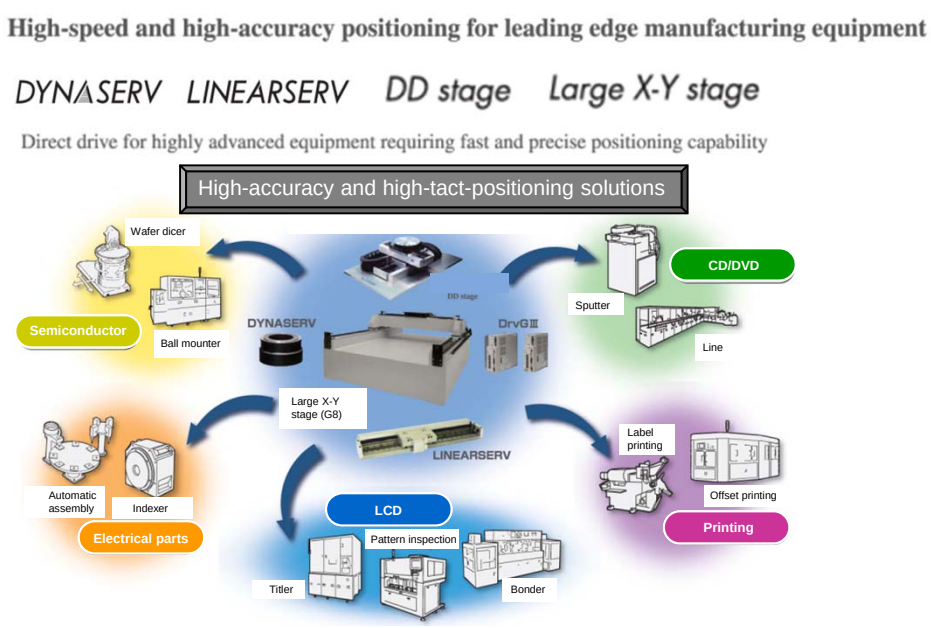
<Motion Control Business>

Yokogawa's Leading-Edge Advanced Positioning Technology Contributes to the Future of Advanced Factory Automation Technology

In the areas of equipment for motion control, image-processing and testing, Yokogawa takes advantage of its leading-edge development capability and state-of-the-art control technology to develop new motion solutions with outstanding results.

In the 1980s when factory automation started, a typical device that was used to automate production was a robot. The actuators consisted of a motor and a reduction mechanism. However, over time, the precision and speed of the robot could not meet the demands for mass production and miniaturization over time. In 1981, Yokogawa began development of the next-generation robot for adjustment and inspection. This technology relied on multiple axis and was highly accurate and intelligent. The robot had a visual function and six axis with multiple vertically moving joints, which were all driven by a Direct Drive Motor (DDM) without a reduction mechanism. The DDM had four advantages: low heat generation, high precision, high torque, and high stiffness. In 1984, the DDM was presented at an academic conference and received great appraisals within the Japanese community and overseas. Thus Yokogawa's DDM was derived from the application of a robot. Yokogawa promoted the commercialization of DDM as an FA component and began producing and selling it under the brand name of DYNASERV in April 1987. Later, Yokogawa launched a linear DDM series under the brand name of LINEARSERV. In order to meet the growing demand for higher precision and faster tact time of production equipment that had to deal with the increasing miniaturization of semiconductors and electronic components, Yokogawa launched a plane DDM series under the brand name PLANESERV. Yokogawa's DDMs are widely used by manufacturers of electronic components, semiconductor equipment and CD/DVD production equipment. The number of DDMs sold to date exceeds hundreds of thousands of units.

Today, Yokogawa's actuators are also used in the areas such as solar cells, LCD, semiconductor (chip on glass) manufacturing and 3D packaging. It increases the speed, precision, and cleanliness of the manufacturing process, there by making equipment compact. It reduces the development man-hours of customers by providing an all-in-one solution.



High Precision
・High resolution of more than 4 million pulses per revolution
・Positioning ±1 pulse
High Speed
・5 rps
・55 ms for 90 degree index
Intelligent Driver
・Auto tuning
・PC support tool
・Simulation run without motor

<Communication Equipment Business>

Yokogawa's Leading-Edge Compound Semiconductor Technology Contributes to the Future of Communication Networks

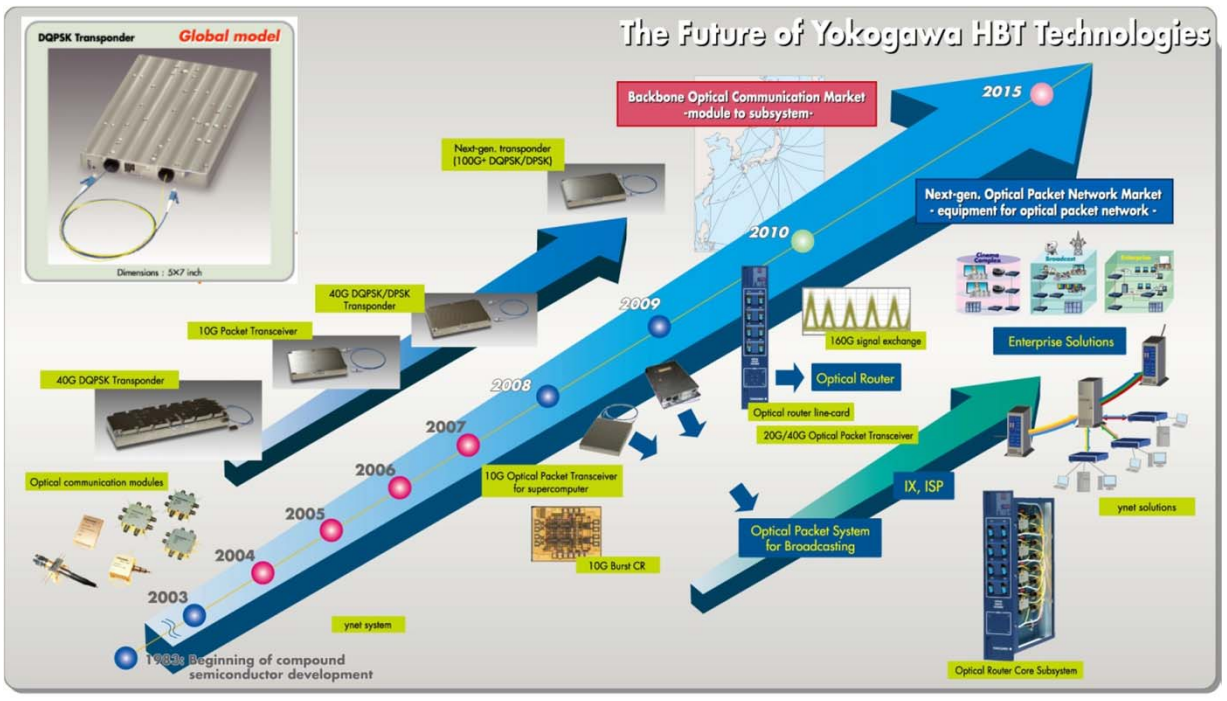
Traffic flowing through the communication networks is growing rapidly. The optical communication technology met the requirement for larger capacity by increasing speed and using the WDM (Wavelength Division Multiplexing) technology. However, a further increase in speed and capacity is required to meet today's rapidly growing flow of communication.
Yokogawa started developing compound semiconductor devices in 1983, more than a quarter century ago from today, with the aim of developing in-house key devices for high-frequency measuring instruments. After approximately 10 years of research and development, Yokogawa equipped its digital oscilloscopes, semiconductor test systems, and optical spectrum analyzers with its self-developed devices. In the optical communication area, Yokogawa equips its wavelength monitors for WDM networks with its photodiode array (PDA).

Yokogawa regards the optical communication networks, as an important social infrastructure of the 21st century. With this in mind, Yokogawa announced that it will enter the optical communication business on a full scale. Taking advantage of its compound semiconductor technology as a core competence and its 40Gbps optical communication modules, Yokogawa built the foundation of the business by mass producing photodiodes, modulator drivers, clock management modules, and its likes. In 2007, Yokogawa commercialized the 40Gbps return-to-zero DQPSK (RZ-DQPSK) transponder ahead of other competitors in the world.

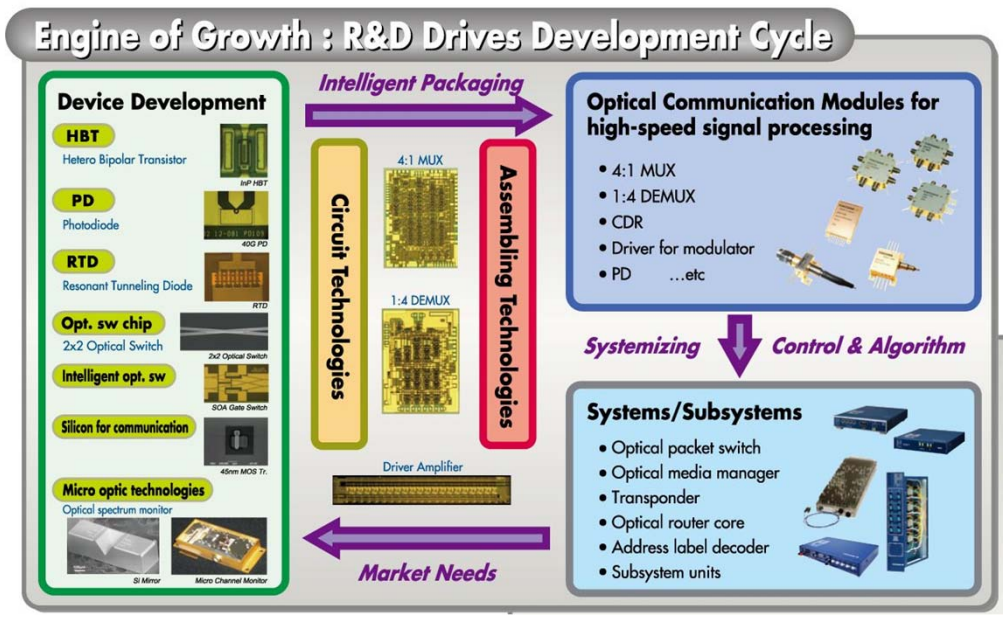
In 2003, Yokogawa developed an optical switch that operates in less than 2 nanoseconds. Yokogawa expects this optical switch will be applicable not only to optical packet network systems but also to connections among computation nodes of supercomputer systems and packet exchanges on the backplanes of optical routers. In 2005, Yokogawa announced the world's first 40Gbps optical packet network system, the ynet™.

Towards the end of 2006, Yokogawa established Sagamihara Technology Center in Sagamihara City, Kanagawa Prefecture, as a base to launch the optical communication business. The center is in charge of the research, development, manufacturing, sales, and marketing of semiconductor devices and systems related to communication equipments. The main building is designed to be advanced seismic isolation system with the aim of reducing earthquake damage to the building and the expensive semiconductor manufacturing equipment. Thus, Yokogawa is able to reliably supply its products using the leading-edge technology to its customers not only in Japan but also around the world.

Yokogawa reflects the requirements from customers and markets in its products by running the following development cycle: bringing to market optical communication modules and systems based on its technologies, such as device development, circuit and assembling, system building, and control algorithms, and feeding the advanced market needs back to development.
Yokogawa believes the optical communication technology will continue to advance in terms of increase in speed and flexibility. The 40Gbps is already in the mass production phase and the 100Gbps-plus (100G+) technology will become the mainstream for development. Yokogawa is also developing core technologies toward the 100G+, and is willing to help construct the communication infrastructure after the 40G period. In terms of flexibility, ROADM (Re-configurable Optical Add-Drop Multiplexer), a device capable of switching optical paths within milliseconds, was put into practical use, which represents the first step in the evolution from peer-to-peer connection to dynamic switching. Yokogawa will help construct more dynamic networks using its ultra-high speed optical switch and optical packet-related technologies.



<1> Compound semi. area
<2> Si semi. area
<3> Compound semiconductor
<4> Vertical furnaces
<5> CVD process
<6> Exposure process
<7> Electron beam stepper (nano-size)



<Bio Analytical Business>

Yokogawa's Leading-Edge Bio-Measurement Technology Contributes to the Well-Being of Society in the Future

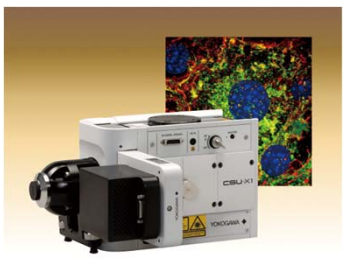
Gaining a tool to "observe the dynamics of living cells in real-time at high resolution instead of still images" has been a long-cherished dream of life science researchers. A technique to observe on a molecular level when, where, and at what time life phenomena occurred in individual living cells, so-called "live cell imaging" is expected to bring to a breakthrough in the life science research to elucidate many unknown mechanisms of the body.

To make the dream come true, in 1996 Yokogawa released the Confocal Scanner Unit CSU series, which is capable of observing a living sample at a higher speed for a long period of time with less damage to the sample. The CSU is widely used around the world as a de facto standard tool for the live cell imaging studies. Yokogawa has the top share in the live cell confocal microscope market. The newest model, CSU-X1, released in April 2007, is the choice of many researchers because of its outstanding differentiating features, such as the substantially enhanced optical performance to give high-resolution images with high sensitivity, a wider variety of options, and the industry's top imaging speed at 2,000 full frames per second.

Today, the pharmaceutical industry faces problems, such as the expiration of patents for blockbuster drugs and the decrease in lucrative blockbusters, so it is required to speed up the development of new drugs.
While development costs are increasing year after year, the number of approvals for new drugs is not growing, so there is a compelling need to improve development efficiency. To achieve this, focuses are on the automating and speeding up the screening process to identify promising new drug candidates from hundreds of thousands to millions of candidate compounds.

Yokogawa offered a solution by using its proprietary knowledge to build systems, as well as its technologies, such as an image acquisition at high-resolution and high-speed using the confocal scanner unit, plate handling mechanism using the precision positioning technology to enable repeated observation of many samples at a high speed, and incubation system to cultivate a large number of sample plates.
Yokogawa's CellVoyager High-Throughput Cytological Discovery System released in February 2009, is an epoch-making drug discovery support system which meets the requirements of industry. The CellVoyager runs the following process automatically at the highest speed in the world: putting a drug candidate compound into the sample plates, imaging changes in the cells at the world's highest level of resolution, processing the captured images, and checking the effects of the input compound.
Yokogawa works together with customers, and proposes and provides the most appropriate solution, thus gaining trust and contributing to the development of life sciences from R&D through to the drug discovery business.

CellVoyager High-Throughput Cytological Discovery System

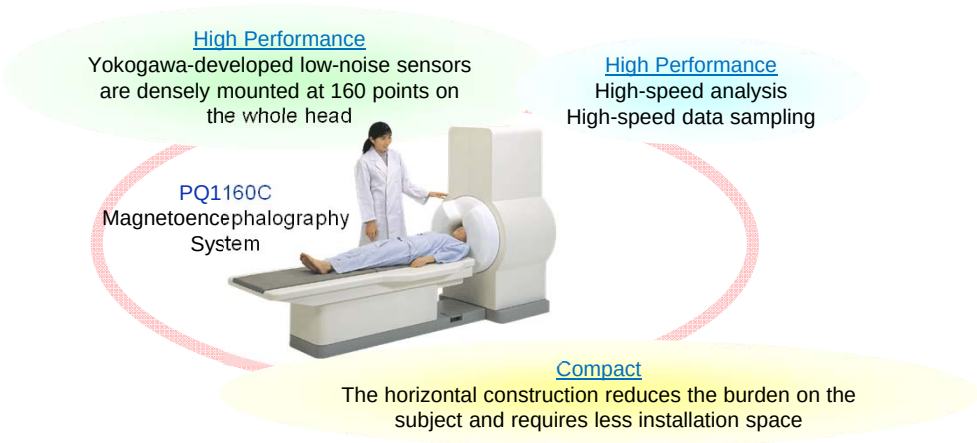


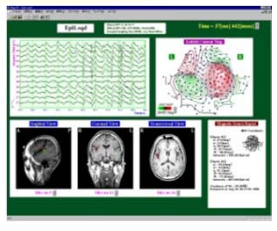
CSU-X1 Confocal Scanner Unit

CSU-Frontier Confocal Microscope System

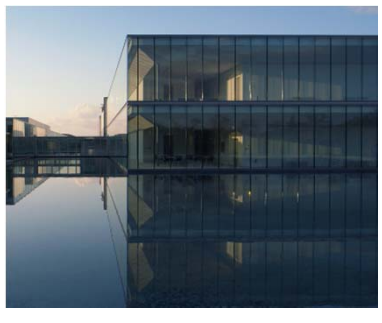
The 21st century is said to be the "era of brain science". The progress of "shedding light on brain functions" in both the research and clinical fields is accelerating these days, as well as a technique to diagnose diseases of patients. Research on the following areas is active:

- The future information-communication technology derived from the understanding of brain functions.
- Early diagnostics for dementia and brain ischemia, and understanding of development disorders and mental illnesses, which will be important in the coming aging society with fewer children.
- Research into Brain Machine Interface (BMI) to improve the quality of life (QOL) for elderly and disabled persons.





To meet such leading-edge needs to"measure the brain function," Yokogawa pursues the research without pause and has developed an ultra-high sensitive magnetic sensor of superconductivity. This research has led to the commercialization of the magnetoencephalograph (MEG), which is used as medical and laboratory equipment both inside and outside of Japan.
The most remarkable feature of MEG is its ability to directly capture magnetic fields generated by the activity of nerve cells, (1) non-invasively, (2) with a high temporal resolution, and (3) with a high spatial resolution. MEG is an essentially safe equipment, and maximizes patient comfort. The activity of nerve cells in the brain is in the order of milliseconds. Many of the researchers who study brain functions and the physicians who diagnose diseases and illnesses have high expectations for MEG system because of its user-friendliness and high temporal resolution. Magnetic fields generated by nerve cells are extremely weak, so it is required to capture changes in the magnetic fields on a scale of one hundred millionth to one billionth of the earth's magnetic field. Today, the sole solution to capturing changes in such weak magnetic fields is the Superconducting Quantum Interference Device (SQUID) that uses the superconductivity. SQUID sensors have the function of first order coaxial gradiometer, which are superior in reducing external noise and in measuring the deep area of the brain. Yokogawa's MEG system was developed by combining its measurement technologies, including SQUID sensor, high-performance magnetic shield, cryostat, multichannel high-precision data acquisition and recording, and excellent analytical software.
Yokogawa believes that this leading-edge measurement tool will help cure brain diseases and contribute to the ever accelerating development of the brain science.



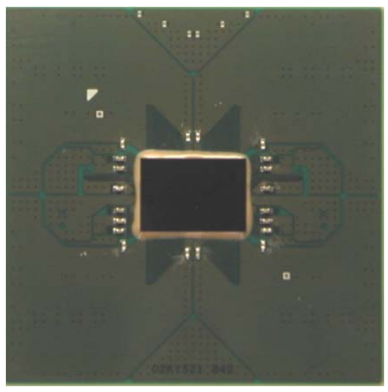
Kanazawa Office & Research Center

Proprietary Technology Enables High Fidelity Waveform Measurement

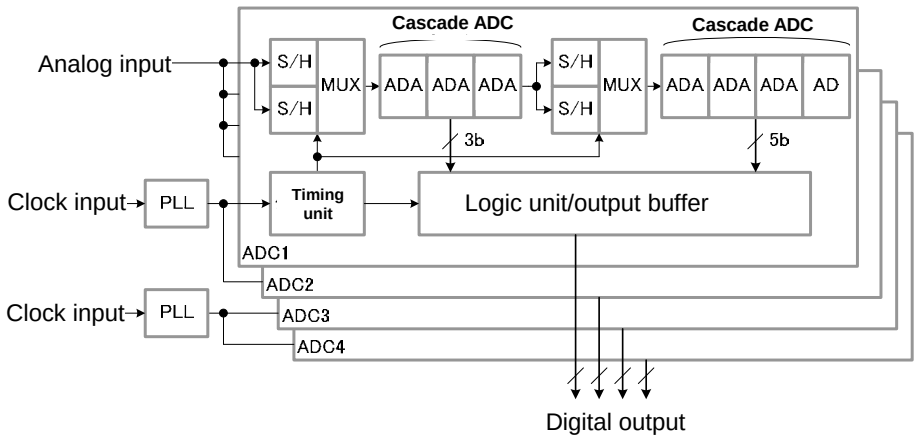
<10GS/s High-Speed Analog-to-Digital Converter Technology>

An analog-to-digital (AD) converter, which converts an analog input signal to a digital output signal, is a key component of digital oscilloscopes. AD converters capable of handling video and wireless modulated signals at up to several hundred MS/s* are available in the market. However, digital oscilloscopes require the speed to be several GS/s or faster, and measurement characteristics capable of faithfully representing waveforms, so the range of applications of the AD converters available in the market is limited. Accordingly, Yokogawa is continually developing high-speed and high-accuracy AD converters for its own digital oscilloscopes.

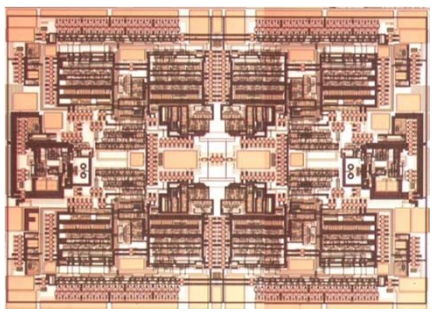
Yokogawa's high-speed AD converters employ an AD conversion architecture, called a cascade method, which was developed by Yokogawa (and received an award for encouraging local inventions in 2004. Compared with a parallel type (flash type) AD conversion architecture that is used for general high-speed converters, the cascade architecture uses far less comparators for basic circuits, thus reducing the size and conserving power.
To perform the AD conversion, the cascade architecture sequentially determines the digital code for the corresponding analog input voltage bit by bit, starting from the most significant bit. Hence, it is, in principle, able to perform AD conversion of 8 bits using only 8 comparators. However, this design faces an obstacle. If the difference from the reference voltage, which is used for comparison with the analog input voltage, is very small, the digital value cannot be determined distinctly, because the gain of the comparator is not infinite. To solve this problem, Yokogawa developed a method to determine the digital code by detecting if the analog input voltage approaches the threshold, and running an error prevention circuit only at that time. In this way, the circuit size and power consumption were substantially reduced compared with the parallel architecture.
The 10GS/s AD converter in the figure is packaged into one chip using the leading-edge 120GHz fT SiGe bipolar process.
* Sampling rate (S/s): Number of samples acquired per second



10GS/s 8bit AD Converter



10GS/s Cascade AD Converter Block Diagram



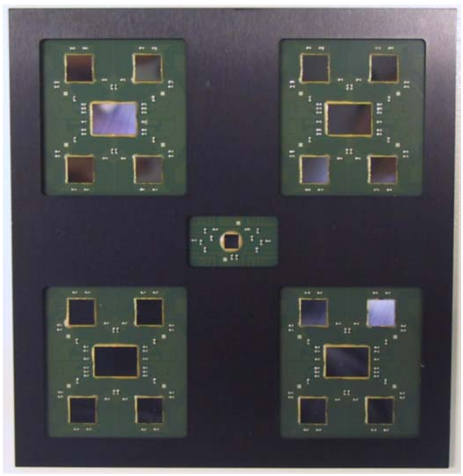
Die Photograph

<LSI Mounting Technology Supporting 40GS/s>

If a measured signal exceeds several GHz, the inductance caused by the wire bonding wire connecting the LSI and the package will affect the waveform quality.

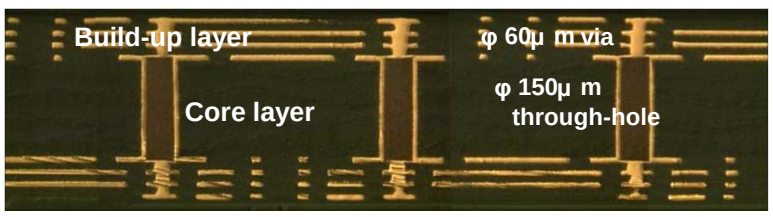
In particular, oscilloscopes are required to faithfully represent waveforms, so a flip chip (FC) bonding that eliminates the bonding wire bond becomes necessary. In the case of the FC bonding, signal retrieval is not limited to the vicinity of the chip, as in the case of the wire bonding. As a result, it is easier to separate analog and digital signals, and power wiring does not occupy a large area of the chip. Furthermore, a smaller mounting area enables multiple chips to be mounted to enhance function and performance.
Yokogawa is developing a Au-Sn FC bonding technique, which maximizes the performance of its developed high-speed LSIs, which is also applicable to multi-chip mounting, and which reduces the bonding pad area, as well as a high-density build-up substrate technique that is suitable for the FC bonding.

The figure shows a prototype of a multi-chip, high-sampling-rate AD converter. The 40GS/s AD converter was developed by mounting four 10GS/s AD converter LSIs and peripheral ICs using the FC bonding technique.
To evaluate the construction and heat-dissipation designs, FEM simulation was used to check effects such as a stress to the FC joints and warpage of the substrate. To evaluate the reliability of the FC joints, a test device with approximately 2,000pin FC bonding in a daisy chain connection was prototyped to perform an extended time evaluation.



40GS/s AD Converter Module

Cross-section of 80μm-pitch Au-Sn Joints



Cross-section Photo of 8-layer (3-2-3) Build-up Substrate

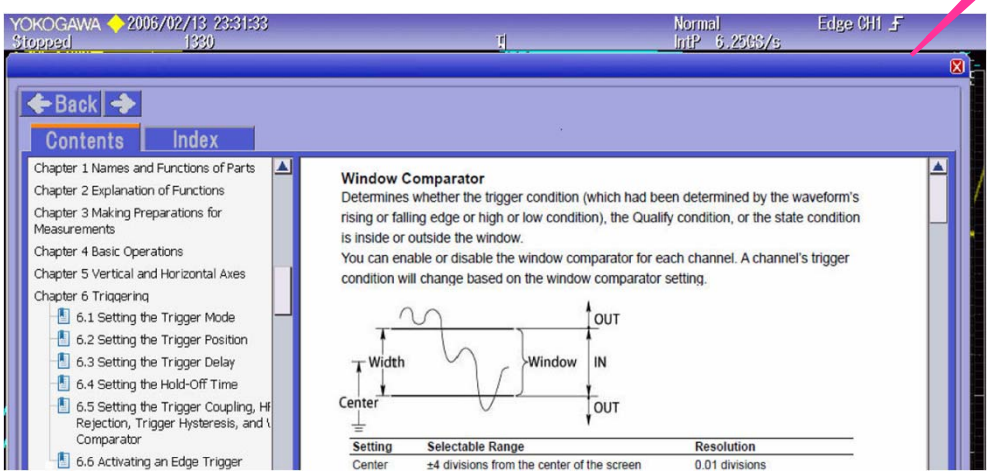
“Smart Operating Concept” Achieves the Goal of Being Easy to Use
<On-Demand Design, Intuitive Operation, and On-Demand Help>

The models of consumer products, such as digital home appliances, mobile phones, air-conditioners, and cars, change rapidly, so development engineers need to develop their products in ever decreasing design cycles. On the other hand, designers must assure quality in order to prevent market problems. It is important to remove bugs from the designed circuit and verify the operation margin even with short development times.
General-purpose measuring instruments such as an oscilloscope are used as debugging “tools” just in the same way as physical tools such as a pair of scissors and ruler. It is inconvenient for users to have to rely on the operation manual for an oscilloscope.

The DLM2000 is a mixed signal oscilloscope based on the smart operating concept that achieves the goal of being easy to use, and can be used in the same way as physical tools.

- An easy-to-use universal design is used; the keyboard is divided into areas according to function, and the operation panel is laid out under the screen.
- An optimal key layout to suite various applications, and a dedicated knob makes intuitive operation possible.
- An on-demand help function allows users to view an explanation on the screen during measurement, thus providing a sense of interactive operation.

Universal design where operation panel is laid out under the screen



On-demand help function provides a sense of interactive operation

Optimal key layout where the keyboard is divided into areas according to function

Mathematical Logical Trigger Technology Captures Complex and Rare Events
<Combination of 17 Types of Event Triggers>

To evaluate digital signal processing circuits for embedded systems , it is often necessary to not only activate a trigger by a logic pattern but also to define one channel as a strobe (clock) signal and activate a trigger by a logic state, pulse width or serial data code.

Yokogawa’s trigger state machine for high-speed trigger processing LSI developed for the DL9000 series confirms that trigger event 1, whose logic state is defined, is activated, then checks that trigger event 2 is activated according to the time conditions such as a defined delay time, and then activates a trigger.

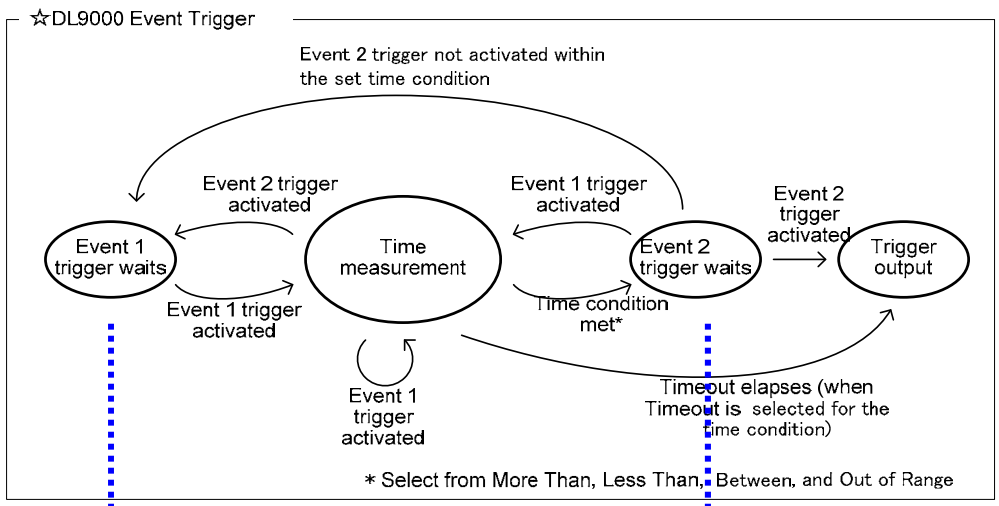
As for trigger events, not only is it possible to select a waveform edge or state, but also a pulse width, decode data of a serial bus, or so on. For example, a trigger can be activated by combining different logic data items as shown below, so it is possible to perform a complex analysis of digital signal processor.

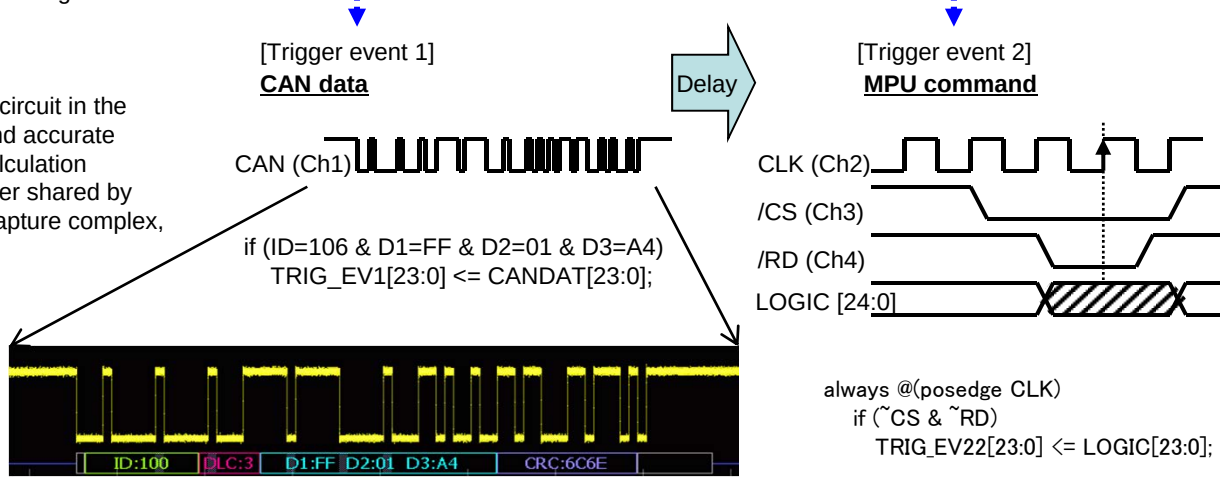
(1) Trigger event 1: Bit stream data of a CAN bus

↓ ・・・ After a certain time period elapses after CAN data is generated

(2) Trigger event 2: MPU command issue

The high-speed processing LSI realizes a wideband trigger circuit in the SiGe process, thus making possible a pulse width trigger and accurate measurement of time between triggers. As for the logical calculation function for logical patterns and the complex serial bus trigger shared by CMOS process LSI, two types of trigger LSI’s are used to capture complex, high-speed patterns.





Example of CAN bus trigger

<High-Frequency Probe Design and Mounting Technology>

In the area of high-frequency waveform measurements using an oscilloscope, the importance of probes is growing as the speed of observed signals is increasing.
Yokogawa uses its high-frequency circuit design and mounting technologies to develop active probes with excellent high-frequency characteristics, and commercializes products that are more convenient to use, thanks to their compact size and automatic probe recognition functions.
(The development of this active probe was announced in SICE-ICCAS 2006.)

Wide-Band Active Probe (PBA2500)

Yokogawa's Technologies

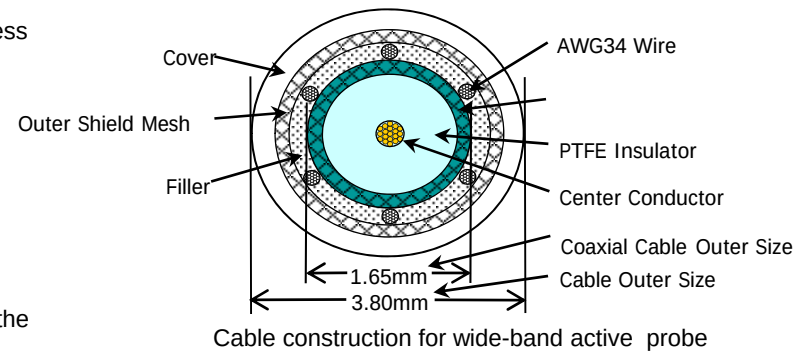
■ High-Frequency Circuit Design Technology
The input attenuation unit performs signal conditioning, optimal constant setting and elaborate pattern design. This design makes it possible to achieve high-input impedance and a flat, high-frequency characteristic.

■ Amplifier IC Design Technology
The amplifier circuit buffers the input signal and drives the cable, and a custom IC utilizing the SiGe process is used to expand the bandwidth.

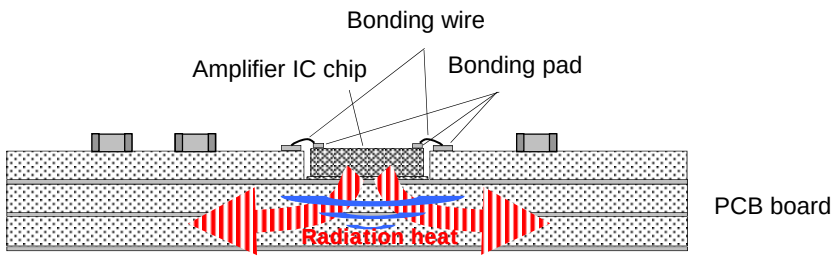
■ High-Frequency and High-Density Mounting Technology
Embedding amplifier ICs as bare chips on the PCB minimizes the parasitic inductance caused by wire bonding, thus achieving an excellent heat dissipation characteristics.

■ Cable Design Technology
Construction was optimized using foamed Teflon material for the coaxial signal cable's dielectric material. The power supply to probe head, high-frequency characteristics, and cable laying are well balanced by reducing the cable external diameter to 3.8 millimeters.

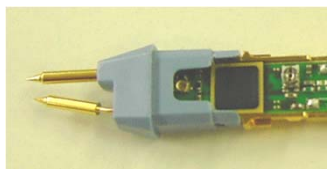
■ Interface between Probe and Oscilloscope
The probe interface employed enables the connection to the BNC input of the oscilloscope and supports the power supply and probe's automatic recognition function.



Cable construction for wide-band active probe



Amplifier IC mounting



Probe head in which parasitic inductance was minimized by high-density IC chip mounting

<High-Speed Data Processing IC for Waveform Measurement>

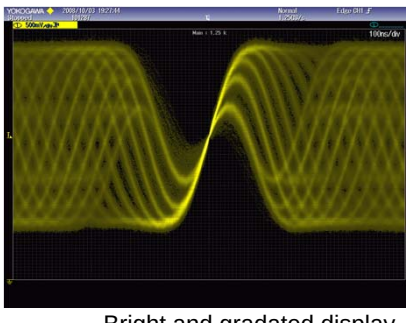
Processors and software are used to implement functions in various industries from digital home appliances through to automotives, so it is necessary to observe the waveform quality and digital control signals.
Digital signal processing functions including the trigger function of the oscilloscope are packaged into one ASIC chip, thus enabling the processing of 4 analog channels and 8bit logic on the hardware, capturing waveforms at a high speed, and enabling a bright and gradated display.

A ScopeCORE engine switches between analog input and logic input in the data capturing unit.
The captured data is stored in the area on analog channel 4, and the data flows without distinction from the analog data (display data processing is the processing dedicated to logic), so the high-speed waveform update rate is maintained, even when the logic display is enabled, thus preventing rare events from being overlooked.
Logic waveforms can be displayed (overlaid) without distinction together with analog waveforms, so the timing relationship and differences between analog and digital signals can be recognized intuitively.
All analog and logic inputs are connected to the trigger circuit, so mixed triggers in all combinations of inputs are possible, regardless of the display switching between analog and logic.

ScopeCORE™ Engine

DLM2000 Series

The signal processing unit captures the waveform data together at one time to acquisition memory, asynchronous with the display updates, thus increasing the speed of capturing waveforms (at a waveform capturing rate of up to 20,000 records per second).
Frequency-to-brightness conversion is performed for the intensity gradated display, in order to allow the visualization of multiple waveforms which are overlaid upon each other.
Acquisition memory is managed by Yokogawa's proprietary "*History Memory*", which allows users to track waveforms in the past for analysis. (Up to 20,000 data records can be stored)
The combination of the intensity gradated display, which allows users to see events intuitively, and the History function, is a novel and useful. Used together, advanced event recognition and analysis is possible in ways that are not available in competitors' products.



Bright and gradated display of DVD RF signal

One waveform can be retrieved

A feature to perform large-memory analysis without extended lag was one of the ScopeCORE design goals.
When dealing with extremely long waveform acquisitions, it is often difficult to visually recognize information from the entire record, so a search engine that uses trigger conditions is employed to allow users to derive the desired data from buried waveforms.
The ScopeCORE design achieves a processing capability of up to 50million edge search per second, so 125 million points of memory can be searched in approximately 3 seconds.
The searched data can be enlarged and displayed in the zoom window, and the zoom factor can be set with finer resolution than T/Div, so the desired waveform can be viewed with the maximum resolution.

The engine was implemented completely in hardware, to improve response, so the DLM2000 can be used without stress. Robust data processing capability with high-speed waveforms rate has been achieved, and as a result, rare events are not overlooked during debugging, substantially improving work efficiency.

Core technology

World Top Level Measurement Accuracy
<WT Series Precision Power Analyzers>

The requirements for energy conservation in electronic equipment has been increasing in recent years from the perspective of global environment issues and effective use of energy resources. With the growing popularity of hybrid vehicles and inverter refrigerators and air-conditioners, it is necessary to improve accuracy and increase bandwidth in measuring power consumption and efficiency.
Yokogawa meets these requirements with its high accuracy, wide bandwidth, precision power measurement technology.

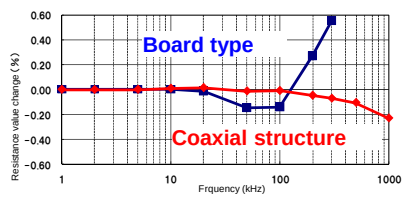
WT3000 Series

Yokogawa's Technology

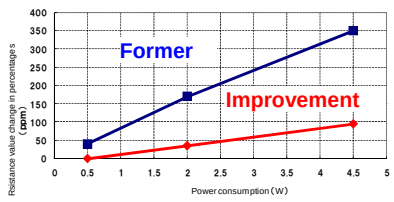
■ Current Sensing Technology

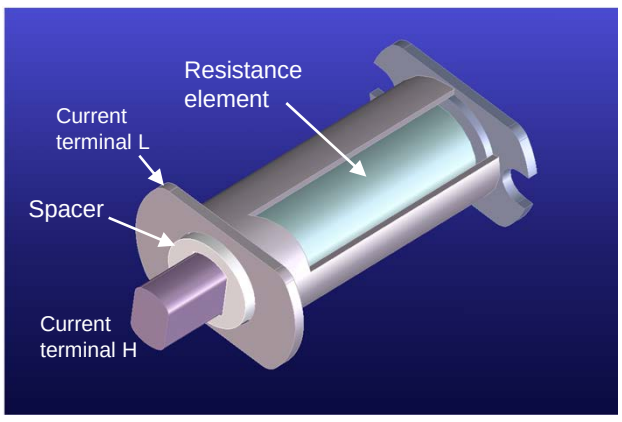
Power measurement requires the measurement of voltage and current. A shunt resistor used for the current measurement must be low in resistance, and its resistance value must be constant over a wide frequency range. Generally, if the resistance value becomes smaller, the inductance becomes relatively larger, which makes it difficult to achieve a wide range. So Yokogawa employs a proprietary coaxial construction for the shunt resistor to achieve a 1MHz frequency range while maintaining the resistance at 5 mΩ.
Furthermore, a shunt resistor is heated by consuming the measurement current, resulting in a change in the resistance value. To solve this problem, Yokogawa employs a special construction for the resistor to minimize the change in the resistance value, thus achieving highly accurate measurement.

Frequency Characteristics of Shunt Resistor

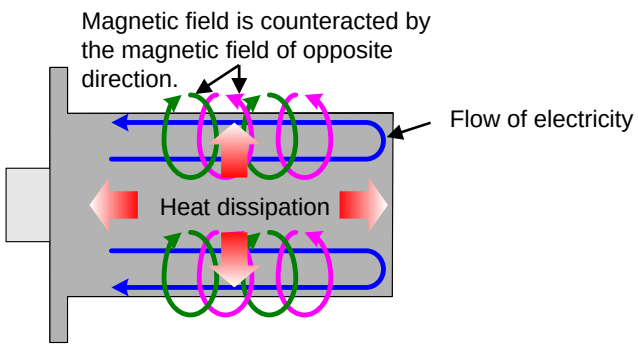


Power Characteristics of Shunt Resistor





3-D diagram of shunt resistor



・Symmetrical structure that counteracts the magnetic field.
・Heat dissipation structure that equalizes the thermal elevation.

Cross-section diagram of shunt resistor

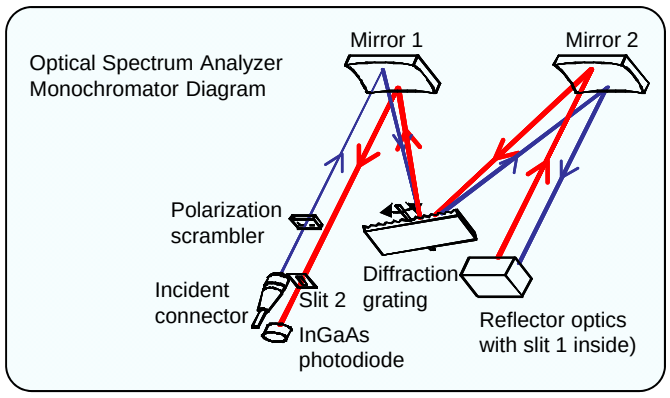
Dissolving Light Waves to Ultimate Level for Measurement
<High Performance Spectral Technology of Optical Spectrum Analyzer>

In the optical communication area, establishment of the wavelength division multiplexing (WDM) technology substantially increased the optical communication capacity and helped construct flexible optical communication networks. As a result, a higher wavelength resolution and wider optical dynamic range are required for the spectrum measurement of optical signals. To enhance the optical performance of conventional optical spectrum analyzers, a double monochromator consisting of two cascade-connected monochromators was used. However, it had problems, for example, the configuration was too large and complex, the price was too high, and it was not reliable for a long period of time.
Yokogawa's high performance spectral technology is applicable to the wide wavelength range from the visible optical band through to a long wavelength exceeding 2 µm, so it can meet various optical spectrum measurement needs in a variety of applications from information and communication through to biomedical and environmental measurements.

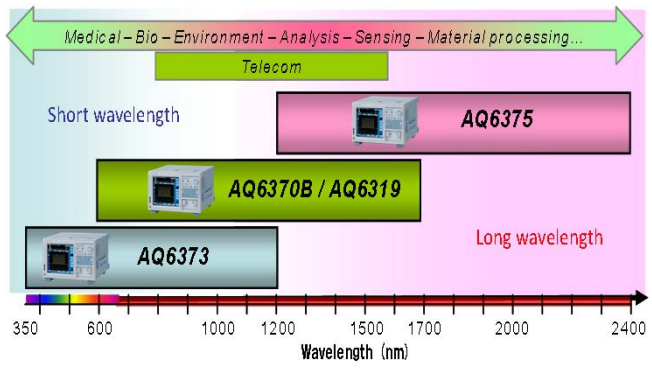
AQ6370 Series

Yokogawa's Technologies

■ Yokogawa's high precision Czerny-Turner multipath monochromator, which is very compact compared with a standalone spectrometer, achieves a high wavelength resolution and wide dynamic range.
■ A wide measurable range enables an across-the-board measurement of not only the semiconductor laser light but also the spectrum of light sources in a wide bandwidth. Furthermore, a variable slit in the monochromator allows users to set the wavelength resolution from 0.02 to 2 nm according to the measurement condition.
■ A highly sensitive photodiode is used for the light-receiving element. Furthermore, coding of all optical components, including the reflector optics of the monochromator, was optimized to reduce the loss of the monochromator and to make possible highly sensitive and high speed measurement.
■ As for optical input interface, Yokogawa's monochromators employ a "free space" interface, which makes possible the direct input of not only single-mode fiber but also multi-mode fiber. The non-contact design prevents the end face of optical fiber from being scratched and improves maintainability.



Yokogawa's optical spectrum analyzers are used at many research institutes, universities, and corporations in the world for the research and development of optical communication technology and for the development and manufacturing of optical transmission devices and optical components. Yokogawa has the world's top share in the optical spectrum analyzer market. (Data: Yokogawa's research in 2008)



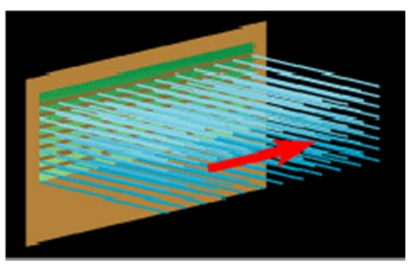
AQ6370 Series Optical Spectrum Analyzer

Observing Living Cells
<Dual Nipkow Disk Method with Microlens Array>

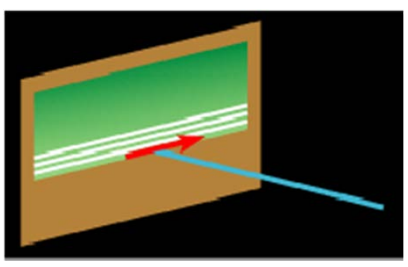
Yokogawa's CSU series employs Dual Nipkow Disk scanning method, having a second Nipkow disk with microlens array, which is proprietary to Yokogawa. The first Nipkow disk is a pinhole disk on which approximately 20,000 pinholes are arranged to enable raster scanning entire field of view. The other is a microlens disk on which the same number of microlens are placed so that each microlens focuses excitation laser beam onto its corresponding pinhole. The two disks are mechanically fixed together with a spinning motor and runs at up to 10,000 rpm to raster scan the entire field of view at up to 2,000 fps.
The expanded and collimated laser illuminates the microlens array to be focused on each pinhole, and about 1,000 beams passing through the dichroic mirror and the pinhole go through the objective lens to illuminate the sample to excite fluorescence. The fluorescent images emitted from the sample returns to the same pinhole, reflected by the dichroic mirror and then captured by the camera.
Microlens array is not only effective to enhance laser power but also to significantly reduce backscattering at the disk surface which results in minimizing background noise.
In comparison to a conventional confocal microscopy which employs a single-beam, line scanning method, the multi-beam scanning of the CSU is not only fast, but can effectively excite fluorescence with substantially lower laser intensity thus can reduce the phototoxicity and fluorescence photobleaching of the sample.

The speed, minimal background noise, and reduced laser intensity are the exquisite features of the CSU technology to enable real-time observation of living samples at high-resolution and for a long time with minimal damages.
Unsurpassed by any competing technologies, the CSU technology is now the de facto standard tool for live cell imaging and thus have been used by over 2,000 top gear researchers world-wide.

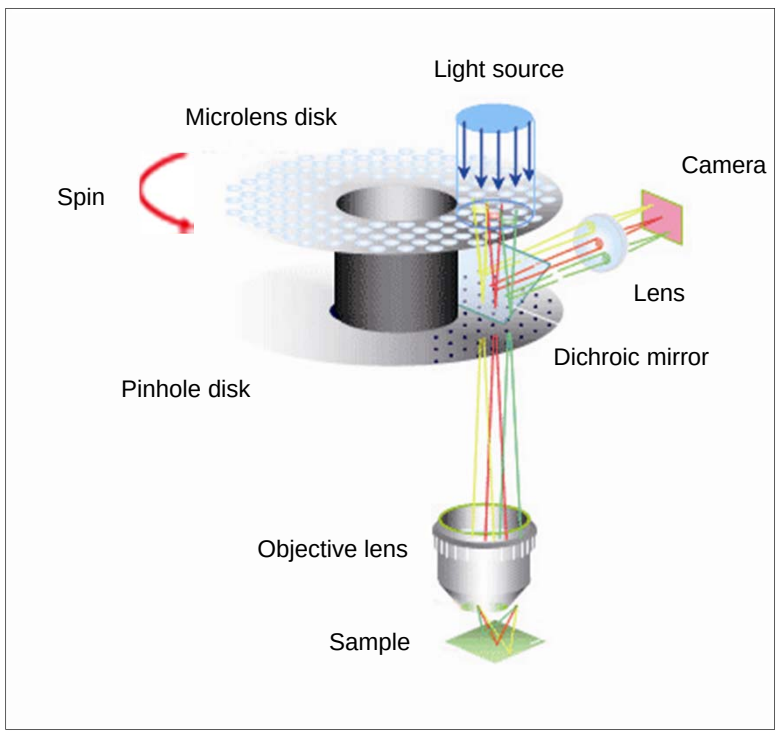
Comparison of scanning methods



Nipkow method

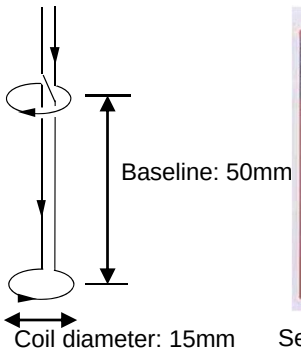


Conventional Galvano method

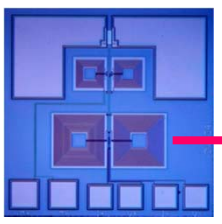


Receiving the Body's Faint Magnetic Signals with High Sensitivity
<High Density Mounting of High Precision SQUID Sensors into Whole Head Dewar>

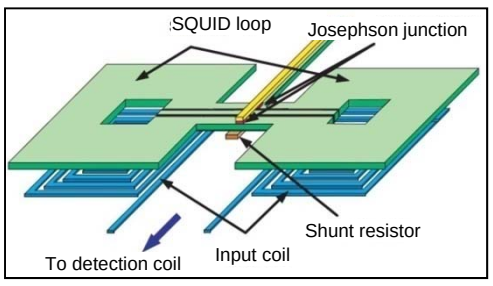
Yokogawa's first order coaxial gradiometer effectively reduces external noise and captures a magnetic field signal from a deep area of the brain with high sensitivity.
Yokogawa's magnetoencephalograph (MEG) system densely mounts SQUID sensors that cover the whole head. Furthermore, the sensors are mounted into a horizontal dewar that prevents vibration and enables reduction in size, so a particular part of the brain can be identified with extremely high reliability.



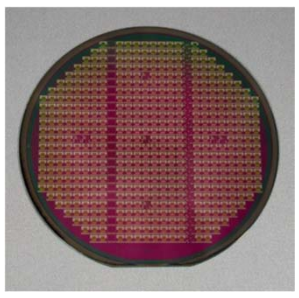
Sensor view



Thin-film DC-SQUID chip
(2.5 x 2.5 mm)

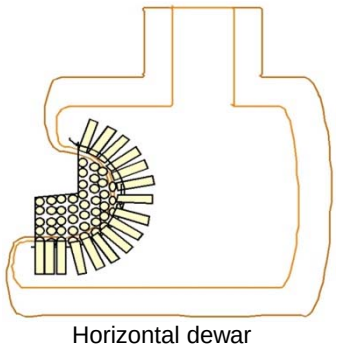


Construction diagram



Waver view

Whole-head sensor holder
(Compliant with JIS-T8133 large head model)



Horizontal dewar

Features of the world's first horizontal construction
- Less effect of vibration
- Helps reduce the size of the whole device
- Reduces the consumption of liquid helium (10ℓ per day or less)

Core technology

High-Precision, High-Efficiency, and Maintenance-Free
<Direct Drive Motor>

Yokogawa uses its proprietary core technologies to develop a low heat-generating (high-efficiency), high-precision, high-torque, and high-servo-strength direct drive motor. The motor is based on unique encoder and driver developed by Yokogawa. Yokogawa motor is all-in-one motion control which enables to support customers to reduce their development time.

■ **Low heat-generation (high efficiency) and high torque**: The magnetic circuit employs "magnetic bias method" that uses rare permanent magnet that has a high magnetic force to be housed in the stator core. As a result, rotary torque T is proportional to the square of the sum of *excitation magnetic flux* φc that is caused by the current and the *magnetic flux* of permanent magnet φm. As a result very high torque is achieved.

$$\text{Rotary torque } T \propto (\varphi m+\varphi c)^2 - (\varphi m-\varphi c)^2 = 4\varphi m\varphi c$$

Comparing to AC servo motor, Yokogawa's Motor can generate the same amount of torque with approximately one-ninth of electric power, and approximately three-times higher torque is generated with the same power consumption. Even comparing to conventional direct drive motor, Yokogawa's motor has the excellent torque-to-weight ratio thanks to two factors. One is the fact hat *excitation torque* φc is proportional to the *exciting coil current* Ic, i.e. the generated torque T is proportional to the exiting coil current Ic. The other is usage of neodymium magnet that has the higher performance than samarium-cobalt magnet. Additional advantages of Yokogawa motor are; Because the current-torque characteristic is linear, smooth rotation is achieved even at a low current. For the rotation-torque characteristic is proportional, no need to control torque according to fluctuation in rotational speed.

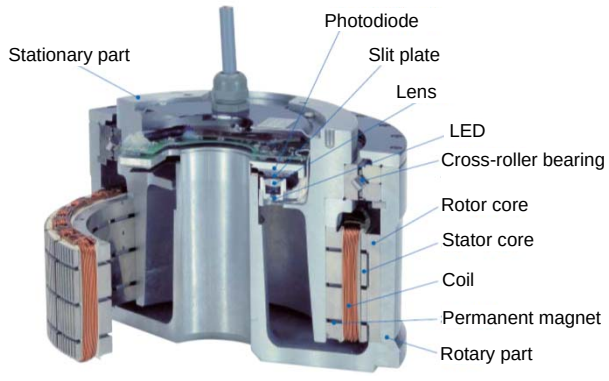
■**High precision:** Absolute accuracy of ±15 arc-sec and repeatability accuracy of ±1 arc-sec are achieved due to following two factors. Yokogawa's original high-resolution encoder is used to achieve a high resolution of up to 4,096,000 pulses per rotation. Since no reduction mechanism is required, no backlash is generated.

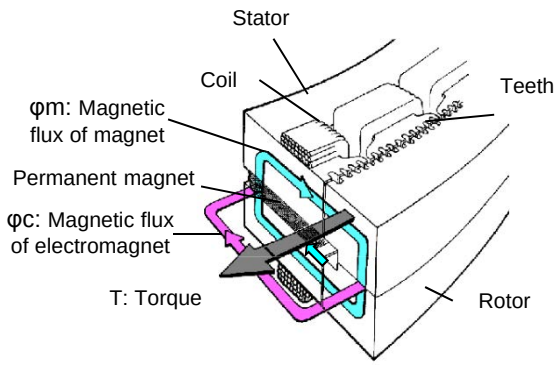
■**Short-time setting, vibration-less, optimal tuning (auto tuning)**: The special intelligent driver employs an I-PD position control method that makes it possible to resist changes in the load, and to sets the position in a short time. Using auto tuning function, the motor automatically configures the optimal servo parameters according to the load inertia (load mass).

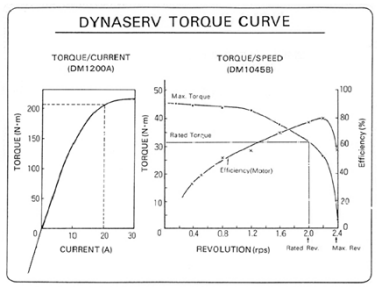
■**Support software:** This software supports the setting of the operation table and the advanced servo tuning. Using the support software, it is easy to change various servo parameters and filter settings. The motor-less operation function makes it possible to simulate operation without a motor. Furthermore, this enables to debug operation program without connecting to host controller.

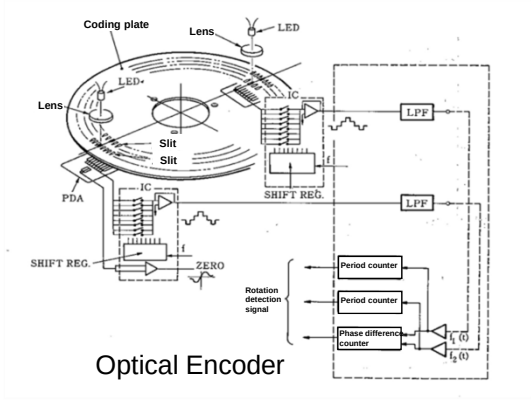
■**Maintenance-free, high-reliability and clean class 10:** The only sliding part is a cross-roller-bearing, and there is no brush and reducer. Thereby very few particles are generated during operation. This leads to the excellent cleanliness of class 10 (10 or less particles of 0.5 μm per square feet). Moreover, this unique structure that has minimum internal friction avoids wear, therefore it also avoid requirement of frequent maintenance.

The DYNASERV that incorporate these core technologies helps customer's device to achieve high precision, high speed and high cleanliness and reduce machine size and development effort.

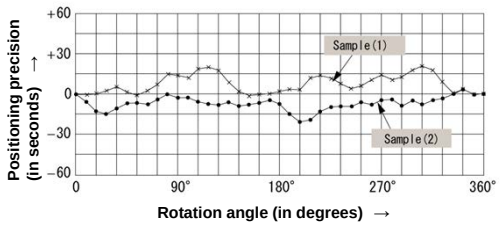








Optical Encoder

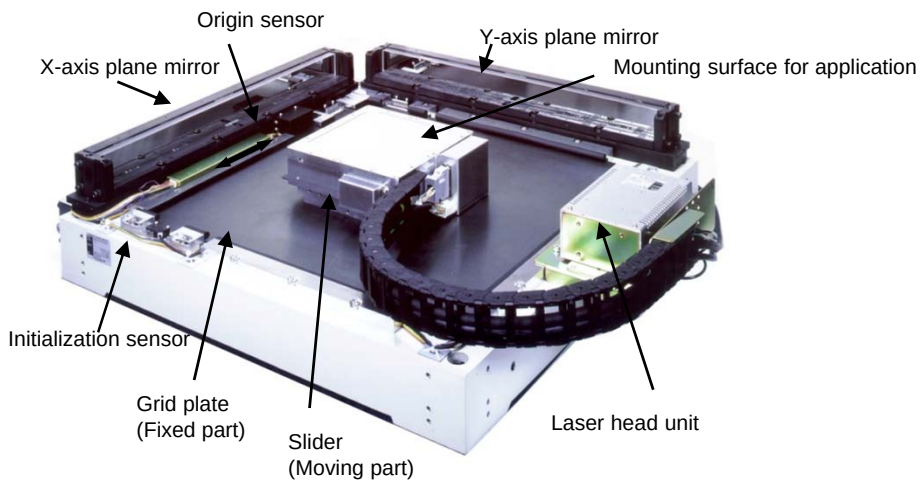


Pneumatic Floating and Moving for 0.1μm Positioning
<Plane Servo Motor>

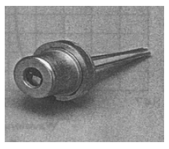
Yokogawa's plane servo motors are designed to be simple, compact, and lightweight with a low center of gravity. The pneumatic floating slider eliminates friction and keeps motor clean and maintenance free. The high bearing rigidity and the high resonance resistance increase speed and precision.

- ■ High-precision system: Position repeatability ±0.1 μm
- ■ Semiconductor laser interferometer: Resolution of 27 nm
- ■ Pulse train position command method: 0.1 μm per pulse
- ■ High-precision and high-speed positioning similar to a pulse motor
- ■ Return-to-origin control by both Origin sensor and initialization sensors
- ■ High-speed setting: 20 ms (for a setting width of 1 μm)
- ■ Bearing: Guide-less Air (hovering) bearing
- ■ Control: Non-interference three-axis (XYθ) control
- ■ Driver: High-precision, high-speed inverter
- ■ Speed: 0.5 m/s

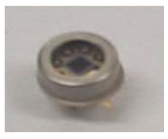
The PLANESERV that incorporate these core technologies helps customer's device to achieve high precision, high speed and high cleanliness and reduce machine size and development effort.

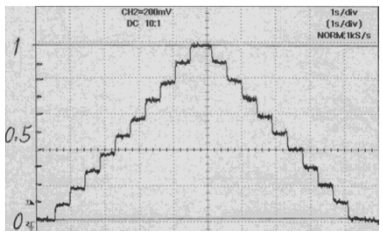


DBR laser light source



PDA (Interferometer sensor)





0.1 μm feed with PLANESERV

<Compound Semiconductor Core Technologies>

Helping Establish Ultra-High Speed Optical Communication

Products for optical communication lines, including transponders, and high-speed and high-frequency measuring instruments require devices with very high operation speeds. In the 1980s, Yokogawa started concentrating its resources on the development of devices and has continuously employed them in its products. The following uses figures and photos to present the compound semiconductor core technology that is one of Yokogawa's core competences.
In contrast to a silicon semiconductor that uses a single element, silicon, a compound semiconductor refers to a semiconductor that uses multiple elements as materials. A very famous example is gallium arsenide (GaAs), which is a compound of gallium and arsenic; the former belongs to the III group of the periodic system and the latter to the V group. As described below, Yokogawa owns various device technologies centering on indium phosphor (InP) that is a compound of indium and phosphorus; the former belongs to the III group and the latter to the V group. In the case of the compound semiconductor, it is possible to develop various characteristics by using multiple elements; for example, by appropriately mixing elements that belong to the III and V groups, and increasing the flexibility of band gap design. This technology provides excellent characteristics not only for high-speed electronic devices but also for optical electric converters (such as a photodiode). Yokogawa has focused on this point from the beginning of development to develop various devices and employs this technology for its products.

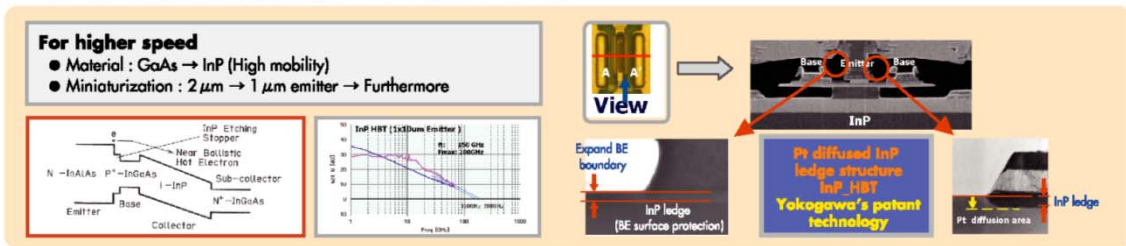
The first device to be presented is a Heterojunction Bipolar Transistor (HBT), which is used as a three-terminal amplifier device. Heterojunction refers to combining different types of crystals. Other elements are added to provide an indium phoshor semiconductor transistor with excellent characteristics, including high-speed operation.
(deleted sentence). Early in development, in an effort to increase the speed of devices, Yokogawa switched the material from gallium arsenide (GaAs) to indium phosphorus (InP) . Yokogawa also miniaturized the device structure (reduced the emitter width from 2 μm to 1 μm) to achieve high speed characteristics; the cutoff frequency (FT) is 150GHz and the maximum oscillating frequency (Fmax) is 200GHz. Yokogawa also developed a proprietary Pt-diffused InP ledge structure, which protects the surface of the interface of the emitter and bases, helping to increase the reliability of the HBT.

Yokogawa also integrated not only a transistor but also elements such as a diode, resistor, capacitor, interconnection and transmission line into a monolithic integrated circuit to add the necessary functions. These technologies and efforts provided devices with high speed, high integration, and high reliability.
The next device to be presented is a photodiode, which converts optical signals to electrical signals. Photodiodes are used in WDM monitors, spectrum analysis instruments, and communication line applications, including a transponder for optical communication. The vertical structure of the device (the band design of the compound semiconductor that constitutes the PIN type photodiode) and the electrode's structure size were optimized for a wide wavelength band, high frequency response, and high sensitivity. The characteristics on the long-wavelength side was improved compared to conventional photodiodes, so up to the wavelength band called a U-band in the terminology of WDM can be supported. In the spectrum application area, the band design of the device was optimized to enable the necessary sensitivity to be maintained up to a wide wavelength band of 2.5 μm or more. Yokogawa employs the solution in its products.

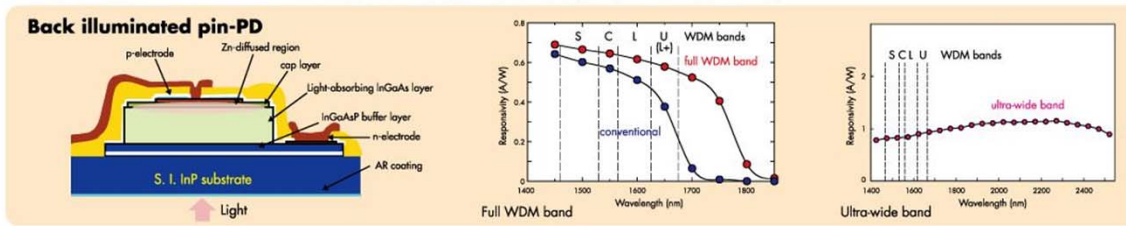
A resonant tunneling diode (RTD) is a next-generation ultra-high speed device that uses the resonant tunneling phenomenon of a quantum well structure. The figures on the right shows a transmission electron microscope (TEM) atomic image of RTD in high voltage transmission, and the I-V characteristic of RTD in high voltage switching. It was confirmed that the switching speed of the device achieved 2 ps or less. Yokogawa expects the device to be applicable to a wide range of applications in the future. Also in the case of RTD, the band design of the quantum well structure for the compound semiconductor was optimized to implement a high switching voltage. A tunneling diode is better known as the Esaki diode. Modifying the band structure in this way dramatically improved the device's characteristics.

A RBT (Resonant Bipolar Transistor) is a new device developed by combining the above RTD and HBT. RTD has an excellent high-speed characteristic; however, it is a two-terminal device, so to use it, for example, as an amplifier device, a means must be provided to separate the input and output signals. RBT is a device that was developed by incorporating an RTD into the structure of HBT, which is a three-terminal device by optimizing the design. The figures on the right show a static characteristic and the photo of the structure. Yokogawa believes that the advantages of RTD and HBT will be applicable to a wide range of next-generation ultra-high speed device applications in the future.
The next device is an optoelectronic and quantum-dynamic device that was developed by mounting electronic and optical devices on the same semiconductor substrate. The example shown on the right was implemented by integrating a photodiode (PD), resonant tunneling diode (RTD), and HBT-based data buffer circuit (DB) on a single InP semiconductor substrate in a monolithic manner. Wire bonding or pattern for interconnection on alumina substrate is not used for the connection between these devices, so excellent characteristics, including high-speed, are achieved, and the size of the entire function can be reduced. In this way, a technology to implement devices with various functions on compound semiconductor substrates such as InP is expected to be applicable to a wide range of applications in the future.

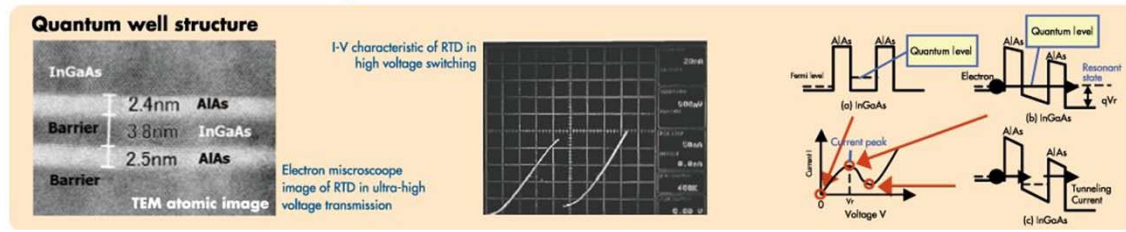
● InP HBT (Hetero Bipolar Transistor)



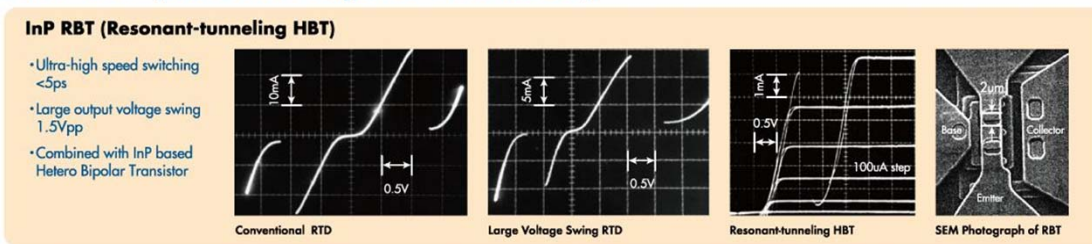
● Photodiode with High Responsivity (Full WDM)



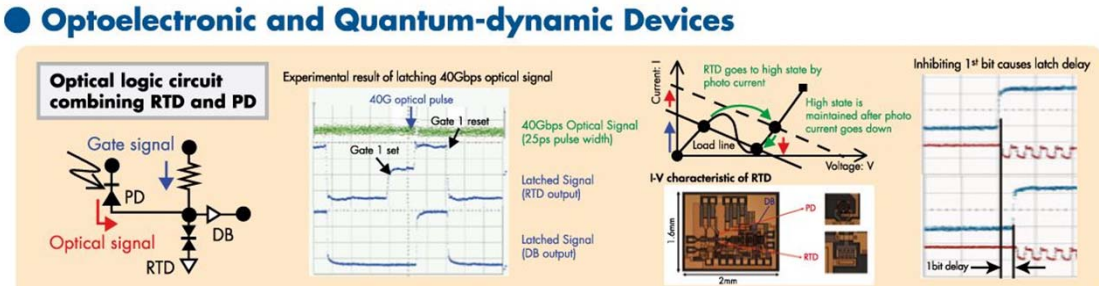
● Resonant Tunneling Diode RTD



● InP RBT (Resonant Bipolar Transistor)



● Optoelectronic and Quantum-dynamic Devices

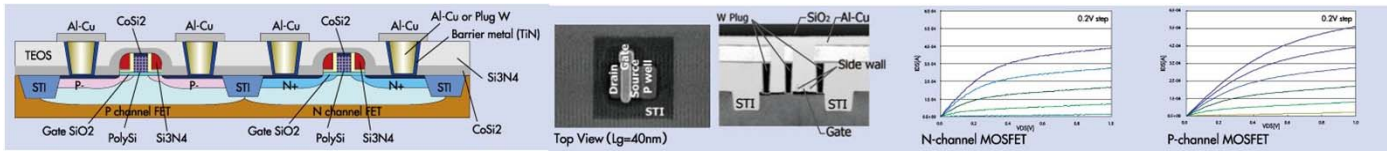


Core technology

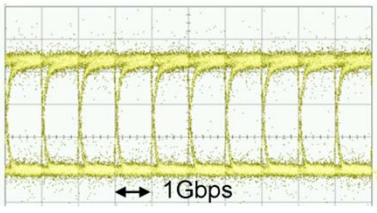
<Optical Communication Core Technologies>

The compound semiconductor core technology described in the previous section and the nano-CMOS technology for communication described in this section have not only the characteristic of, for example, an individual transistor but also an excellent characteristics as an integrated circuit that is made by combining devices. Also, a circuit structure technology within integrated circuits is important (for instance, the “bust-mode CR” described below is one such example), and so is a “high-frequency circuit implementation technology” that actually implements the integrated circuit in the package and provides an appropriate interface for external blocks. This page describes these technologies and presents devices for high-speed communications, as well as a “micro optics delay interferometer” and “optical switch.”

● SerDes, ADC, and more (nano-size CMOS technology)

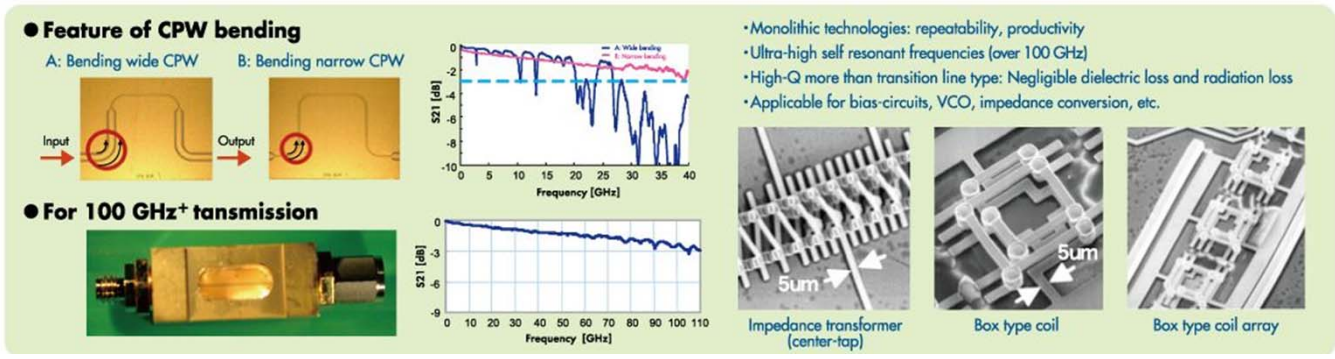


1Gbps bit stream
(IC test output waveform)



There are various silicon semiconductor devices available. This paragraph describes a CMOS technology that is capable of implementing high integration. CMOS is made by combining the n-channel MOS transistor and the p-channel MOS transistor. By reducing the gate length of the MOS transistors, higher speed, higher integration, and less power consumption are achieved as shown in the figure. Yokogawa developed a device with a 40 nm gate length, which is the most advanced technology in the world in terms of practical use. The compound semiconductor is characterized by its ultra-high speed operation; however, it is difficult to integrate many, for example, hundreds of thousands of devices. On the other hand, CMOS does not have the speed of the compound semiconductor but allows for implementing high integration. Yokogawa develops excellent equipment and systems by combining the characteristics of the CMOS and compound semiconductors.

● Fine Assembly

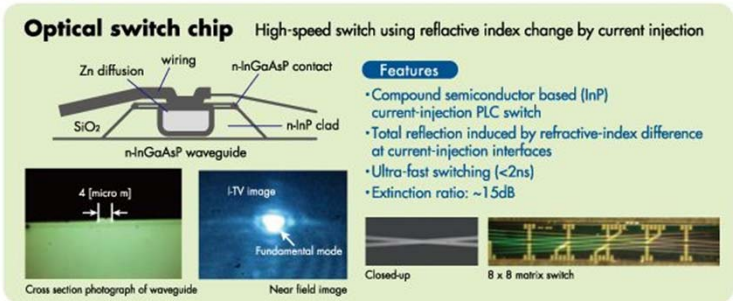


This paragraph describes examples of Yokogawa’s high-frequency circuit implementation technology, “CPW bending transmission characteristic,” “100GHz+ transmission characteristic evaluation,” and “ultra-small air core coil.” CPW (coplanar waveguide) refers to a transmission line widely used for high-speed circuits. The photos on the upper left show CPW transmission lines on alumina substrate. When the width of the center conductor in the bending part is wide, transmission loss at a low frequency is slightly smaller, but a lot of unnecessary resonances are generated, so it is not practical. When the width of the line is narrow, the difference in the GND (ground) lengths outside and inside is small, and resonance is not generated at up to a high frequency, so it can be used in a wide band. The photo on the lower left shows an implementation example of a 1 mm connector that can be used at 100GHz or more. An ultra-small air core coil, which is excellent with regards to repeatability and productivity, was developed using semiconductor integration technology. The coil is characterized by its low losses and high Q-value in up to the ultra-high frequency band. The photos show an impedance transformer, box type coil, and its array. The coil is applicable to a wide range of applications, such as a resonant circuit of an oscillator or an impedance converter.

● Micro Optics (Delay Interferometer)

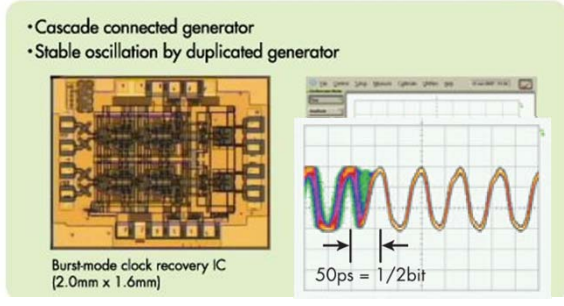
A delay interferometer is a device that can be used as a demodulator for the differential phase shift keying (for example, in DQPSK and DPSK modulation). This paragraph describes a delay interferometer that uses micro optics technology. The micro optics are made by combining a prism and various optical devices. Compared with a planar waveguide made on substrate using the semiconductor processing technology, the characteristic of individual devices is excellent and it is easy to isolate the devices from each other. The interferometer shown in the figure above is an unbalanced Mach-Zehnder (MZ) interferometer, in which the light from two output ports is reflected by the mirror and focused into Twin-PD. By combining optical devices, blocks having various functions can be created.

● Optical Switch



Optical switching devices are described in detail in the section Optical Packet Switching Core Technology. Optical switching devices are made using compound semiconductor technology. As shown in the cross-section view in the figure, a waveguide is formed on compound semiconductor chip, and electrodes are formed on part of it. The light is switched by changing the dielectric constant, which in turn is changed by the presence and absence of current flow. In this way, an optical switch with no moving parts is made using the semiconductor technology. Ultra-high speed operation (less than 2ns) is achieved by electronically operated switching with no moving parts.

● Burst-mode Clock Recovery



The figure above shows a clock recovery IC, which extracts a clock signal—from a packet signal (burst signal) arriving sporadically—that is synchronized to that signal. The clock signal must be generated instantaneously when a signal arrives sporadically, and the data signal that has arrived must start operation from the beginning. The photo shows a cascade-type, burst-mode clock recovery IC, in which two oscillators are connected in series, and which acquires a recovered clock. The photo shows an IC chip and the figure shows the waveform of the recovered clock (the beginning of data). The recovery clock can acquire synchronization in 50 ps, which is equivalent to 1/2 bit from the beginning of the packet data.

<Core Technology for Optical Packet Switching (1)>

The following describes the core technology for optical switching using figures and photos. In the communication area, there is a packet communication method, in which information to be transmitted is divided into a data stream of a certain length (packet), and information called a header that contains the destination or the like is added for transmission. Furthermore, the current optical network converts optical signals to electrical signals, for example, to switch signal routes, and after the switching processing is performed, the signals are converted back to optical signals. Therefore, conversion from optical to electrical to optical is performed. In contrast, the next-generation technology switches optical signals without changing them to electrical signals, and the key component for that network is the optical switch. This section describes a waveguide optical switch that is characterized by its high-speed switching (less than 2 ns), the high extinction ratio achieved by the integration (4 x 4), and an optical switch equipped with a gain unit that compensates for loss.

■ The following describes Yokogawa's optical switching principles. Two crossing plane waveguides are formed on a compound semiconductor InP or GaAs substrate. An electrode is formed in the crossing part. By injecting current to the electrodes, a high carrier density layer is formed in the waveguides directly under the electrodes. This change in the carrier density changes the refractive index by the plasma dispersion effect, and the incident light is fully reflected because the dielectric constant differs from other parts of the waveguides. Thus the optical signal path is switched by the current. The refractive index change is obtained using the equation on the right. The refractive index changes by -0.5% with a 150 mA injection current. "e" of the equation refers to the electric charge of the electron, "me" and "mh" refer to the effective mass of the electron and the hole, respectively. "λ" and "c" refer to the wavelength and the speed of an optical signal in vacuum, and "ε_0" refers to the dielectric constant in vacuum. If a carrier density in the order of N = 1.0 x 10^{18} counts/cm^3 is obtained, a decrease in the refractive index in the order of 0.1% is estimated. The structure of this optical switch is the same as that with the semiconductor integrated circuit technology. The optical switch is one of the important applications of the compound semiconductors that represent one of the core competences of Yokogawa. As shown in the figure on the right, many switching devices can be fabricated on the 4inch wafer (10 cm in diameter).

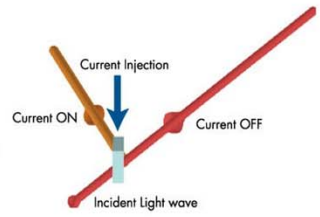
■ As described above, Yokogawa's optical switch that uses no moving parts is characterized by very high-speed switching because of its principles. Another advantage is its non-dependency on the optical wavelength. The following shows the main characteristics of the optical switching device.

- Switching time: <2ns
- Extinction ratio: Approx. 15 dB (32:1)
- Optical loss: Approx. 10 dB (fiber to fiber)
- Operation current: 150 mA (typical)
- Wavelength dependency: None (C-band)

■ The data on the right shows the results of a test that continuously switched pseudo packet signals using this optical switch device. The transmission bit rate for the packet data and optical modulation method used for the test were in accordance with the 40Gbps NRZ signal, in which the transmission rate is equivalent to 25 ps per bit and 200 ps per byte. The control system used for the test was configured with a frame gap of the packet of 2.4 ns (12 bytes in length) and a packet length of 3.2 ns (16 bytes). The figure on the right shows that the optical packet signals were switched according to destinations A and B and output alternately, that the optical waveform of the packet was not degraded at both the front and back edges of the packet (the optical eye pattern at the front and back edges is open in the same way as the waveforms in other parts; there is no signal degradation). On the other hand, in the case where the signal is output on one port and not on the other port, signal leakage to the latter port was insignificant and isolation was effective.
As described above, the core technology for optical switching using the compound semiconductor features excellent characteristics such as switching speed. By adding further modifications as described below, this technology will greatly contribute to the advancement of optical networks. An optical switch that switches optical signals without converting to electrical signals is a key component for implementing optical packet networks.

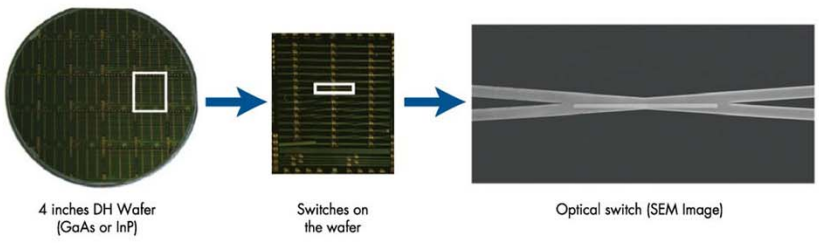
Principles

- Crossing planer waveguides
- Refractive index change by current injection
- Total reflection of incident light beam at the surface plane of current flow



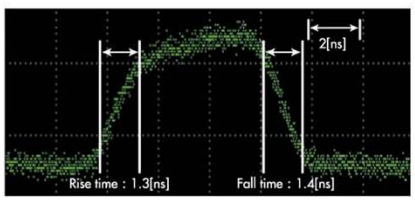
Refractive Index Change $\Delta n = -\left(\frac{e^2\lambda^2}{8\pi^2c^2\varepsilon_0 n}\right)\left(\frac{N}{m_e}+\frac{P}{m_h}\right)$

-0.5% refractive index change by 150mA current injection

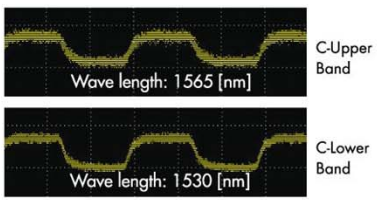


Features

- Switching time: < 2ns
- Extinction ratio: ~15dB (32:1)
- Optical loss: ~10dB (Fiber-to-Fiber)
- Operation current: 150mA typ.
- Wavelength dependency: None



Switching Speed Test

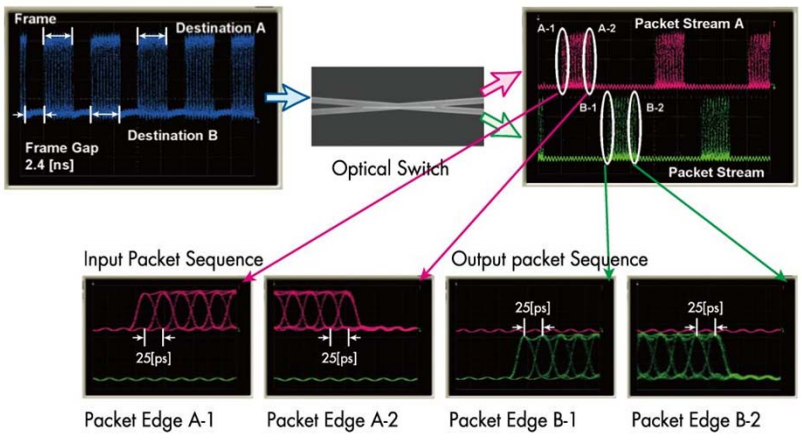


Independency of wavelength

Test Results

- Continuous switching of short pseudo packets

Frame gap: 2.4ns (12 byte-length of 40Gbps)
Packet length: 3.2ns (16 bytes)



<Core Technology for Optical Packet Switching (2)>

■ A 4x4 matrix switch is an optical device that is fabricated by integrating four waveguides in order to enhance functionality and performance. The multiple-time reflection design (introducing the leaked light into the unused port in the crossing section) improved the extinction ratio to 25 dB or more. The figure on the right shows an optical microscope photo image of the 4x4 switch and signal waveforms in which the extinction ratio was improved. The diagram below shows in a simple way that the extinction ratio is improved by two time reflection compared with one time refection. Specifically, the optical signal coming from the second waveguide (blue arrow) is reflected to the upper right direction by the first optical switch. On the other hand, there is light that is not reflected by the switch but travels straight to the lower right direction as leak light (red arrow) which should not be output. By reflecting this light again by the switch as shown in the figure in the center, the amount of leak light can be reduced (green arrow). The figure on the right shows the case where the output direction of the optical signal is reversed. The light that is travelling straight (blue arrow) is output to the lower right, while out of the leak light in the upper right direction, the light reflected by the first switch (red arrow) is reflected again by the second-stage light switch, and the leak light that is output to the upper right direction passes through two time switching so that it is suppressed sufficiently. The switch device is structured using semiconductor technology so it is easy to design this kind of integration. Yokogawa has already prototyped an 8x8 matrix switch and verified the prescribed operations (the information on this switch is not shown in the figure). The integration technology for semiconductors provides solutions for improving the complex switch structure and isolation as described above.

■ The following describes the development of the next-generation optical switch. As described above, many optical switches can be mounted on a semiconductor chip. However, optical signals are attenuated by being passed through the multi-stage optical switches and total length of the waveguides. In other words, the optical loss becomes large and some compensation is required. To solve this problem Yokogawa developed an optical switch that compensates for the loss mentioned above by integrating the optical amplifier function and removes the loss as a whole or provides some necessary gain. The figure on the right shows a photo image of the switch chip and main characteristics. The optical amplifier was designed so that the compound semiconductor waveguide has the optical amplifier function.
The following shows the main characteristics of the device.

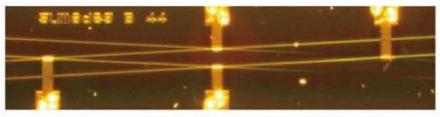
- Extinction ratio: 50 to 55 dB
- Loss compensation gain: +7 to +8dB
- Ultra-fast switching; 2 to 5 ns
- Gain saturation (-3 dB): +11 dBm

The figure shows a simple 2x2 switch, but it is possible to integrate many devices using the semiconductor technology. The following describes the waveforms shown in the lower part of the figure on the right. The figures on the left show 10Gbps NRZ modulated signals. The upper figure shows the input signal to the optical switch while the lower figure shows the output signal from the optical switch. The gain in this case is 6.4 dB; a good eye opening characteristic is obtained for the output signal, and no signal degradation is observed. The figure in the center shows waveforms obtained by applying a 40Gbps NRZ modulated signal. The upper figure shows the waveform of the input signal to the optical switch, while the lower figure shows the waveform of the output signal from the optical switch. The gain is 4.5 dB; also in this case, a good output signal is obtained. The figure on the right shows a waveform obtained by applying a 10Gbps optical packet signal stream. The figure shows not eye waveforms but input and output waveforms synchronized to the packet. Sag patterns on the high level side are observed; however, these do not become a problem if the threshold is appropriately selected. In this way, many switches can be integrated on a single chip using the compound semiconductor technology, and integration can be performed to provide advanced functions. These core technologies become very important in mass producing optical switches and putting them into practical use.

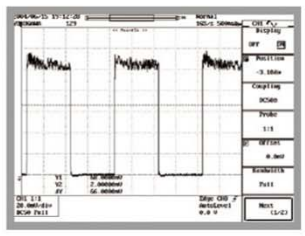
Performance

4x4 Matrix switch

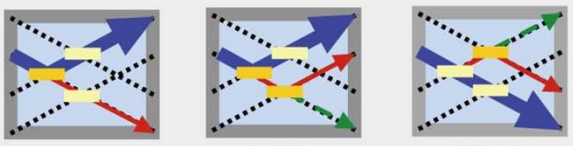
- Dispose of optical leaked signal using multi-stage reflection
- Removing leaked light causes extinction ratio improvement of 10dB.



4x4 switch matrix
(Image of optical microscope)



Significant small optical leak at OFF
Improved signal waveform (@500KHz)

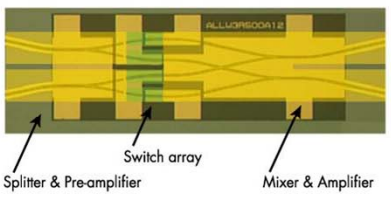


15[dB] One time reflection
25[dB] 25[dB] Two times reflection

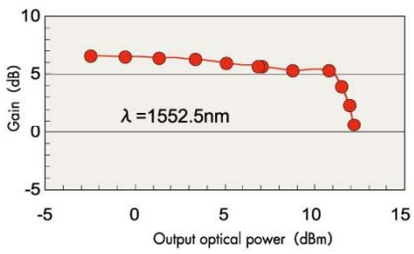
Development: Next-generation

Loss compensation optical switch for optical packet switching

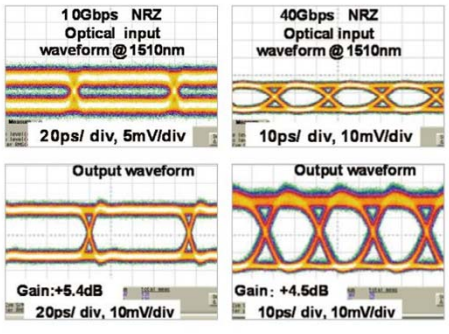
- Extinction ratio: 50~55dB
  Loss by injection current off
- Loss compensation gain: +7~+8dB
  Fiber insertion loss is compensated by optical amplifier
- Ultra-fast switching: 2~5ns
- Gain saturation (-3dB): +11dBm



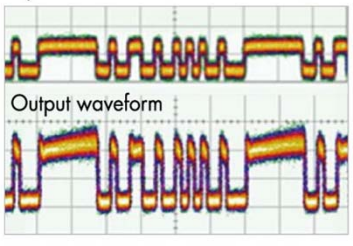
2x2 loss compensation optical switch



- Lower distortion waveforms: 10G/40G signals



10G/40G NRZ input/output



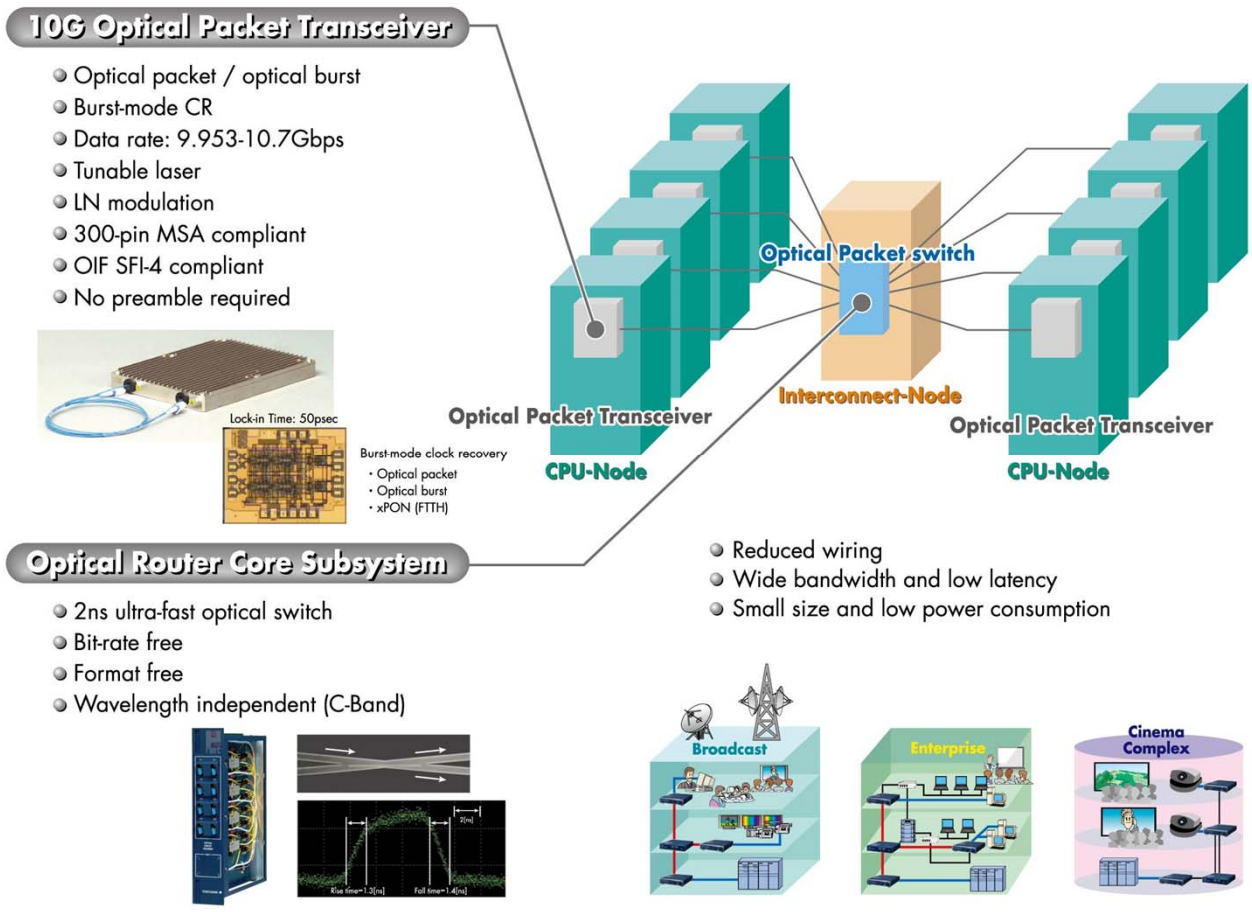
10G Optical packet stream input/output

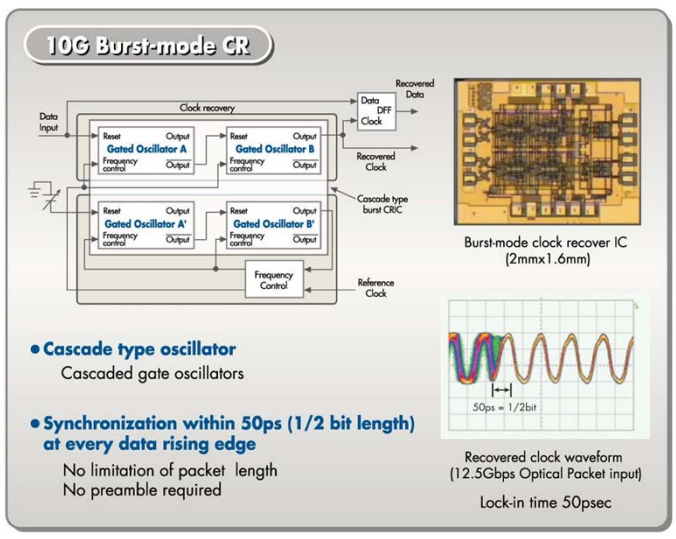
<Optical Packet and Optical Burst Core Technology>

The following describes the core technologies supporting the optical packet and optical burst systems using figures and photos.
Furthermore, the following presents a DC-operated optical modulator, burst-mode clock recovery, optical packet transceiver combining these elements, and their application examples.

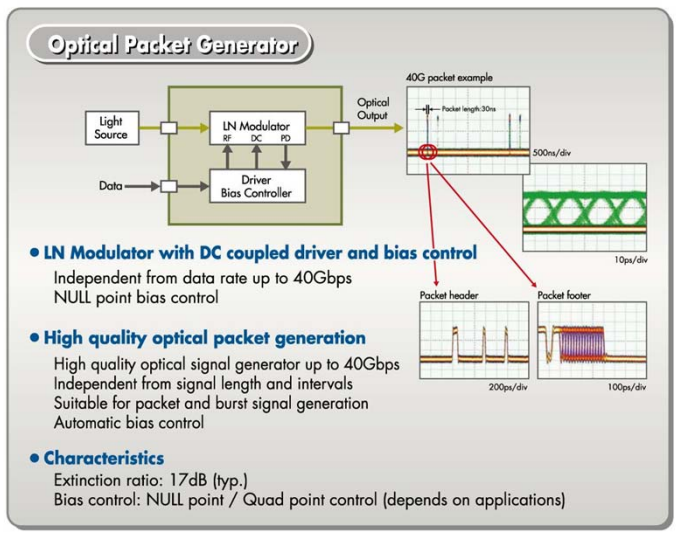
The figure on the right illustrates the application of a 10G optical transceiver and optical router core subsystem in supercomputing, which reduces wiring, achieves ultra-wide bandwidth, low latency, small size and low power consumption. This application can be used for broadcasting, enterprises, digital cinemas, and similar applications

■ 10G Optical Packet Transceiver
An optical packet transmit and receive function was packaged into a small transceiver mainly using the optical packet generator and burst-mode clock recovery technologies as described below.
■ Optical Router Core Subsystem
The routers that are widely used today are capable of inputting and outputting optical signals, but the optical signals have to be converted to electrical signals inside the router, which are switched and converted to optical signals again. Routers that repeat such conversions will be replaced in the future with optical routers that switch optical signals without converting them. Yokogawa's optical switching device is used as the core part of such a router.





■ 10G Burst-mode Clock Recovery IC
The clock rates of optical packets coming from multiple sources differ slightly in optical packet networks. Accordingly, the packet receiver needs to recover the clock phase immediately upon the arrival of a packet which requires a burst-mode clock recovery function that can instantaneously perform clock recovery in response to the burst signal. The InP-HBT-based 10G burst-mode clock recovery IC shown in the figure was made by integrating four current controlled oscillator circuits that can control the frequency by the current. Each oscillator is a gated oscillator that is designed based on a ring oscillator and equipped with an oscillation on-off function. Two oscillators are connected in cascade; the front-stage oscillator synchronizes to the edge of the incoming signal and the back-stage oscillator continuously performs clock output. The lock-in time is as fast as 50 ps (1/2bit length) from the rise of the data. Another line consisting of two oscillators that are cascade-connected in the same way is added and synchronized to the reference clock of the receiver with a phase locked loop (PLL). If there is no input data available, rough frequency tuning is performed by applying the same control current to the cascade-connected oscillators mentioned above. This IC uses the uniform characteristic of adjacent circuits found in semiconductor chips fabricated in a monolithic fashion using the compound semiconductor technology.



■ Optical Packet Generator
An optical packet signal transmitter needs to generate a signal in burst mode instead of generating transmission signals at all times. That is, the data modulator must be able to modulate the signal immediately if necessary after a random length of idle time. Specifically, an LN modulator with DC-coupled driver is required. The figure shows an optical packet generator that was made by combining an InP-HBT driver and bias control circuit. A stable DC level and excellent eye waveform are observed.

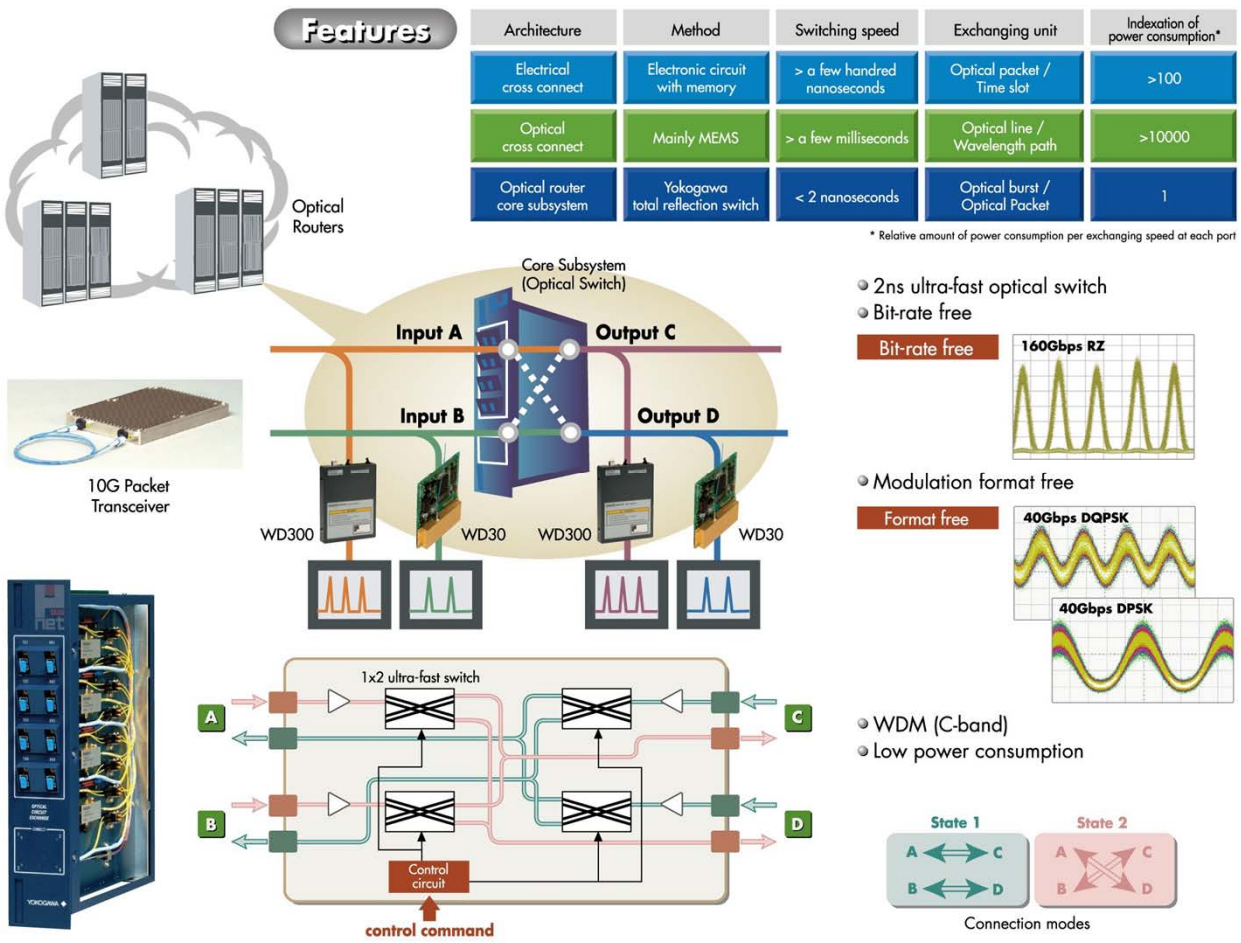
<Optical Router Core Basic Technology>

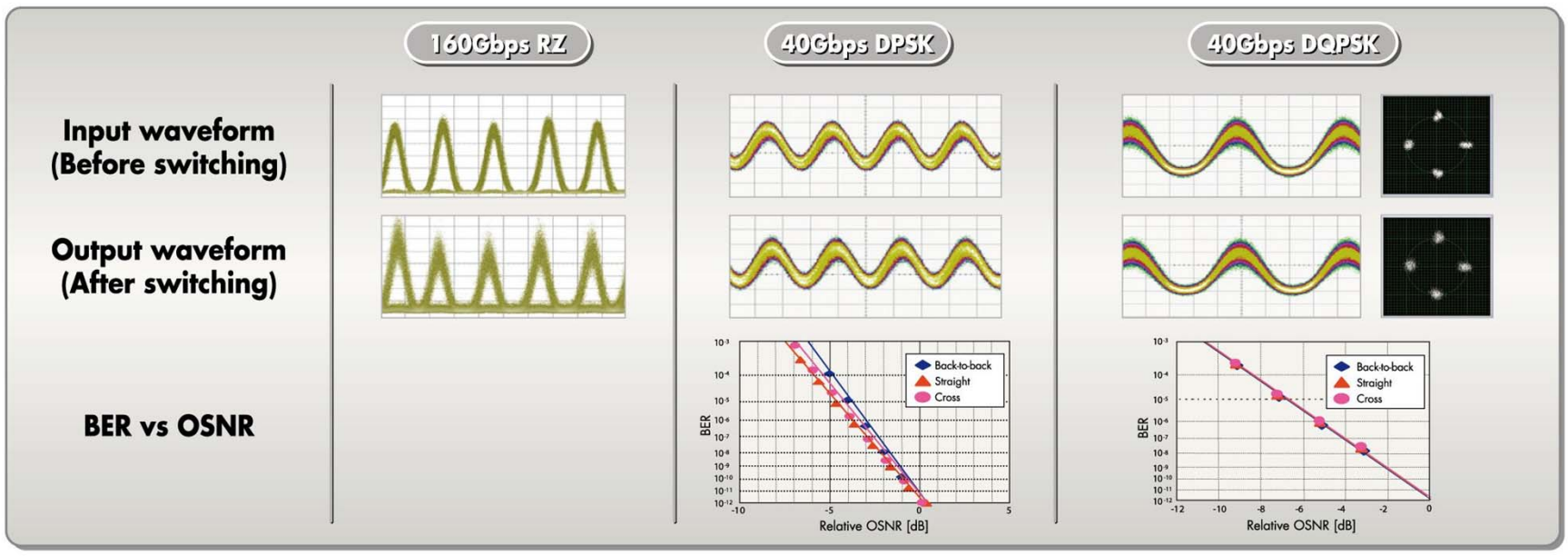
The following describes the optical router core basic technology using figures and photos.
The key device is a compound semiconductor-based optical switching device that features of a 2 ns-switching speed and works as a switch inside the optical router.
Conventional optical device-based switching needs conversion from optical to electrical to optical signals; on the other hand, the optical switching device can switch optical signals as optical signals.
The figure below shows that switching can be performed regardless of modulation format, specifically, the 40G DPSK, 40G DQPSK, and 160G RZ formats.

Yokogawa developed a switching core subsystem inside future optical routers (referred to as an optical router core) using the compound semiconductor-based optical switching device (with less than 2 ns switching speed). As shown in the figure on the right, four 4x4 switches (with improved extinction ratio, see pages 16 and 17) are used to perform switching between two nodes A and B on two lines and two nodes C and D on two lines in full-duplex communication. An optical amplifier is inserted in each line to compensate for loss.
As shown in the figure on the lower right, A is connected to C and B is connected to D so that they are capable of full-duplex communication in State 1. In State 2 A is connected to D while B is connected to C so that they are capable of full-duplex communication.
The following shows the main characteristics of this optical router core.

- Nanosecond-order line switching
- Bit-rate free
- Modulation format independent
- Compliant with WDM (C-band)
- Low power consumption

The figure in the middle shows a connection example for experiments and demonstrations. The example shows that WDM monitors (see page 69) are connected to the input and output ports on the optical router core to show the wavelength-multiplexed waveform switching.



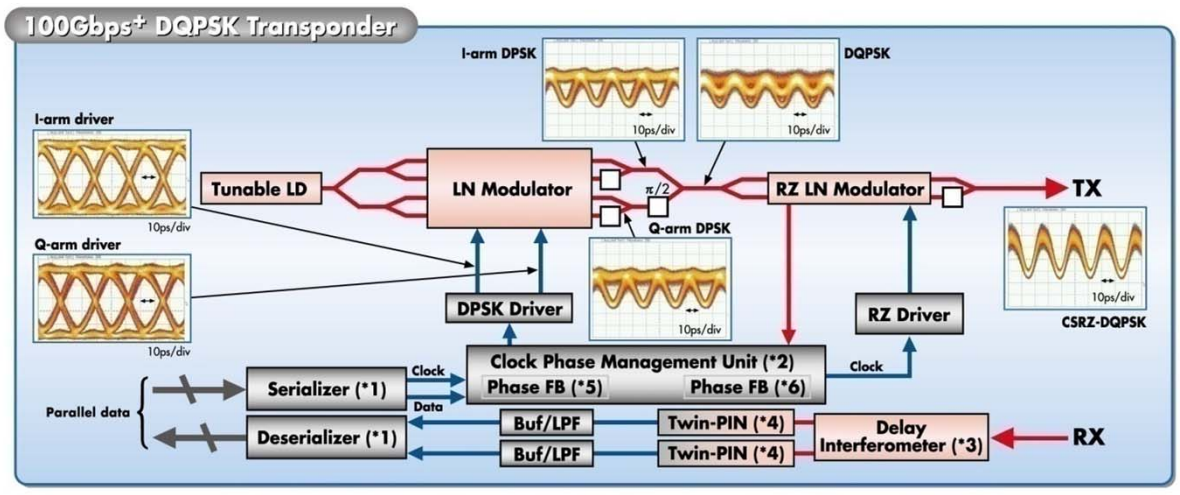


The figure above shows waveforms before and after the 160Gbps RZ, 40Gbps DPSK, and 40Gbps DQPSK optical signals pass through this switching subsystem. In principle, there should be no difference in the switching characteristic depending on the differences of these signals. Actually, the subsystem allows both 160Gbps and 40Gbps signals to be passed through and can perform switching independent of the bit rate. Furthermore, 40Gbps RZ-DPSK and 40Gbps RZ-DQPSK signals were compared. A comparison of the waveforms and a comparison of the OSNR and BER characteristics revealed that the input and output signals are equivalent and switching can be performed independent from the modulation format. In this way, Yokogawa's router core technology that uses the compound semiconductor-based ultra-fast optical switch as the key device can be used even in applications where multiple modulation formats are mixed.

<100G+ DQPSK/OFDM Transponder Core Technologies (1)>

Yokogawa is developing core technologies for an ultra-fast 100Gbps+ transponder that supports next-generation optical communication networks. This section describes the core technologies for the 100G+ DQPSK and OFDM transponders using figures and photos. These technologies were developed based on the technologies described on the previous pages and are key technologies that will support long-distance high-speed transmission networks in the future.

The figure on the right shows an example of a block diagram of a transponder for optical communication. The 40Gbps RZ-DQPSK transponder, which is mass produced and used in commercial networks, was developed using the differential quadrature phase shift keying (DQPSK) modulation technology. DQPSK modulation technology was used as the basis to increase the speed to some degree, and the Orthogonal Frequency Division Multiplexing (OFDM) method or the Polarization Multiplexing was used to double the speed to achieve the 100Gbps+ ultra-fast transmission speed. Although not included in the figure, there is another method, called a coherent transmission method, which is one of the promising next-generation optical communication methods. In the coherent method, the local light source is housed in the receiver, and analog to digital conversion of received signals is performed at the frontend, the digital signals are processed and the data recovery is performed. An ultra-fast AD converter that copes with the data baud rate and digital circuits that require high integration will play an important role in this method.



■ Key elements of the 100Gbps+ ultra-fast transponder include a delay interferometer, phase tracking control, ultra-wide band HBT DQPSK driver plus phase controller, SerDes/nano-CMOS technology, twin-pin photodiode, high-density packaging technology, thermal balanced design, and compact and highly reliable packaging.

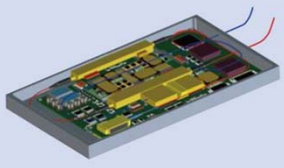
■ The following describes the CMOS IC technology that is characterized by its capability to increase integration and operation speed. Its applications include serial-parallel converters, ultra-fast AD converters (ADC) used in the coherent transmission method, and digital circuits. The gate length of the MOS transistor in the CMOS IC in the photo is 40 nm, which is a leading-edge size on a practical level. In general, this level of CMOS IC technology requires a large amount of investment, because the phase shift method requires expensive masks. To recover the investment, there must be applications that use a large number of ICs. On the other hand, the applications Yokogawa is targeting, such as ultra-fast backbone communication and measuring instruments, require high performance, with ultra-high speed and high integration, but do not need a large number of ICs. So Yokogawa utilizes an electron beam device to etch fine patterns directly on the semiconductor wafer instead of using the phase shift mask. Though the production throughput in this method is slightly lower than when using the phase shift mask, the performance of the device is enhanced by modifying the equipment configuration. This CMOS technology and production method will play a key role in the next-generation applications.

■ A delay interferometer is the key element of a receiver using the optical PSK modulation method. Delay interferometers for the optical PSK modulation/demodulation include an unbalanced MZ interferometer for DPSK, twin unbalanced MZ interferometer for DQPSK, and 90 degree unbalanced interferometer for the optical PSK modulation receiver frontend for OFDM as shown in the figure. They include features such as a thermal mechanism that does not require stable temperatures but uses a Peltier device or a high-speed phase positioning mechanism. The optimal combination of the thermal mechanisms with the thermal expansion of components used in the mechanism compensates for changes in the optical path length. Furthermore, the optimized design of the mechanism that controls the optical phase realizes high speed response.

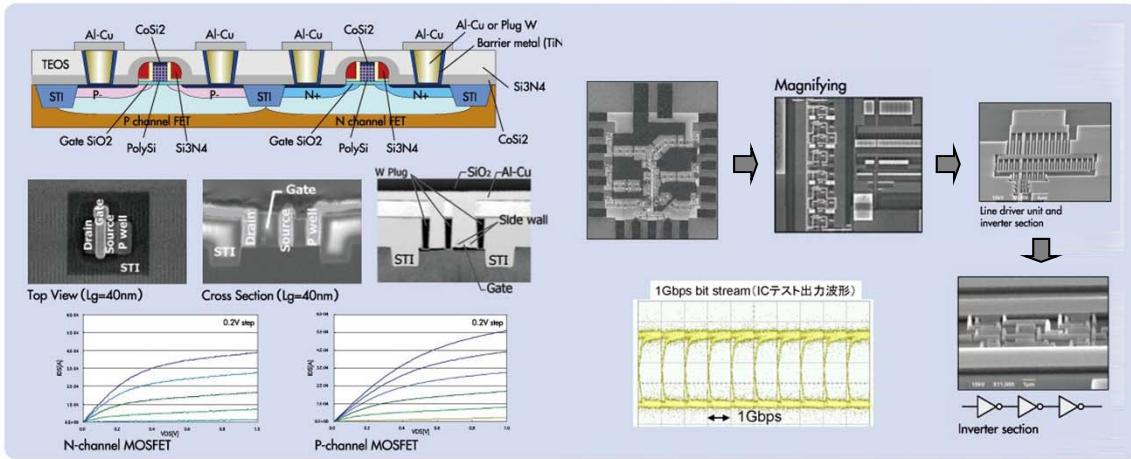
■ The figure on the right shows the implementation of a photodiode that converts high-speed optical signals to electric signals. It uses a back incidence method in which the light almost vertically enters the device from the backside. As shown in the figure, a silicon mirror is used to refract the light. The microstructures of the mirrors are mass fabricated using a silicon anisotropic etching technique. A twin-pin photodiode is required for the optical PSK modulation method. This is packaged by fabricating diodes having a uniform characteristic in a monolithic fashion using the above-described packaging technology. The figure on the right shows a photo of the package view, ultra-wide bandwidth characteristic, and waveform.

● Key elements and layout

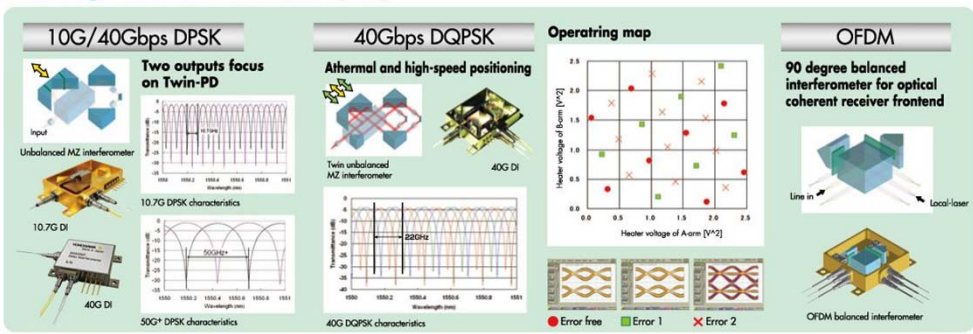
- Sub pico sec. control technologies
  - Delay interferometer
  - Phase tracking control
  - Ultra-wide band HBT DQPSK driver + phase controller
- SerDes / nano-size CMOS technology
- Twin-PIN Photodiode
- High-density packaging
- Thermal balanced design
- Compact and highly reliable packaging



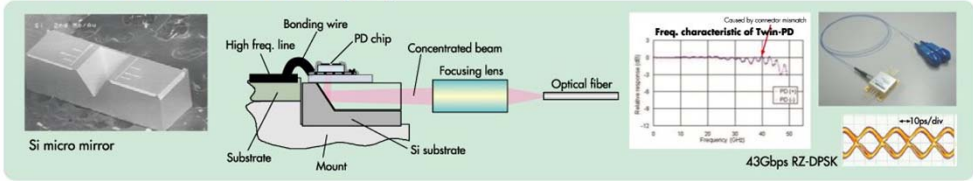
● SerDes, ADC, and more (nano-size CMOS technology) (*1)



● Delay interferometer (*3)

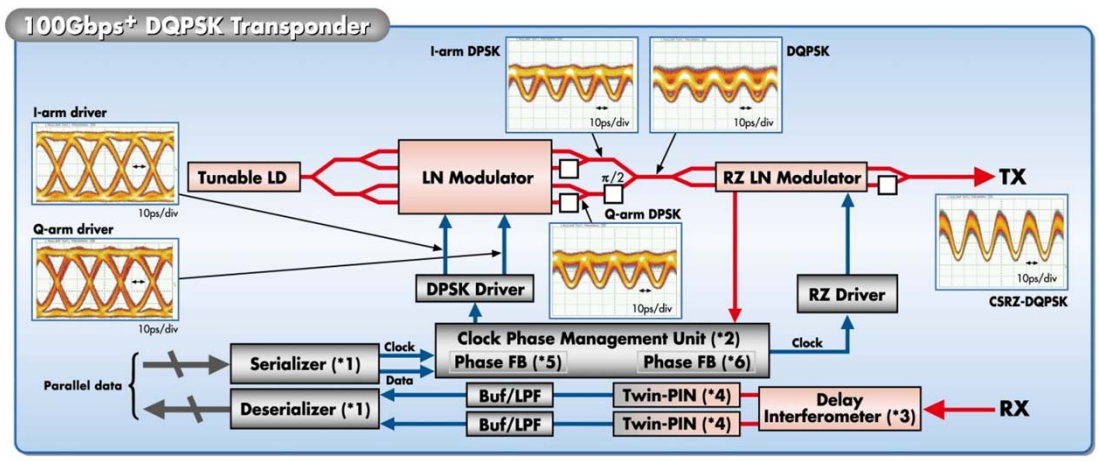


● Twin-PIN Photodiode (*4)

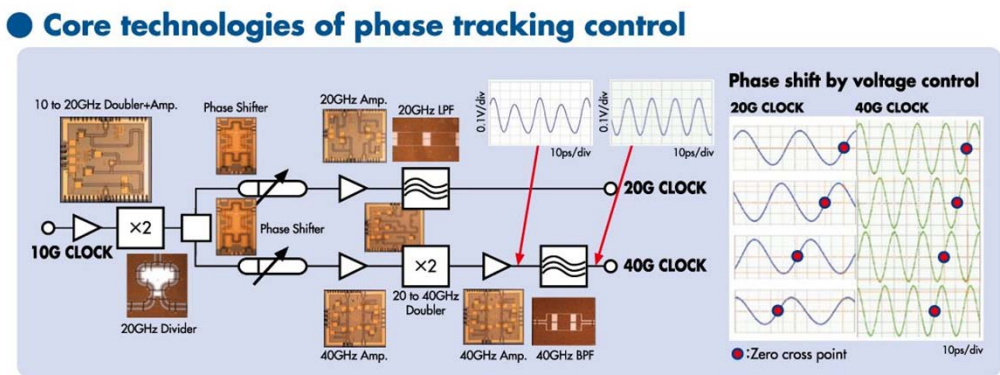


<100G+ DQPSK/OFDM Transponder Core Technology (2)>

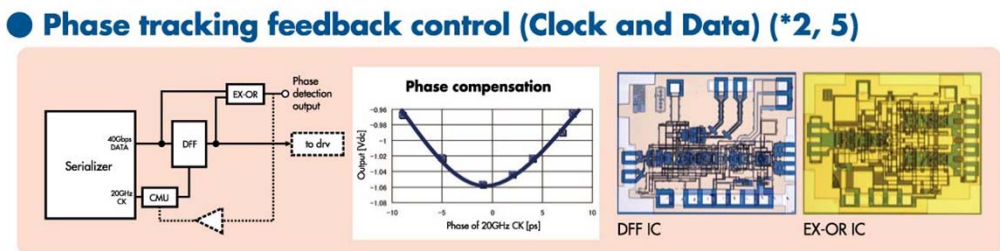
The figure on the right shows the same block diagram as that on the previous page. Phase tracking control is required to appropriately adjust the phase relations of the electrical signals among the multiple elements. To do so, first, a variable phase function that can continuously change the phase of an electrical signal is required. The key element to do this is a phase shifter IC that changes the signal phase by the electric control voltage as shown below. Second, a control circuit to generate that control voltage and its method are important. In addition, this page describes an element block that incorporates a modulator driver circuit and a phase control circuit, and the implementation of them. Furthermore, as the core technology for ultra-fast clock sources, a 147GHz oscillator and a parallel synchronous oscillator that increases the power of that oscillator are presented.



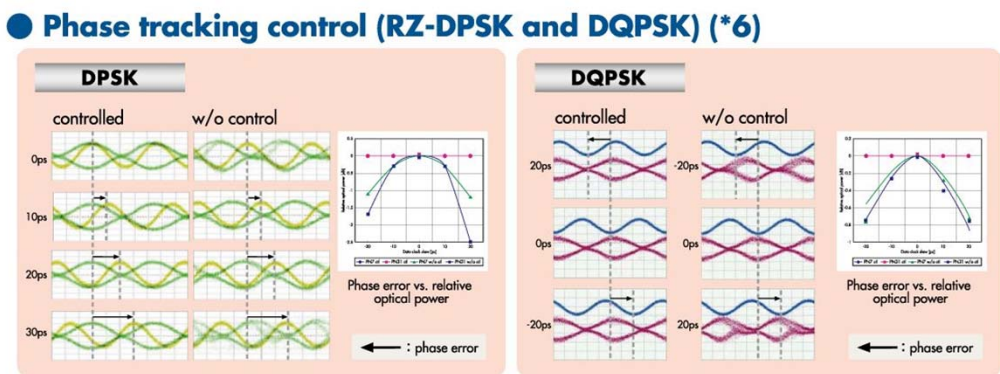
■ The figure on the right shows a configuration example of a phase variable circuit (clock management unit: CMU) for the phase tracking control. There are many compound semiconductor-based ICs; however, the first key element is a phase shifter. This is a combination of a compound semiconductor-based variable capacitance diode and transmission line, which can shift the output phase by the applied control voltage. The second element is a multiplier that generates a signal at a frequency that is double the input. The third element is an amplifier IC that uses an active InP-HBT device to amplify each frequency. Each function is implemented by designing the optimized stab length of the I/O units and appropriately applying the DC bias. In addition, a signal divider and filter are added to the alumina circuit substrate. The right part of the figure shows output waveforms when the control voltage applied to this block is changed, demonstrating that the signal phase can be freely shifted.



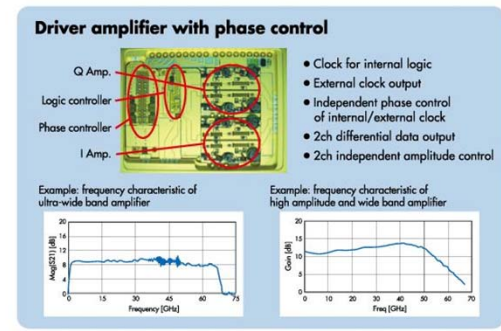
■ The figure on the right shows an example of phase tracking control between the data and clock. It is based on a CMU, which consists of a compound semiconductor-based exclusive-or (EX-OR) IC, D-type flip flop (DFF) IC, phase shifter mentioned above, and other elements. EX-OR detects phase shifting between the data and clock, shifts the phase, and the feedback is sent via CMU to DFF that adjusts the timing. The feedback is given so that the minimum output point is reached in the characteristic curve of the EX-OR IC shown in the graph.



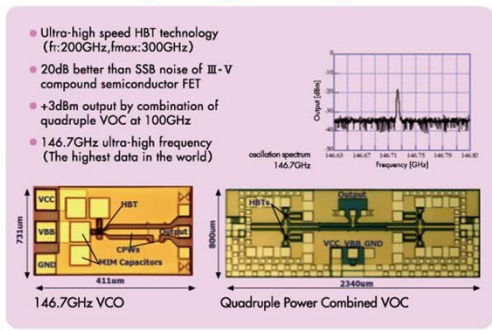
■ The figure on the right shows the results of automatic phase tracking control between the RZ curving signal and data signal. The figure shows waveforms in the DPSK and DQPSK methods, respectively. As for the waveforms at 0 ps, the phases match each other in both methods. The eye of the data waveform is open enough, and no degradation is observed. However, when the phase is shifted just slightly from 0 ps, part of the data waveform degrades in the case of w/o control, while no degradation is observed for the data waveform in the case of controlled.



■ An HBT DQPSK driver + phase controller is a unit that integrates a DQPSK driver function for the data modulation and a phase control circuit to control the retiming phase. It consists of many InP-HBT ICs and alumina substrate-based transmission lines. The graph in the figure shows an example of frequency characteristic of a driver amplifier, showing that a ultra-wideband circuit can be implemented.



■ The figure shows examples of ultra-high frequency clock generator devices which are both ICs using InP-HBT. The figure shows ICs of a voltage-controlled oscillator (VCO) at 147GHz ultra-high frequency and of a parallel synchronous oscillation that increases power using an oscillation function. Both are implemented by correctly modeling the device characteristic and designing the optimized resonant circuit.



Application

Resources & Energy

Machines & Mechatronics

Hybrid & Electric Vehicles, Power Electronic, etc.

New Energy

Electronic Components

Home Appliances & OA Equipment

Motors

Inverters

Equipment & Plant

Information & Communication

Optical Fiber

Optical Network

Optical Modules

Home Appliances

Semiconductors

Security

Life Sciences

Medical Care

Drug Discovery

Application

DL/SL Series ScopeCorder

DL Series Digital Oscilloscope

WT/PZ Series Power Meter

GS Series Source Measure Unit

AQ/AE/WD/FB Series Optical & NGN/IP Measuring Instruments

DYNASERV Direct Drive Motor

Confocal Scanner & MEG

Others

Machine and Electronic Component Durability Test

ScopeCorder
DL750

Application Overview
With machine and electronic component durability tests, it is difficult to foresee when a component will break down (malfunction).
That is why the following procedure is usually used: understand the whole trend by low-speed sampling and monitoring using a recorder or the like, and only when an error occurs, perform high-speed signal measurement using an oscilloscope or the like. However, this procedure is not very efficient. A more efficient measurement procedure is absolutely essential in this economic environment.

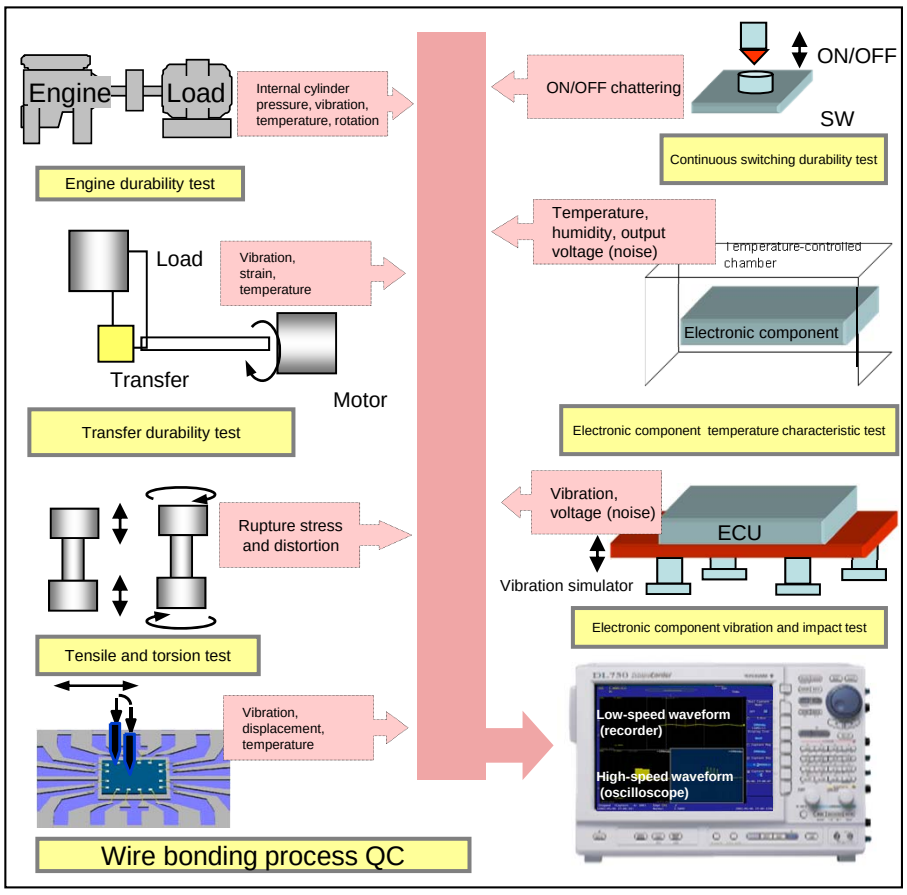
Application Points
Efficiency is increased by incorporating two functions in a single measuring instrument. First, the ability to perform low-speed measurement over a long period of time and only when an error occurs, sample signals at a high speed, . Second, the ability to analyze the details before the error occurred.

Product Features

- **Dual Capture function**
This function allows users to collect transition event data at high speed while collecting trend data at low speed.

- **Sub-waveform display**
This function allows users to display waveforms acquired with high speed in the whole and enlarged waveform views, and waveforms sampled with high speed in the enlarged view.

- **GIGA Zoom function**
This function enables a 1GW, real-time, whole-length display by a large high-speed ASIC, and an enlarged display within 0.1 second on two arbitrary-size zoom windows, regardless of whether the instrument is measuring or not.



Robot Continuous Motion Test

Mixed-Signal Oscilloscope
DLM2000

Application Overview
A continuous motion test is performed after a robot is adjusted. The test measures vibrations and position displacement of the arms and joints, and collects data linked with the motion speed of the robot. The test modes can be automatically controlled, and data can be automatically measured and recorded.

Application Point
In the case of testing moving parts, a series of evaluations over a couple seconds is required.

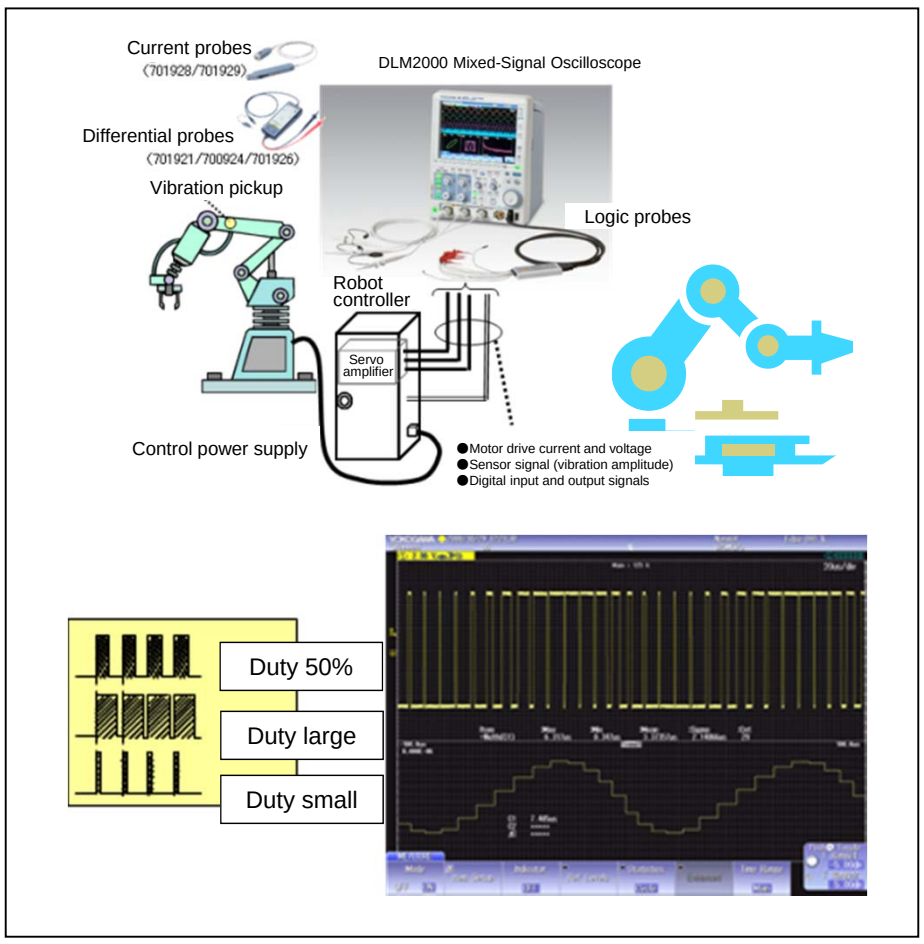
Product Features

- Long-time measurement over 100 seconds at 1.25MS/s
A 60 second, low-speed robot motion can be measured using 125MPoints large memory (/M2 option).

- Multiple-point, simultaneous measurement of analog waveforms and control signals
It is possible to simultaneously observe logic control signals and analog voltage and current waveforms.

- Trend display of PWM waveform measure parameters
Trends of every periodical change in the pulse width, period, duty, etc., of input signals can be displayed simultaneously with the waveforms.

* Trend display refers to a graph display in which the horizontal and vertical axes represent the time axis and data values, respectively.



Motion Timing Measurement of Paper Processing Machine

ScopeCorder
SL1400

Application Overview
For splicers, such as a corrugating machine (*) and paper processing machine, it is important to understand their operational characteristics. A stable, high yield rate can be achieved by performing adjustments according to the characteristics of individual machines.

Application Points
Corrugating machines, paper processing machines, etc., are required to be able to continuously operate to reduce downtime. Fine timing adjustment for the device is important to maintain stable operation. The SL1400 can be effectively used for this kind of device adjustment and troubleshooting. The SL1400 allows users to check waveforms on the screen and print out charts on the spot. Furthermore, waveform data can be saved in a file to allow detailed analysis to be performed at a later time.

Product Features

- **Simultaneous recording of charts and digital values**

Data can be directly recorded on A4-size chart paper and to the internal hard disk drive, or saved to a USB stick, memory card, or the like as a file, in order to make it convenient to perform on the spot checks of the data on paper or process it at a later time.

- **Multi-channel, large memory (totaling 50 M data points)**

Up to 16-channel input plus 16-bit logic input, 30-minute (at 1kS/s on 16 channels) measurement is possible.

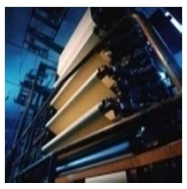
- **Total of 11 types of plug-in modules**

It is possible to perform synchronous measurement using modules for measuring high-speed voltage, high voltage, high-precision voltage, frequency, temperature, distortion, acceleration, or other signals.

- **Variety of PC interfaces**

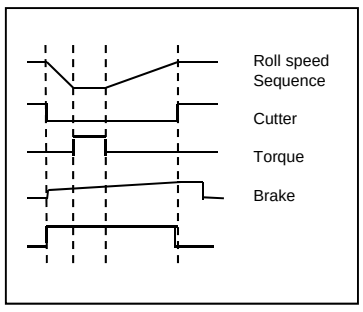
Interfaces to a PC, including USB, GP-IB, RS-232-C, or Ethernet (option), are available. In particular, the Ethernet option provides functions such as a WWW server, FTP, and e-mail. Yokogawa offers new network measurement.

* A corrugating machine refers to a machine to manufacture corrugated paper, which is used as the material of cardboard boxes.



- Roll speed
- Torque
- Timing (suction pressure, cutter, etc.)
- Brake characteristic

Paper feed switching sequence example



Measurement and Analysis of Tablet Pressure in Rotary Tablet Machine

ScopeCorder
DL750

Application Overview
When manufacturing tablets using a rotary tablet machine, the quality of tablets is determined by the evaluation of tablet forming pressure. Pre-pressure, main pressures from above and below, and pressure for removing the tablet are measured. As well, a pressure error that periodically occurs during a 360degree turn indicates an error in the punching of the rotary palette. Furthermore, statistical analysis of each pressure is required to find out the variations in tablets made over a long period of time,

Application Points

- Must measure not only 5 pressure signals but also a timing pulse indicating the rotary palette position and ambient temperature.
- Measurement by direct input from the load cell for pressure measurement
- Must measure the pressure peak value for each punching operation and directly read the rotation and punch counts.

Product Features

- **Multi-channel, large memory (up to 1GW)**

Up to 16 channel inputs with 16bit logic is possible. Ultra-large memory with up to 1GW storage for 1 channel and up to 50MW for each of the 16 channels is available (option).

- **11 types of isolated-input modules**

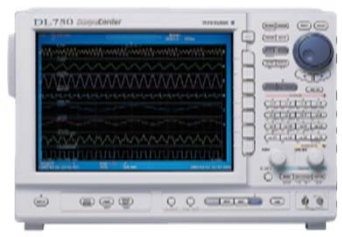
Isolated-input measurement can be performed using modules for measuring high-speed voltage, high voltage, high-precision voltage, frequency, temperature, distortion, acceleration, or other signals.

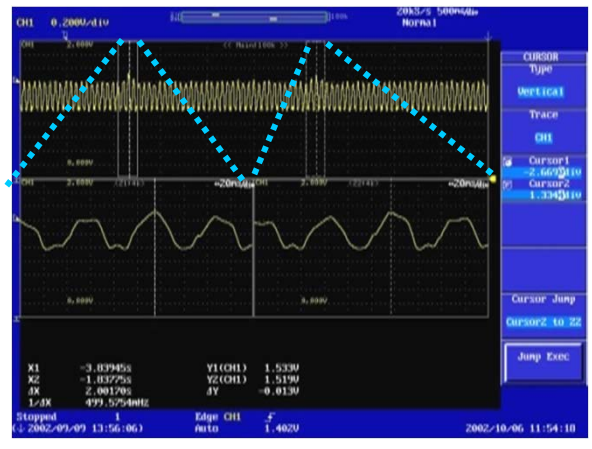
- **Cycle statistical calculations**

Waveform parameters can be used to automatically measure not only the maximum value, minimum value, average value, and frequency but also the pulse count, etc. Automatic calculation of the maximum value, minimum value, average value, and standard deviation of these parameters.

Pressure signal

Rotary tablet machine





Main screen

Zoom screen

Example of measuring one pressure signal for main pressure

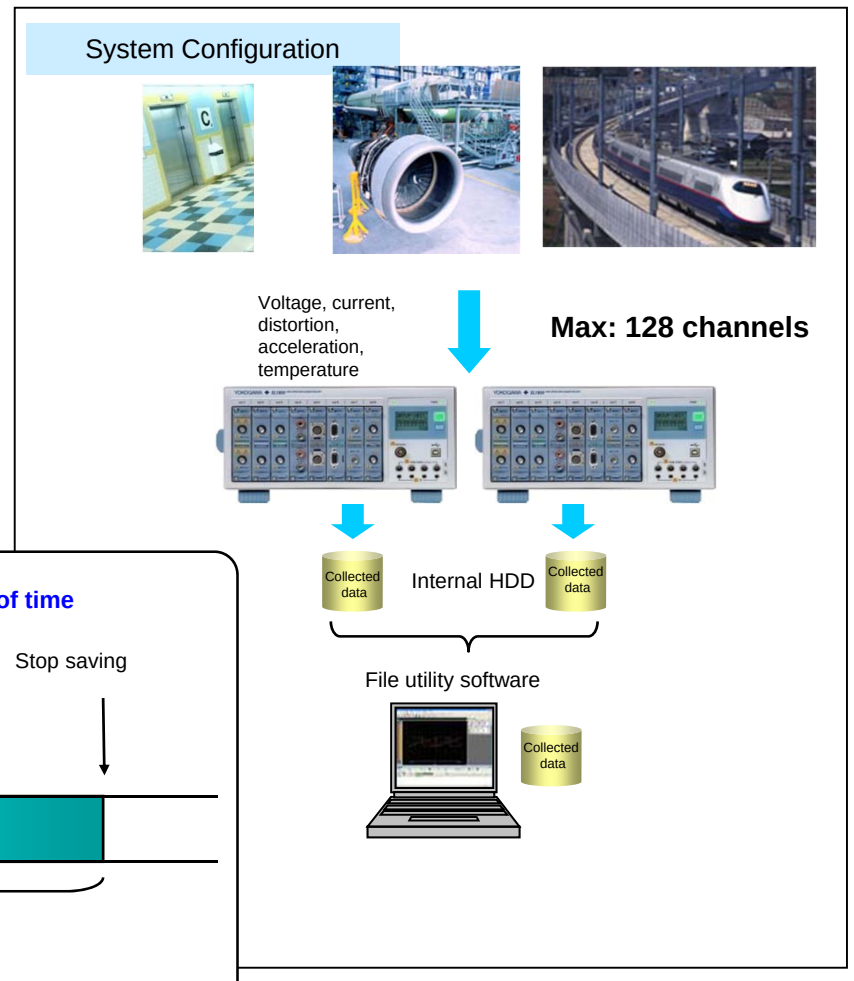
Performance and Reliability Evaluation Test of Large Equipment

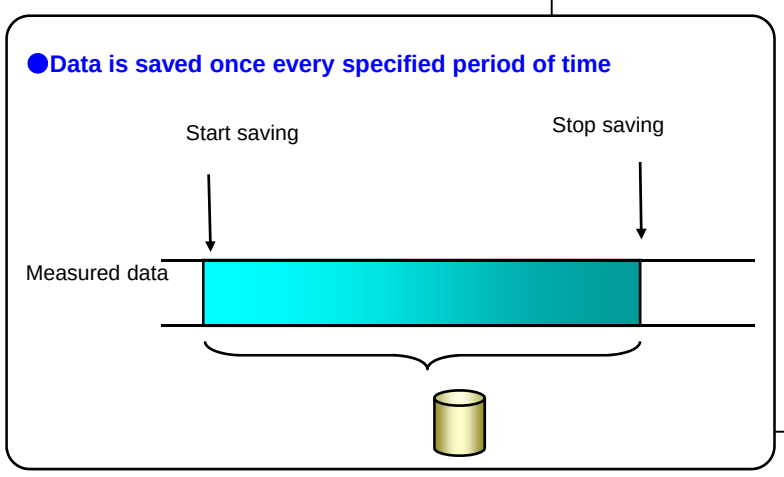
High-Speed Data Acquisition Unit
SL1000

Application Overview
Large equipment for transporting passengers, such as aircraft, railway cars, or elevators, are required to be highly durable and reliable.
Such equipment use a large number of components which requires a long term, detailed evaluation test for each component.

Application Points
- It is possible to simultaneously observe various physical quantities such as voltage, current, distortion, acceleration, temperature, rotation, or the like on multiple channels (up to 128 channels).
- Long-term, continuous measurement, such as a durability test, is required.
- 100kS/s and 1MS/s, 16bit modules can be used to perform highly accurate data collection.
- The collected data can be checked immediately on a PC, and the maximum, minimum, rise time, or other values can be easily obtained.

Product Features
- Multi-channel, long-term measurement
- High-resolution, 16bit module
- Fast data saving





Status Observation by Power Consumption Measurement of Rice Polisher and Agitator

Power Analyzer
WT500

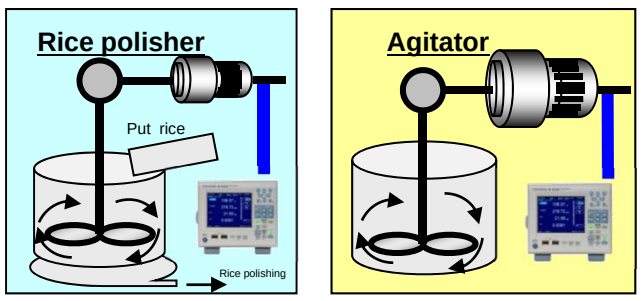
Application Overview
Rice polishers are used to agitate the rice for polishing, and agitators are used for agitation in food, chemical, biological, and water processes. Power consumption values can be obtained from the load resistance in such a work process. Even if viscosity cannot be directly measured, relative changes in the current and power consumption can be observed as the consumption fluctuates in conjunction with the load variation. If the final correlation between the viscosity and current/power is known beforehand, targets such as the timing for completion of work can be determined.

Application Points
- High current compatible
- High voltage compatible
- Variety of display forms
- Monitoring of fluctuations in the voltage, current, and power values
- Image saving and exporting of data to PC software

Product Features
- High current compatible: 40A range (direct input)
- High voltage compatible: 1000V range (direct input)
- Data can be checked in the forms of values, waveforms, trend, bar graphs, etc.
- Fluctuations in the voltage, current, and power can be checked in the trend view.
- Screen images and measured values can be saved to the internal memory or a USB stick. Reports and graphs can be created on a PC.

•Trend display refers to a graph display in which the horizontal and vertical axis represent the time and data values, respectively.

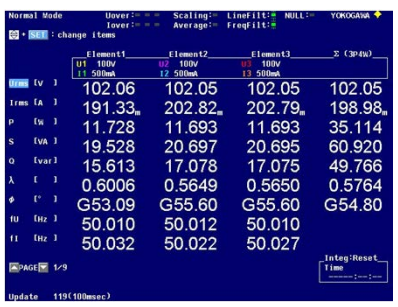
■Overview of measuring power consumption of rice polisher and agitator



A smaller load on the agitator blade indicates less current (power) consumption, that is, lower viscosity, while higher viscosity indicates larger power consumption.

■WT500 display screen

Measurement examples of voltage, current, power, frequency, and power factor



Observation example of fluctuation in the power consumption

Average Internal Cylinder Pressure of Engine

ScopeCorder
DL750

Application Overview
Evaluation of a vehicle engine is required to capture changes in the internal cylinder pressure over 1300 continuous cycles, and then determine the average waveform for one cycle (average internal cylinder pressure curve). (*)
A crank angle signal is used as the sample clock to acquire the output voltage of the pressure converter and obtain the average waveform at a 720degree crank angle per cycle in the case of a 4cycle engine.

Application Points
For example, valve operation noise overlaid on the internal cylinder pressure signal can be removed by the averaging method. The DL750 allows users to display the average internal cylinder pressure curve over the continuous waveforms (with no dead time) using a user calculation function called Cycle Average.
Any number of data records (up to 1800) can be used to set the one cycle (length of period) of the desired average internal cylinder pressure curve over the continuous waveforms.

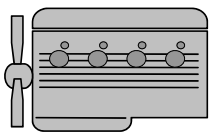
Product Features

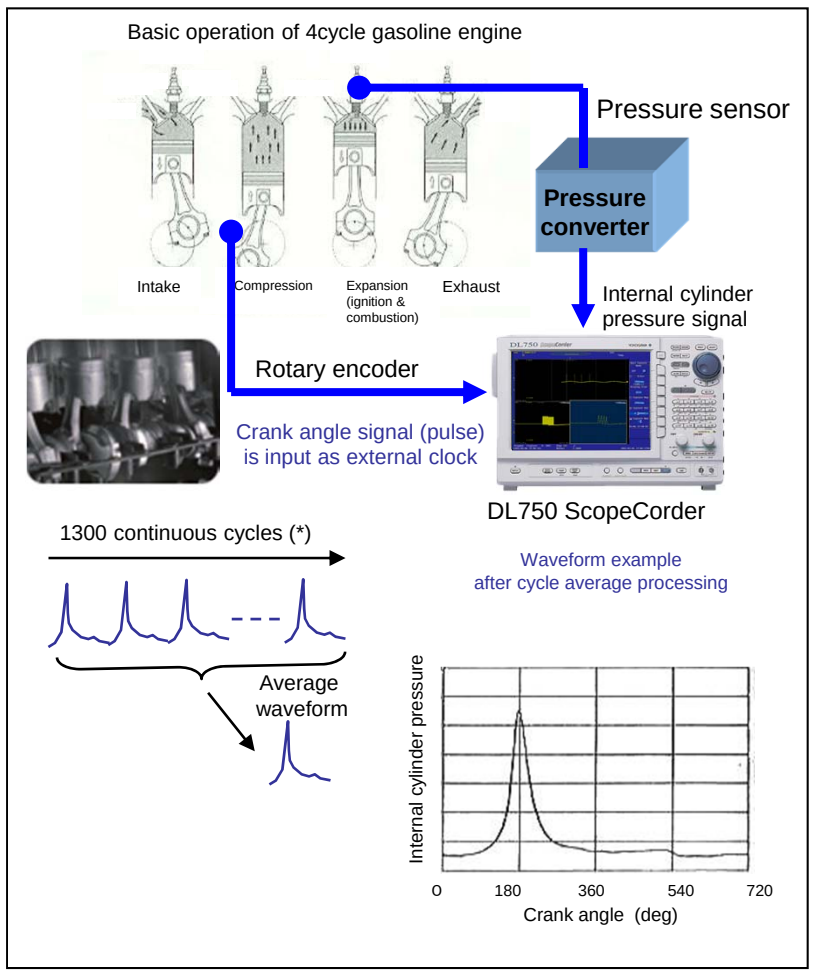
- **Multi-channel, large memory (up to 1GW)**
Up to 16 channel inputs with 16bit logic is possible. Ultra-large memory with up to 1GW storage for 1 channel and up to 50MW for each of the 16 channels is available (option).

- **User-defined calculations (when adding /G2 option)**
The addition of the user-defined calculation option allows users to define 8 arithmetic expressions using functions, including trigonometric, differential, integral, square root, digital filter, 7 types of FFT functions, and cycle average.

- **External clock input**
Pulse waveform is input to the external clock so it is possible to perform data sampling (at up to 1MS/s) synchronized with the pulse frequency.

(*) Number of measurable cycles varies depending on the memory size.





Visualization of Welding Process in Laser Welding Machine

ScopeCorder DL750
XviewerEYE

Application Overview
Developers of laser welding machines make the best use of advanced control in order to reduce the operation voltage of the laser radiation power, while ensuring reliable welding to minimize effects on the welded material. As the quality of laser welding greatly varies depending on the surrounding environment it is necessary to use on the spot information to see how the welding process (from melting to solidification) is performed.

Application Points

- Single-screen display and analysis of high-speed camera video synchronous to the measured data
- High-speed data measurement at 1000 to 2000 frames per second
- Simple waveform analysis operation synchronized with the video

Features of XviewerEYE

- **Synchronous single-screen display of high-speed camera video and measurement data**
It is possible to precisely synchronize and simultaneously display waveform data acquired by multi-channel, long term measurement using Yokogawa's DL750/SL1000 and the video data recorded with a Photron high-speed camera.

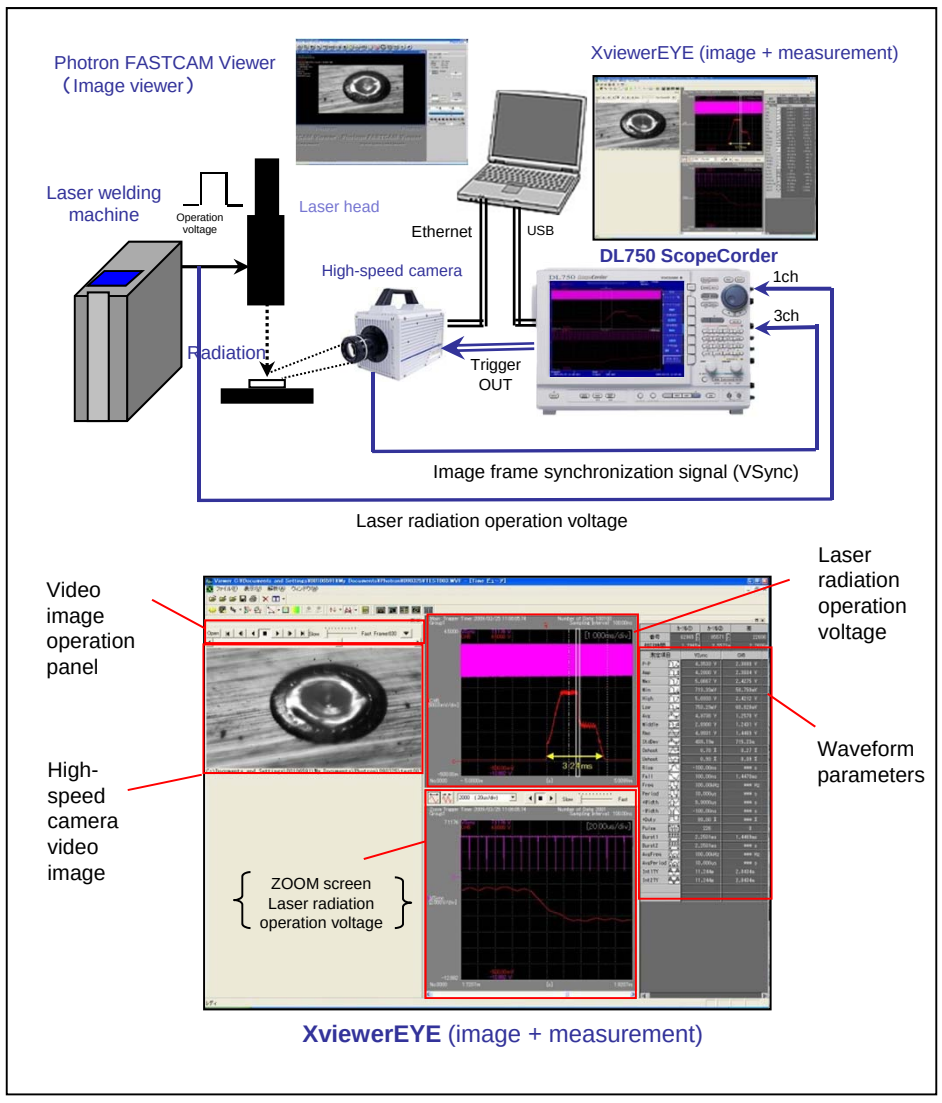
- **Detailed video image operation from waveform ZOOM screen**
It is possible to display any part of a video image linked to the waveform ZOOM screen.

- **Parameter setup and calculation function (option)**
Waveforms can be automatically measured using 26 parameters, including P-P, Freq, or Rise Time. Furthermore, calculation results can be checked in the waveform view using a waveform calculation function (option).

Features of DL750

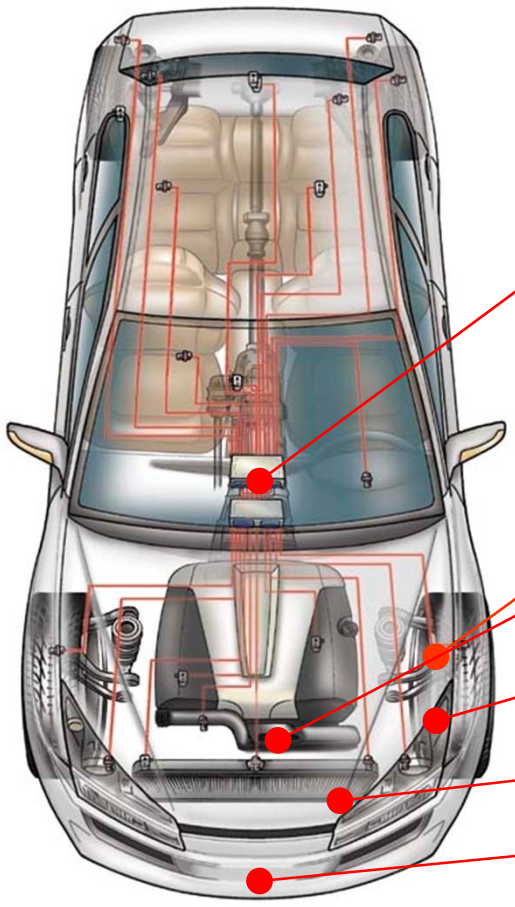
- **11 types of input modules**
Different events can be measured synchronously using modules for high-speed voltage, high voltage, high-precision voltage, frequency, temperature, distortion, acceleration, and other signals.

- **Multi-channel, large memory (up to 1GW)**
Up to 16 channel inputs with 16bit logic is possible. Ultra-large memory with up to 1GW storage for 1 channel and up to 50MW for each of the 16 channels is available (option).



Measurements for Vehicle Development

Application Overview
In recent years, measurements related to vehicle development have increased in their requirements for precision. At the same time, expanded system complexities demand niche measurement solutions which are suited to specific applications. Yokogawa provides a variety of products to support the complete vehicle development process, ranging from electronic control unit (ECU) design, through to the evaluation of mechanical characteristics.



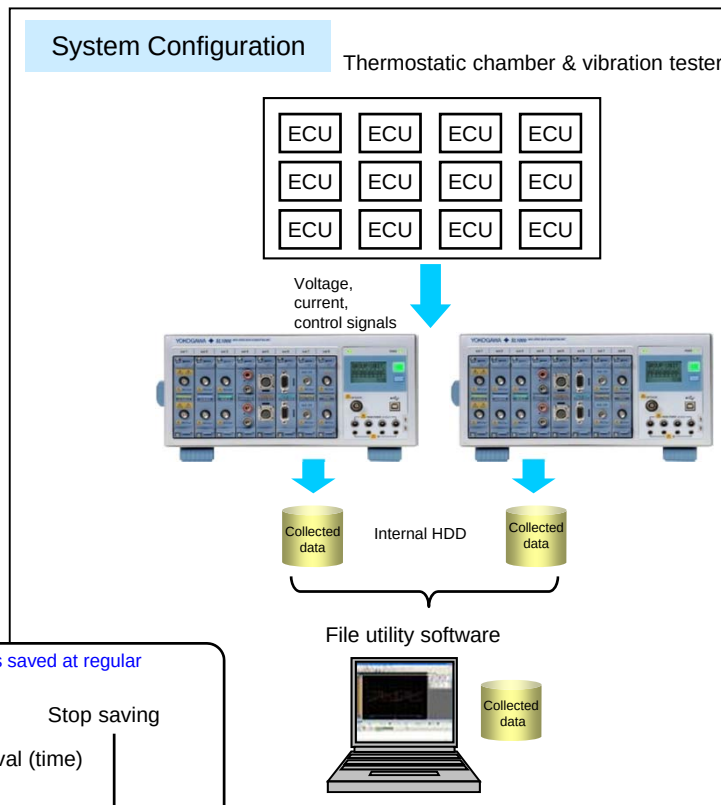
ECU Reliability and Evaluation Testing

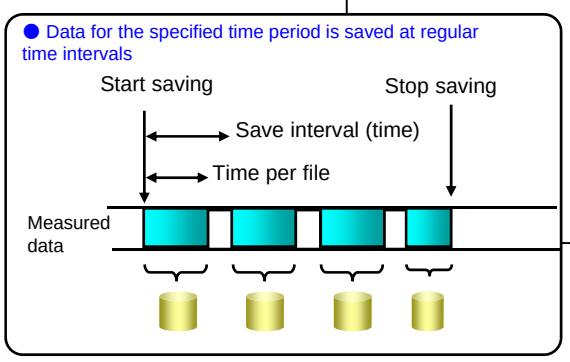
High-Speed Data Acquisition Unit
SL1000

Application Overview
Electronic components used in automobiles, aircraft, and other transportation equipment are required to be highly reliable even in harsh environments. In particular, long-term reliability evaluations and environmental tests are required, because of the increase in the number of ECUs as a result of increased use of electronic control in recent years.

Application Points
- 100 million samples per second enables more detail in waveform observations.
- Each test record can be automatically saved with minimal dead time.
- The collected data can be checked immediately on a PC, and parametric measurements such as maximum, minimum, rise time, etc. can be easily obtained.

Product Features
- 100MS/s,12bit isolated module
- Autonomous operation
- Fast data saving





Hybrid Vehicle Motor Drive Circuit Evaluation

ScopeCorder DL750
High-Speed Data Acquisition Unit SL1000

Application Overview
Evaluation and analysis of waveform from the inverter, a central part of the hybrid vehicle motor drive, is vital. However, noise from the switching circuit is present and superimposed on this inverter signal. Accurately monitoring the inverter waveforms without interference from switching noise is key to making a reliable evaluation of the motor drive circuit.

Application Points
Isolated-inputs, high-speed sample rates, and long-time observation are all essential to making measurements of electrical signals from the motor drive.

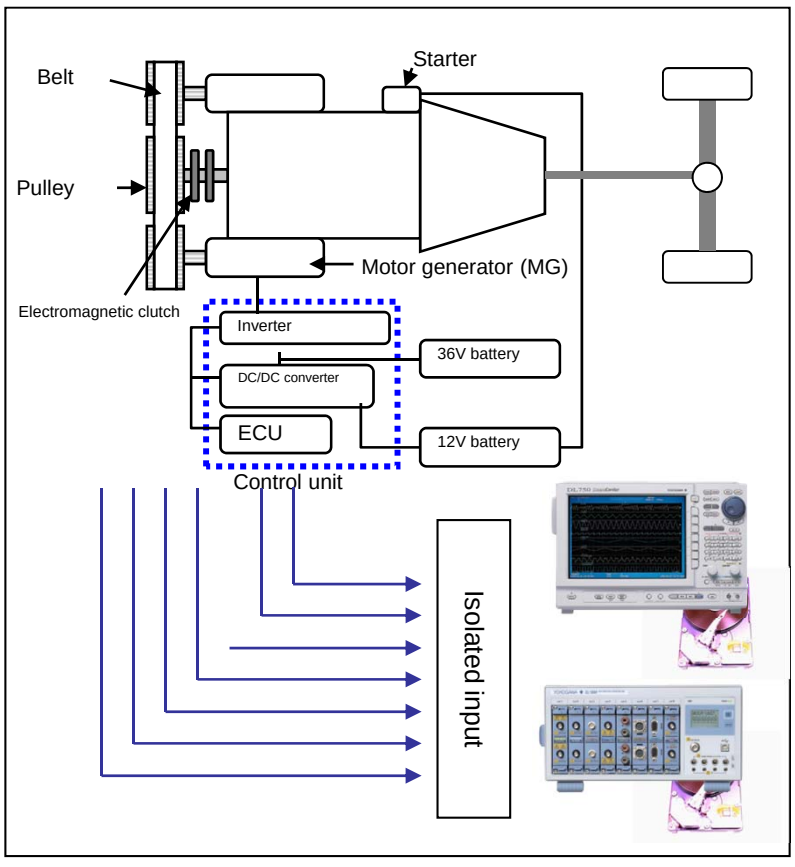
Product Features

- **12 types of isolated-input modules (*)**
  Isolated-input measurements can be performed using modules for measuring high-speed voltage, high voltage, high-precision voltage, frequency, temperature, distortion, acceleration, and other signals.

- **Multi-channel input**
  DL750: Max. 16 channels
  SL1000: Max. 128 channels (when 8 units are synchronized)

- **Real-time data recording**
  DL750：Data can be recorded in real-time to the internal HDD, for 2 channel recording at max.1GW/100kS/s.
  SL1000：Data can be recorded in real-time to the internal HDD, or HDD on a PC , for 16 channel recording at 100kS/s.

(*) 11 types available for the DL750.



In-Vehicle Equipment Voltage Fluctuation Simulation

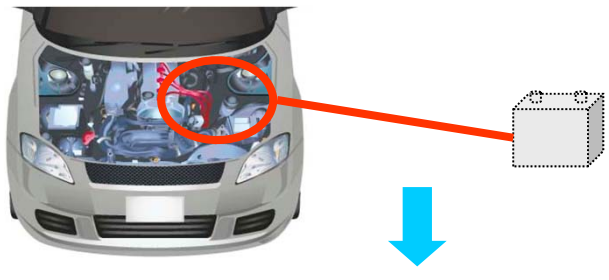
Source Measure Unit GS610
ScopeCorder DL750

Application Overview
Power supply fluctuations including voltage drops and overvoltage conditions in automotive power lines (12V/24V) are programmed and output. In a laboratory setting, the same power supply voltage fluctuations as those of an actual vehicle are reproduced for testing.

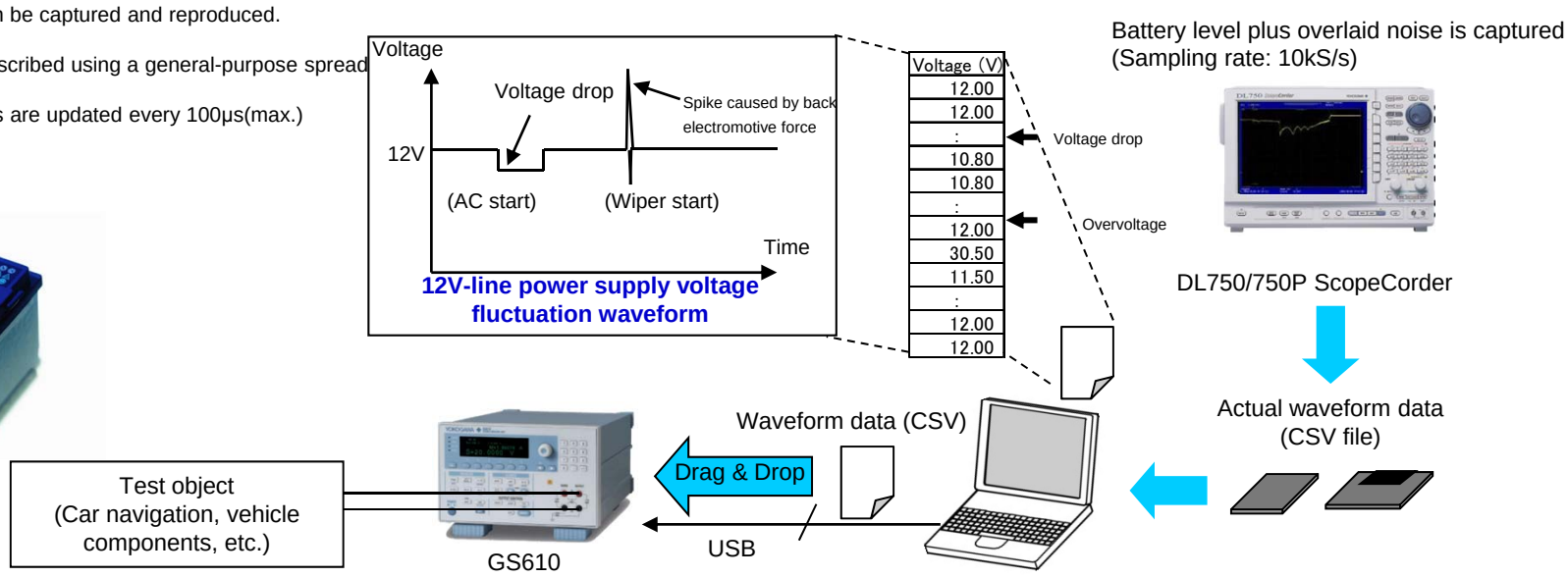
Application Points
Power supply voltage fluctuation waveforms are captured by a digital oscilloscope, and the waveform data is saved to the internal memory of the GS610. This allows the instrument to playback the actual recordings of power supply voltage fluctuations, yielding the most realistic experimental results.

Product Features

- Actual waveforms can be captured and reproduced.
- Waveform data is described using a general-purpose spread
- Programmed voltages are updated every 100μs(max.)



Battery level plus overlaid noise is captured
(Sampling rate: 10kS/s)



Transmission Control Signal Measurements

ScopeCorder DL750
High-Speed Data Acquisition Unit SL1000

Application Overview
For vehicles to be able to efficiently convert engine speed to vehicle power, engine crankshaft rotations must be reduced optimally according to the driving condition, in a similar manner as the gears on a bicycle. The vehicle transmission is responsible for this job. Transmission controls optimize the transfer of engine output and improves both fuel consumption and drivability.

Application Points
One key requirement of transmission control signal measurements is the synchronized acquisition of electrical signals involved in the transmission operation. Such signals include the variable solenoid command, clutch hydraulic control command, transmission position, distortion, and vehicle speed sensor. The nature of this testing necessitates checking the interaction of all measured signals on the same time axis, and often on a single screen.
It can also be important to display real-time scaled waveforms, in order to directly represent signals from sensors.

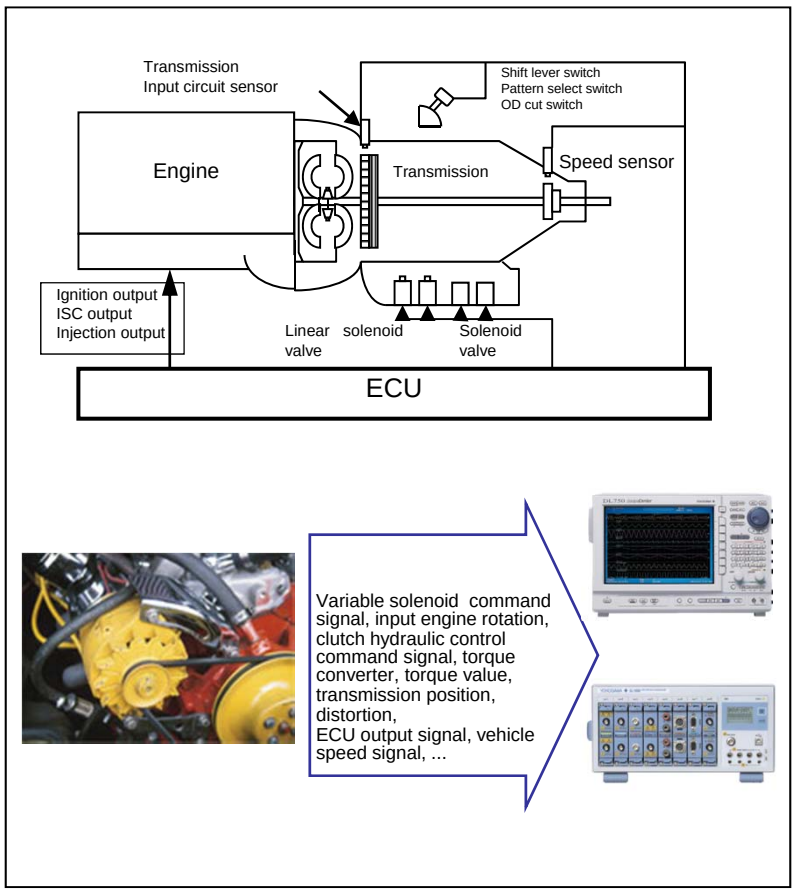
Product Features

- **DSP channel (option)**
  Six digital signal processing (DSP) chips are installed, independent from input channels. These DSP channels allow the user to execute inter-channel calculations in real-time, during waveform capture.

- **Total of 12 types of plug-in modules (*)**
  Synchronous measurements can be performed using modules for measuring high-speed voltage, high voltage, high-precision voltage, frequency, distortion, acceleration, and other signals.

- **Multi-channel input**
  DL750: Max 16 channels
  SL1000: Max 128 channels (when 8 units are synchronized)

(*) 11 types are available for the DL750.



Engine Control Signal Analysis

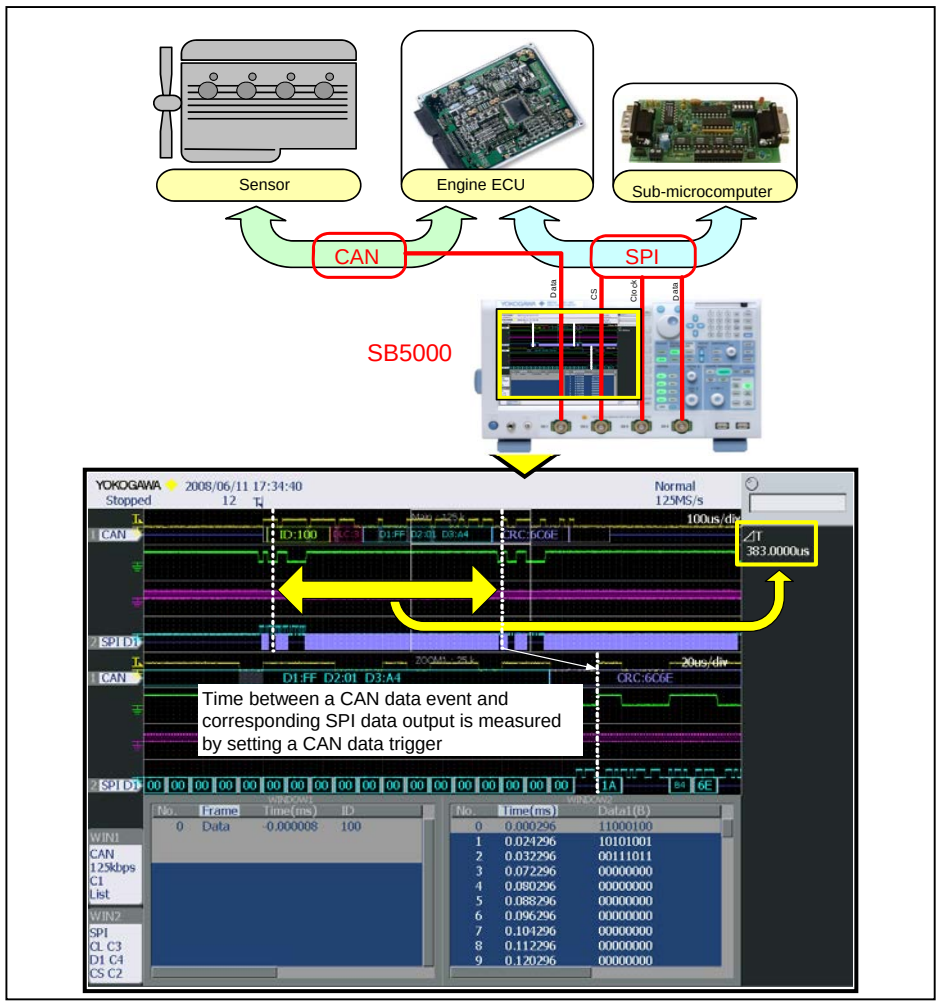
Mixed-Signal Oscilloscope DL9000
Vehicle Serial Bus Analyzer SB5000

Application Overview
The SB5000 and DL9000 are capable of performing a simultaneous analysis of two serial buses. Going beyond the ability of a protocol analyzer, detailed temporal relationships between data can be analyzed. Two buses, such as CAN and CAN, or CAN and LIN, can be analyzed simultaneously. This is most useful when developing areas where multiple buses are concentrated, such as a gateway.

Application Points
An engine ECU communicates with each sensor of the engine via a CAN bus, and part of the processing is performed by a sub-microcomputer via an SPI bus. Conventionally, two protocol analyzers were run using external synchronization, and the results were compared against each other, one by one. Furthermore, in order to perform physical layer analysis, data had to be time aligned by combining several pieces of equipment. For example, to test an oscillator in combination with a digital bus, real-time data analysis was difficult.

Product Features

- Out of the serial buses (CAN, LIN, SPI, I²C, UART, and FlexRay), any two serial buses can be decoded and analyzed simultaneously.
  The SB5000 and DL9000 are useful in debugging two buses, such as CAN and SPI, CAN and CAN, or CAN and LIN, as well as useful in physical layer analysis for final system evaluation. The analysis results can be displayed on two screens in list views.
- Variety of trigger functions
  You can detect or isolate nearly any portion of a serial bus stream, using dedicated serial bus triggers that isolate any part of a serial bus packet.
- Detailed temporal relationships between serial data that become readily apparent in ways which are invisible to traditional protocol analyzers.
- All-in-one configuration that needs no external hardware for serial bus analysis.
- Analog and logic mixed inputs
  It is possible to measure 4 analog channels plus 32bit logic input signals, more than other mixed signal instruments.
  It is possible to simultaneously analyze logic signals inside the ECU and CAN signals output from the ECU.



Steering Dynamic Tester

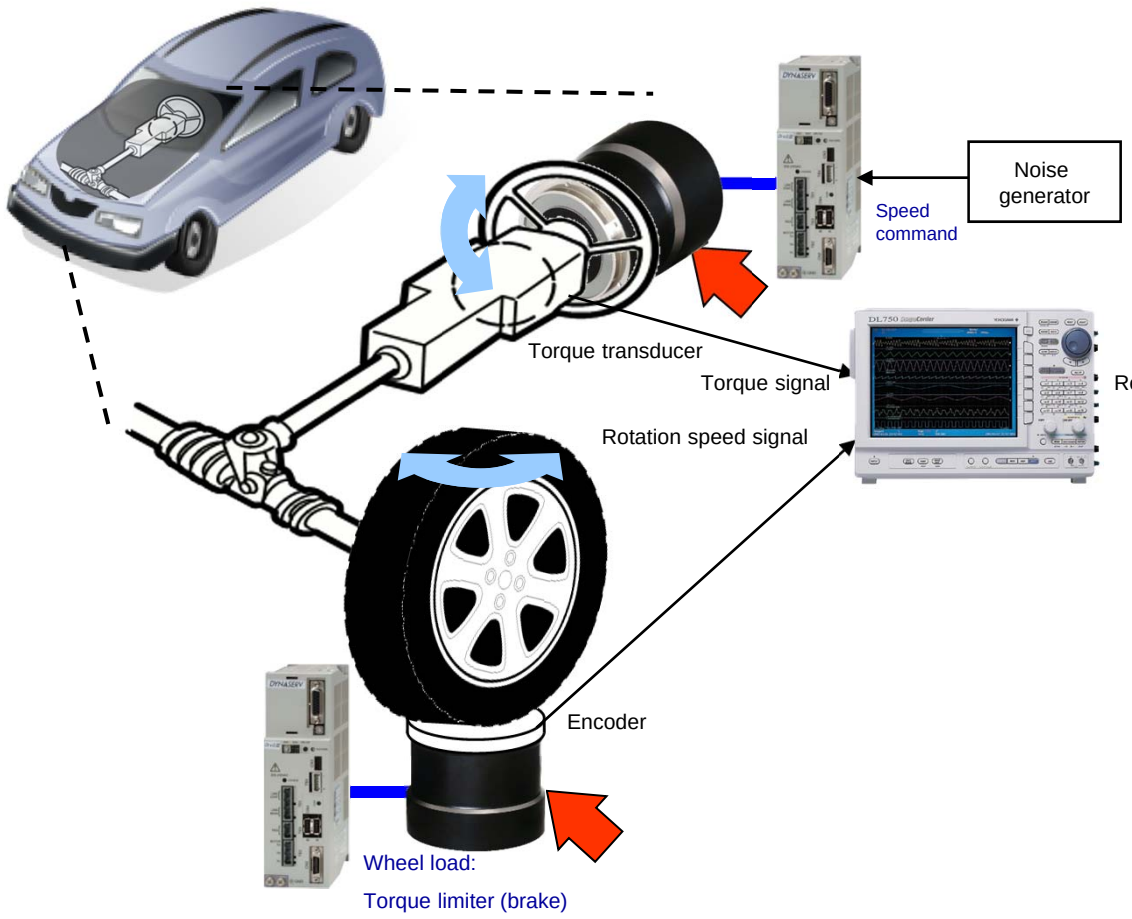
DYNASERV
ScopeCorder DL750

Application
The DYNASERV motor is used to test in a vehicle steering dynamic characteristics. It inputs a speed command and implements it as a wheel load.

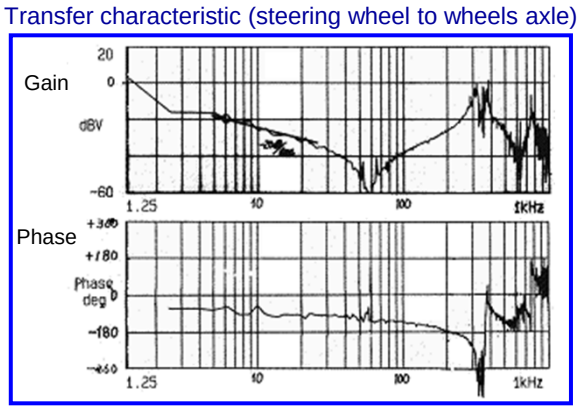
User benefits
Increase in the repeatability of evaluation results
Maintenance free

Solutions
High precision, high torque, high stiffness, low heat generation, no rattle and no lost motion

The DYNASERV motor, which is free from rattle and lost motion, is used in a steering dynamic tester, which measures the dynamic transfer characteristic from the vehicle steering wheel to the wheels, in order to increase evaluation precision and test repeatability. Inputting a speed command into the DYNASERV from a noise generator and turning the steering wheel randomly moves the wheels via the steering system (pinion, tie rod, hydraulic booster, etc.). The steering wheel to wheels transfer characteristic can be obtained by measuring the input torque of the steering wheel and the movement speed of the wheels. To perform an evaluation in a condition more similar to that of an actual vehicle, the DYNASERV can also be used as a load on the axle side to simulate the ground contact resistance of the wheels.



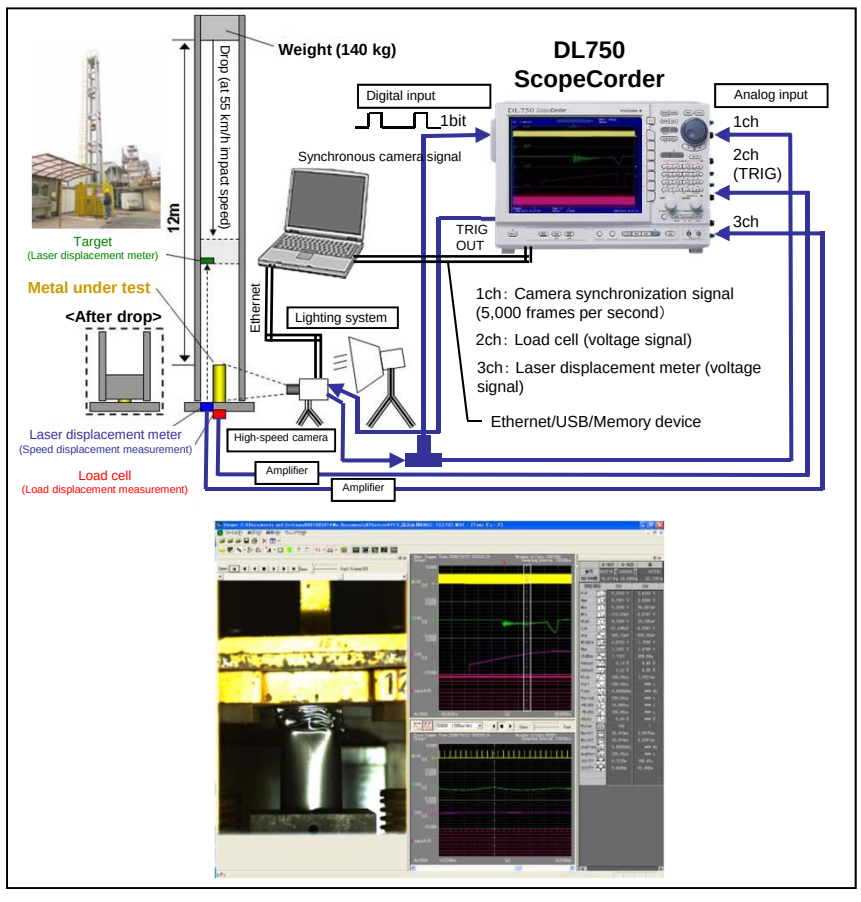
Transfer characteristic (steering wheel to wheels axle)



Drop Weight Test of Automotive Component

ScopeCorder DL750
XviewerEYE

Application Overview
Automotive components are required not only to be highly durable and functional, but also to be soft enough to absorb the impact of a crash. To test the shape, material, and properties of automotive components, it is necessary to perform a drop weight test (*), in which the instantaneous behavior of the impact is illuminated with a special light source and recorded with a high-speed video camera (at 5,000 to 10,0000 frames per second). Sensor signals (from a load cell and laser displacement meter) are synchronized and added to the recorded image data. Finally, both sets of data are synthesized, displayed, and analyzed on a PC.
(*) A weight is freely dropped onto the object under test (OUT) to apply an impact. Afterwards, fractures in the OUT are examined to understand the impact brittleness and fracture properties of the material.



Application Points
- Synchronous measurement of triggered data and high-speed video
- High-speed actual measurement at 1,000 to 2,000 frames per second
- Xviewer software allows users to add time axis information and perform CSV conversion
- It is easy to merge the recorded image data together with waveform data on a PC.

Features of XviewerEYE
- **Advanced synchronization of video image and waveform data**
  It is possible to precisely synchronize and simultaneously display multi-channel, long-time measured waveform data from any of Yokogawa's ScopeCorder or oscilloscope families, and video data recorded with a Photron high-speed camera.

- **Video 4screen display**
  It is possible to simultaneously display video images synchronized with the measured data on up to 4 screens.

- **Main & Zoom display**
  The whole and enlarged waveforms can be displayed simultaneously. A waveform can be enlarged both vertically and horizontally, and large waveform data saved to the large memory can be displayed quickly.

Features of DL750
- **11 types of input modules**
  Different events can be synchronized and observed using modules for measuring high-speed voltage, high voltage, high-precision voltage, frequency, temperature, distortion, acceleration, and other signals.

- **Multi-channel, large memory (up to 1GW)**
  Up to 16 channel input plus 16bit logic input are possible. Ultra-large memory with up to 1 GW storage for 1 channel and up to 50MW for 16 channels is available (option).

LIN Bus Signal Evaluation (Trigger)

Mixed Signal Oscilloscope
DLM2000

Application Overview
Local Interconnect Network (LIN) is a single-master serial communication protocol designed to reduce the cost for in-vehicle LAN.

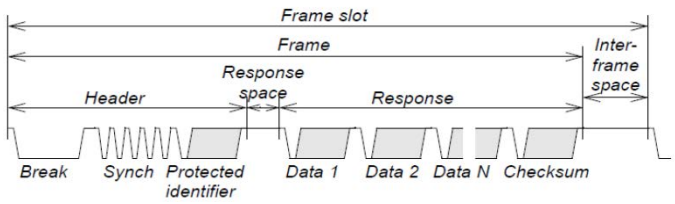
Application Points
The timing of LIN data with sensor and start signals can be evaluated, by setting a LIN signal as a trigger, and then simultaneously measuring analog signals.

Product Features
Triggers can also be activated by combining the trigger conditions of the LIN bus signal and that of the CAN bus signal, or by combining the trigger conditions of the LIN bus signal and that of the analog signal.

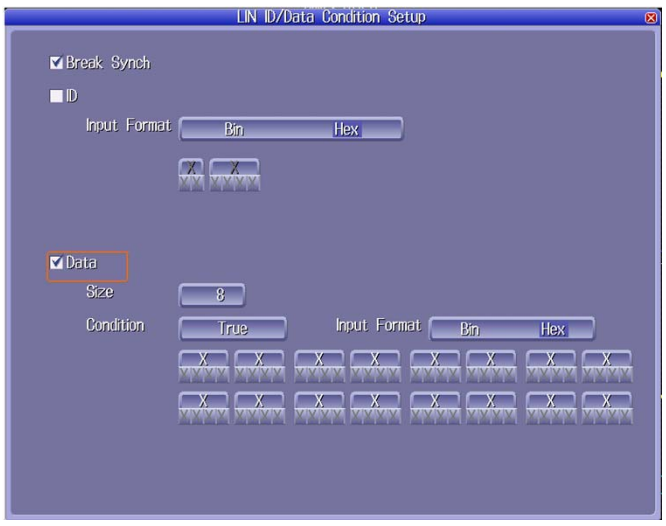
- Trigger modes
  Break Synch: The trigger is activated when the Break and Synch fields are detected consecutively.
  ID/Data: The trigger is activated by the set ID and the AND condition for DATA.
  ID/Data OR: The trigger is activated by the set multiple IDs and the OR condition for DATA.
  Error: The trigger is activated when an error is detected.

- Bit rate
  19,200 bps, 9,600 bps, 4,800 bps, 2,400 bps, 1,200 bps, User (when User is selected, the bit rate can be set in the range of 1,000 to 20,000 bps)

- Revision setting
  The LIN revision is selected from LIN2.0 or LIN1.3.
  LIN2.0: Detects errors of the Enhanced Checksum including the protected identifier.
  LIN1.3: Detects errors of the Classic Checksum just consisting of the Data fields.



LIN Frame Structure



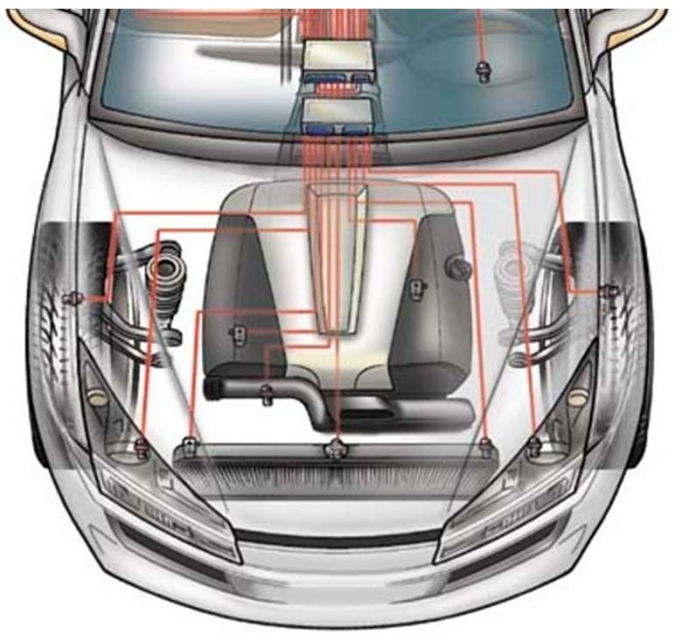
LIN Bus ID/Data Trigger Condition Setting Dialog Screen

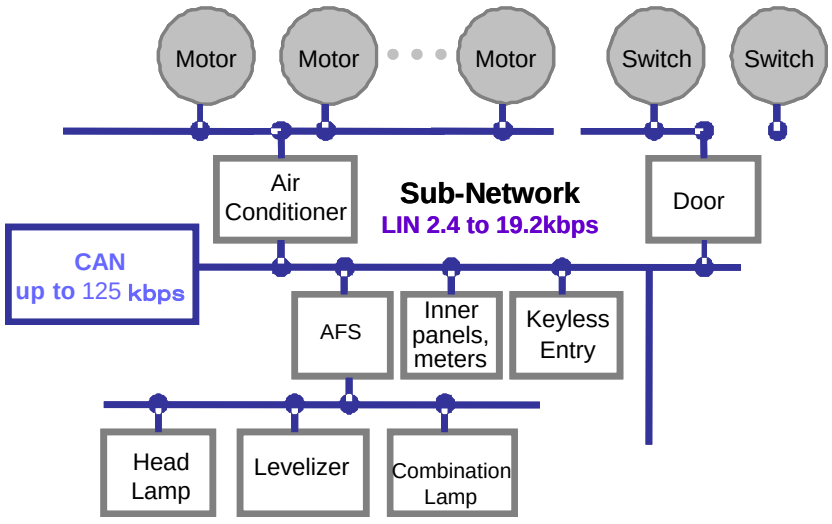
LIN Bus Signal Evaluation (Analysis, Decode, and Search)

Mixed Signal Oscilloscope
DLM2000 Series

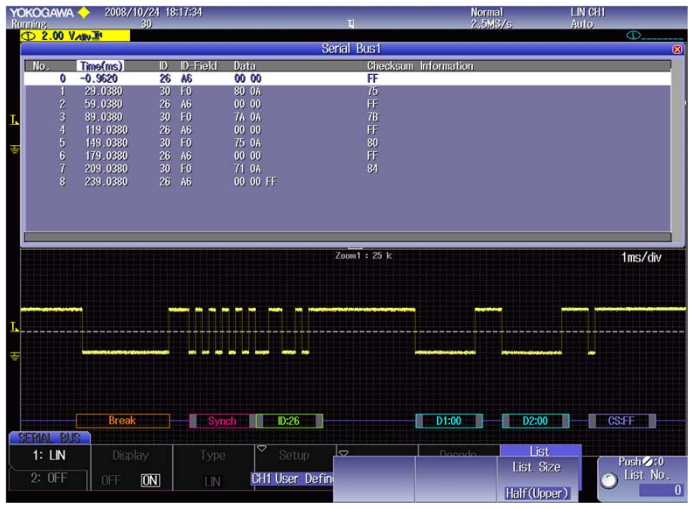
Application Point
LIN signals are analyzed, the results can be displayed in the Decode and List views, and a search can be performed.

Product Features
- LIN bus data signals are analyzed, and the analysis results are displayed in the List view. The analysis result list includes the analysis number, ID, Data, Checksum, Time from the trigger event, ID Field, ID Parity, and Checksum errors.
- The analysis result data can be saved to any storage media in CSV format.
- Any field in the analysis result list can be selected, to automatically display the corresponding LIN bus waveform (Zoom Link).
- Any particular field of a LIN bus signal data can be searched. When the search is executed, the zoom box moves to the data that matches the condition, and the data is enlarged and displayed in the zoom waveform display area (Zoom 1 or Zoom 2).





Body System-Related In-Vehicle LAN Sub-Network



LIN Bus Analysis Screen

Hybrid & Electric Vehicles
Power Electronics, etc.

CAN Bus Signal Evaluation (Trigger)

Mixed-Signal Oscilloscope
DLM2000 Series

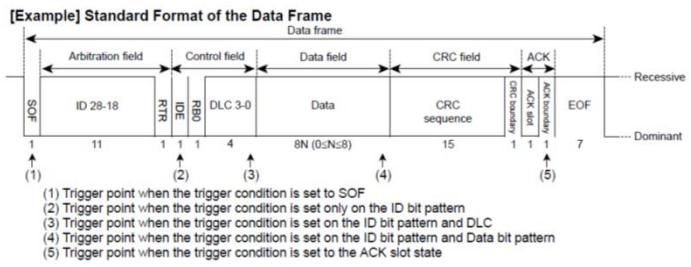
Application Overview
Controller Area Network (CAN) was created by Bosch in 1985 for in-vehicle communication networks. Today, CAN is widely used in the automotive industry as the in-vehicle network standard. In 1993, it became recognized as an international standard called ISO11898. Since 1994, some additional buses built on CAN protocols such as CANopen or DeviceNet have been standardized.
Thanks to its reliability and sophisticated fault detection functions, CAN is highly regarded in markets other than automotive and continues to attract attention in a wide range of areas.
<CAN application examples>
Automobile, truck, bus, off-road vehicle, vessel control, navigation system, medical equipment, FA, sensor, machine control, switch gear, control gear, agricultural equipment, forestry equipment

Application Point
The timing of CAN data with sensor and start signals can be evaluated, using a CAN signal as a trigger and simultaneously measuring analog signals.

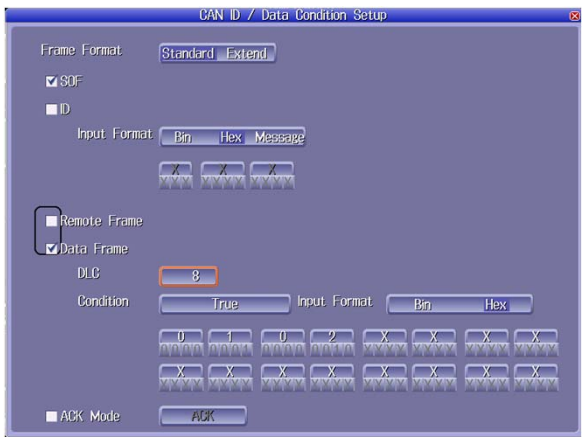
Product Features
The trigger can be activated by setting the CAN bus ID bit pattern, DLC, Data, ACK slot status, or defining a specific data frame/remote frame as the trigger condition. Up to 4 types of ID/Data conditions can be set, so a trigger can be activated using these OR conditions.

- Trigger mode
  SOF: The trigger is activated using SOF (Start of Frame).
  Error: The trigger is activated by errors (error frame, stuff error, CRC error).
  ID/Data: The trigger is activated by the data frame/remote frame that matches the set condition.
  ID OR: The trigger is activated by the OR conditions of 4 types of data frames/remote frames.

- Bit rate
  1Mbps, 500 kbps, 250 kbps, 125 kbps, 83.8 kbps, 33.3 kbps, User.
  (When User is selected, the bit rate can be set to any value from 10k to 1Mbps)



CAN Bus Trigger Operation Example



CAN Bus Trigger Condition Setting Dialog Screen

CAN Bus Signal Analysis (Analysis, Decode, and Search)

Mixed Signal Oscilloscope
DLM2000

Application Point
CAN signals are analyzed, the results can be displayed in the Decode or List views, and a search can be performed.

Product Features
- When CAN bus signal data is analyzed, the analysis results are displayed in the List view. The analysis result list includes the analysis number, type of the analyzed frame, ID, Data, ACK slot status, Time from the trigger event, DLC, and CRC sequence.

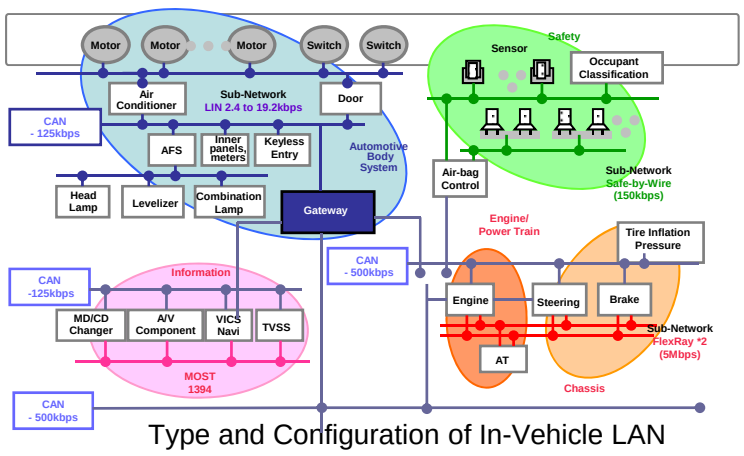
- **Serial analysis decode display and real-time analysis**
  CAN message frame information (ID, DATA, etc.) is displayed under the analog waveform in an easy-to-understand decoded display. Furthermore, the decoded display is executed in real-time.

- The analysis result data can be saved to any storage media in CSV format.

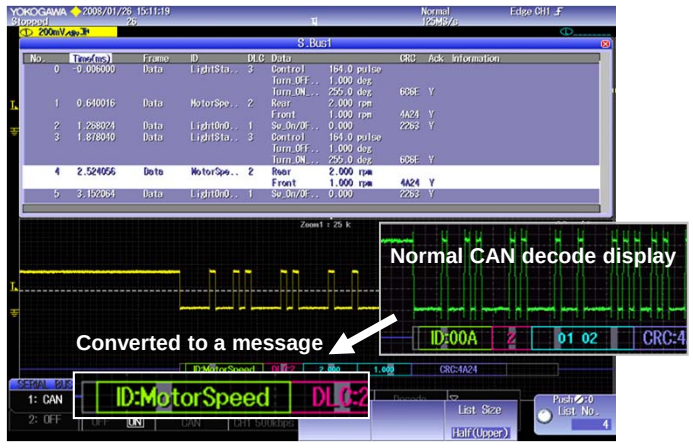
- Any field in the analysis result list can be selected, to automatically display the corresponding CAN bus waveform (Zoom Link). Furthermore, it is also possible to automatically align the zoom window to the a specific field of each frame (the center of the zoom box) (Field Jump).

- A search can be performed using SOF, ID, Data Frame, etc. as the condition, in the same manner as the trigger conditions. When a search is executed, the zoom box centers on the first search result, and the data is enlarged and displayed in the zoom waveform display frame (Zoom 1 or Zoom 2).

- Setting triggers with either physical values (message or signal) or analysis result (decode) can be accomplished by importing a CAN DBC database file (.dbc). Physical values can be read directly from the waveforms for increased efficiency of failure analysis and troubleshooting.



Type and Configuration of In-Vehicle LAN



Example of decoded result (converted to a message) using CAN database file

Application

Resources Energy

In-Vehicle LAN Design and Functional and Performance Evaluation

Vehicle Serial Bus Analyzer SB5000

Bus Analyzer / Data Generator GT300/GT350/GT200
(Yokogawa Digital Computer Corporation)

Overview

Today, CAN is used as the standard in-vehicle LAN for automotive control systems; however, a faster and more reliable next-generation in-vehicle LAN is required as the electrification and computerization of vehicles accelerate each year. Many automotive companies are considering using FlexRay, which was developed and standardized in Europe, as the next-generation standard in-vehicle LAN. European automotive manufacturers are already using FlexRay on production vehicles.

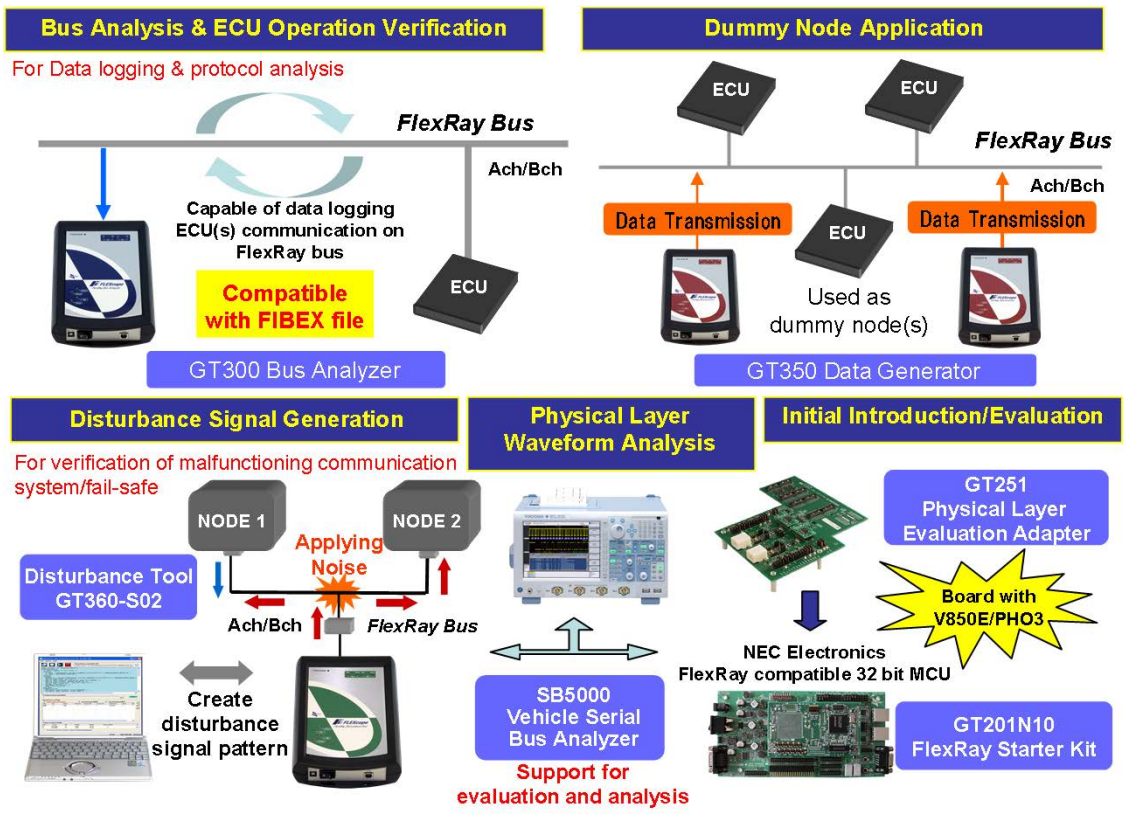
Future electric vehicles will have to handle an increasing amount of communication data, so they are expected to use FlexRay to replace CAN FlexRay also enables X-by-Wire technology, which does not rely on mechanical linkages to transmit operation data from braking and steering systems systems.

Application Points

- Introducing and planning FlexRay:
  Educational equipment for prototyping and communication functions
- FlexRay system designing and verification:
  Bus analysis for ECU evaluation, and transmit/receive tests using simulated data
- FlexRay system functional and performance evaluation
  Physical layer verification, continuous or one-time performance test, and fault analysis

Product Features

- FlexRay introducing evaluation and educational starter kit (GT200)
- FlexRay system monitoring and long-time data logging (GT300)
- FlexRay simulation data transmission and dummy node application (GT350)
- Communication data corruption, error and fail-safe process verification (GT360-S02)
- Physical layer verification and analysis, and fault analysis(SB5000)



Hybrid & Electric Vehicles
Power Electronics, etc.

Hybrid Vehicle Efficiency Evaluation Test

Power Analyzer
WT3000

Because of social and economic factors related to energy conservation, hybrid vehicle development is experiencing increased requirements for motor evaluation and inverter control in order to achieve higher precision and higher efficiency.

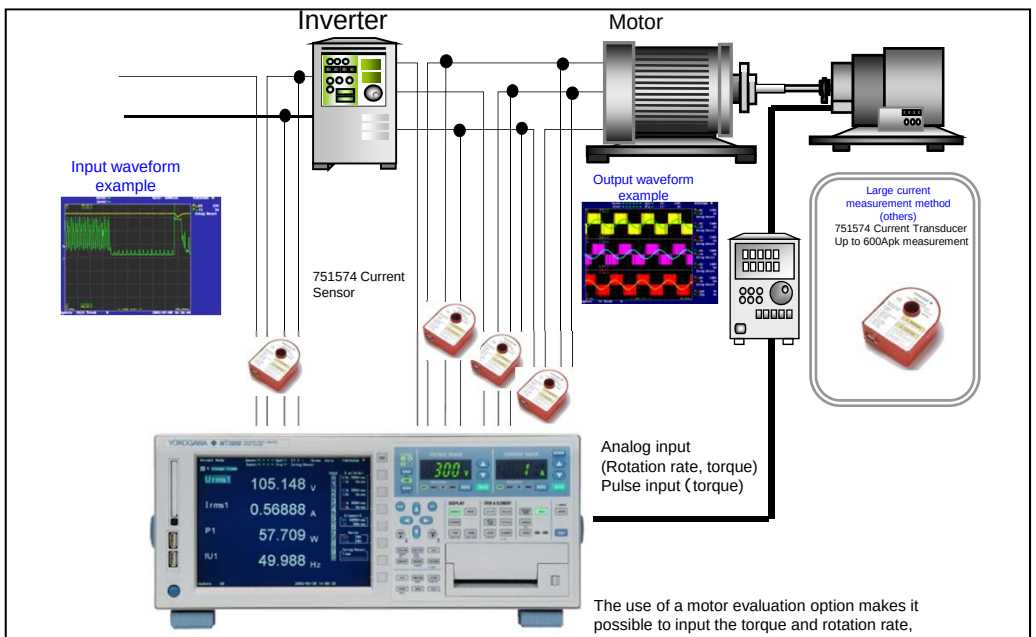
The WT3000 Precision Power Analyzer is capable of up to 4 channel input, and precision measurements can be made of inverter efficiency between the input and output sections. Furthermore, the use of a motor evaluation function (option) allows users to simultaneously observe the voltage, current, and power fluctuations, together with changes in the rotation rate and torque. This function also allows calculation and display of mechanical power, total efficiency, and more.

Application Points

- High-precision, wide-band measurements
- A wide selection of voltage ranges allows the same unit to accurately measure very low to very high voltages.
- Up to 30A direct input is available to support high-precision measurements. If more than 30A input is required, the 751574 Current Transducer supports up to 600A input measurements.
- Simultaneous measurement of normal values with harmonics, which are essential for over modulation PWM, etc.
- High-speed measurement of power fluctuations
- The internal printer (/BS) allows users to easily print out measured values and waveforms.

Product Features

- Basic power accuracy：0.06%, measurement bandwidth: 0.1Hz to 1MHz
- For rated input range, select from the 15V range to 1,000V range.
- Two types of current input elements are available: Selectable from a 2A input element (5mA to 2A range) and 30A input element (500 mA to 30A range).
- It is possible to simultaneously measure the voltage, current, power, and power factor, as well as total harmonic distortion (THD) and harmonic data (from fundamental harmonic to the100th order harmonic).
- High-speed data acquisition at 20 times per second (with a 50ms duration)
- The internal printer (option) allows users to simply print out values, waveforms, trends, harmonics, bar graphs, two-screen display (values and waveforms), etc.



The use of a motor evaluation option makes it possible to input the torque and rotation rate, and perform total efficiency evaluation.

■WT3000 Display and Setting Screens

【4input screen and connection display example】

Power Consumption & Power Conversion Efficiency Measurement of Solar Power Generation

Power Analyzer
WT500

Application Overview

Solar power generation is one application area which is currently attracting attention, in part due to the fight against global warming.

Thermal power generation using limited resources such as oil and coal as fuel emits CO_2. This is the leading cause of global warming, due to the adverse affects of CO_2 on the environment. In contrast, solar power generation is a clean new energy source that neither emits CO_2 nor needs such resources, so it is regarded as an important alternative energy source for the future. The WT500 Power Analyzer, which is capable of measuring the DC and AC signal accuracy, is a very useful tool to evaluate the voltage, current, and power conversion efficiency in solar power generation.

Application Points

- High-precision DC measurements
- Simultaneous DC and AC measurements
- High current and high voltage compatible
- Efficiency measurements
- Variety of screen display setting options

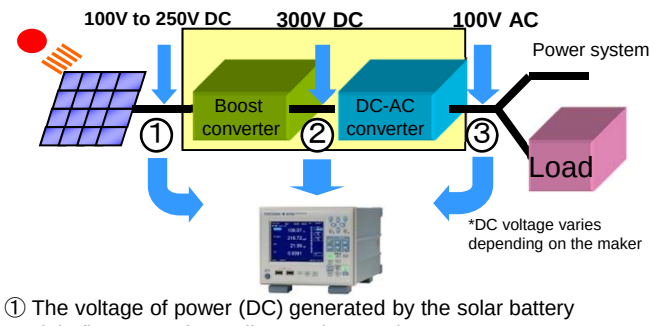
Product Features

- High-precision DC measurements : 0.2%
- Simultaneous measurement of input and output signals
- High current compatible: 40A range (direct input)
- High voltage compatible: 1,000V range (direct input)
- Efficiency calculation function available

Create a customized screen and display values as you like.

It is possible to display both measurement items and efficiency calculations on the screen, simplifying simultaneous monitoring and verification.

■Power Conditioner for Solar Power Generation

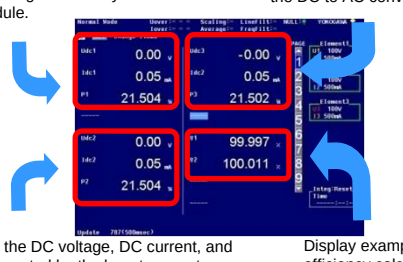


① The voltage of power (DC) generated by the solar battery module fluctuates depending on the weather.
② The voltage is boosted to a certain level.
③ This signal is converted to a 100V AC signal.

■WT500 Display Screen

① Displays the DC voltage, DC current, and DC power generated by the solar battery module.

③ Displays measured values of the commercial power supply output from the DC to AC converter.



② Displays the DC voltage, DC current, and DC power boosted by the boost converter.

Display example of efficiency calculation

Power Evaluation of Generators and Pumps at Thermal Power and Hydroelectric Plants

Power Analyzer
WT500

Application Overview

Hydroelectric and thermal power plants operate by discharging water stored behind a dam, turning screws with the released water pressure, and using the turning force to produce electricity with generators. More than 100 generators may be installed in a large dam. Periodic diagnosis is performed to check the performance of these generators.

Furthermore, emergency sump pumps are also installed, and these also need to be checked periodically.
The WT500 allows operators to check the performance of generators by measuring instantaneous generator and pump power output, integrated power, or other data.

Application Points

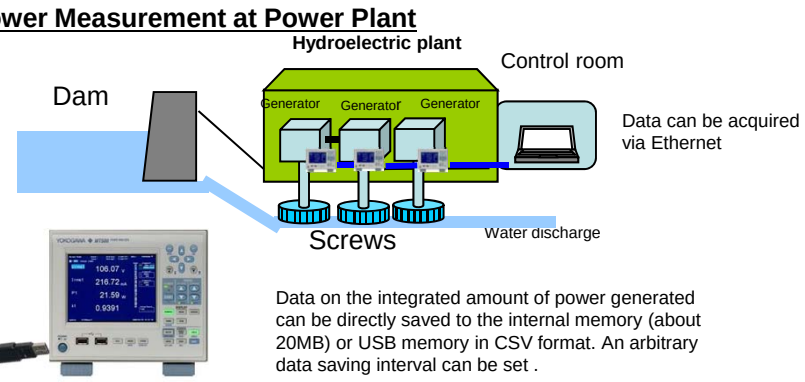
- High-precision power measurement of generators and pumps
- Data on the integrated amount of power generated is saved at regular intervals.
- Trend display allows operators to monitor fluctuations in the voltage, current, and power
- Simultaneous measurement of voltage, current, power, and frequency at multiple points away from each other
- A variety of integration functions enable high-precision measurement of the amount of power generated

Product Features

- High-precision voltage, current, and power accuracy: 0.2%
- Necessary data such as the integrated amount of power can be saved at set intervals (e.g., at 5 minute intervals) in CSV format, and the values can be displayed and graphs can be easily created in Excel or other software.
- Data can be acquired at a high speeds (up to 100ms) and displayed in the trend view. Also, long-time monitoring of fluctuations in the voltage, current, and power is possible.
- Power at separate physical locations can be monitored simultaneously using the Ethernet function and multiple WT500 power analyzers.
- Amounts of active, reactive, and apparent power can be integrated.

• Trend display refers to a graph display in which the horizontal and vertical axes represent a time axis and data values, respectively.

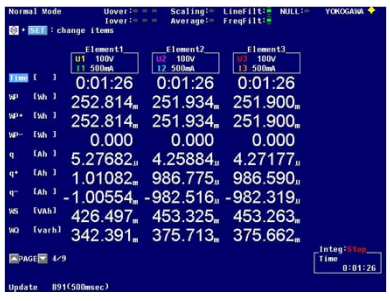
■Power Measurement at Power Plant



Data on the integrated amount of power generated can be directly saved to the internal memory (about 20MB) or USB memory in CSV format. An arbitrary data saving interval can be set .

■WT500 Display Screen

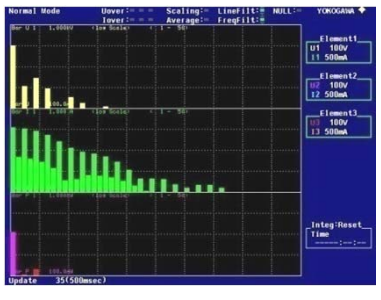
[Example of power measurements]



[Trend display allows checking of power fluctuations]

[Example of measurement of voltage, current, power, and total]

[Example of checking the effect of harmonic distortion]



Measurement of Power & Energy for Wave & Tidal Power Generation

Power Analyzer
WT500

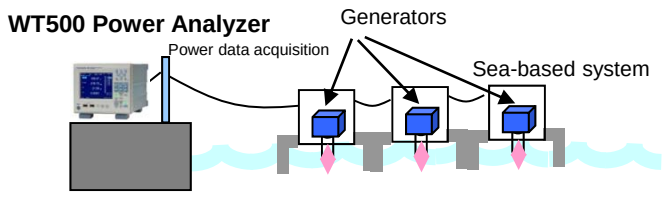
Application Overview
Wave and tidal power generation is attracting attention as a clean energy source. The technology to generate wave and tidal energy, however, is evolving steadily rather than progressing rapidly. Presently, several generation technologies are being studied and evaluated. These technologies use the waves and tides, for example, to turn a turbine, generate power, and obtain electric energy. The main issue is how to efficiently transfer this energy to generators.
The WT500 is capable of observing the amount of power generated by generators for long time periods.

Application Points
- The integrated values of power generated can be measured with high precision at intervals of one hour, or a user-specified time.
- High-precision measurement of voltage, current, and power
- The WT500 can be used as a power logger to acquire power data for a long periods.
- Changes in the generating capacity can be saved quickly.

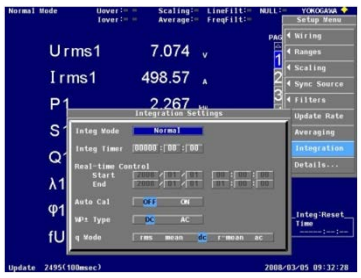
Product Features
- The active power (Wh) can be measured simultaneously on 3 channels for a long time.
- High-precision voltage, current, and power accuracy：0.2%
- Harmonic elements and total harmonic distortion (THD) can be measured simultaneously with voltage, current, and power data, and up to 1GB of data can be saved to external memory such as a USB stick.
- Trend display at a high speed data acquisition rate of 10 times per second
Changes in the voltage, current, and power can be intuitively understood.

* Trend display refers to a graph display in which the horizontal and vertical axes represent the time axis and data values, respectively.

■Example of Wave and Tidal Power Generation System



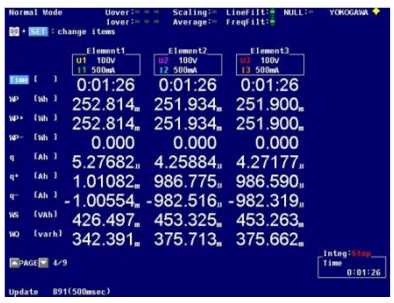
The WT500 is capable of acquiring data at a high speed rate of 10 times per second, and the data includes voltage, current, power, power factor, harmonic, and distortion factor of generators that generate electricity using dynamic waves.



Setting screen for measurement of the total energy

■WT500 Display Screen

[Example of measurement results of generator]



[Trend display allows operators to check the stability]

Measurement of Voltage, Current, and Power & Frequency Fluctuations for Wind Power Generation

Power Analyzer
WT500

Application Overview
Wind power generation is one of the Earth's natural energy sources, and it is widely used in Europe to reduce greenhouse gas emissions, the main cause of global warming. The benefits of wind power generation, a natural energy source, include no requirement for fuel and the ability to generate electricity during the day or night.
There are two types of generation methods, DC link and AC link. The WT500, which is capable of performing measurement with a high DC and AC signal accuracy, is a very effective tool to evaluate the voltage, current, and power conversion efficiency for each system. In particular, the WT500 High Precision Power Analyzer enables high-precision measurement in these generation systems.

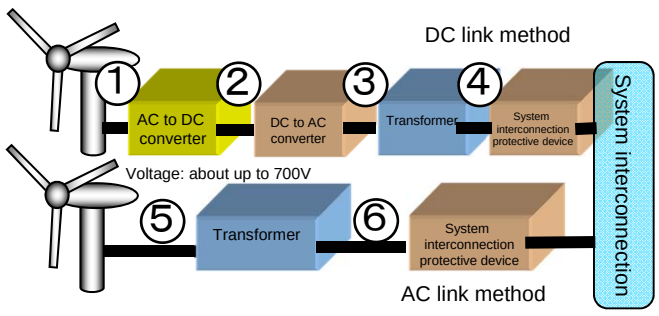
Application Points
- High-precision DC measurement
- Simultaneous DC and AC measurement
- High current and high voltage compatible
- Trend display of waveform fluctuations in the voltage, current, and power
- Images can be saved and data can be transferred to PC software

Product Features
- High-precision DC measurement: 0.2%
- Simultaneous measurement of input and output signals
- High current compatible: 40A range (direct input)
- High voltage compatible: 1,000V range (direct input)
- Trend display function to display fluctuations in the voltage, current, and power waveforms
- Images can be saved and value data can be transferred to PS software

Trend display, waveform, voltage, current, power values and the like can be saved as image or value data, which can be pasted to a report or analyzed using spreadsheet software.

• Trend display refers to a graph display in which the horizontal and vertical axes represent the time axis and data values, respectively.

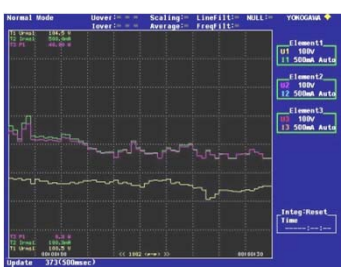
■Power Conditioner for Wind Power Generation System



① Observe the fluctuations in the voltage frequency and voltage values
② Observe the voltage value of the converted DC signal
③ Observe the voltage level of the converted AC signal (50Hz or 60Hz)
④ Observe the stability, irregular events or the like of the 100V/200V signal at 50Hz/60Hz
⑤ Observe the voltage level of the signal output at 50Hz/60Hz.
⑥ Check that the output at 100V/200V is stable.

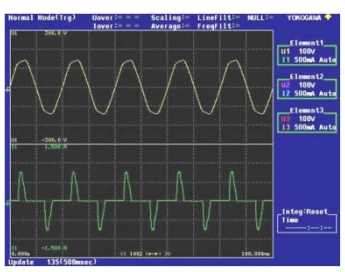
■WT500 Display and Setting Screens

[Trend display example of voltage, current, and power]



The saved image can be pasted to a report as evolution test data.

[Observation example of voltage and current waveforms]



Waveforms of 50Hz/60Hz signals can be observed.

Power Measurement for Selling and Buying Electricity by Power Conditioner

Power Analyzer
WT500

Application Overview

Presently, the energy depletion problem is a hotly debated issue, and the industry is encouraging rigorous energy conservation and use of alternative energy sources. Development of solar power generation or the like is underway in Japan in order to reduce CO_2 and other greenhouse gas emissions.

The WT500 is capable of measuring generated electricity to supply, that is, to sell to the interconnected power grid, and the amount of electricity utilized, or bought. It can simultaneously display the data on the buying and selling of electricity, or the like.

Application Points

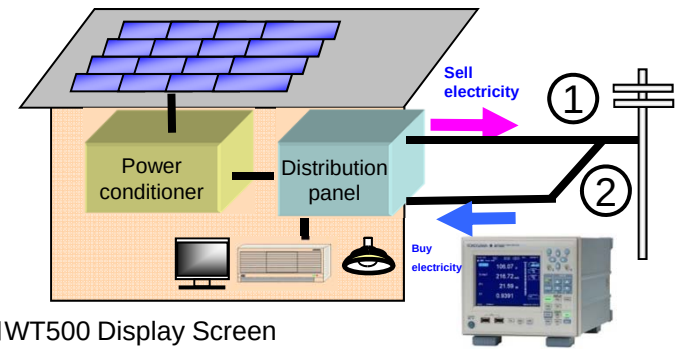
- Simultaneous measurement of electricity sold and bought
- Harmonic and total harmonic distortion (THD) measurements
- Power conditioner input and output efficiency measurements
- High current compatible
- Trend display of voltage, current, and power

Product Features

- A single analyzer simultaneously measures and displays electricity sold and bought.
- Harmonic measurement functions (DC to the 50th order) and total harmonic distortion
- Efficiency calculations and power conditioner input and output measurements
- High current compatible: 40A range (direct input)
- Trend display of fluctuations in voltage, current, and power

*Trend display refers to a graph display in which the horizontal and vertical axes represent the time axis and data values, respectively.

■Power Measurement for Selling and Buying Electricity by Power Conditioner

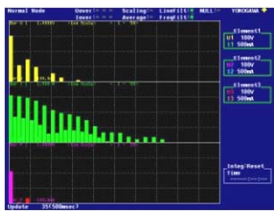


■WT500 Display Screen

The amounts of electricity sold and bought can be obtained, respectively. The varying amount of electricity can be measured for one day at each data update rate and easily displayed in a graph using Excel or other software.

* The WT500 can be used for evaluation.

【Example of distortion measurement of voltage, current, and power】



Crystal Solar Cell Electrode Formation Equipment

DYNASERV

<Application>

The DYNASERV is used as an indexing device for forming electrodes of crystal solar cells (using the screen printing method).

<Benefits>

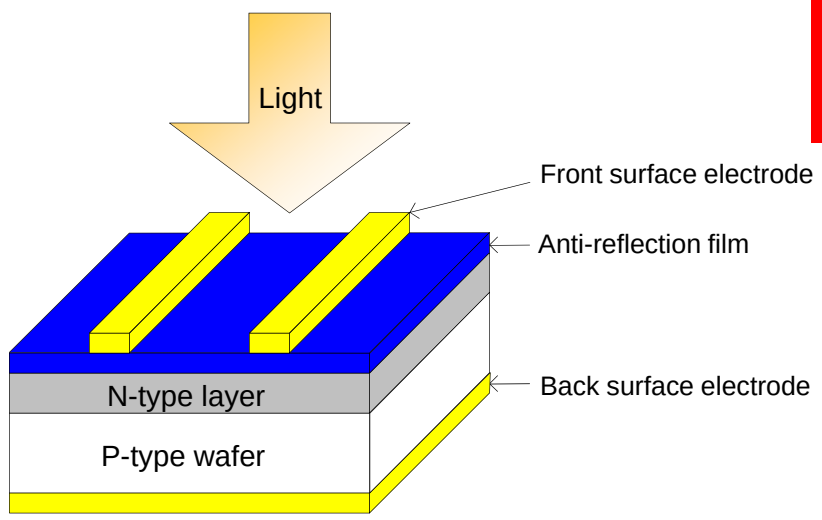
- Reduction of optical loss (shadow loss) caused by a light-receiving surface electrode through improved precision of the printing process.
- Easy changes in set-up allow for quick response to a changes in cell size)
- Shorter cycle times
- Maintenance-free
- Simple structure

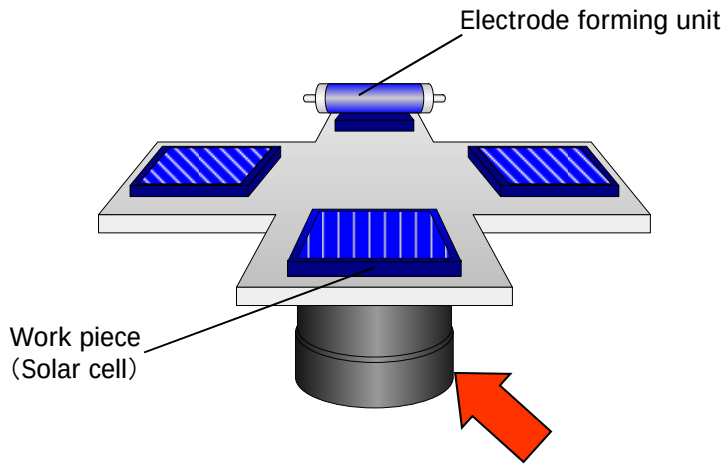
<Solutions>

- All-in-one
- High precision, high torque, high rigidity, and low heat generation

A solar cell utilizes electrodes which collect the photocurrent generated by the incident light. Typically, electrodes are formed on both the front and back surfaces, using the highly efficient screen printing method in a mass production process. However, the electrode on the light-receiving surface blocks incident light, so that light does not reach the solar cell under it, resulting in a loss of the incident light (shadow loss). To manufacture more efficient cells, it is advantageous to reduce the shadow loss caused by the surface electrode by increasing the precision of printing.

The high-precision, highly rigid DYNASERV can be used as an indexing device, to increase the precision of printing. Other mechanical indexing devices must be redesigned to respond to a change in the cell size. On the other hand, the DYNASERV can easily respond to a variable cell sizes since it can make arbitrary position changes through flexible changes in the programming. Furthermore, thanks to its high torque and low heat generation, it is able to perform high-speed positioning, thus contributing to a shorter cycle time.





DYNASERV

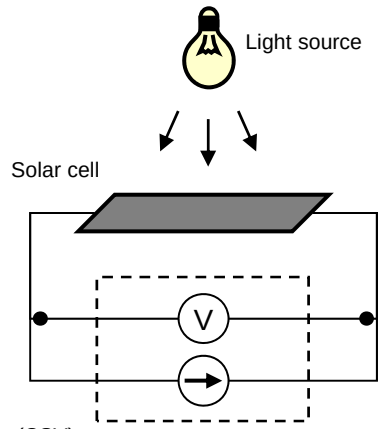
V-I Characteristic Measurement for Small Solar Cell Panel

Source Measure Unit
GS610

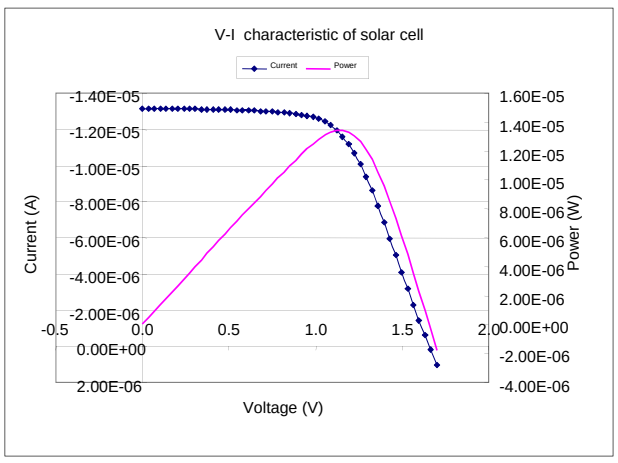
Application Overview
The GS610 draws current from solar cells, consumes power, and measures the cell voltage for each current value. A V-I characteristic graph is created to calculate the open-circuit voltage (cell voltage when the current = 0A), short-circuit current (output current when the voltage = 0V), and maximum power operation point (voltage and current coordinate which generates maximum power).

Application Point
The GS610 is used as a high-precision electronic load to measure solar cell voltages that vary depending on the load current. A CSV file containing the measurement results is stored in the internal USB mass storage of the GS610, which can be easily accessed from a PC.

Product Features
- High precision with basic accuracy of ±0.02% (voltage generation)
- Generation and measurement range of up to 3.2A at 12V output
- Easy access to the internal USB mass storage.



V-I Characteristic Graph



Measurement results file (CSV)

Sweep (V)	Current (A)	Power (W)
1.70E+00	1.05E-06	-1.78E-06
1.67E+00	1.64E-07	-2.74E-07
1.63E+00	-6.09E-07	9.95E-
1.60E+00	-1.42E-06	2.2
1.56E+00	-2.28E-06	06
1.53E+00	-3.17E-06	06
1.50E+00	-4.09E-06	6.12E-06
1.46E+00	-5.02E-06	7.34E-06
1.43E+00	-5.96E-06	8.51E-06
1.39E+00	-6.88E-06	9.59E-06
1.36E+00	-7.76E-06	1.06E-05
1.33E+00	-8.60E-06	1.14E-05
1.29E+00	-9.36E-06	1.21E-05
1.26E+00	-1.01E-05	1.26E-05
1.22E+00	-1.07E-05	1.30E-05
1.19E+00	-1.12E-05	1.33E-05

Drag & drop

Draw graph

GS610 Source Measure Unit

Measurement of Global Warming Gases in the Atmosphere

Optical Spectrum Analyzer
AQ6375

In recent years, the global environment is attracting significant attention, and efforts to reduce greenhouse gas emissions are gaining momentum. These greenhouse gasses include CO_2, SO_2, NOX, and methane. These gases have a strong optical absorption at a wavelength of around 2μm. By measuring this optical absorption, the distribution and density of small amounts of these gases can be measured. Conventionally, large spectrum measurement systems using a spectrometer were developed to measure this wavelength range; however, these systems have had many problems with respect to the optical performance, measurement speed, portability, and maintenance.

Application Points
- Measurement of optical spectrum at around 2μm
- Optical absorption of various gases can be captured
- Short measurement time
- High portability and maintenance performance

Product Feature
- World's first optical spectrum analyzer for long wavelength region
  The AQ6375 is the world's only optical spectrum analyzer capable of measuring a long wavelength range of up to 2.4μm. Its wide measurable wavelength range of 1.2 to 2.4μm enables measurement of the absorption lines of various gases distributed over this band.

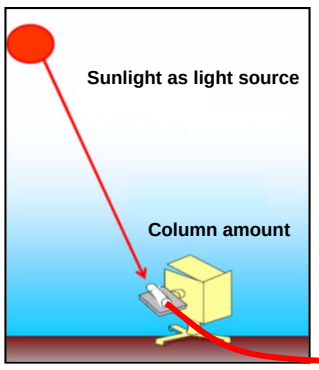
- Excellent optical performance
  The AQ6375 is able to capture the sharp absorption spectra of various gases thanks to its high resolution (0.05 nm), dynamic range (55 dB), and high sensitivity capable of measuring faint light of -70 dBm.

- 0.5 second high-speed optical spectrum measurement

- Excellent portability and maintenance performance
  One compact package is easy to carry around and can be installed anywhere.
  The standard self-calibration function allows the user to start measurement anywhere after a few-minute self-calibration.

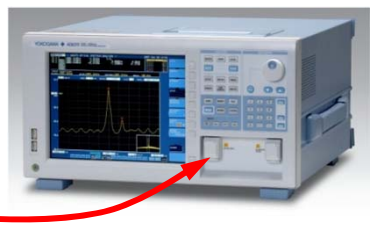
- Outstanding operation performance
  ・PC-like operation: USB interface (mouse, keyboard, and memory) available
  ・Remote operation: Variety of high-speed communication interface options (GP-IBx2, RS-232, Ethernet)
  ・Remote measurement: Remote and explosion-proof measurement using optical fiber cable
  ・Variety of data operation options: Spectrum analysis and calculation, and save functions available as standard

Example of Warming Gas Measurement (Methane)

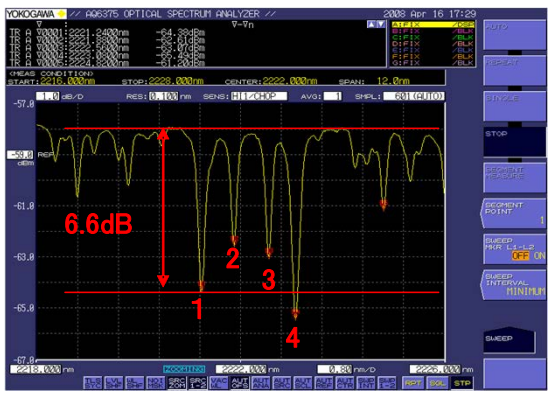


・Just put the collected sunlight with optical fiber
・Measure the absorption corresponding to the column density

AQ6375 Optical Spectrum Analyzer



Optical absorption spectrum of warming gas methane



Measurement of Safe Operating Area (SOA) in Switching Power Supplies

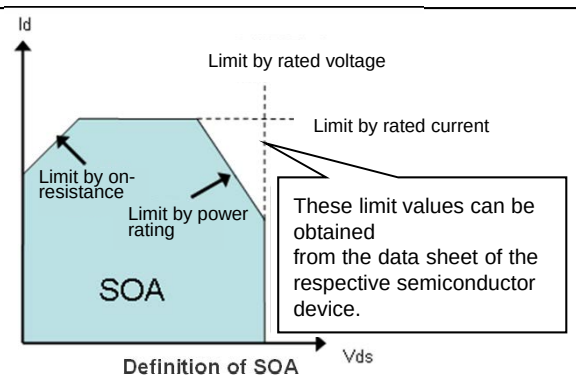
Mixed-Signal Oscilloscope
DLM2000/DL9000 Series

Application Overview
In order to increase the reliability of switching power supplies (circuits), power devices must be designed in such a way that they operate within a limited operation area. For that purpose, the relationship between voltage and current is X-Y plotted to evaluate the operation area characteristics of the device. In the case of a MOSFET, the operation of power devices is checked to ensure it is within the safe operating area (SOA) (which is represented as an enclosed area in the figure).

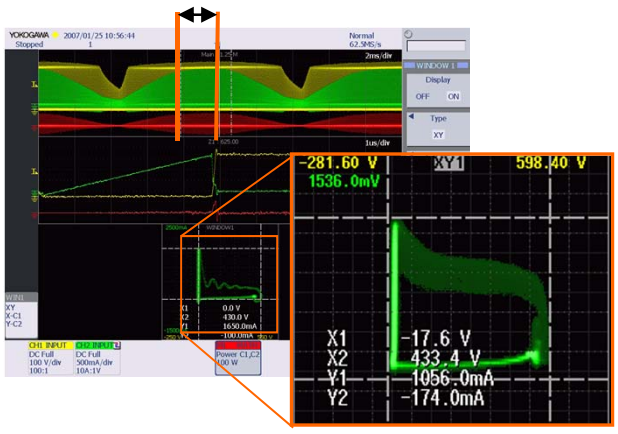
Application Point
A historical view of statistical parameters in the DLM2000/DL9000, lengthy internal memory, and high speed waveform update rates, allow dynamic capture of all switching pulses, as well as measurement of switching loss for every individual pulse.

Product Features
The DLM2000/DL9000 is capable of checking the SOA by displaying the CH1 (Vds) and CH2 (Id) waveforms on the X-axis and the Y-axis, respectively, and observing a correlation between the two input signal levels.
Values can be read by placing the cursor on any place of the displayed SOA waveform, so it is easy to check that the levels are within the limited area by comparing them with the device's data sheet. When the range cursor is placed on the T-Y waveform, the X-Y (SOA) waveform corresponding to that range (cycle) is displayed simultaneously. Accordingly, by selecting the condition (point) for power-on, load fluctuation or the like from the T-Y waveform, the corresponding SOA can be evaluated.

Furthermore, by displaying the waveform cycle (T-Y waveform) for which you want to display the SOA, in the zoom area, the SOA can be displayed on the X-Y axis using only the data in a specified range. By auto-scrolling through the zoom area, the SOA trend of each cycle can be checked consecutively on the X-Y screen.



Definition of SOA



SOA can be displayed in any T-Y waveform range specified by the cursor (DL9000)

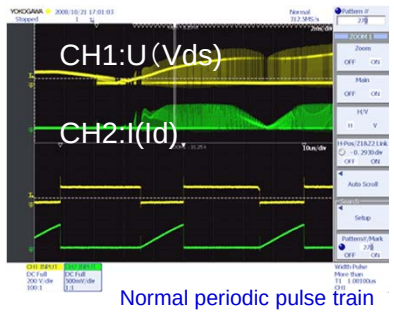
Checking Switching Operation Stability in Switching Power Supplies

Mixed-Signal Oscilloscope
DLM2000/DL9000 Series

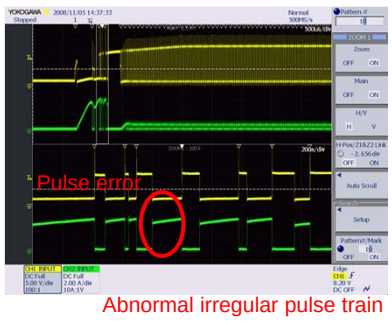
Application Overview
The stability of switching operations (switching transients) must be checked when the power is turned on or off, the load is short-circuited, open-circuited, or changes abruptly. A missing pulse or switching error may cause damage to the circuit.
In order to check for transients, switching waveforms are captured at a high sampling rate over a long period of time, and the waveform is enlarged for each switching pulse to check for abnormal waveforms.
A variety of waveform search functions allows the user to immediately locate abnormal waveforms. Furthermore, use of a cycle statistics function allows the user to perform statistical processing of measured parameters (pulse width) to detect pulse errors. In addition, the zoom area can be automatically scrolled along the time axis. This function is convenient for evaluation.

Application Points
A historical view of statistical parameters in the DLM2000/DL9000, lengthy internal memory, and high speed waveform update rates, allow dynamic capture of all switching pulses, as well as measurement of switching loss for every individual pulse. Furthermore, derating must be applied to the rating, to prevent a surge voltage that occurs in the switching device. Designers suppress a surge voltage by adjusting the component while watching the waveforms and keeping loss in mind. The DLM2000/DL9000 series allows users to observe switching waveforms and measure the peak value of surge voltage.

Product Features
The maximum, minimum, average, and standard deviation can be calculated by statistical functions. The distribution can be displayed in a histogram to check for variations. Large memory provides even commercial frequencies with an adequate time resolution, and to reliably capture less frequent low peak values.

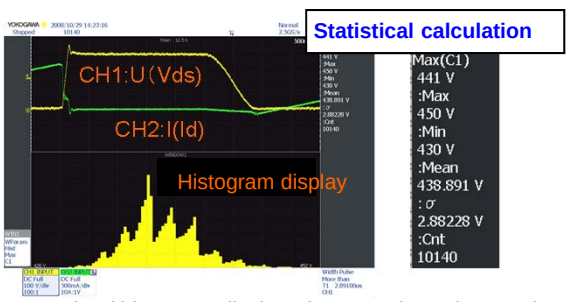


Normal periodic pulse train



Abnormal irregular pulse train

Example of checking transient (DL9000)



Example of histogram display of surge voltage (DL9000)

Power Quality Evaluation Test of Uninterrupted Power Supply (UPS)

Power Analyzer
WT500

Application Overview

An uninterrupted power supply (UPS) refers to a system that always provides stable power supply, even in power supply emergencies such as a blackout, instantaneous power failure, or voltage and frequency fluctuations. A high-precision, high-stability power analyzer is required to evaluate the performance of UPS systems.

A power analyzer is capable of testing the performance of UPS systems by measuring, for example, the voltage, current, power, frequency, distortion, and I/O efficiency of input and output signals, or inverter output signals.

* An oscilloscope is required for the switching evaluation of power supply circuits.

Application Points

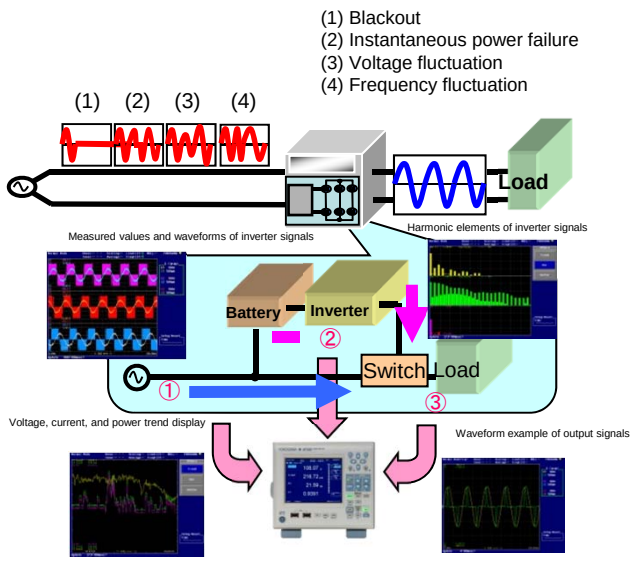
- High-precision measurement of voltage, current, and power
- Harmonic distortion measurement
- Trend display of voltage, current, and power fluctuations
- Variety of value display screens
- Image saving and easy transfer of measurement data to PC applications

Product Features

- High-precision voltage, current, and power accuracy: 0.2%
- Measurement of voltage, frequency, harmonic distortion, and harmonic component (up to the 50th order)
- Capable of checking fluctuations in the voltage, current, and power values over a long period of time
- Variety of display formats such as 4-value or 16-value can be selected.
- Screen images and measured values can be saved to the internal memory or USB memory.
  Reports and graphs can be created on a PC.

* Trend display refers to a graph display in which the horizontal and vertical axes represent the time axis and data values, respectively.

■UPS Power Quality Evaluation Test



[Example of signal measurement with WT500]

① Voltage/frequency (trend display) and waveforms of the power can be monitored.
② Active voltage values, active current values, power, frequency, and waveform of inverter signals can be measured.
③ Voltage/frequency (trend display), distortion, and harmonic components (up to the 50th order) of output voltage can be measured.

Battery Charge/Discharge Test

Power Analyzer
WT500

Application Overview

Battery-operated equipment such as mobile devices, electric vehicles, and electric bicycles sometimes may need a short-time charge/discharge test tailored to the actual usage conditions.
Such a test may require that charge/discharge be repeated even during the display refresh interval, and that the power (energy) charged or discharged be measured, respectively. The WT500, which uses a digital sampling method, is capable of independently integrating the rapidly fluctuating power charge and discharge periods. The WT500 is useful in evaluating the life time and charge time of batteries.

Application Points

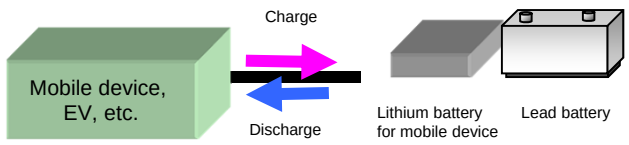
- High-precision DC measurements
- Capable of integrating the charge and discharge, respectively.
- Trend display of the active energy and individual energy for positive and negative polarities
- High current and high voltage compatible
- Data on charge/discharge is saved at the minimum interval of 100ms

Product Features

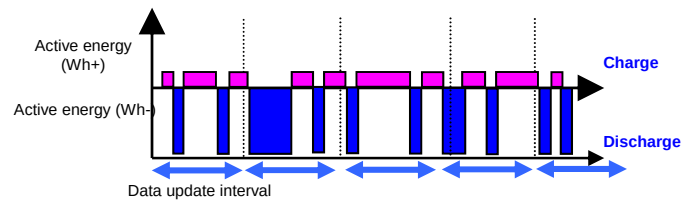
- High-precision DC measurement：0.2%
- Individual calculations of charge/discharge
  Not only the normal active energy but also the charge/discharge can be calculated individually by integration for both positive and negative polarities.
- Trend display of items other than voltage, current, and power
  Temporal changes such as those in the active energy can be checked.
- High current compatible: 40A range (direct input)
- High voltage compatible: 1,000V range (direct input)
- Data fluctuations can be measured at the minimum interval of 100ms and saved in CSV format.
  Graphs can be created on an Excel sheet.

* Trend display refers to a graph display in which the horizontal and vertical axes represent the time axis and data values, respectively.

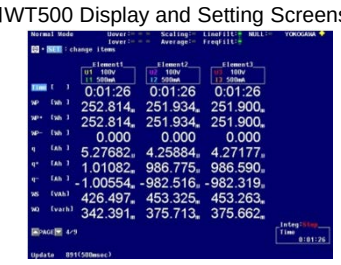
■Battery Charge/Discharge Test



Example of signals for rapid repeated charge/discharge



■WT500 Display and Setting Screens



* Use the WT3000 or WT1600 for more precise measurement.

WT500 Power Analyzer

751574 Current Transducer

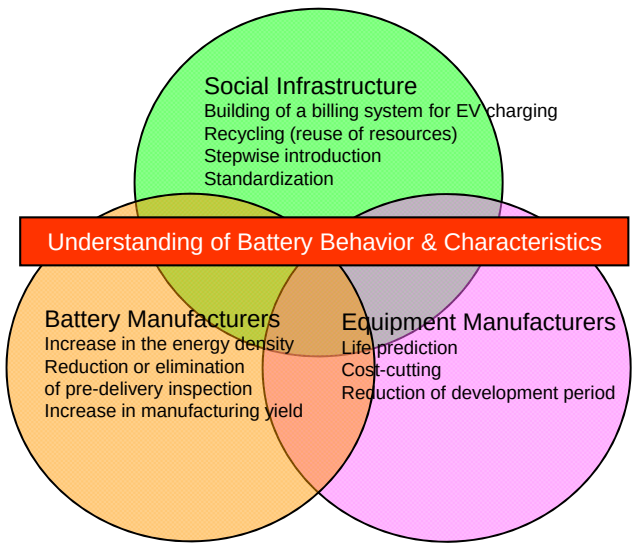
High current of up to 600A can be measured by combined use with the 751574 or 751521.

Modeling Technology of Rechargeable Batteries for Reliable and Safe Use

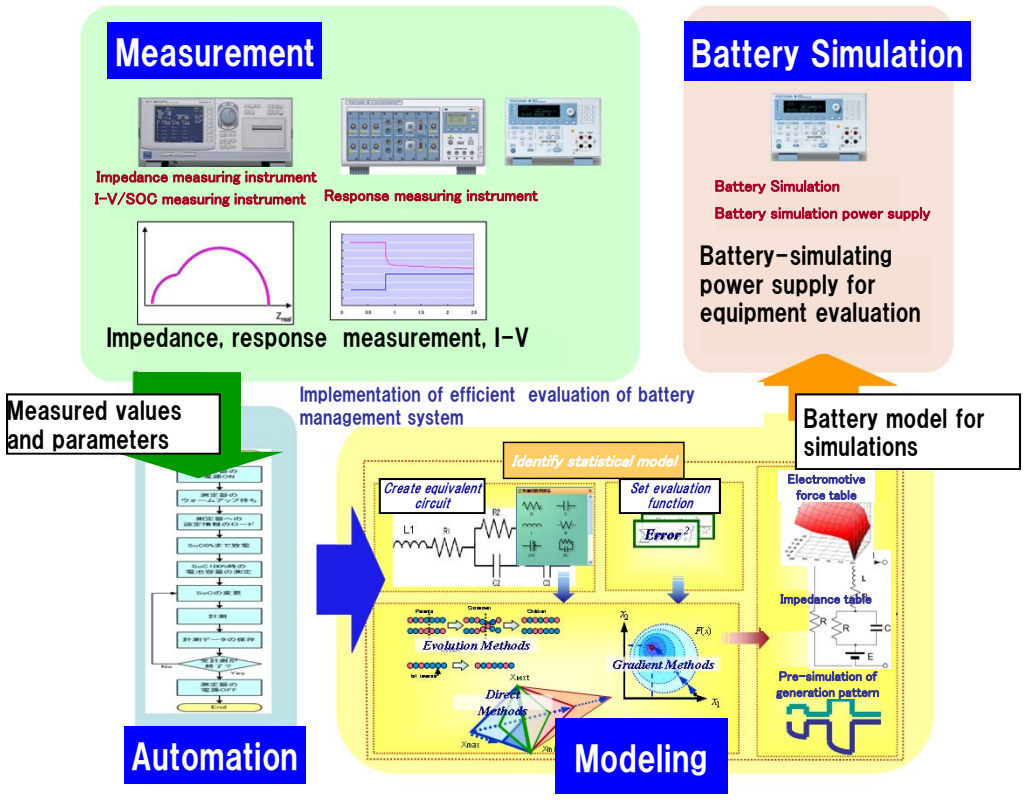
Digital Power Meter WT1600FC
High-Speed Data Acquisition Unit SL1000
Source Measure Unit GS610/GS820

Application Overview
While personal digital assistants as typified by smartphones become more popular, commercialization of hybrid and electric vehicles is rapidly progressing on a global scale toward a sustainable low-carbon society. Under these circumstances, there are great expectations for rechargeable batteries as typified by lithium ion batteries that are key components of these products. However, there are still challenges to be solved, such as increasing energy density, ensuring safety, and increasing production yield.

Application Points
To help solve these challenges, Yokogawa offers a series of battery solutions, such as a variety of high-precision measuring instruments and automated measurement systems that help modeling batteries accurately, a software tool that uses the acquired data to perform fitting to and modeling of equivalent circuits, and battery emulation that combines it with a high-speed, high precision power supply.



Challenges of Rechargeable Batteries



Modeling Technology and Battery Simulation of Rechargeable Batteries

Charge/Discharge Characteristic Measurement of Rechargeable Batteries

Source Measure Unit GS610
Multi Channel Source Measurement Unit GS820

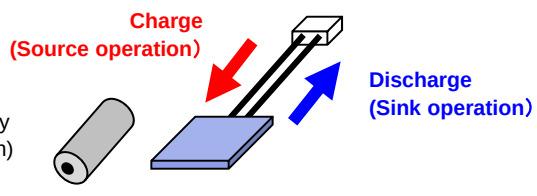
Application Overview
Charge/discharge operations are performed for rechargeable batteries such as lithium ion and nickel hydrogen batteries to measure the battery voltage and current. Programmed operations are performed according to specified charge/discharge sequences, and the generation from the start to the end of the charge and discharge operations and measurement logs are stored.

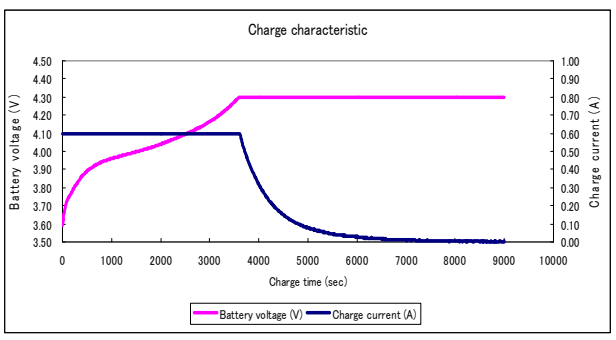
Application Points
An Auto V/I function enables smooth automatic switching from constant-current charge to constant-voltage charge. Seamless high-precision charge/discharge characteristic curves according to specified charge/discharge sequences are obtained.

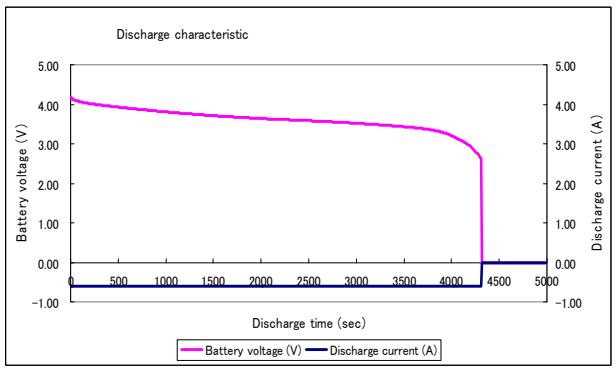
Product Features
- High-precision charge/discharge operations at the maximum current of 3.2A
- Charge/discharge operations by pulse current
- Smooth switching operation from constant-current charge to constant-voltage charge (Auto VI function)

GS610/GS820 Source Measure Unit

Lithium ion battery
Nickel hydrogen battery
(Up to about 1000mA/h)







Checking of Circuit Operation Under Power Supply Voltage Fluctuation

Source Measure Unit
GS610

Application Overview

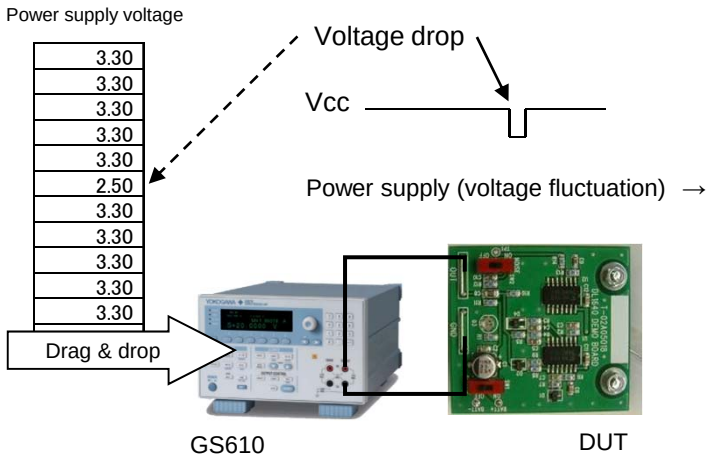
Arbitrary levels of voltage fluctuations such as a voltage drop or overvoltage are generated in a simulation to check for malfunctions of the device under test (DUT).

Application Points

Arbitrary power supply-level fluctuation waveforms are defined using a waveform programming function of the GS610 Source Measure Unit. Simulation outputs of power supply-level fluctuations can be easily programmed by saving the waveform data column described on the general-purpose worksheet to the internal memory of the GS610 in CSV format.

Product Features

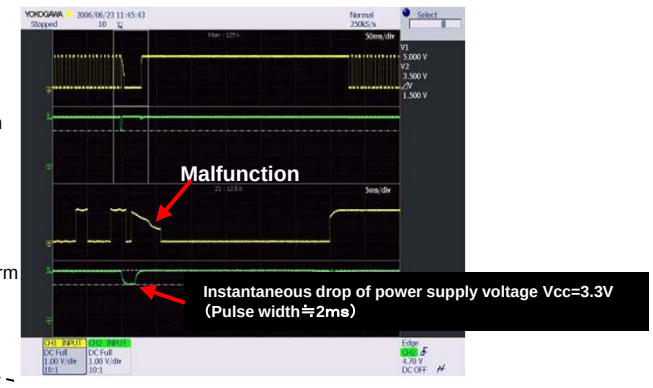
- Definition of arbitrary level fluctuations such as those of a power supply voltage drop or overvoltage
- Program output at the maximum interval of 100μs
- Easy to save and load files using the internal USB memory.



DL9000 Series Digital Oscilloscope

The DL9000 Digital Oscilloscope with large memory and zoom function, capable of high-speed sampling, is recommended for the analysis of malfunction waveforms.

Example of waveform observation for malfunction



Voltage Regulator Power Conversion Efficiency Measurement

Multi Channel Source Measure Unit
GS820

Application Overview

Power conversion efficiency of three-terminal regulators and DC-DC converters is measured.

A source measure for power supply and another source measure for power consumption are connected on the primary and secondary sides, respectively. The energy consumption and power supply are changed by sweeping the load current. Power conversion efficiency is obtained by the ratio of the energy consumption to that of the power supply.

Application Points

One instrument is equipped with an isolated 2 channel source measure system. By using channels 1 and 2 for the power supply and electronic load, respectively, two separate conventional measuring instruments are integrated into one. This eliminates the need for synchronized operation and integration of measured data, as well as conserving physical installation space and reducing evaluation time

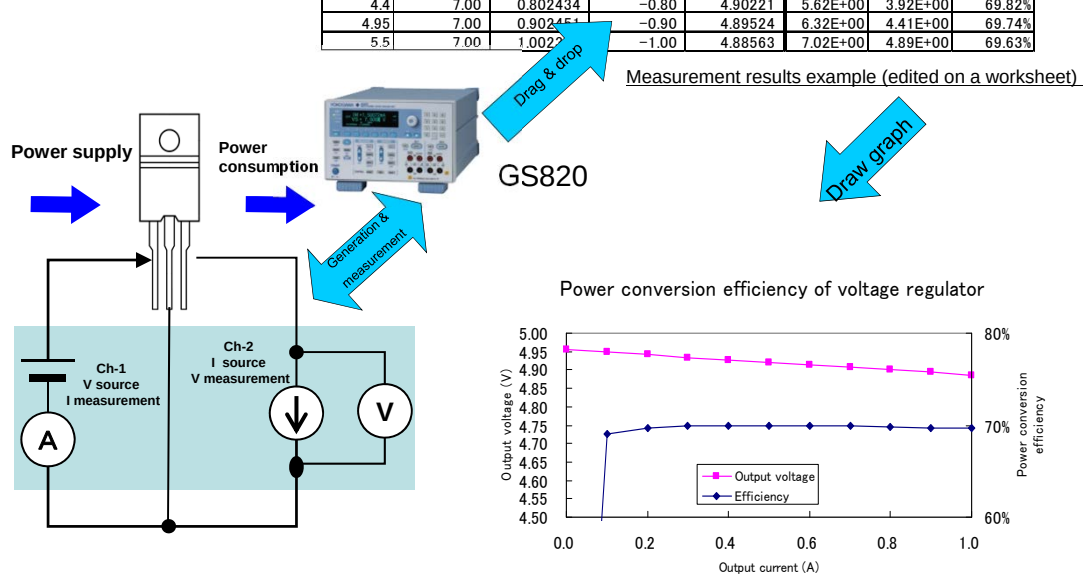
Product Features

- Power supply operation and power consumption (load) operation
- Generation and measurement range of up to 7V and 3.2A or 18V and 1.2A.
- Data acquisition and calculation using a general-purpose worksheet

$$\text{Efficiency} = \frac{\text{Consumed power in the secondary circuit}}{\text{Supplied power in the primary circuity}}$$

	Primary voltage/current		Secondary voltage/current				
Time(s)	Source(V)	Measure(A)	Source(A)	Measure(V)	Input(W)	Output(W)	Efficiency
0	7.00	0.002617	0.00	4.95495	1.83E−02	0.00E+00	0.00%
0.55	7.00	0.102457	−0.10	4.94771	7.17E−01	4.95E−01	68.99%
1.1	7.00	0.202470	−0.20	4.94113	1.42E+00	9.88E−01	69.73%
1.65	7.00	0.302443	−0.30	4.93466	2.12E+00	1.48E+00	69.93%
2.2	7.00	0.402436	−0.40	4.92822	2.82E+00	1.97E+00	69.98%
2.75	7.00	0.502437	−0.50	4.92177	3.52E+00	2.46E+00	69.97%
3.3	7.00	0.602380	−0.60	4.91529	4.22E+00	2.95E+00	69.94%
3.85	7.00	0.702407	−0.70	4.90882	4.92E+00	3.44E+00	69.89%
4.4	7.00	0.802434	−0.80	4.90221	5.62E+00	3.92E+00	69.82%
4.95	7.00	0.902451	−0.90	4.89524	6.32E+00	4.41E+00	69.74%
5.5	7.00	1.0022	−1.00	4.88563	7.02E+00	4.89E+00	69.63%

Measurement results example (edited on a worksheet)



Resources Energy

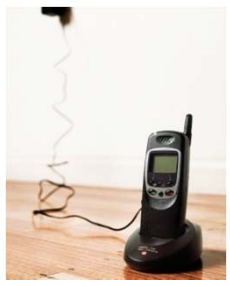
Radio Frequency IC (RFIC) Current Consumption Measurement

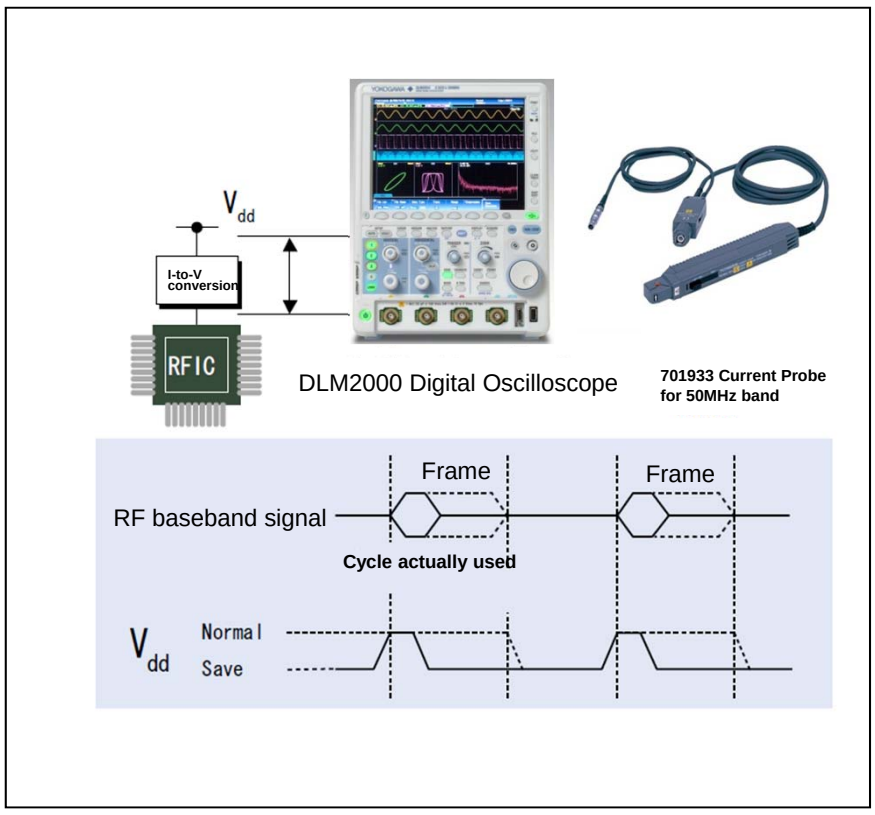
Mixed-Signal Oscilloscope
DLM2000

Application Overview
Mobile phone development focuses on lower power consumption at the component level in order to reduce battery consumption. The on-and-off operation of the power supply for each component is finely controlled to minimize power consumption, so it is necessary to check whether control is functioning properly, and to measure the actual current consumption

Application Points
Radio frequency IC (RFIC) for mobile phones uses a communication frame that has a length in the range from a few milliseconds to about 10 milliseconds. The frame length varies depending on the method, and one frame can consist of multiple cycles. The increase in the processing capacity of the baseband section in recent years makes it possible to perform control in such a way that the power for ICs is off while the data is not being sent and received in order to reduce battery consumption. Furthermore, the increase in the communication capacity due to the transmission of images and the like decreases communication idle time, so development to reduce current consumption during communication is also underway.

Product Features
- 125MPoints super large memory
  Current waveforms of multiple frames can be measured at a fast sampling rate.
- Variety of measurement functions
- The average, P-P, maximum, and other values of the current for each frame can be easily displayed in digital format.





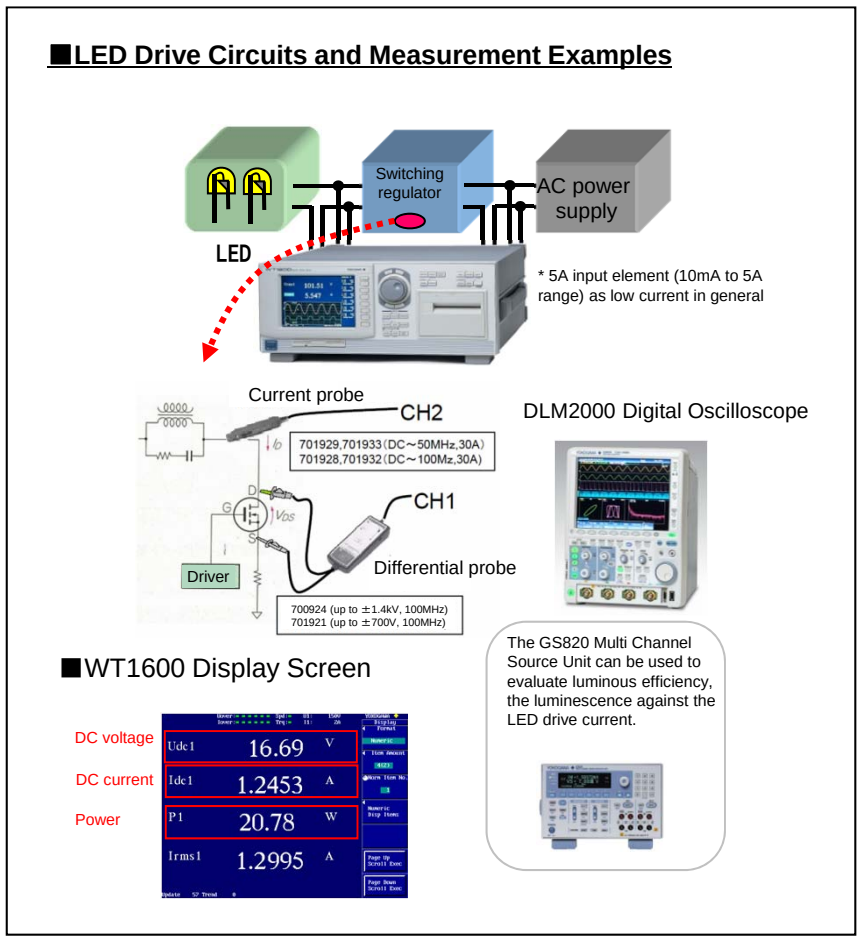
Voltage, Current, and Power Conversion Efficiency Measurement for LED Drive Circuit

Digital Power Meter
WT1600

Application Overview
Lighting technology is shifting from the use of fluorescent, incandescent, or other traditional lamps, which have been in use for many years, to the use of longer-life, low-power consumption LEDs. LED lights are used in various areas including automotive headlamps and traffic lights. A power analyzer is used to measure the DC voltage, DC current, and other signals. By increasing the power conversion efficiency of LED drive circuits (drive modules), the efficiency of LED lights is also increased, and their usage is expected to become more popular. The power analyzer is also able to measure the power of AC signals, as well as DC signals.

Application Points
- High-precision, wide frequency range measurement
- High voltage input, and two types of current inputs (for the 5 A and 50 A models)
- Dual-screen display, such as “value + waveform” and “value + trend”
- Monitoring of fluctuations in the voltage, current, and power values
- Efficiency measurement between input and output
  Data acquisition at the maximum data update speed of 50ms (20 times per second)

Product Features
- Basic power accuracy：0.06%, measurement range：DC, 0.5Hz to 1MHz
- Maximum voltage input of 1,000V
  Current range：5A input (in the range from 10mA to 5A)
  50A input (in the range from 1 A to 50A)
- Not only value, trend, and waveform displays but also combination displays are available. This is convenient because temporal fluctuations can be visually displayed while checking the values.
- Display of fluctuations in the voltage, current, and power on the trend screen
- The efficiency between input and output can be calculated and displayed by measuring input and output values.
  The data update rate are selectable from 50ms to 5 seconds.



Electronic Components

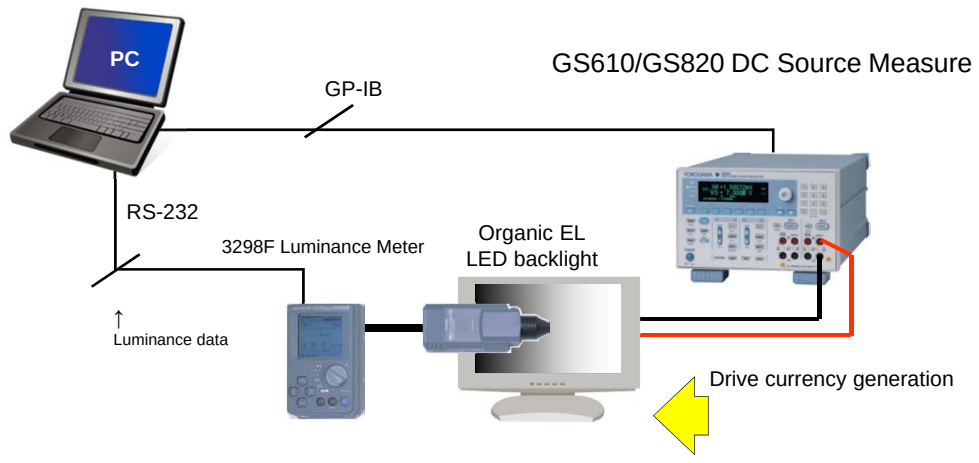
Luminous Efficiency Measurement of Organic EL and LED Backlights

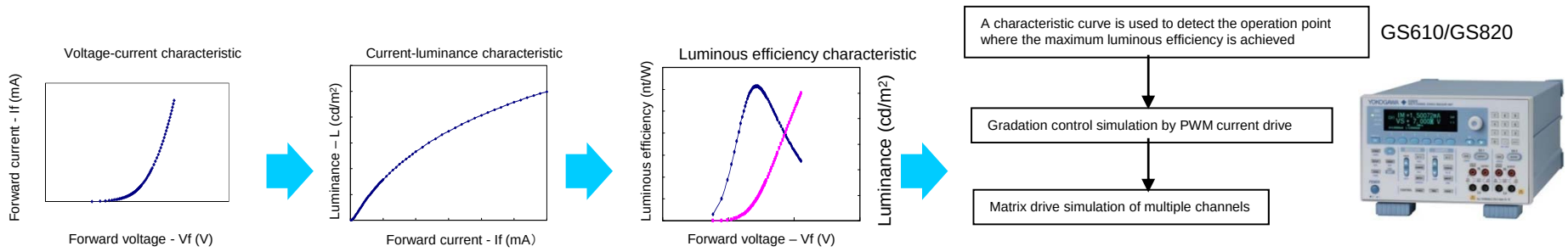
Source Measure Unit GS610
Multi Channel Source Measure Unit GS820

Application Overview
The GS Series Source Measure Unit is used to drive light emitters such as an organic EL display and LED backlight, and to measure electro-optical characteristics. The measurement results are used to obtain the operation point at which the maximum luminous efficiency (luminance/power consumption) is achieved. PWM gradation control, matrix drive, or the like can be performed at this operation point to simulate the actual drive conditions of an implemented display module.

Application Points
Voltage and current drive can be performed according to the type of display and drive method. Furthermore, not only DC drive but also pulse drive and arbitrary waveform drive are supported.

Product Features
- Variety of generation modes by DC, pulse, and arbitrary waveform
- High-precision drive signal generation with a basic accuracy of ±0.03%
- Compact, inexpensive, and scalable system configuration





Organic EL & LED Display PWM Gradation Control and Various measurements included Driver Drive Emulation for Matrix Drive

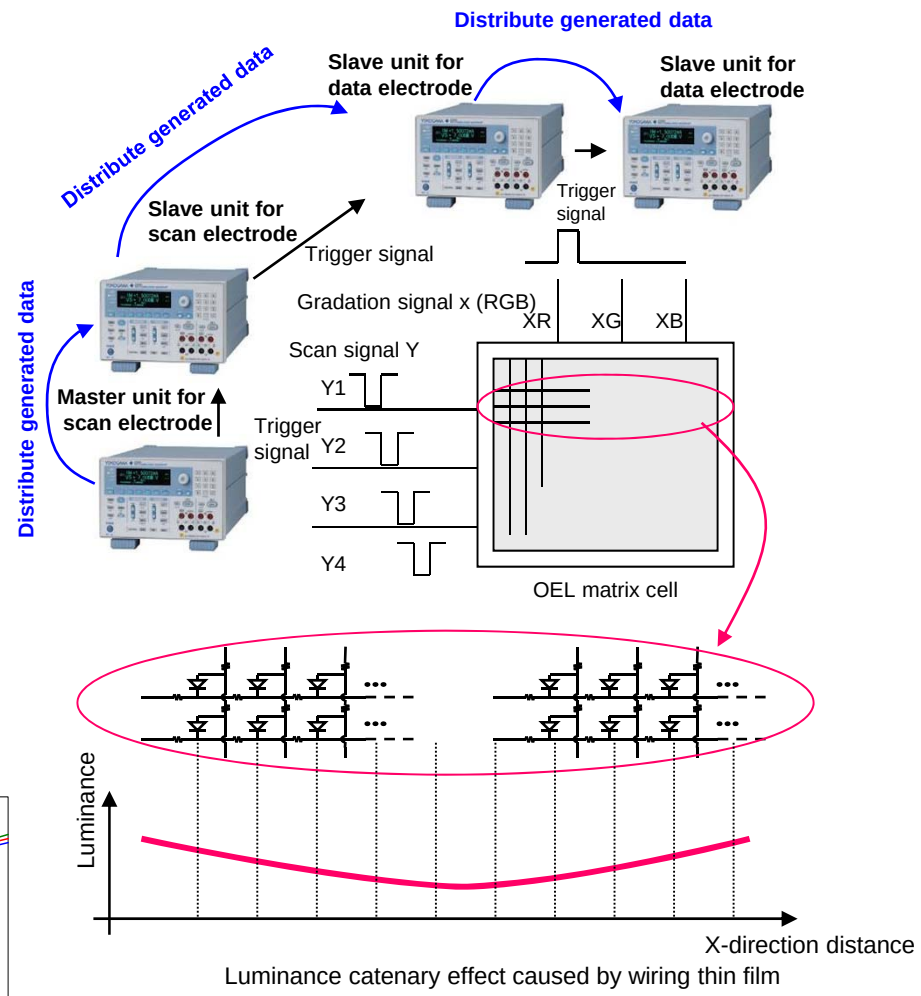
Multi Channel Source Measure Unit
GS820

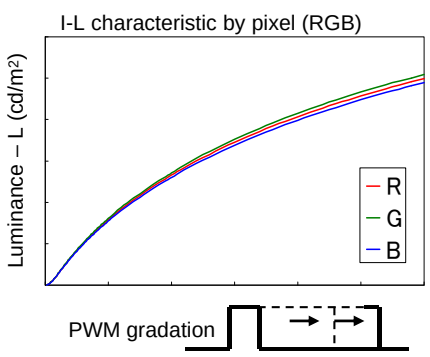
Application Overview
Unlike LCDs, organic EL and LED display cells drive a current. Therefore, when large screens such as TV's are driven by matrix control, luminance in the center of the screen may decrease due to a catenary line effect caused by the internal resistance of wiring thin film, or luminance may be uneven due to a sheet resistance distribution. There is also a problem with the luminance aging deterioration characteristic. These problems with the drive method have to be addressed.
In this section, PWM gradation control is performed for each of the organic EL and LED cells that are matrix-controlled to evaluate the following.
- Luminance linearity and pixel-to-pixel differences
- Gradation linearity of each of the RGB colors and color balance

As shown in the figure, one unit for the scan signal and another unit for the gradation signal are used. One master unit sends a trigger signal to multiple slave units and outputs synchronized multi-channel signals. A scan signal and gradation signal are fed to the matrix cell to perform PWM control for the pulse width of the gradation signal.

Application Points
A synchronous master-slave link method is used to output synchronized multi-channel voltage and current. Level, timing, pulse width, and the like of each channel are defined on a worksheet, and presetting is performed by saving them by the drag and drop operation to the internal ROM of the unit. Synchronous operation can be performed with just key operation of the master unit. Furthermore, the master unit distributes the generated data to the slave units, acquires measured data from the slave units, and merges them to one file.

Product Features
- Programmed output of PWM current pulse
- Synchronized multi-channel output of voltage and current
- Data management of slave units by master unit





Rotary Encoder Evaluation

Digital Oscilloscope
DL9000 Series

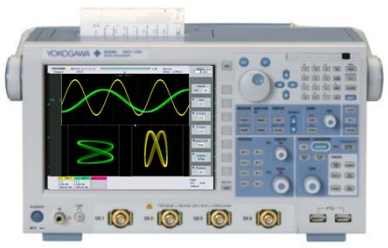
Application Overview
High precision servo and stepper motors utilize a rotary encoder for precisely sensing the angle and speed of a rotational axis.
An optical rotary encoder outputs two pulse train signals, 90degrees out of phase, based on light passing through a slitted disk as the encoder rotates.

Application Points
Rotation speed is obtained from the frequency of output pulse, and rotation direction is obtained from the phase relationship of phases A and B. In order to evaluate the encoder, data on a phase difference, pulse period, or the like are measured to determine, for example, the precision of the slit shape. Furthermore, statistical values such as the maximum and standard deviation of the period and phase difference are measured for each pulse.

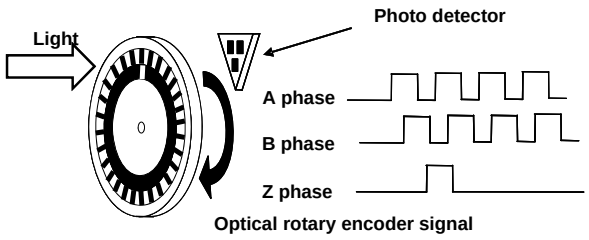
Measurement item examples of encoder

Period of each encoder pulse phase	Measures the period multiple times, and calculates the average, maximum, and minimum values
Duty of each encoder pulse phase	Measures the phase width multiple times, and calculates the average, maximum, and minimum values
Each encoder pulse-to-pulse phase difference	Measures the phase differences (A↑-B↑, B↑-A↓, A↓-B↓, B↓-A↑) multiple times, and calculates the average, maximum, and minimum values

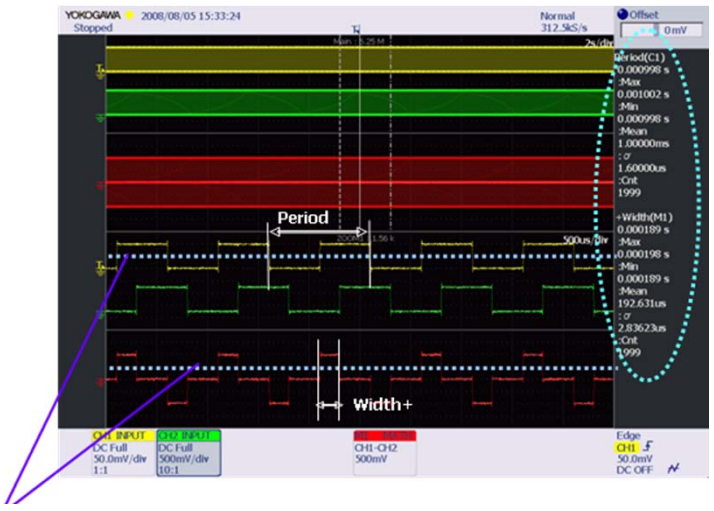
Product Features
- Maximum sampling rate of 5GS/s (10GS/s for the DL9240 series) enables the measurement of the encoder pulse period at a high-resolution of 0.2ns (0.1ns for the DL9240 series).
- A variety of analysis functions such as statistical analysis of waveform parameters are available.
- Use of a histogram display function allows users to visualize data and make work more efficient.



DL9000 Series



Optical rotary encoder signal
(Incremental method)



Threshold levels

Measurement of Dynamic BH Characteristic of Magnetic Materials and Magnetic Electronic Components

ScopeCorder DL750
Digital Oscilloscope DL9000
Synthesized Function Generators FG320

Application Overview
Magnetic materials are widely used for inductors and transformers of power supply circuits, inverter circuits, motors, and so on. In particular, an annoying humming noise from the motor and inverter is a big problem for hybrid vehicles. Drive frequency changes in conjunction with the accelerator, so passing through an inductively coupled frequency is unavoidable. The main cause of vibrations is magnetostriction, which causes energy loss and which appears in the dynamic BH characteristic of the drive frequency. It is necessary to measure the dynamic BH characteristic of magnetic materials and improve the internal magnetic friction loss, eddy current loss, and the like.
The operating frequency of motors ranges from a DC level to a few kilohertz. A magnetic bridge measurement method is required to accurately measure the BH characteristic of magnetic materials. When a closed-loop magnetic circuit is created as in this example, and a sine wave AC voltage is applied, the dynamic BH characteristic can be checked in a simple way using a waveform measurement instrument. Measurement of dynamic BH characteristic is one application example that takes advantage of a waveform measuring instrument capable of performing measurements from DC to high frequency.

Application Points
Use of a waveform calculation (integration) function allows users to measure the voltage and current of a coil. Users can then calculate the magnetic flux density (B) and magnetic field intensity (H) by just setting the calculation, and draw a BH curve using the X-Y display. The following waveform calculations are performed for the measured voltage and current waveforms.
- Voltage waveform = Voltage waveform - (Coil resistance x Current waveform)
- Magnetic flux density B = Temporal integration of voltage waveform / (Coil turn N x Cross-section area S)
- Magnetic field intensity H = Excitation current x (Coil turn N)/(Magnetic path length)

The voltage waveform measured here includes the voltage caused by the resistive component of the coil; however, the effect of the coil resistance can be removed by compensation using the current waveform and resistance value of the coil. This measurement example shows a comparison between waveforms at the drive frequency of 50Hz and 100Hz, which were obtained by applying a sine wave AC voltage to the transformer and overlaying them using a snapshot function, and waveforms at 150Hz. Dynamic BH characteristics can be observed.

Features of DL Series Calculations
- X-Y Display

X-Y display between arbitrary channels (or of calculated waveforms) can be performed to match the T-Y display.
- User-defined calculations (when adding the /G2 option)

Arithmetic expressions can be defined using functions such as trigonometric, differential, integral, square root, digital filter, FFT functions, and cycle average.
- Waveform parameter automatic measurement

29types of waveform parameters such as maximum, minimum, average, and frequency of waveform are automatically measured.
Use of an integral function called INTEGX-Y allows users to automatically calculate the area of an X-Y display waveform.

ScopeCorder/Digital Oscilloscope

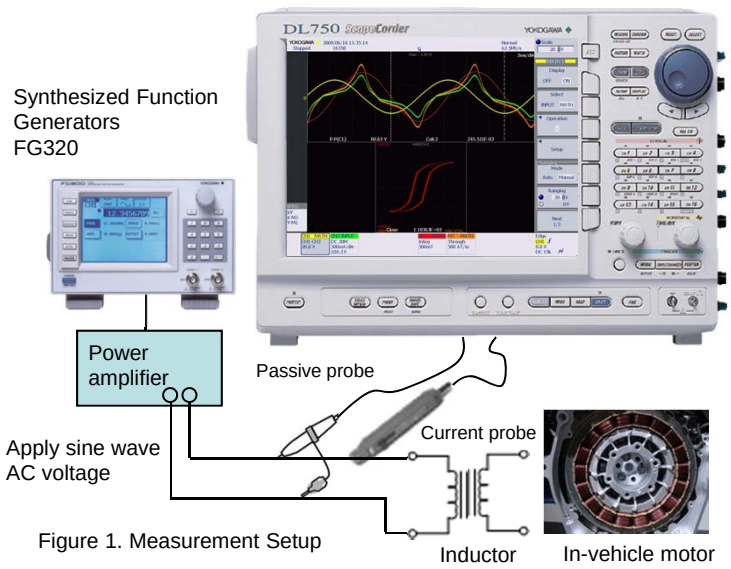


Figure 1. Measurement Setup

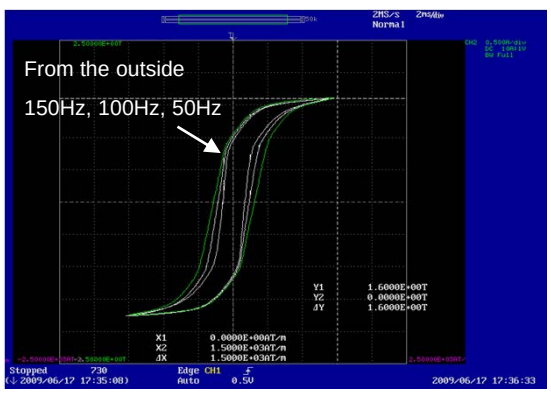


Figure 2. BH Curve Measurement Example

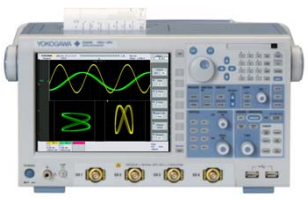
Observation and Analysis of A/D Converters

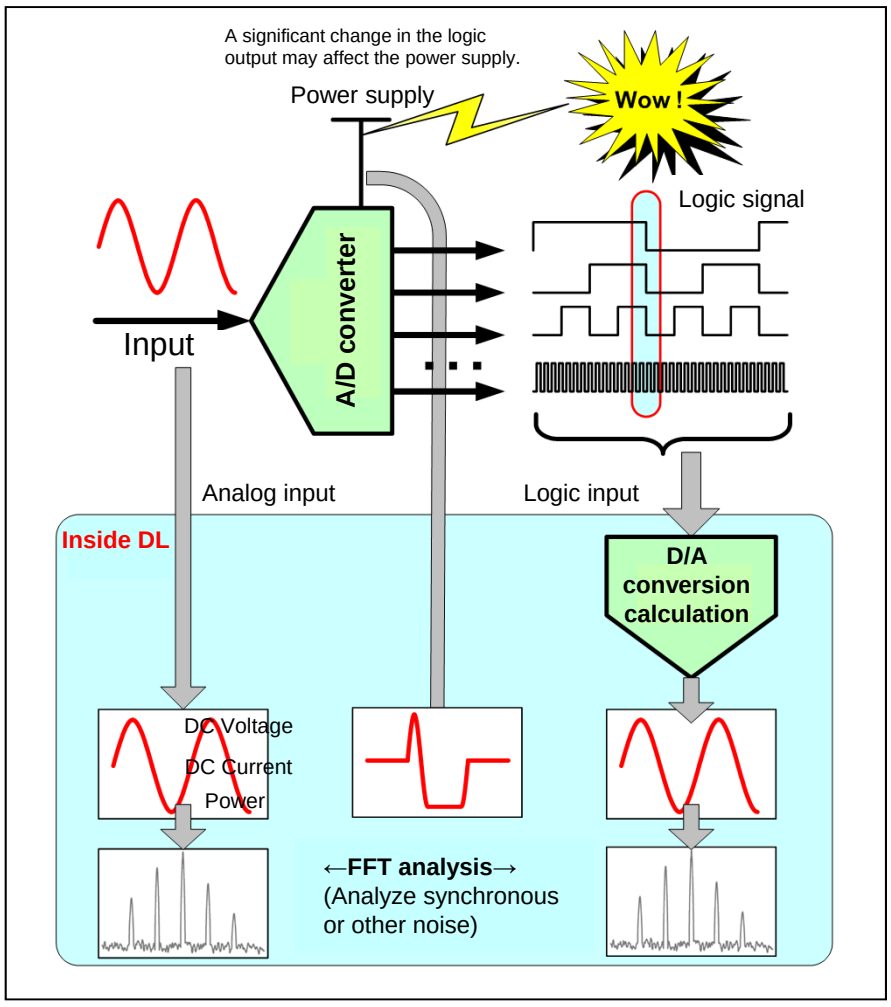
Mixed-Signal Oscilloscope
DL9700/9500 Series

Application Overview
Along with the logic output of an A/D converter, the input waveform and power supply signals are observed. Furthermore, logic signals are translated to virtual analog values and displayed visually in the time domain and frequency waveform display areas.
A variety of trigger functions and analysis options can be used to observe problematic events.

Application Points
This application activates a trigger at the point that the logic signal significantly changes to observe the fluctuations of the power supply, and the like. Furthermore, logic signals are translated to virtual analog values and displayed visually in the time domain and frequency waveform display areas. Conventionally, a multi-channel oscilloscope, or an oscilloscope synchronized with an external logic analyzer was necessary to view all signals simultaneously. To view the virtual D/A signals, a conventional solution required, measurements to be transferred to a PC, where a D/A conversion calculation and then an FFT calculation were performed. This was a time consuming process which prevented real-time analysis.

Product Features
- Analog/logic signal mixed inputs
4 channel analog waveforms and 32bit logic signals can be simultaneously observed with a single oscilloscope.
Simultaneous observation of input signals (analog) and output signals (digital) of an A/D converter is possible, and a multi-bit A/D converter can also be used.
- Variety of trigger functions
A variety of triggers can be used for analog/logic inputs to capture target signals (waveforms).
- A state display function, which displays logic signals in a state status, is available.
Logic signals can be checked in a state mode, where the signal is captured at the edge of a clock signal, instead of at fixed sampling intervals.





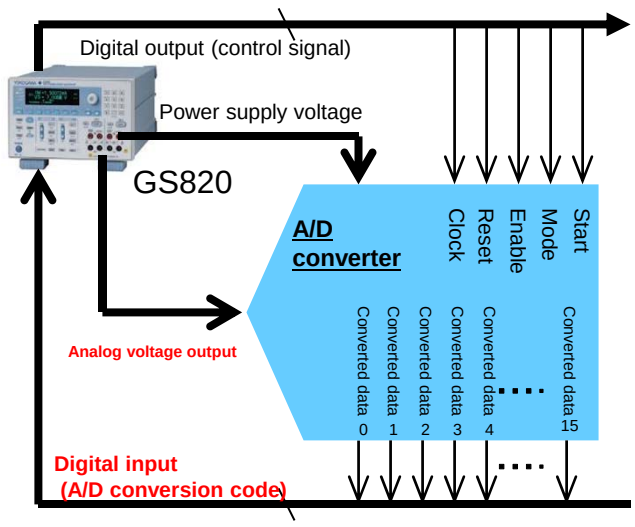
A/D Converter Linearity Testing

Multi Channel Source Measure Unit
GS820

Application Overview
Analog signals to be input to an A/D converter are generated, and digital signals for control are output. Furthermore, digital data, for which A/D conversion was performed, is loaded.

Application Points
The GS820, which is capable of 2 channel analog inputs and outputs and 16-bit digital inputs and outputs, is suitable for testing analog/digital mixed devices. The definition of digital pattern output data and loading of digital input data can be easily performed using a CSV worksheet.

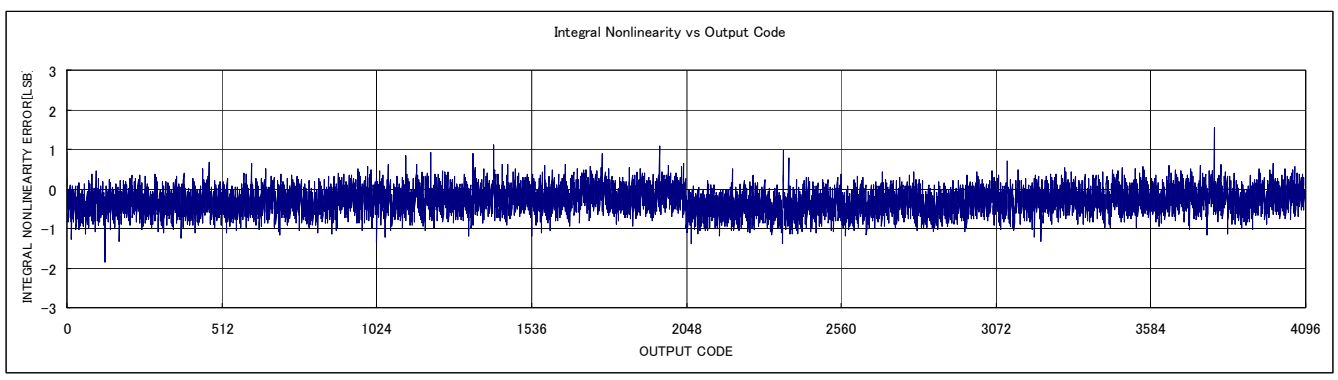
Product Features
- 5.5digit output voltage setting resolution
- Analog 2 channel plus 16bit digital inputs and outputs
- Generation and measurement period: Up to 500µs



Measurement results example

Digital In	Source(V)
0x0FFC	0.00E+00
0x0FFC	1.00E-03
0x0FFB	2.00E-03
0x0FFA	3.00E-03
0x0FF9	4.00E-03
0x0FF9	5.00E-03
0x0FF8	6.00E-03
0x0FF7	7.00E-03
0x0FF6	8.00E-03
0x0FF5	9.00E-03
0x0FF5	1.00E-02
0x0FF4	1.10E-02

Linearity Analysis (Output Code – Integral Nonlinearity Error)



Large current & Power Measurement in Inductive Cooking appliances

Power Analyzer
WT500

Application Overview

Driven by a campaign to promote the use of electricity for all home appliances, including kitchen appliances and water heaters in recent years, demand for inductive heating (IH) cook tops is growing as a safer alternative to gas stoves. In order to increase the heat, IH cooking heaters use a large amount of current which is converted to heat.

The WT500 is able to measure a large current that flows through an IH cooking heater without using a current sensor. It achieves this by directly inputting the voltage, current, power, total harmonic distortion (THD), or other data. Data can be updated at a maximum rate of 100ms, so it is able to cope with an increased need for power measurements speed.

Application Points

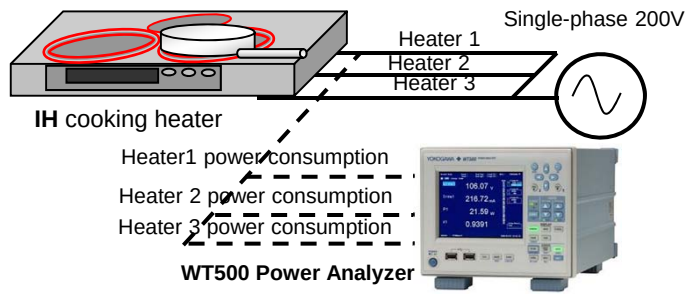
- High current compatible
- High-precision measurement of current flow and power consumption
- High-speed data acquisition
- Simultaneous display of the voltage, current, and power of each heater, and trends
- Measurement of harmonics and total harmonic distortion (THD)

Product Features

- High current compatible: 40 Arms range
- High-precision measurement of current flow and power consumption by 40 A direct input
- High-speed data acquisition: up to 100ms interval (for simultaneous 3 channel input)
- Customizable screen display setting:
  Measurement items or efficiency calculations that need screen display can be set, and measured values can be laid out in such a way that they can be easily checked.
- Harmonics (DC to the 50th order) and THD can be measured along with normal measuring items such as voltage, current, and power. No switching is needed between normal and harmonic modes.

* Trend display refers to a graph display in which the horizontal and vertical axes represent the time axis and data values, respectively.

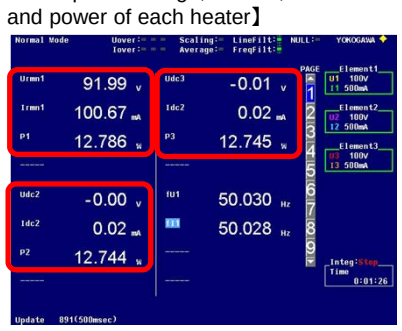
■Large Current Measurement Example of IH Cooking Heater



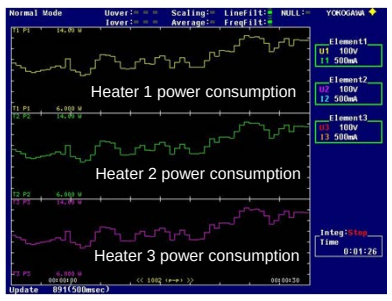
The WT500, which is capable of 3 channel inputs, is able to measure, for example, the voltage, current, power, and THD of up to 3heaters. Furthermore, it is also able to simultaneously measure the total power consumption and total current flow of the heaters, thus it can be used for various kinds of evaluation.

■WT500 Display & Setting Screens

【Example of voltage, current, and power of each heater】



【Trend display example of values of different heaters】



Overhead Projector Power and Current Consumption Measurements

Digital Power Analyzer
WT210

Application Overview

Developers for consumer equipment such as home appliances focus on the development of energy-saving products to fight global warming.
On the business front, video projectors are used by many companies for conferences and presentations, and one of the important issues for developers is to reduce power consumption like as in the case of lighting equipment and photo copiers. Most of the power in video projectors is consumed by the lamp. Furthermore, projectors generate heat so a cooling fan runs a high speed, resulting in high energy consumption. Various measures must be taken.
The WT210 Power Analyzer is capable of measuring the current consumption, power consumption, total current consumption, and total energy, and other items in the operation, standby, and power-saving modes of a projector.

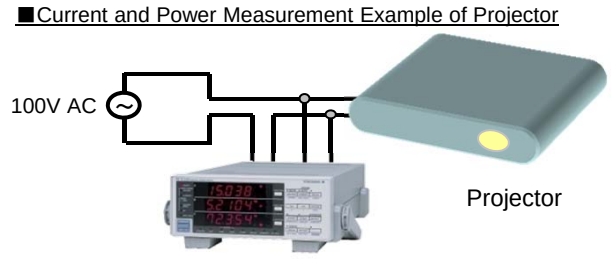
Application Points

- High-precision measurement of current value (A), power value (W), amount of current (Ah), and energy (Wh)
- Direct input range capable of measuring the current in operation and standby modes
- Compact and light so it is convenient to carry around
- Capable of harmonic measurement indispensable for distortion and other measurement
- Data acquisition at the maximum data update speed of 100ms (10 times per second)

Product Features

- Basic power accuracy: ±0.2%. Capable of measurement of the total current, total energy, frequency, and power factor, in addition to the voltage, current, and power values
- Current measurement range: From around 50μA to 26A for direct input measurement (Current range: 5mA to 20Arms)
- Compact and light at about 3kg
- Up to the 50th order harmonic component and distortion can be measured.
- The data update rate can be selected from 100ms to 5 seconds.
- The data measured with the WT210 can be saved to a PC using the free software WTViewer. The data can be converted to CSV format so it is easy to create graphs.

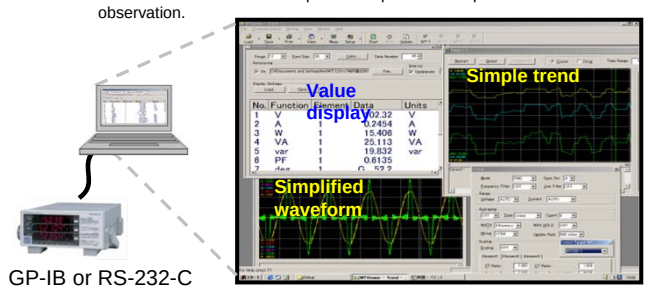
■Current and Power Measurement Example of Projector



Three large 7-segment LED displays provide a high level of visibility. The light and half-rack-width WT210 is a cost-effective, single-phase power analyzer capable of performing measurement of parameters, such as voltage, current, active power, reactive power, apparent power, frequency, power factor, total current, and total energy.

■WTViewer Software (for the WT210/230)

* A harmonic measurement option is required for simplified waveform observation.



Measurement of Current Consumption in Fire Alarm Devices

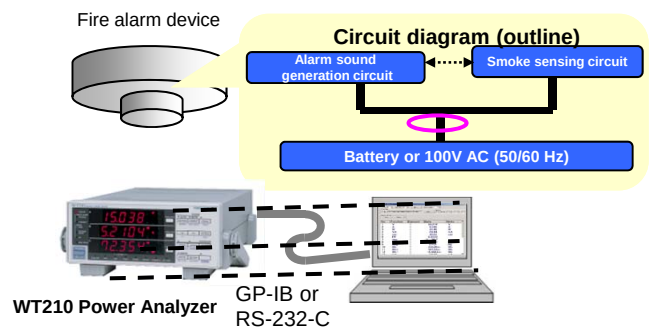
Digital Power Analyzer
WT210

Application Overview
Roughly speaking, there are two types of fire alarm devices. One is a heat sensor and the other is a smoke sensor. Furthermore, there are two types of power supplies for fire alarm devices. One is AC line powered and the other is battery-powered. In order to evaluate the energy-saving measures of these fire alarm devices, the current value and total current may be tested. Furthermore, in the case of battery-operated devices, the current amount has influence to the life time of service.
The WT210 Power Meter is able to measure the DC voltage, current, power consumption, amount of current, and energy consumption in order to evaluate the fire alarm devices (heat sensors).

Application Points
- High-precision measurement of current value (A) and energy consumption (Ah)
- Direct input range capable of measuring the standby current and sleep current
- Compact and light so it is convenient to carry around
- Not only current but also voltage, power, and harmonic can be measured.
- Data acquisition with the maximum data update speed of 100ms (10 times per second)
- Data acquisition and saving by free software

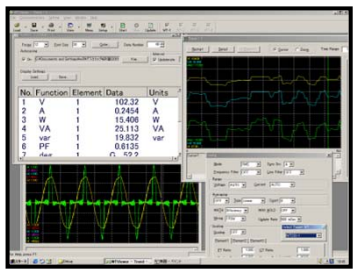
Product Features
- Basic power accuracy: ±0.2%. Capable of measuring both the current and total current consumption without any other help
- Current measurement range: About 50μA to 26A for direct input measurement (Current range: As wide as 5mA to 20Arms)
- Compact and light about 3kg
- Voltage, current, power, frequency, power factor, and harmonic can be measured.
- The data update rate can be selected from 100ms to 5 seconds.
- The data measured with the WT210 can be saved to a PC using the free software WTViewer. The data can be converted to CSV format and graphs can be easily created.

■Measurement Example of Fire Alarm Device/Heat Sensor



■WTViewer Software
This application software allows users to load value and waveform data measured with the WT210/WT230 Digital Power Analyzer to a PC via GPIB and Serial (RS-232-C) communication, and display and save the measurement data on the PC.
* A harmonic waveform measurement option is required for simplified waveform observation.

WTViewer software screen (for the WT210/WT230)



Note: If the current consumption is very small (about 50μA or less), the current cannot be measured.

Measurement of Energy Consumption (kWh) for Electric Toilet Seat

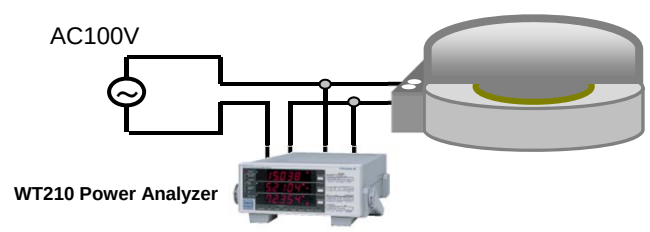
Digital Power Analyzer
WT210

Application Overview
The Act on Rational Uses of Energy and Recycled Resources (Energy Saving Act), which sets targets for energy consuming equipment to reduce energy consumption, is attracting greater attention. A Top Runner standard, which requires manufacturers to exceed the best performance among existing products on the market, is applied to equipment that consumes a large amount of energy (products that emit a large amount of CO_2) such as automobiles, air-conditioners, and refrigerators.
Electric toilet seats (hot water washing toilet seats and heated toilet seats) are designated to meet the Top Runner standard. Therefore, the power and energy consumption in the operation and non-operation modes must be measured in order to calculate the energy consumption efficiency, and specifically, the annual energy consumption. The WT210 Power Meter is able to precisely measure the power, energy, voltage, and current consumed by electric toilet seats.

Application Points
- High-precision measurement of the energy with direct voltage and current inputs.
- Capable of integrating the energy over a long period of time
- Capable of integration for preset periods of time (e.g., 1 minute, 1hour)
- Wide measurable current range from a very low to a very high current
- Compact and light
- Data acquisition with the maximum data update speed of 100ms (10 times per second)

Product Features
- Capable of measuring with precision not only the energy (Wh and kWh displays) but also the power value (W), average active power (Wh/elapsed time), amount of current (Ah), energy (Wh), voltage, frequency, and the like.
- Capable of integration for up to 10,000hours.
- The integration time can be set by second; for example, 30 seconds, 1minute, 5minutes, 10minutes, 1hour, 24hours, and the like can be set for the integration time.
- Current measurement range: From around 50μA to 26A for direct input measurement (Current range: from 50mA to 20Arms)
- Light and compact at approximately 3kg so it is convenient to carry around.
- The data update rate can be selected from 100ms to 5 seconds.

■Power Consumption Measurement of Electric Toilet Seat



■Function to calculate the average active power during integration operation

It is possible to calculate the average active power within the integrated period. It is obtained by dividing the energy (total active power) by the elapsed integration time, and can be displayed on the screen.

$$\text{Average active power (W) during integration operation} = \frac{\text{Energy (Wh)}}{\text{Elapsed integration time (h)}}$$

■Integration function used to calculate the energy

○Manual integration mode
Manually press the START key to start the integration, and manually press the STOP key to stop the integration. All operations are performed manually, so it is convenient when you want to start and stop the integration according to the operation mode of equipment.

○Standard integration mode
Manually press the START key to start integration. When the elapsed integration time reaches the set integration time, the integration stops automatically. For example, if the measurement time is 1hour, the integration will stop automatically after 1hour has elapsed since the button was pressed. So this is convenient when you want to calculate the energy (Wh) or the average power value (W) after 1hour has elapsed.

* Voltage and current ranges are held during the integration.

16A to 75A IEC61000-3-11 Flicker Standard Test

Precision Power Analyzer
WT3000

Application Overview
With respect to equipment connected to public power supply systems, an international standard defines limits for power supply voltage changes. This standard exists to prevent interference with other equipment, and such equipment is required to be subjected to a test in accordance with the standard. The WT3000 can be used in conjunction with 761921 Harmonic/Flicker Measurement Software to run standard compliance tests in accordance with the IEC61000-3-3 and IEC61000-3-11 international voltage change/flicker standards.

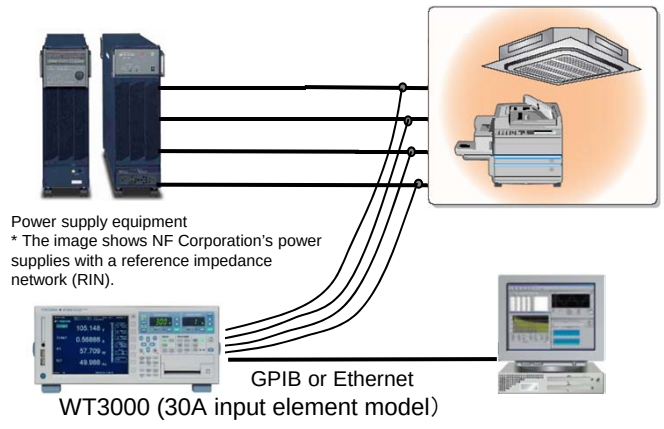
Application Points

- Total support from measurements through to judgment
- Capable of measurements at up to the 75A required by the standard. The WT3000 also enables the running of a test at less than 16A in accordance with the IEC61000-3-3 without changing measuring instruments.
- Single-phase and three-phase equipment compatible

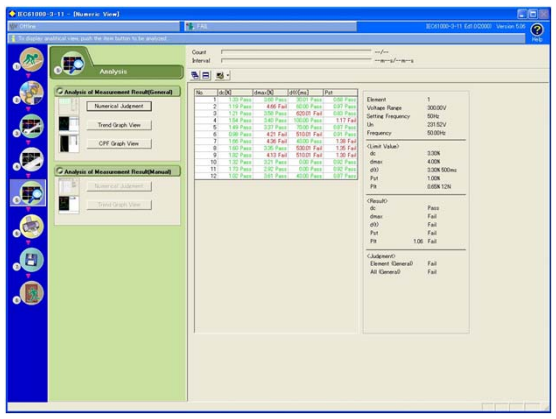
Product Features

- Easy setup and easy measurements through to generating report with judgment
- World top class high-precision current and power measurements
- The WT3000 (with 30 A input element option) with 761921 software covers the whole standards mentioned above, supporting from measurements to test report including judgment.

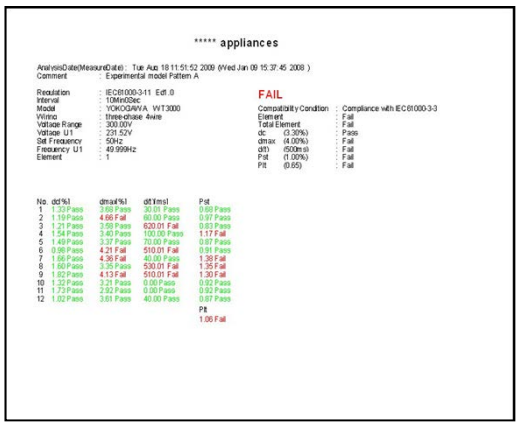
■Measurement Example of IEC61000-3-11 Test



IEC61000-3-11 test screen
(Display example of dc, dmax, d(t) and Pst data)



Example of flicker data report output



16A to 75A IEC61000-3-12 Harmonic Standard Test

Precision Power Analyzer
WT3000

Application Overview
Products covered by the EMC regulation are required to be subjected to a test in accordance with the standard. The WT3000 can be used in conjunction with 761921 Harmonic/Flicker Measurement Software to run the compliance tests in accordance with not only single-phase but also three-phase IEC61000-3-2 and IEC61000-3-12 test standards.

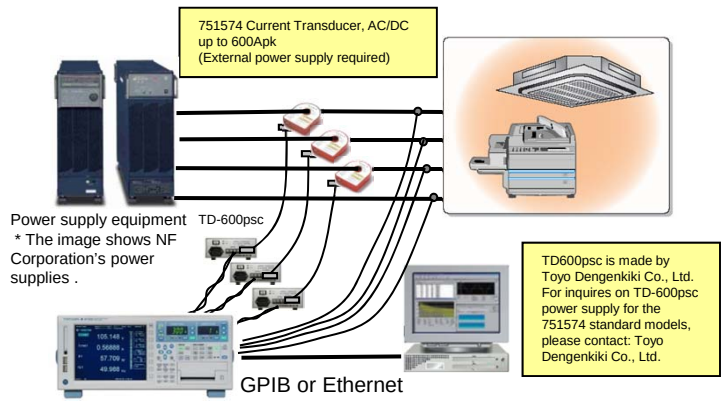
Application Points

- Total support from measurements through to judgment
- Capable of measurements at up to 75A required by the standard. The WT3000 also enables the running of a test at less than 16A in accordance with the IEC61000-3-2 without changing measuring instruments (measurements at less than 16A are performed by directly inputting signals).

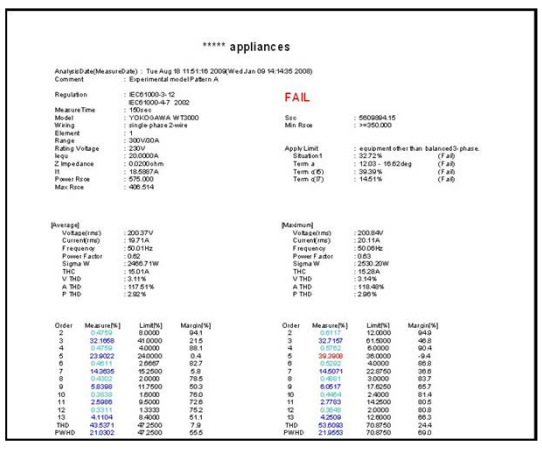
Product Features

- Easy setup and easy measurements trough to generating report with judgment.
- World top class high-precision current and power measurements
- The WT3000 (with 30A input element option) is able to run the tests in accordance with the above all standards, and the WT3000 (plus a current transducer) and 761921 software are able to perform measurements and judgment.

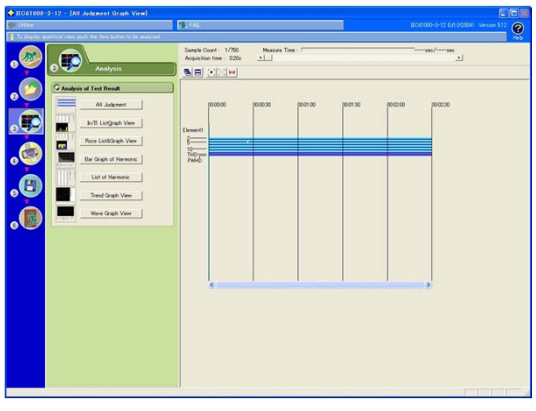
■Measurement Example of IEC61000-3-12 Test



Example of harmonic data report output



IEC61000-3-12 test screen
(The screen shows a temporal total judgment graph)



Large Digital Copier and Printer Performance Evaluation

High-Speed Data Acquisition Unit
SL1000

Application Overview

It is important for large digital copiers and printers to improve the print quality and speed.

Furthermore, it is also desirable to improve, the energy efficiency and durability.

Engineers spend time on the evaluation of individual components and timing control in order to always maintain a high print quality.

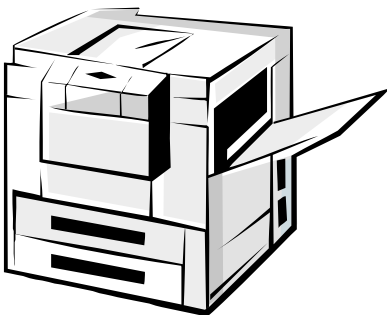
The SL1000, which is capable of acquiring and transferring a large amount of data with multiple channels, at high speeds and observation times, is useful for this kind of evaluation.

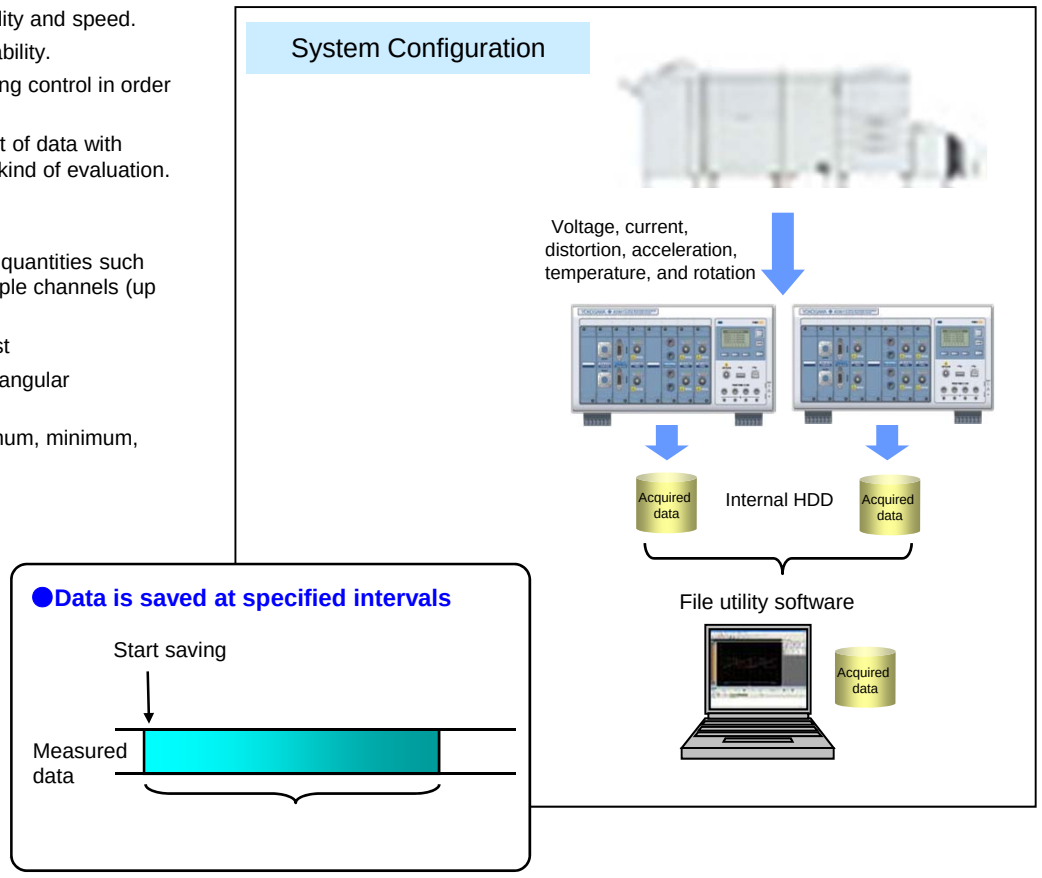
Application Points

- Capable of simultaneously observing a variety of electrical and physical quantities such as voltage, current, distortion, acceleration, temperature, rotation, on multiple channels (up to 128 channels)
- Capable of long-time, continuous measurements such as a durability test
- Capable of precisely measuring rotation, changes in rotation, and other angular measurements, using a frequency measurement module.
- The acquired data can be checked immediately on a PC, and the maximum, minimum, rise time, and other parametric measurements can be easily obtained.

Product Features

- Multi-channel, long-time measurement
- High-resolution, 16bit module
- Fast data saving





High-Speed Measurement of Voltage, Current, Power, & Total Harmonic Distortion (THD) of Lighting

Power Analyzer
WT500

Application Overview

With the increased use of electronic equipment, harmonic disturbance problems are also rising. A Guideline for Reduction of Harmonic Emission for Appliances and General-Use Equipment was published to help control these kinds of problems and encourage the development of products which produce less harmonic distortion. Furthermore, there are some cases where harmonic distortion of voltage and current are inspected on lighting equipment pre-delivery inspection lines. Harmonic measurements are performed along with measurement of voltage, current value, power value, power factor, etc.

Conventionally, there were some problems with the measurement of harmonic distortion on manufacturing lines. For example, the distortion must be measured in a dedicated instrument mode, or the time to acquire data became a bottleneck, making it difficult to achieve acceptable cycle times in production. The WT500 is capable of acquiring harmonic data, harmonic distortion, voltage, current, and power values simultaneously. It has a maximum update rate of 100ms, which helps increase production line efficiency by reducing cycle time.

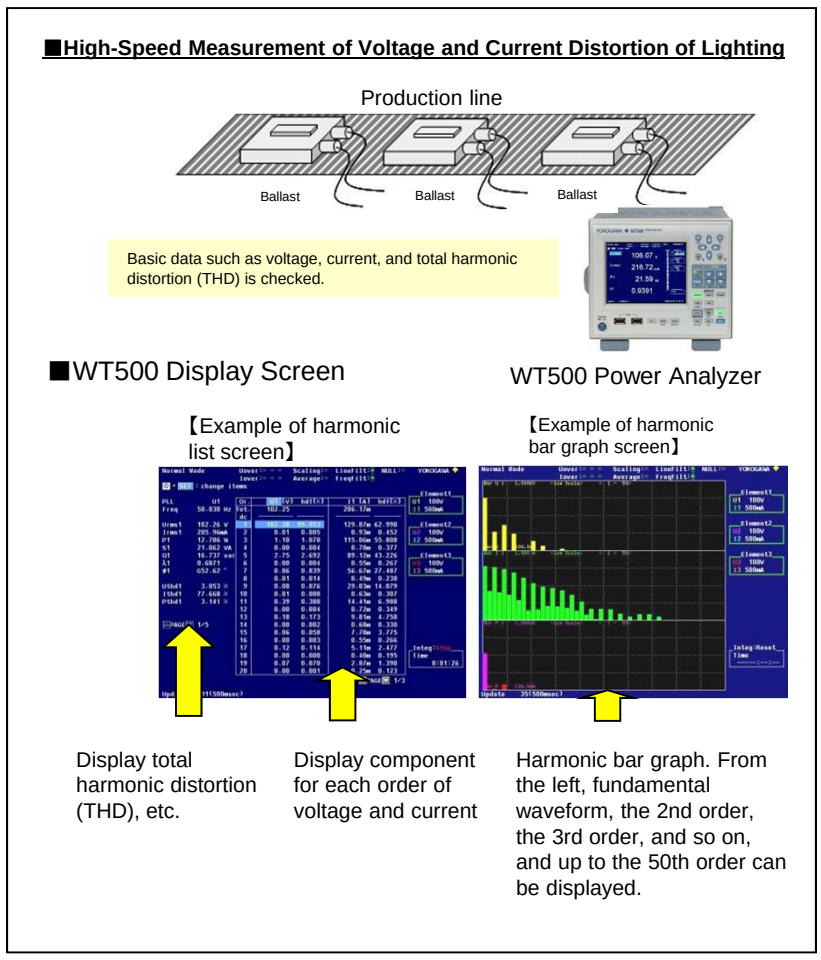
Application Points

- High-speed data acquisition
- Simultaneous measurement of normal measurement values and total harmonic distortion (THD)
- Capable of high-speed acquisition and simultaneous measurement for 3 simultaneous inputs
- Variety of communication interface options
- Image saving, and easy to transfer measurement data to PC applications

Product Features

- High-speed data acquisition: up to100ms interval
- Simultaneous measurement of voltage, current, power, harmonic, and THD
- Simultaneous measurement of voltage, current, power, harmonic, and THD at the maximum speed of 100ms for 3 inputs
- The communication interface can be selected from USB (standard), GPIB, and Ethernet.
- The screen images and measured values can be saved to the internal memory or USB memory.

Reports and graphs can be created on a PC.



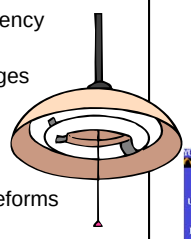
Current, Power, and Inverter Efficiency Evaluation of Fluorescent Lamp

High-Speed Data Acquisition Unit SL1000
Power Analyzer PZ4000

Application Overview
The main focus in the development of various lighting equipment, including home lighting fixtures, is to increase the life of lamps and improve energy consumption efficiency. Another key focus is also on the development and improvement of high-frequency (HF) fluorescent lamps. Development of lighting that contains these high-frequency components requires a measurement device that can analyze the power and waveforms up to the megahertz bandwidth.

Application Points
Measurement by wide-bandwidth power meter:
The PZ4000 Power Analyzer is a power meter covering a frequency range of up to 5 MHz. It can be used as a power measuring instrument to measure voltage, current, power. It can also be used as a high-precision power meter to analyze waveforms. For example, the PZ4000 can measure and evaluate the efficiency of a wide-range of inputs and outputs of ballasts.

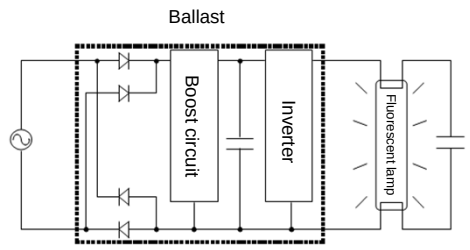
- A high-speed sampling and frequency range capable of measuring high-frequency components
- Analysis of the starting characteristic, transient response and frequency changes
- The averaging period can be specified from waveform data
- Efficiency measurement of ballasts
- Evaluation of high-frequency lighting components
- A power meter equipped with direct input terminals capable of observing waveforms



Measurement of high-frequency power with high-speed data acquisition system:
High-frequency fluorescent lamps with an operating frequency exceeding 2.5 MHz are being developed with the aim of increasing the life of lamps. Yokogawa develops and offers solutions to measure voltage and current waveforms to determine the power. Yokogawa calculates power accurately by performing skew adjustment to cancel the phase difference inherent in measurement systems with probes.

- High resolution, high-speed sampling (12bit, 100 MS/s)
- 1,000 V isolated input
- Multi-channel simultaneous measurement
- Variety of calculation functions in PC software available

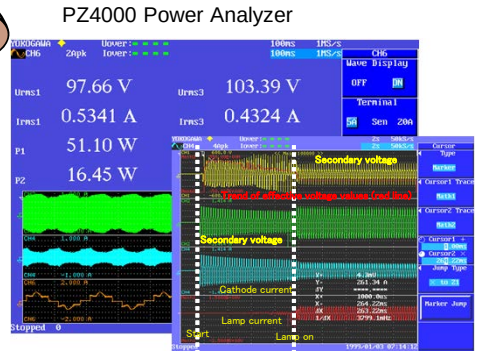
■Example of Power and Current Consumption Measurement of Fluorescent Lamp



Example of measurement items for evaluating lamps
1. Check inrush current and power waveforms for starting.
2. Measure the input/output current, power, and efficiency of the booster circuits and inverter.
3. Check the harmonic current of the lamp.
4. Check the starting control for the inverter and the load loss in each lamp's ON mode.
5. Check efficiency by dimming control (check the ON time and load loss)

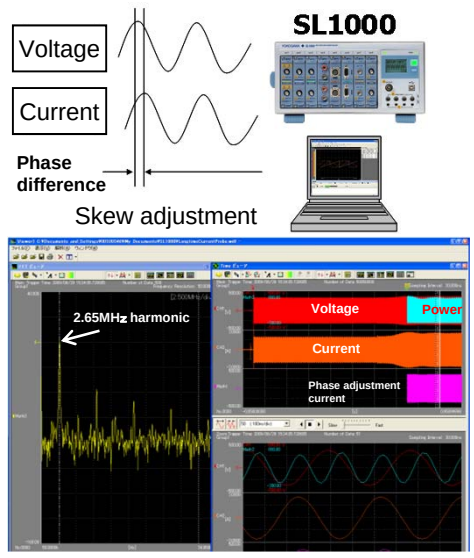
[Example of efficiency measurement of ballast by the PZ4000]

PZ4000 Power Analyzer



The efficiency of the ballast can be checked by calculating the power values of the input (on the commercial power supply side) and the output (on the lamp side). Furthermore, input and output voltage and current values, and waveforms can be observed simultaneously.

Example of high-frequency power measurement by high-speed data acquisition system]



Current, Power, and Inverter Efficiency Evaluation of Fluorescent Lamp

Precision Power Analyzer WT3000

Application Overview
The development of various kinds of lighting equipment focuses on increasing the life of lamps and improving energy consumption efficiency. Manufacturers today are trying to develop more efficient products with a longer life by reducing the undesirable voltage behavior in the ON operation and thermal effects on efficiency.

On the other hand, increased switching frequency of inverters used in electronic ballasts of lighting, enables fine control to improve efficiency, reduce noise and build more compact solutions. Today switching frequencies can go up to several 10 kHz these days, so the development of electronic ballasts (inverters) requires oscilloscopes that can capture these signals more precisely. Furthermore, it needs devices like broadband power meters that is capable of making measurements in the megahertz range .

To evaluate lamps, a digital oscilloscope is used to observe lamp drive waveforms, and check the operation of ballasts (inverters). Furthermore, a power meter is used to measure the current and power on the primary (50/60Hz) and secondary side outputs of the ballast and to also measure efficiency between input and output.

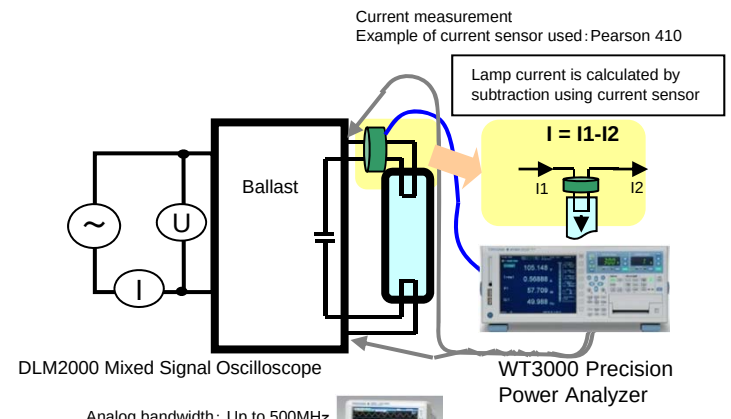
Application Points

- High-precision, broadband measurement
- High-voltage input, two types of current inputs (2A and30A input models)
- Dual screen display, such as "numeric value + waveform" or "numeric value + numeric trend"
- Monitoring of fluctuations in the voltage, current and power values
- Simultaneous display of the harmonic component and total harmonic distortion (THD)
- Data acquisition at the maximum data update speed of 50ms (20 times per second)

Product Features

- Basic power accuracy：0.06%, measurement range：DC, 0.5Hz to 1MHz
- Up to 1,000voltage input compatible
- Current range: 2A input (5mA to 2A input range)
  30A input (0.5A to 30A input range)
- Not only numeric, trend, and waveform displays but also combination displays are possible. It is convenient because temporal fluctuations in waveforms can be visually checked while still reading numeric values.
- Voltage, current, and power fluctuations can be monitored in the trend display mode.
- Not only the voltage, current, and power but also harmonic components and total harmonic distortion (THD) can be simultaneously measured and displayed.
- The data update rate can be selected from 50ms to 5 seconds.

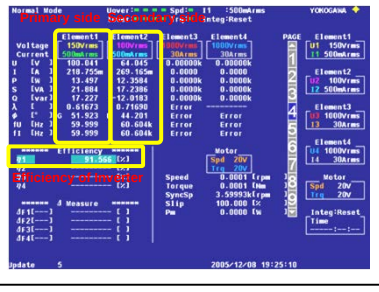
■Example of Connections for Fluorescent Lamp Measurement



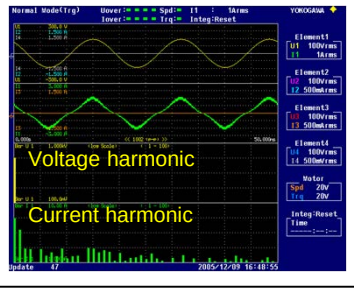
Analog bandwidth：Up to 500MHz
Sampling rate: Up to 2.5GS/s
History memory function included

■WT3000 Display Screen

【Example of input and output side measured data display】



【Example of waveform and harmonic data display】



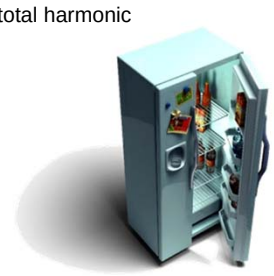
Performance Evaluation Test of Home Appliances and OA Equipment

Power Analyzer
WT500

Application Overview
In recent years, the industry is pushing for rigorous energy consumption regulations and use of alternative energy sources to fight against global warming.
On the consumer front, ENERGY STAR, Energy Saving Act and other initiatives encourage the reduction of power consumption. For example, focus is directed to the operation mode of house appliances. The WT500 is able to measure the changing power parameters with various display formats.

Application Points

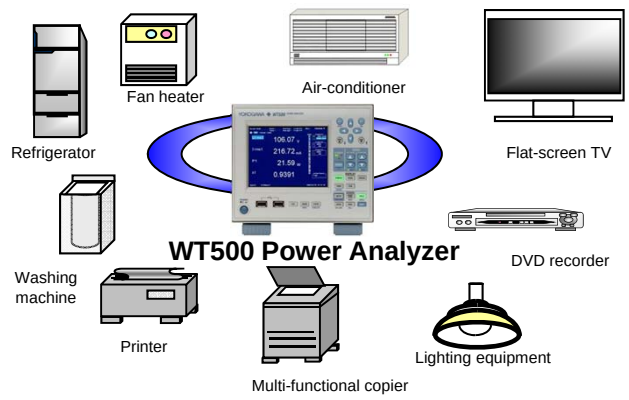
- Large-current, high-voltage direct input compatibility
- Simultaneous measurement of effective values and DC values of equipment (with single measurement mode)
- Simultaneous multi-item display of numeric, trend and waveforms values
- Various integral functions available as standard
- Simultaneous measurement of voltage, current, power and total harmonic distortion (THD)
- Saving both image and numeric data to PC applications



Product Features

- High current compatibility: 40A range (direct input)
- High voltage compatibility: 1,000V range (direct input)
- Simultaneous display of RMS, MEAN, DC, and AC RMEAN of voltage and current with single measurement mode
- Variety of measurement items and display formats
- Numeric, trend, waveform and other display formats of voltage, current, power, total harmonic distortion, harmonic component (DC to the 50th order) and input/output efficiency
- Current, active power, reactive power, and apparent power integral functions available as standard
- Harmonic data (THD and DC to the 50th order) can be measured along with normal measurement data.
- Distortion of waveforms can always be checked along with the voltage, current, and power measurements.
- Screen images and measured values can be saved to the internal memory or USB memory. Reports and graphs can be created in PC software.

■Home Appliance Performance Test



■WT500 Display Screen

[Display of voltage, current, power, and THD]

Display voltage, current, THD, and the like

Display the harmonic components of voltage and current (DC to the 20th order per screen)

[Simultaneous multi-item display}

All-item display screen in which all items can be checked simultaneously

Power Measurement by Calorie Meter

Power Analyzer
WT500

Application Overview
Test system for air-conditioning, refrigeration and environment incorporate a power meter to measure the power consumption for continuous operation and switching between operation modes. Power meters for this application sometimes need high-precision, high-current and high-voltage inputs.
The WT500 has a voltage and current input range of approximately 1.7and 2 times wider, respectively, than conventional power measuring devices. This features allows testing a wide range of products for which direct input is needed, thereby eliminating the need for external sensors and other signal conditioning devices.
Furthermore, with data update rates of up to 100ms, each phase voltage, current, power and total harmonic distortion can be measured and calculated accurately. This results in shorter test cycles.

Application Points

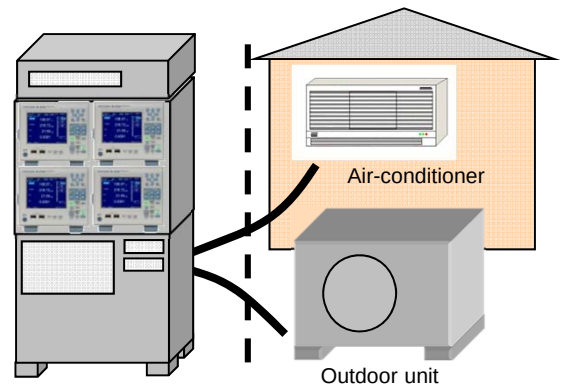
- High current compatibility
- High voltage compatibility
- High-speed data acquisition
- Current consumption and power consumption measurement
- Variety of communication interface options

Product Features

- High current compatibility: 40A range (direct input)
- High voltage compatibility: 1,000V range (direct input)
- Capable of high-speed data acquisition at the maximum speed of 100ms
- Voltage, current, and power changes can be monitored in the both numeric and trend display.
- Various communication interface options: GPIB, USB or Ethernet

* Trend display refers to a graph display in which the horizontal and vertical axes represent a time axis and data values, respectively.

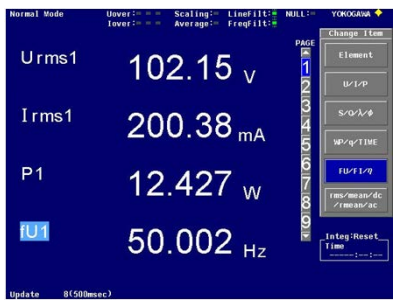
■Power Measurement with Calorie Meter



Test system (example)

■WT500 Display and Setting Screens

[Display of voltage, current, power consumption, and frequency]



[Example of trend display]

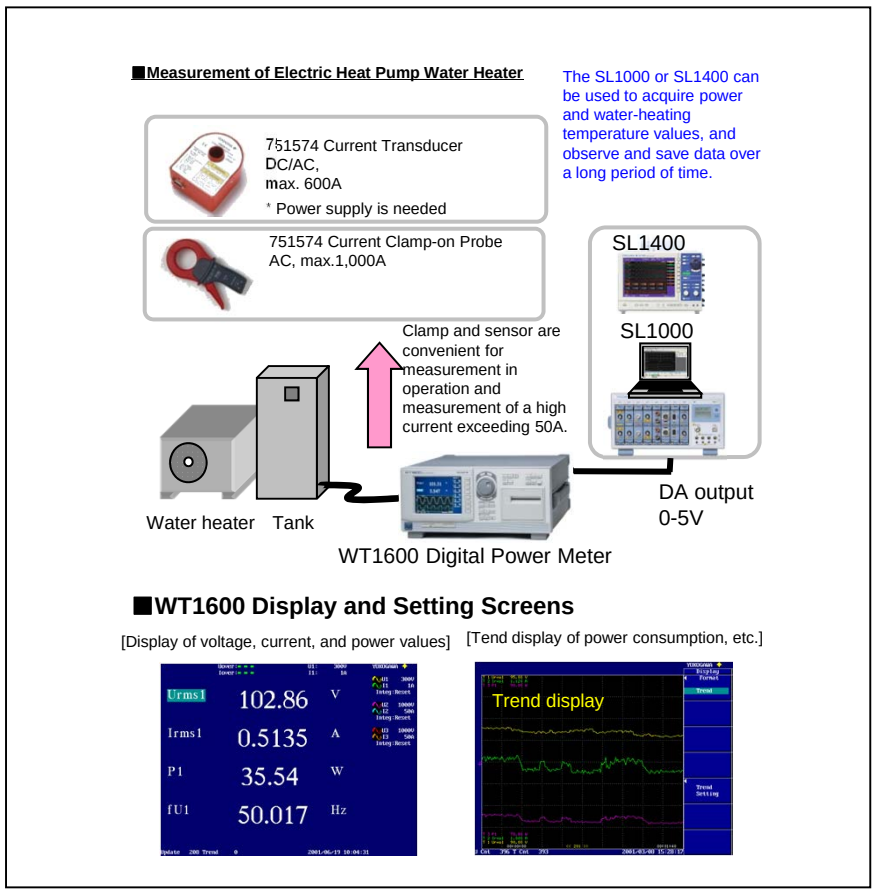
Power Measurement of Electric Heat Pump Water Heater and Other Equipment

Digital Power Meter
WT1600

Application Overview
The use of heat pump technology in heating devices such as water heaters and air-conditioners is becoming very popular in the recent years. Devices using heat pump technology use less energy thereby resulting in monetary savings. Furthermore water heaters can heat water using power when it is cheaper, in the middle of the night, resulting in the conservation of both power and money.
The WT1600 is able to measure both single-phase and three-phase powered devices. It can measure voltage, current, power and frequency that can be used to evaluate the performance and capacity of heat pump water heaters (Eco Cute) and heat pump air-conditioners.

Application Points
- High-precision measurement
- Up to 50A high-current direct input measurements
- Both single-phase and three-phase power measurement
- Dual-line three-phase simultaneous measurement by 6input element
- Dual screen display, such as “value + waveform” and “value + trend”
- Monitoring of fluctuations in the voltage, current, and power values

Product Features
- Basic power accuracy：0.15%, measurement range: 0.5Hz to 1MHz
- Voltage range：1.5V to 1,000V range
  Current range:5A input (10mA to 5A range)
  50A input (1A to 50A range)
- Not only value, trend, and waveform displays but also combination displays are available. This is convenient because temporal changes can be visually checked while observing the values.
- Voltage, current, and power changes can be checked in the trend display screen.



Efficiency Improvement of Product Test in Long Time Operation

High-Speed Data Acquisition Unit
SL1000

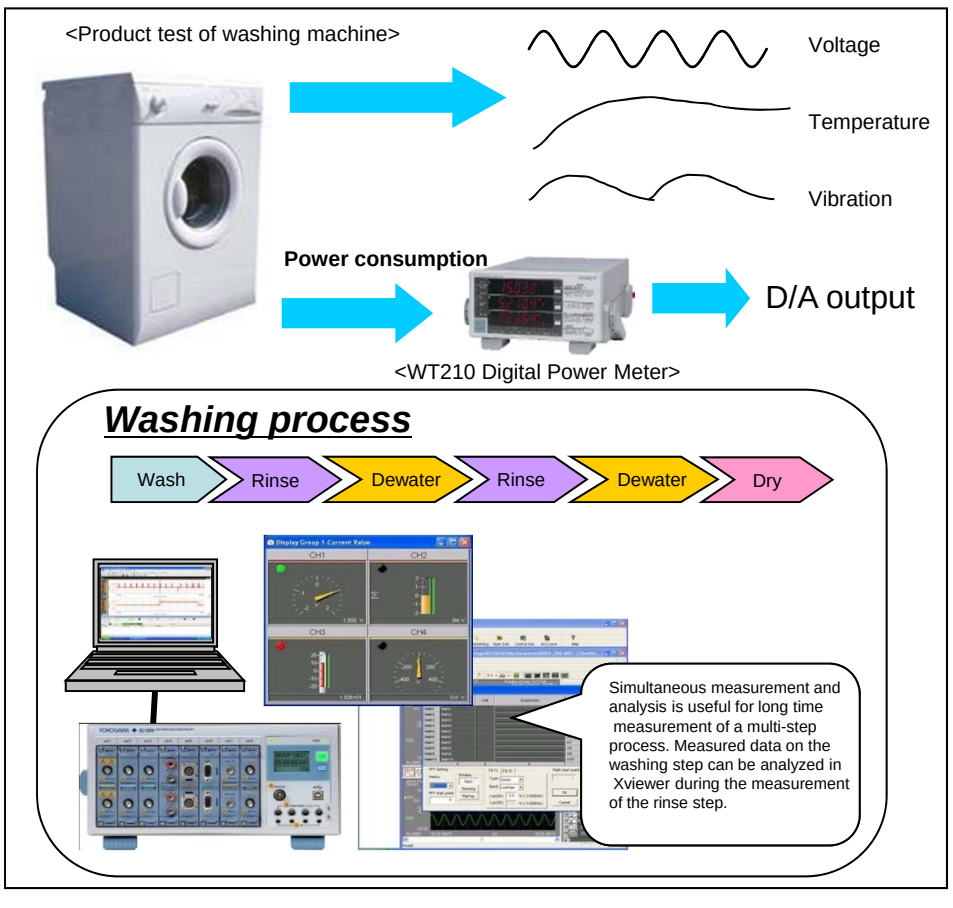
Application Overview
In recent years, home appliances are required to have improved operating performance and characteristics during long periods of operation at home, such as power consumption, quietness, and the like.
Accordingly, it is important to test and evaluate products over long periods of operation in an environment similar to that where the finished product will be actually used.
To evaluate finished products, a measuring instrument must be able to measure and analyze multiple items such as temperature, voltage, current, vibration and noise over a long period of time.

Application Points
- A single measuring instrument is able to acquire a variety of signals.
- File generation of data for each step in continuous operation

Product Features
- **12 types of input modules**
  Different events can be synchronized and observed using modules for measuring various signals, such as high-speed voltage, high voltage, high-precision voltage, frequency, temperature, distortion, and acceleration.

- **Generation of separate data files of one continuous operation**
  Measured data can be generated in different files for each trigger so another file can be analyzed in Xviewer during measurement.

- **Bar graph display**
  A real-time simplified bar graph display is convenient when you monitor data changes over a long period of time while performing other tasks.



Multi-Power Supply Start Timing Verification

Multi Channel Source Measure Unit
GS820

Application Overview

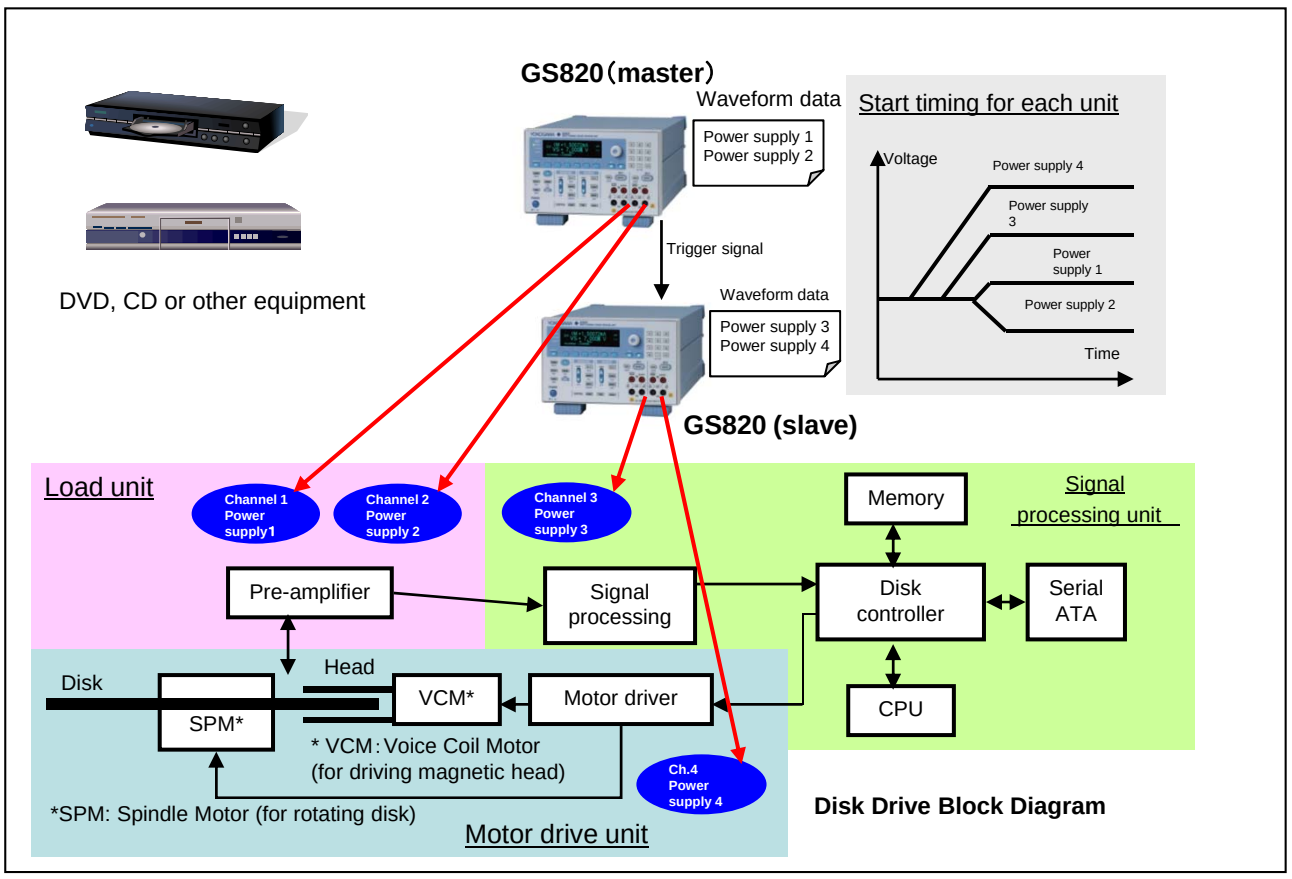
The operating margin is verified for equipment incorporating multiple power supplies, such as DVDs, CDs, and hard disk drives, by providing a power start timing.

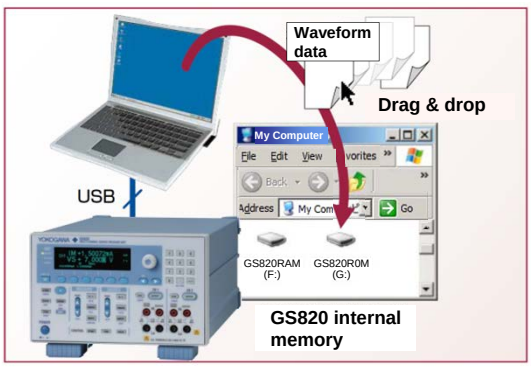
Application Points

Multiple power supplies can be implemented by the master-slave synchronization link method. Output waveform data can be easily preset just by defining a voltage waveform for power supply startup on a worksheet and drag-dropping it to the internal memory of the GS820.

Product Features

- Synchronized output of multiple power supplies
- Up to 3.2 A/ channel output current
- Simple voltage programming





Observation of Analog RGB and V-Sync/H-Sync Signals

Series Mixed Signal Oscilloscope
DLM2000

Application Overview

Three channels of analog RGB signals, and two timing signals (vertical-sync/horizontal-sync signals) can be simultaneously measured.

Application Points

- The DLM2000 can use its 4 analog input channel as a "hybrid channel" by switching to logic 8bit input.

- The DLM2000's hybrid channel is useful for the measurement of multiple channels, including timing signals such as V/H-sync signals or control signals.

Product Features

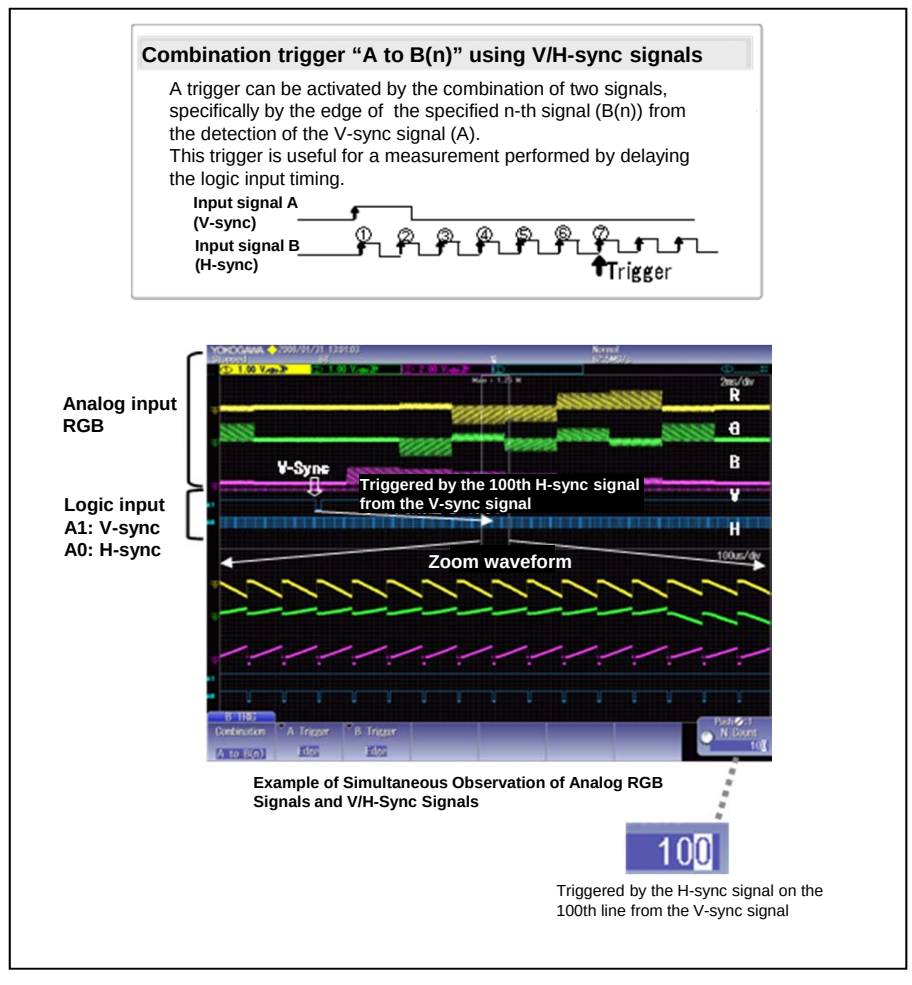
- Measurement of 5 channels (R, G, B, V/H-sync) by a 4 channel oscilloscope
  Analog 4 channels ⇔ analog 3 channels plus logic 8bit (hybrid channel)

- Variety of trigger functions including HDTV trigger are available as standard
NTSC, PAL, SDTV, HDTV (TV trigger is available as standard)
Combination trigger "A to B(n)" using V/H-sync signals

- Long time measurements with large (when /M2 option is included)
Up to 125MPoints large memory is available. One-second video signals can be captured at a high sampling-speed of 125MS/s.

DLM2000 series TV trigger

・Standards:	NTSC, PAL
・SDTV:	480/60p
・HDTV:	1080/60i, 1080/50i, 720/60p, 1080/25p, 1080/24p, 1080/24sF, 1080/60p



I²C Bus Signal Evaluation (Trigger)

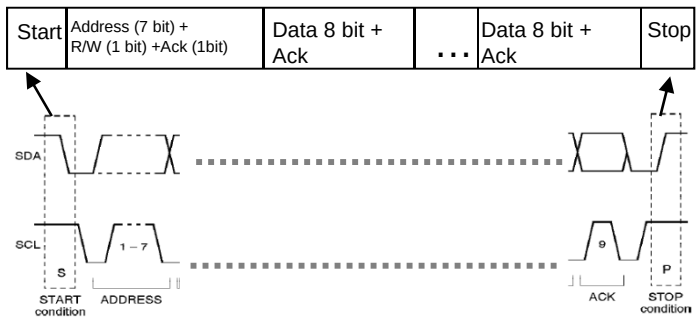
Series Mixed Signal Oscilloscope
DLM2000

Application Overview
An I²C bus refers to synchronous serial communication that uses two signal lines (excluding GND) for communication: one serial clock (SCL) line and one bi-directional serial data (SDA) line. Multiple slaves can be connected to the bus and the master selects a slave by specifying the address of the slave assigned individually to communicate with the slave. There are three modes depending on the bit rate: standard, fast, and high-speed modes.

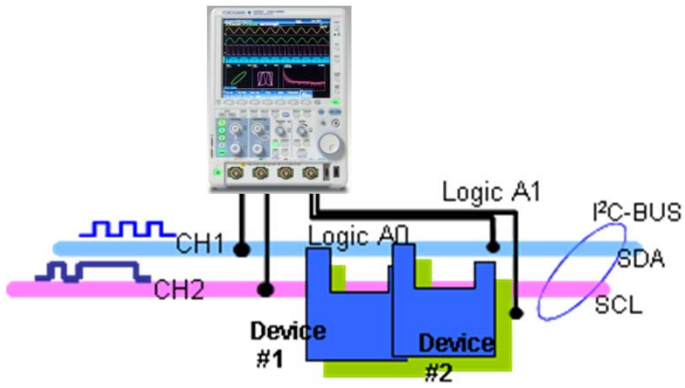
Application Points
I²C signal is used as a trigger to measure analog signals simultaneously and evaluate the timing of LIN data with sensor and start signals.

Product Features
A trigger can be activated by the following conditions.

- Every-Start trigger: Triggered by all start conditions
- Address-Data trigger: Triggered by the set address or data
- Non-Ack trigger: Triggered by the absence of acknowledgement
- General-Call trigger: Triggered by issuance of general call
  Select from the Don't care, 0000 0100 / 0000 0110 / Master Adr setting
- Start-Byte trigger: Triggered by the start byte
- HS-Mode trigger: Triggered by the HS mode
  <Trigger setting by address and data>
- Set the IC address and R/W bit
- 7-bit address, 7-bit plus sub-address, and 10-bit address can be set.
- True or False can be selected for specifying data.
- A trigger becomes valid after a byte specified by the byte count.



Example of data format (7bit address)



Example of I²C bus structure and signal observation

SPI Bus Signal Evaluation (Analysis, Decode, and Search)

Mixed Signal Oscilloscope
DLM2000 Series

Application Overview
An SPI bus refers to synchronous serial communication that uses three signal lines (excluding GND) for communication: one serial clock (SCK) line and two one-way SDI and SDO lines. Multiple slaves can be connected to the bus and the master selects salves by identifying them using a chip select (CS) signal. An increase in the number of signal lines does not affect the communication speed because the data format and principle are simple.

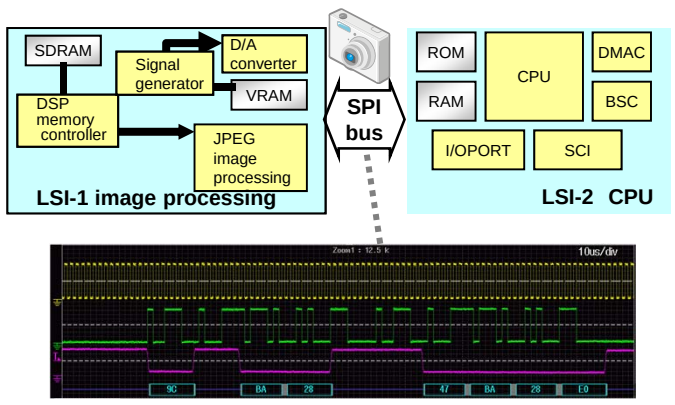
Application Points
The DLM2000 is able to analyze SPI signals, display the decoded list and perform a search.

Product Features

- Simultaneous real-time display of SPI bus signal waveforms and decode analysis results
- Analysis results include the display of time from the trigger point and data 1 and data 2.
- High-speed analysis and waveform display
- Analysis results (list) can be saved to a text file in CSV format.
- The desired data can be extracted by an SPI bus condition from the data captured to large memory.

■Example of SPI Bus Application

SPI is used for data communication between ICs embedded in digital cameras. The DLM2000's bus analysis function allows users to observe waveforms to check that inter IC communication works correctly while checking the data.



Application Example of SPI Bus for Digital Camera

Transfer Characteristic Evaluation of Servo Motor

Mixed Signal Oscilloscope DLM2000
Function Generators FG200/FG300

Application Overview

To control a servo motor at high speed, the response frequency for control must be increased while maintaining stable operation against the varying load. To do this, the transfer characteristics of control loop must be evaluated.

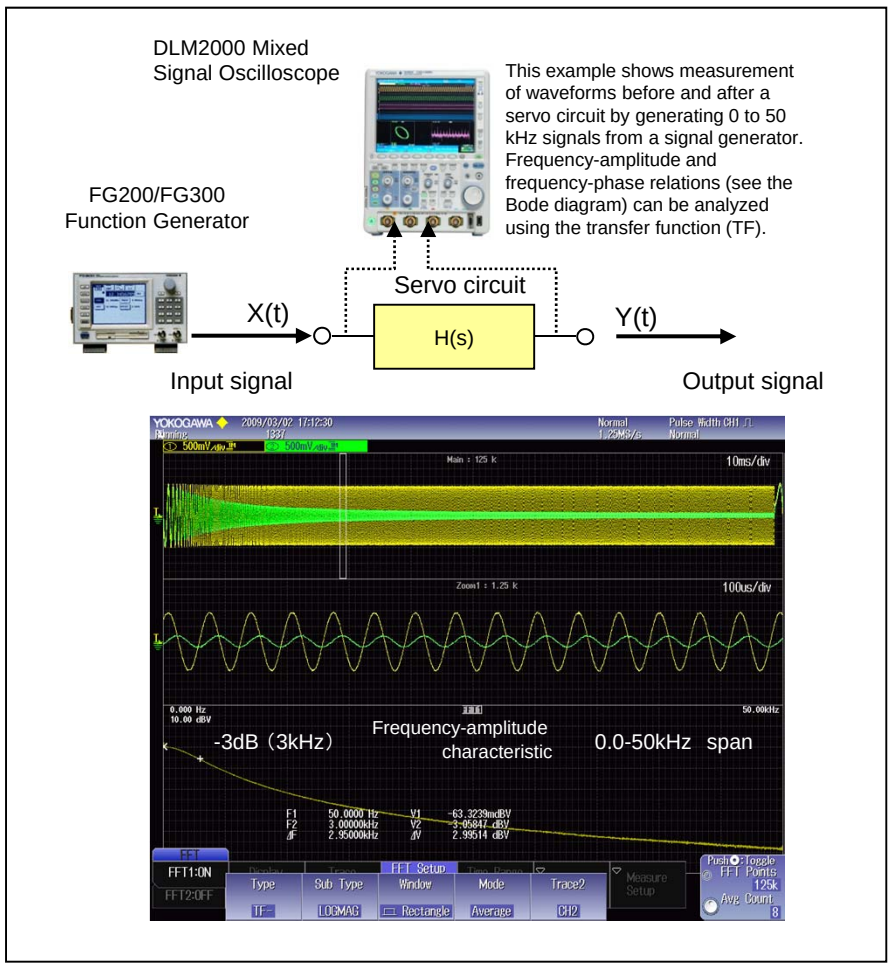
The FFT analysis included in the user-defined mathematics (option) of the DLM2000 is able to measure transfer functions in addition to normal power spectrum analysis, so it is able to analyze the frequency characteristics of amplitude and the phase of the servo motor in real-time.

Application Points

- Capable of analyzing a wide range of frequencies (up to 500MHz) while analyzing waveforms
- Capable of evaluating the gain characteristic and phase margin by displaying the transfer functions in frequency-amplitude and frequency-phase graphs (Bode diagrams)
- An internal hardware filter removes unnecessary aliases and enables correct analysis of frequencies.
- Capable of high dynamic range measurement in the Hi-res mode.

Product Features

- Up to 250KPoints high-speed FFT analysis
- Variety of FFT functions: transfer function, linear spectrum, power spectrum, power spectrum density, cross spectrum, and coherence function
- High sampling rate of 1.25GS/s



Start-up Characteristic Measurement of Small DC Motor

Source Measure Units GS610
ScopeCorder DL750

Application Overview

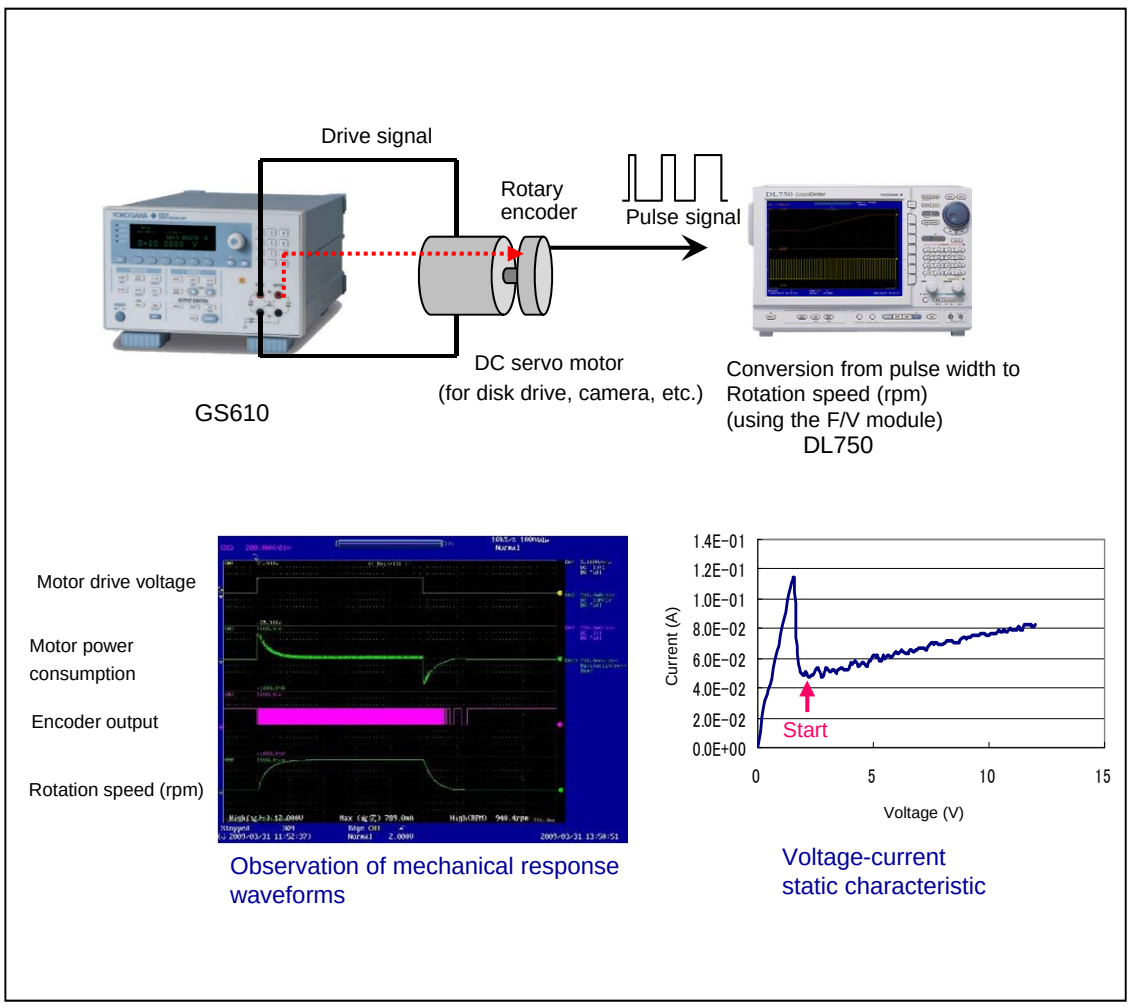
A small DC motor used in disk drives, digital cameras or other media devices is driven to measure the mechanical starting response and signal waveforms of each motor part. Furthermore, current consumption for the motor drive voltage is measured and a I/V characteristic is drawn.

Application Points

The GS610 Source Measure Unit drives a small DC motor directly by generating a pulse voltage. The DL750 ScopeCorder measures the drive signal and power consumption for the moment when the motor starts and converts the pulse signal from the encoder to analog signal of rotation speed (rpm).

Product Features

- The GS610 is able to drive the small DC motor directly (at the maximum current of 3.2A)
- Measurement of the number of rotations (rpm) by the DL750's F/V conversion module
- Compact and inexpensive device composition



Inverter Evaluation Test

ScopeCorder
DL750

Application Overview

The evaluation of inverters that perform high-speed switching between high voltages, such as an IGBT inverter, is indispensable for the development of efficient inverters. The observation of inverter waveforms requires a measuring instrument that features a high channel-to-channel isolation, high frequency range, high withstand voltage and high common-mode rejection ratio (CMRR) at high frequencies.

Application Points

The DL750 has a high CMRR and is able to observe the output voltage and control signal of inverters using an isolated probe. (Voltage signals that switch at high frequency an be measured without using a differential probe.)

Features

- **16bit high-resolution modules**

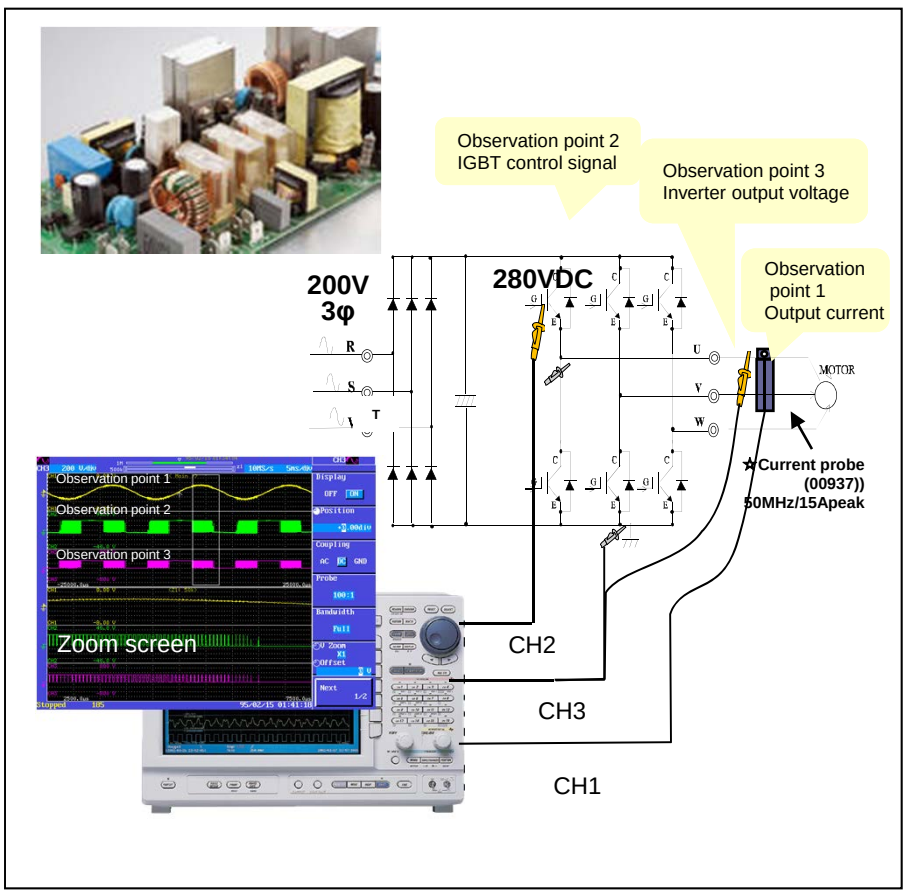
Measurement can be performed at 16bit resolution using modules for measuring various signals such as high-speed voltage, high voltage, high-precision voltage, frequency, temperature and acceleration.

- **Multi-channel large memory (up to 1GW)**

Up to 16 channel analog inputs plus 16bit logic input are possible. Ultra-large memory of up to 1GW for one channel and up 50MW/ch is available (option).

- **GIGA Zoom function**

Capable of a simultaneous 1GW real-time full-length display by a high-speed large ASIC and zoom display within 0.1 second in two arbitrary-sized Zoom windows, regardless of whether the instrument is in operation or not.



Switching Timing Analysis of Switching Power Supply

Mixed Signal Oscilloscope DLM2000 Series
Digital Oscilloscope DL9000 Series

Application Overview

Inverters have a high-side and a low-side switch. If the two switches turn on simultaneously, high through-current flows and causes a loss, so they are turned on alternately with dead time in between. A shorter dead time reduces the loss but decreases the operating margin, so that the through-current risk increases. The DLM2000/DL9000 series is able to observe the high-side and low-side Vgs waveforms and check whether the dead time is in order.

Application Points

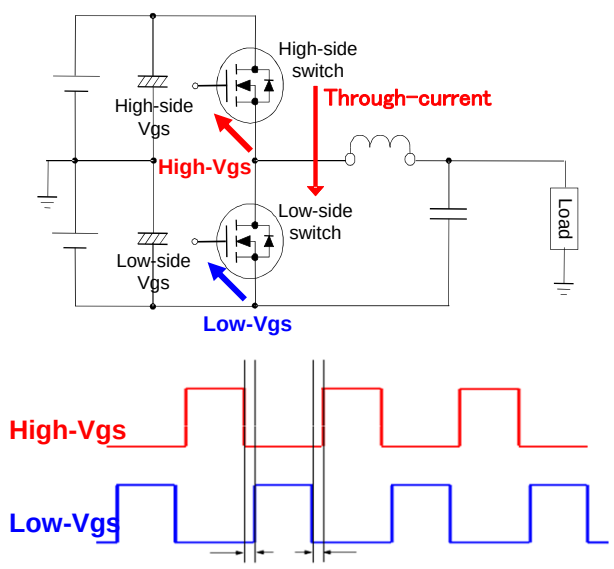
A State-Width trigger* included in the variety of trigger functions of the DLM2000/DL9000 series is useful for setting a trigger for a place where the dead time is insufficient. Superimposing waveforms makes it possible to ensure less frequent events are captured and the data is recorded.

Product Features

If a trigger is set in such a way that the condition is met during the period of time when both CH1 and CH2 is low (t) is less than the set time (T), the trigger is defective in the design.

Superimposed individual waveforms are recorded to the history memory of the DLM2000/DL9000, so they can be tracked in the history and the desired waveform can be extracted from the recorded data.

*A State-Width trigger is activated when the relation between the set input logical condition (state) time width (t) and the set time (T) is met.



Through-Current and Dead Time

Power Evaluation for Inverter/Motor Test (1)

Precision Power Analyzer
WT3000

Application Overview

With the development of the electronic circuit technology, motor control is getting more complex. On the other hand, driven by social background factors such as energy conservation, demand for more precise evaluation of motor and inverter control to achieve higher efficiency is increasing.

The WT3000, which is capable of measuring up to 4 channel inputs, is able to run an inverter efficiency test between input and output to evaluate inverters. Furthermore, a motor evaluation function (option) can simultaneously observe changes in the rotational speed and torque, along with the observation of voltage, current and power changes.

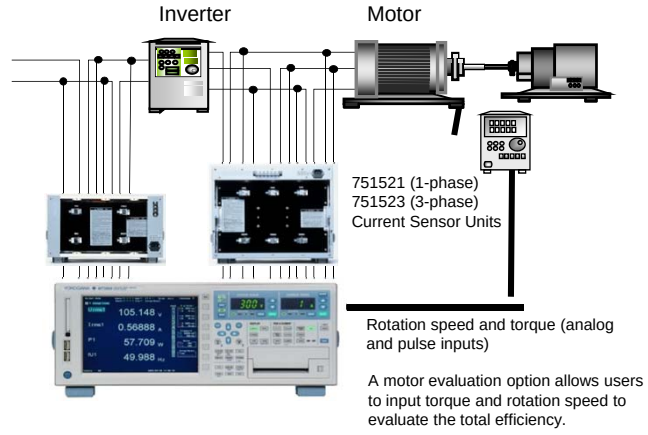
Application Points

- High-precision, wide frequency range measurement
- A wide voltage range allows one unit to measure from very low to very high voltages.
- Capable of up to 30A direct input. For an input exceeding 30A, up to 600A is available for testing using the 751574 Current Transducer.
- Simultaneous measurement of normal measurement value and harmonic measurement data
- High-speed measurement of fluctuating power
- Simple printout of measured values and waveforms with the internal printer (/B5)

Product Features

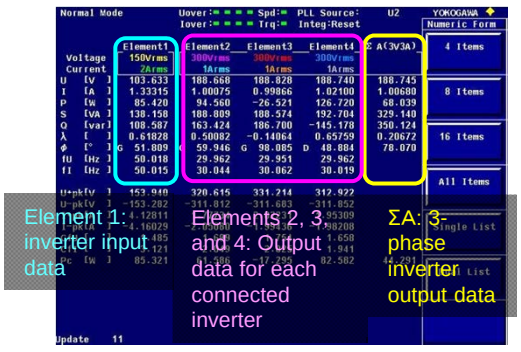
- Basic power accuracy: 0.06%, frequency range: 0.1Hz to 1MHz
- The rated input range can be selected from the 15V range to up to the 1,000V range
- Two types of current input elements: Either the 2A input element (5mA to 2A range) or 30A input element (500mA to 30A range) can be selected.
- Simultaneous measurement of total harmonic distortion (THD) and harmonic data (from fundamental harmonic up to the 100th order), along with voltage, current, power, power factor, and the like
- High-speed data acquisition at a rate of 20 times per second (50ms intervals)
- For example, the value, waveform, trend, harmonic bar graph and dual screen display (value and waveform) can easily be printed with the internal printer (option).

■Example of Measurement for Motor/Inverter Evaluation

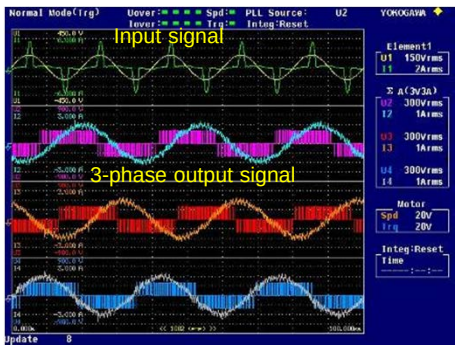


■WT3000 Display and Setting Screens

[Example of 4- channel input screen and connections]



Example of waveforms of input and output signals]



Power Evaluation for Inverter/Motor Test (2)

Digital Power Meter
WT1600

Application Overview

Demand for more precise evaluation of motor and inverter control is increasing for the same reason as described in the above application.

The WT1600, which is capable of measuring up to 6 channel inputs, is able to test the inverter efficiency, such as single-phase input/three-phase output signals and three-phase input/three-phase output signals for the evaluation of inverters. Furthermore, a motor evaluation function (option) can observe changes in the rotational speed and torque, along with the observation of voltage, current and power changes.

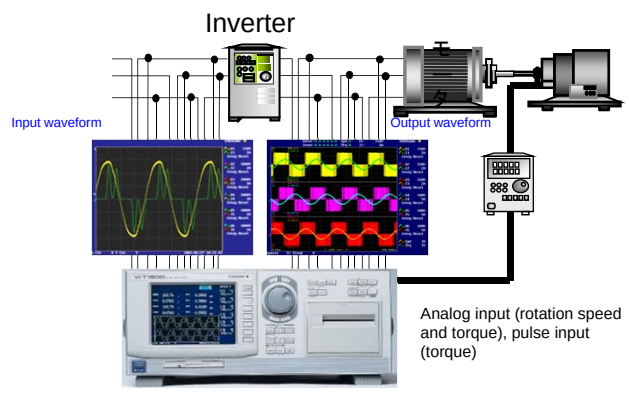
Application Points

- High-precision, wide frequency range measurement
- A wide voltage range allows one unit to measure from very low to very high voltages.
- Capable of up to 50A direct input. For an input exceeding 50A, up to 600A is available for testing using the 751574 Current Transducer.
- High-speed measurement of fluctuating power
- Up to 24 channel inputs by the WTViewer. Data evaluation of a multi-phase motor, and the like
- Simple printout of measured values and waveforms with the internal printer (/B5)

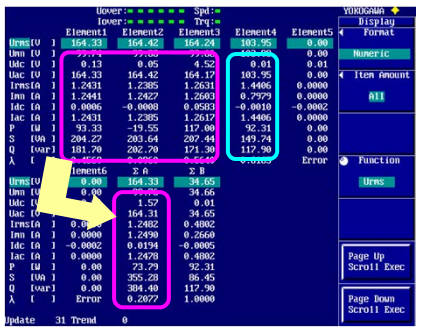
Product Features

- Basic power accuracy: 0.15%, frequency range: 0.5Hz to 1MHz
- The rated input range can be selected from the 1.5V range (mV order measurable) to up to the 1,000V range.
- Two types of current input elements: Either the 5A input element (10mA to 5A range) or 50A input element (1A to 50A range) can be selected.
- High-speed data acquisition at a rate of 20 times per second (50ms intervals)
- The 760121 WTViewer is capable of simultaneous measurement of up to 4units (6 channel inputs per unit totaling up to 24 channel inputs).
- For example, the value, waveform, trend, harmonic bar graph, and dual screen display (value and waveform) can be easily printed with the internal printer (option).

■Example of Measurement for Motor/Inverter Evaluation



■WT1600 Screen Display



Example of connections
Element 4: Inverter input data
Elements 1, 2, and 3: Output data of each connected inverter
ΣA: 3-phase inverter output data

Dicing Equipment for BGA

DYNASERV

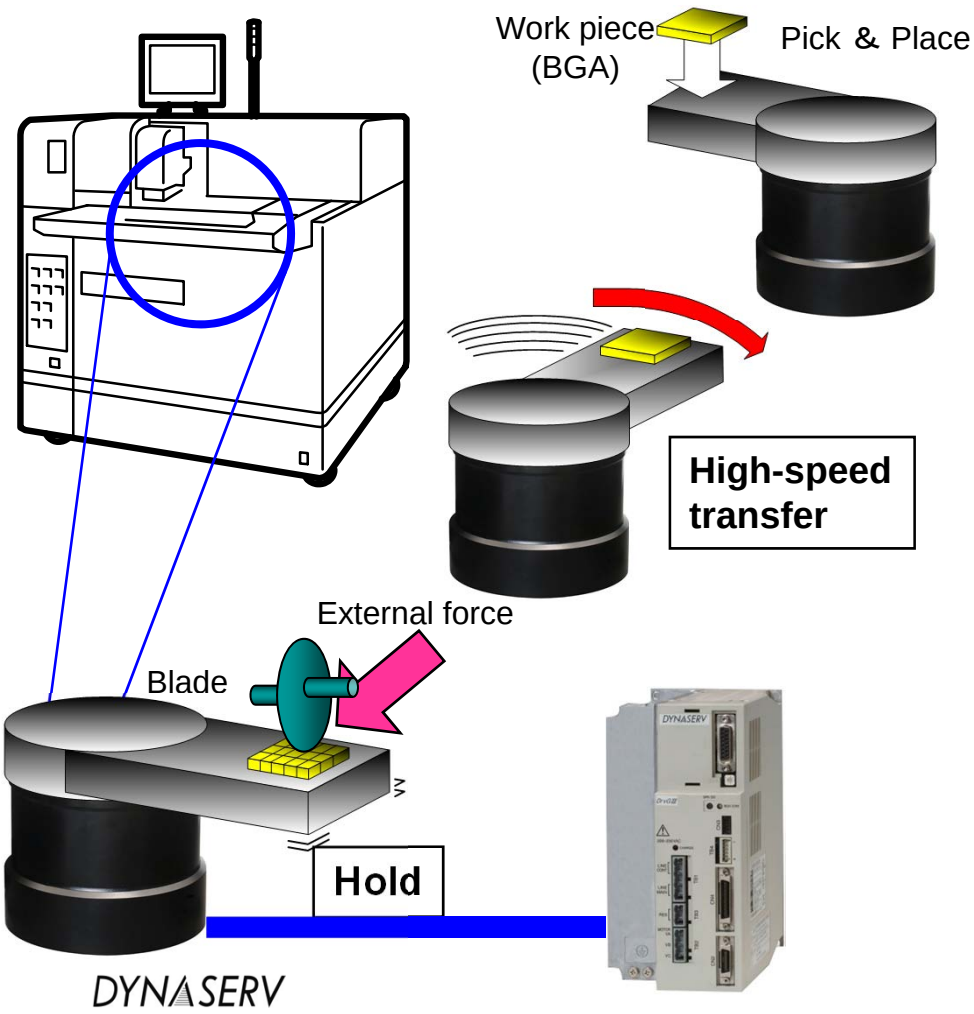
Dicing Equipment for Ball Glide Alley (BGA)

The high-precision, high-stiffness and high-speed direct drive motor, DYNASERV, can be used to process a work piece held in an arm that moves with high speed to transfer it. The DYNASERV achieved high-precision positioning that meets the precision requirement of precision dicing, servo stiffness that withstands the external force coming from processing, high-speed operation and elimination of the need for transferring and placing the work piece on the positioning table, resulting in increased speed and shorter cycle time.

Despite positioning at the front end of a 250mm arm, cutting precision for dicing improved and yield increased. This was accomplished by an increase in the absolute accuracy, as well as accuracy compensation data.

The DYNASERV employs Yokogawa's proprietary encoder with the maximum resolution of 4,096,000pulses per rotation. This high resolution enables high-precision positioning of the arm.

The all-in-one construction minimizes mechanical parts of the equipment, removing rattle and mechanical loss, helping reduce the number of parts, eliminating the need for maintenance and increasing precision. The DYNASERV can also be used for LCD panel glass cutting equipment, beveling equipment and polishing equipment that have the same mechanism as that of dicing equipment for BGA.



LCD Glass Scriber

DYNASERV

<Application>

The DYNASERV is used to drive the table for LCD glass cutting, beveling and polishing equipment.

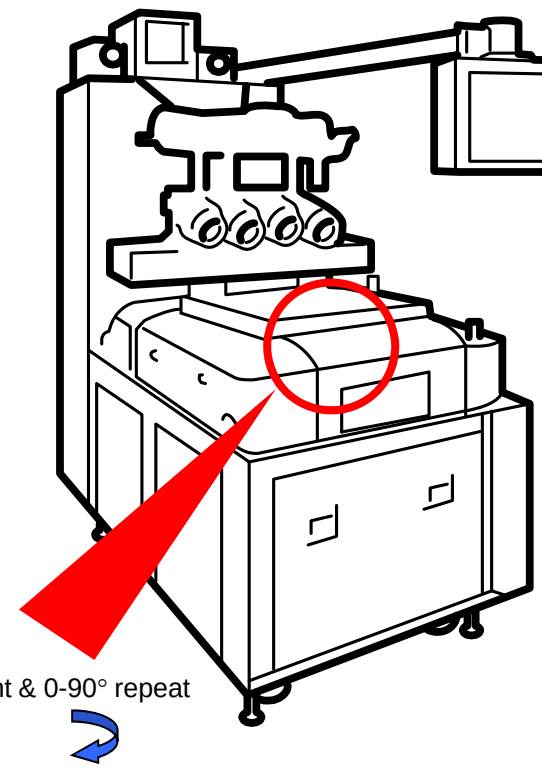
<Benefits>

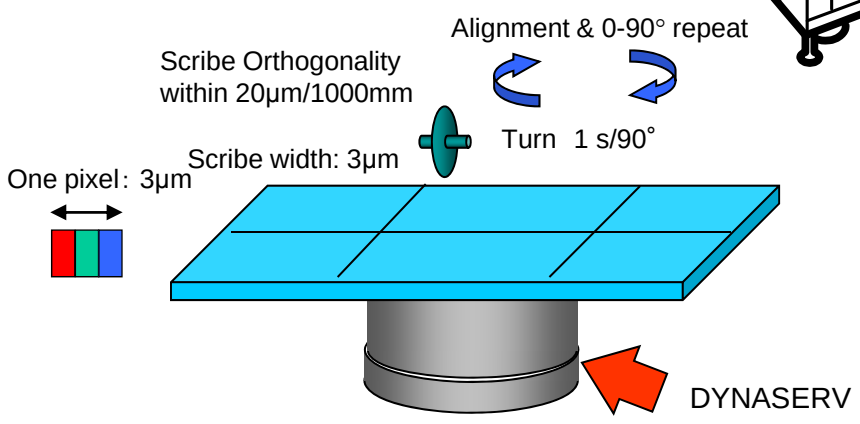
- Increase in yield rate
- Maintenance free
- Reduction in the number of parts

<Solutions>

- All-in-one
- Neither rattle nor lost motion
- High precision, high torque, high stiffness, low heat generation

The DYNASERV is used for a LCD glass scriber to increase cutting precision of LCD glass. Specifically, the high-resolution and high-stiffness DYNASERV can be used to drive the index table for positioning and holding the LCD glass to achieve high-resolution positioning. The DYNASERV is able to hold the LCD glass firmly against external force from the cutting section during the cutting step, thus achieving high-precision cutting and helping improve quality and yield. In the case of the DYNASERV featuring a high resolution of 4,096,000pulses per rotation, resolution per pulse is approximately 0.8μm on a circumference with a radius of 500mm. Furthermore, the all-in-one construction of the DYNASERV helps customers reduce the number of parts and eliminates the need for maintenance, thus reducing manpower.





Optical Disk Sputtering Equipment

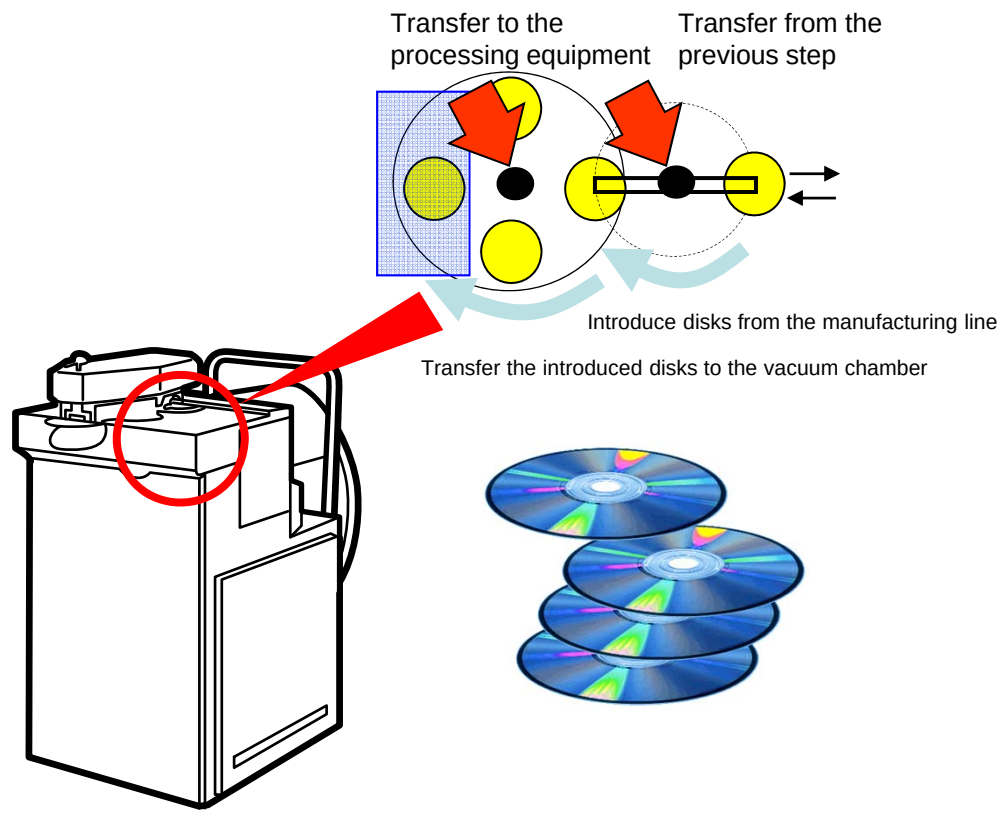
DYNASERV

Application
The DYNASERV is used to transfer disk substrates for sputtering equipment for manufacturing optical disks (transfer from the previous step and transfer to the processing equipment).

User Benefits
More compact (space saving), cost-cutting
Doubling the capacity (= doubling the speed)
・One unit has the transfer capability of two units
Higher cycle speed and shorter cycle time
Example:
180degree operation time down from 0.35s to 0.25s
Cycle time 1.8s (down 10%)

Solutions
- All-in-one
- High reliability (power supply, EMC)
- High precision, high torque, high stiffness, low heat generation

Sputtering, which deposits materials such as aluminum (A) and silicon (Si) on the surface of injection molded disks, is a core step for manufacturing optical disks. Optical disk sputtering equipment introduces disks, which were molded in the previous step from the manufacturing line (transfer from the previous step) and transfers them to a vacuum chamber (transfer to the processing equipment) for sputtering. Conventionally, these two operations, that is, transfer from the previous step and transfer to the processing equipment, are performed by two different pieces of equipment, thus making it difficult to make equipment more compact. The solution is the all-in-one, compact and high-torque DYNASERV that incorporates an integrated motor and encoder. Two DYNASERVs are used for the transfer from the previous step and transfer to the processing equipment, respectively, to make the transfer mechanism compact, and to integrate the two transfer operations into one housing, thus making the equipment more compact. Furthermore, characteristics such as high precision, high torque, high stiffness, and low heat generation help reduce the operation time, increase the cycle speed, reduce the cycle time, and help improve production efficiency. The DYNASERV is highly regarded for its reliability.



Power Consumption Measurement of Pump Fan

Power Analyzer
WT500

Application Overview

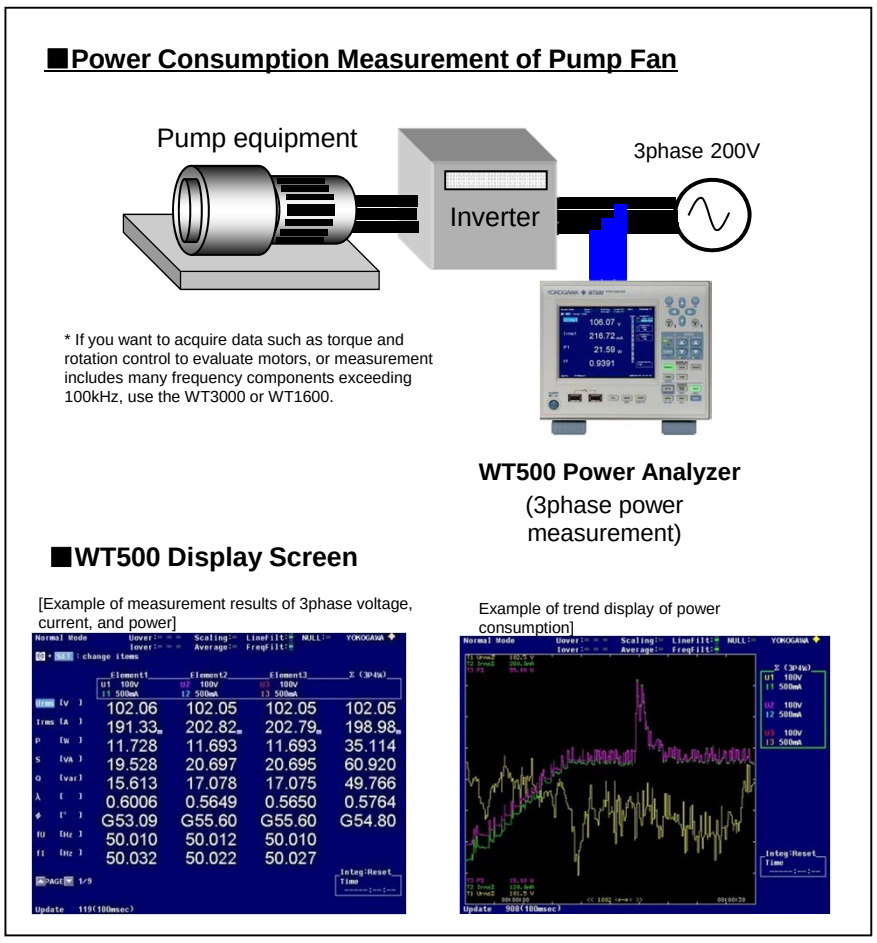
Various pumps such as industrial pumps, large pumps, hydraulic pumps, high-pressure pumps, submersible pumps or air-conditioner fans are used in many facilities including plants. In order to improve energy saving for these pumps and the like, the number of rotations must be finely-controlled. That's why many pumps use an inverter that can perform such control. To evaluate the power consumption of these pumps, voltage, current, power and the like must be measured. Furthermore, a power consumption integral function allows users to check the daily total power consumption, thus helping to find ways to improve energy efficiency and power saving.

Application Points

- High current and high voltage compatible
- Simultaneous measurement of fundamental wave and harmonic data
- Simultaneous measurement of voltage, current, power and harmonics
- Continuous monitoring of load changes
- Variety of screen displays formats

Product Features

- High current compatible : 40A range (direct input)
  High voltage compatible : 1,000V range (direct input)
- Capable of measurement of harmonic data (up to the 50th order) and total harmonic distortion (THD), along with fundamental components of voltage and current.
  Simultaneous observation of the fundamental wave that correlates with the torque and of harmonic
- Capable of measurement of harmonics (DC to the 50th order) and total harmonic distortion along with voltage, current and power
- Voltage, current and power changes can be measured at speeds up to 100ms. Furthermore, it can also be viewed over a long period of time using trend display.
- Not only numeric value display but also waveform, trend, harmonic and vector displays are available.



Power Data Acquisition of Roll Drive Motor in Metal Rolling Process

High-Speed Data Acquisition Unit
SL1000

Application Overview

The power measurement of the roll drive motor is one of equipment monitoring items in the metal rolling process. The roll drive power equipment is large consumes a lot of power, and the power can changes significantly.

Constant measurement and analysis of this power (current) make it possible to estimate the operation conditions of the equipment and the completion level of the product.

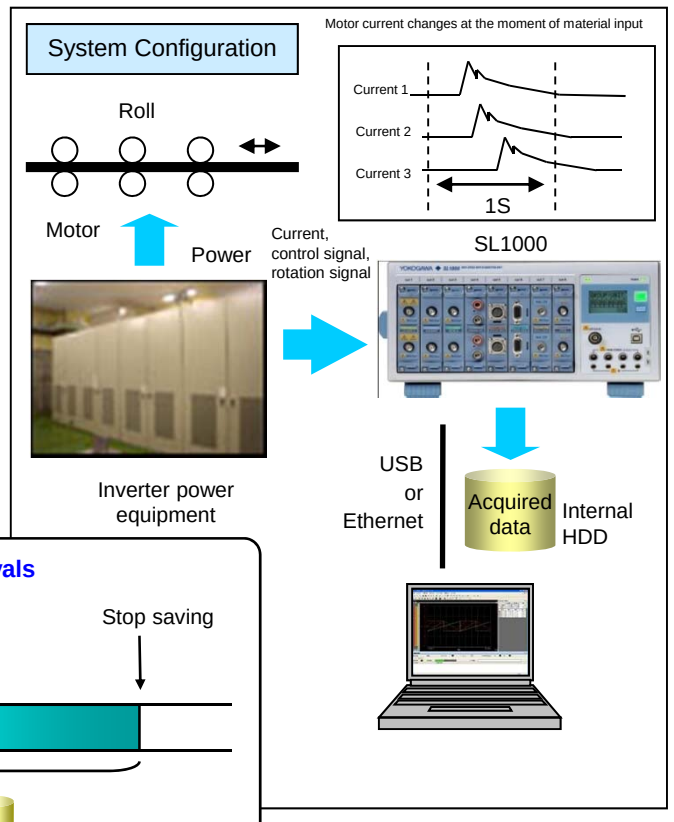
Furthermore, the acquisition of this data is very important for improving, repairing, and examining the equipment.

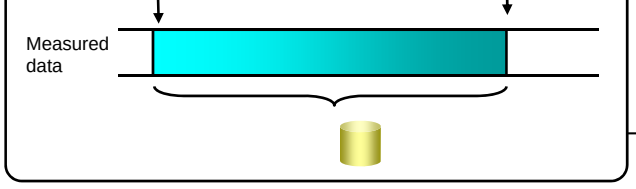
Application Points

- Capable of high-speed simultaneous acquisition of multi-channel signals, such as current, control signal, and number of rotations. Safe because of isolated inputs.
- The rotation signal can also be directly input.
- Capable of fast automatic saving to the internal HDD
- File transfer via a network connection is possible.

Product Features

- 16 channel real-time recording at 100kS/s
- Simultaneous multi-channel measurement
- Isolated input





Voltage & Current Measurement of Arc Welding

High-Speed Data Acquisition Unit
SL1000

Application Overview

The quality of welding cannot be judged clearly by visual inspection of the object.

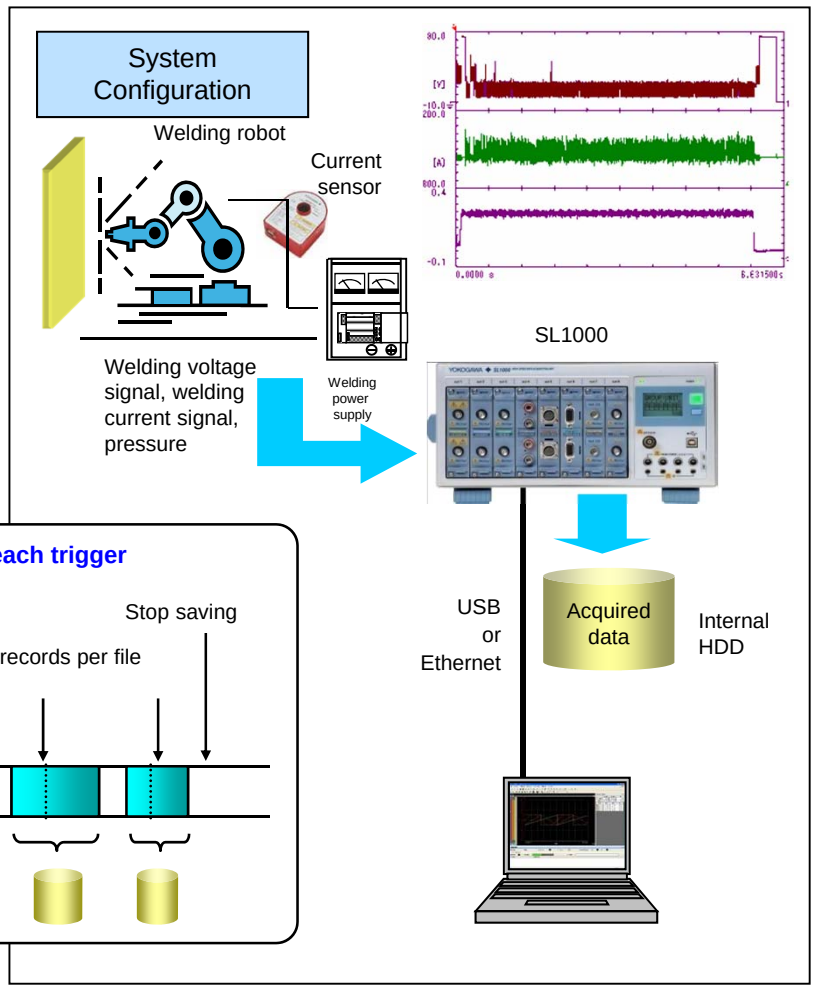
The quality of welding can be judged by the contact of electrodes with the object to be measured and the flow of the current. The method for quality judgment in an automatic welding process by robots, is to measure all the current during the welding.

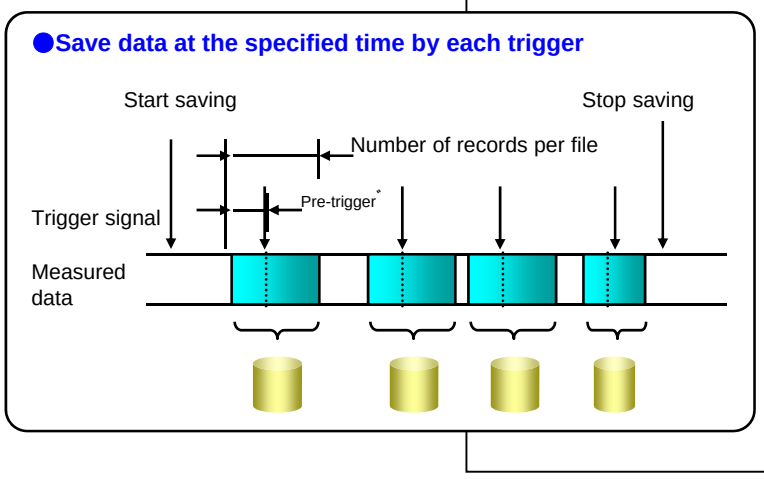
Application Points

- Input isolation and 16bit resolution make it possible to acquire more precise and detailed values.
- The data of effective RMS values can be acquired (using a high-voltage 100kS/s module).
- The acquired data can be automatically saved to the internal HDD.
- The data can be immediately checked on a PC and the maximum, effective, and other values of the current can be easily obtained.

Product Features

- 100kS/s, 16bit module
- Fast data saving
- Autonomous operation





DC/AC Rated Power & Harmonic Distortion Evaluation of Generator

Power Analyzer
WT500

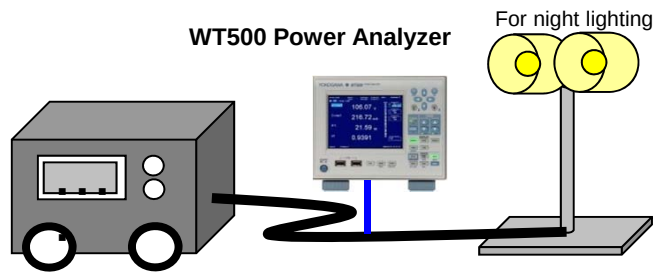
Application Overview
Generators are used for various applications, such as for night lighting at construction sites, for emergency lighting, for electric power tools, and for driving compressors and pumps. Some generators are able to supply power by generating direct current and alternating current, or switching between 50 Hz and 60 Hz. In recent years, generators using an inverter were developed to achieve higher efficiency; however, sometimes harmonic noise and distortion may be generated.
The WT500 is able to precisely measure the DC and AC voltage, current, rated power, frequency and other electrical parameters of these generators.

Application Points
- Capable of measuring the power of single-phase/three-phase generators
- Measurement of harmonic components generated by inverter-type generators
- Trend display enabling monitoring of the stability of voltage, current, and power
- High-precision measurement of the energy by a variety of integral functions

Product Features
- Capable of measuring single-phase power (1 channel input) and three-phase power (3 channel input)
- Capable of simultaneously measuring the harmonic component and total harmonic distortion (THD), along with true RMS voltage, current, and power data
- Trend display at data acquisition intervals of 10 times per second.
  The stability level of voltage, current, and power can be visually checked.
- Data display of active energy (Wh) and saving to the USB memory are possible.

* Trend display refers to a graph display in which the horizontal and vertical axes represent a time axis and data values, respectively.

■Power Consumption Measurement of Generator



The WT500 is able to measure items necessary to evaluate generators, such as voltage, current, power, power factor, harmonic, and distortion.

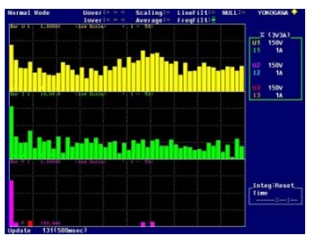
■WT500 Display and Setting Screens

[Example of measurement results of 3phase generator]

[Checking of stability levels in the trend display]

[Example of 3phase checking in the vector display]

[Example of harmonic measurement of inverter equipment]



Overhead Wire Voltage Change Measurement by Regenerative Braking

ScopeCorder DL750
Differential Probe

Application Overview
In recent years, VVVF control is generally used in the railway sector, and a regenerative braking function is widely used. However, there are problems. For example, a normal overhead wire voltage level changes at the moment regenerative brake is applied and railcars come to a stop automatically.

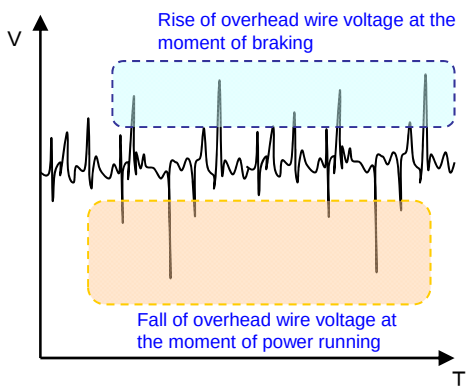
Application Points
Railcar control is performed while overhead wire voltage is monitored, so measurement of overhead wire voltage at the moment the regenerative brake is applied is important, for example, to analyze the braking control of railcars.

Features of the 701926 Differential Probe
- **High-voltage input**
  Measurement by differential input at 5,000Vrms/7,000Vpk makes it useful for the high-voltage-controlled railway sector.

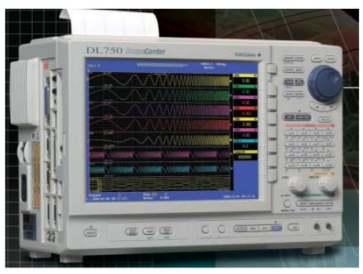
Features of the DL750
- **Multi-channel, large memory (up to 1GW)**
  Up to 16 channel input plus 16bit logic input are possible. Ultra-large memory of up to 1GW for one channel and up to 50MW for 16 channels is available (option).

- **Modules with internal filter function**
  A filter function included in all 7 types of modules for measuring voltage makes them useful for measurement in the railway sector where there is a lot of noise.

* Regenerative Braking and Power Running
Regenerative braking is one of the electrical braking methods that applies braking using a drive motor as a generator and converting kinetic energy to electrical energy to recover energy.
Power running refers to the transferring of motor or engine power to the wheels (drive wheels) for acceleration or keeping balancing speed on up line.



<701926 Differential Probe>



Power Consumption & Total Energy Measurement of Refrigerating & Cooling Showcases

Power Analyzer
WT500

Application Overview

Refrigerating/cooling equipment at convenience stores and supermarkets operates around the clock, using a lot of power. Reducing this power consumption is important in the fight against global warming.

On the consumer front, ENERGY STAR, Energy Saving Act, and other initiatives push for consumption power saving, and the focus is directed to higher efficiency home appliances as well as commercial-use refrigerating/cooling showcases. The WT500 is able to evaluate various parameters such as voltage, current, and power while checking the data in value, waveform, trend, and other display formats.

Application Points

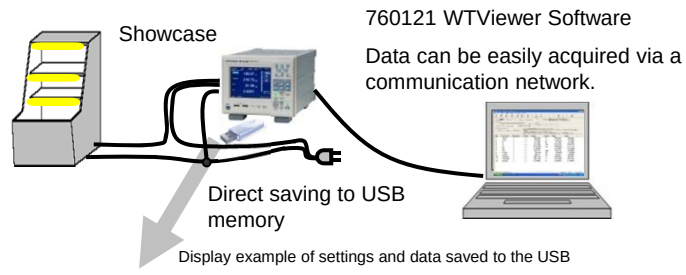
- High precision, high current and high voltage direct input compatible
- Up to 3 power consumption measurements
- Simultaneous multi-item value display, plus waveform and trend displays
- Variety of integral functions enable power evaluation over a long period of time.
- Data can be easily saved to a PC using application software.
- Screen images and measured data are saved to USB memory.

Product Features

- High precision: ±0.2% (current, voltage, and power accuracy)
  High current compatible：40A range (direct input)
  High voltage compatible：1,000V range (direct input)
- Up to 3 channels are available so it is possible to perform 3 power consumption measurements.
- Variety of measurement and display items
  Voltage, current, power, total harmonic distortion (THD), harmonic component (DC to the 50th order), input/output efficiency, etc., are displayed in value, trend, waveform, and other display formats.
- Current, active power, reactive power, apparent power and integral functions available as standard
- The 760121 WTViewer Software is able to display values and simplified waveforms on a PC. The measured data can be saved in CSV format and graphs can be easily created.
- Screen images and measured data are saved to the internal memory or USB.

* Trend display refers to a graph display in which the horizontal and vertical axes represent a time axis and data values, respectively.

■Power Consumption Measurement of Showcase



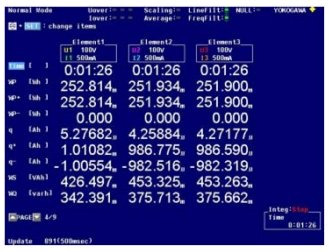
Display example of settings and data saved to the USB

Delta Measure Mode	RMS							
<Settings (Harmonics)>								
PLL Source	U1							
Order	1 To 50							
THD Formula	Total							
Store No.	Date	Time	Urms-E1	Irms-E1	P-E1	Time-E1	Wp-E1	q-E1
1	2008/08/	10:24:05	1.02E+02	2.22E-01	2.18E+01	0:00:00	3.03E-03	-2.39E-08
2	2008/08/	10:24:06	1.02E+02	2.23E-01	2.19E+01	0:00:01	6.08E-03	-5.35E-08
3	2008/08/	10:24:06	1.02E+02	2.23E-01	2.20E+01	0:00:01	9.13E-03	-7.56E-08
4	2008/08/	10:24:07	1.02E+02	2.23E-01	2.20E+01	0:00:02	1.22E-02	-1.05E-07
5	2008/08/	10:24:07	1.02E+02	2.23E-01	2.20E+01	0:00:02	1.52E-02	-1.13E-07
6	2008/08/	10:24:08	1.02E+02	2.23E-01	2.20E+01	0:00:03	1.83E-02	-1.34E-07
7	2008/08/	10:24:08	1.02E+02	2.23E-01	2.20E+01	0:00:03	2.13E-02	-1.43E-07
8	2008/08/	10:24:09	1.02E+02	2.23E-01	2.20E+01	0:00:04	2.44E-02	-1.65E-07
9	2008/08/	10:24:09	1.02E+02	2.23E-01	2.20E+01	0:00:04	2.74E-02	-1.69E-07
10	2008/08/	10:24:10	1.02E+02	2.23E-01	2.20E+01	0:00:05	3.05E-02	-1.87E-07
11	2008/08/	10:24:10	1.01E+02	2.24E-01	2.20E+01	0:00:05	3.35E-02	-1.96E-07
12	2008/08/	10:24:11	1.02E+02	2.23E-01	2.20E+01	0:00:06	3.66E-02	-2.13E-07
13	2008/08/	10:24:11	1.02E+02	2.23E-01	2.20E+01	0:00:06	3.97E-02	-2.29E-07
14	2008/08/	10:24:12	1.01E+02	2.24E-01	2.20E+01	0:00:07	4.27E-02	-2.56E-07
15	2008/08/	10:24:12	1.02E+02	2.23E-01	2.20E+01	0:00:07	4.58E-02	-2.80E-07

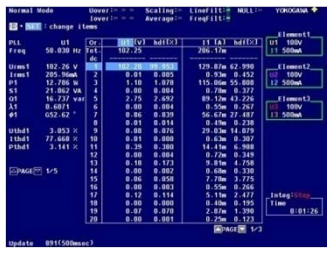
Data can be saved to USB memory and displayed in PC application software. Furthermore, data can be directly transferred to a PC using a communication function and LabVIEW software.

■WT500 Display Screen

[Display example of integration time and total power consumption]



Display example of voltage, current, power, and THD]



Current & Power Consumption Measurement of Electric Power Tool

Digital Power Meter
WT1600

Application Overview

Handheld electric power tools include a wide range of equipment, such as a screw driver, drill, wrench, spanner, and pincers, which are motor-driven work tools with batteries. A large current flows through these electric power tools during operation.
The WT1600 is able to measure the amount of DC (or AC) current and energy used by electric power tools, and display their waveforms and trends. Furthermore, a total energy measurement function is able to measure the total power consumption of batteries.

Application Points

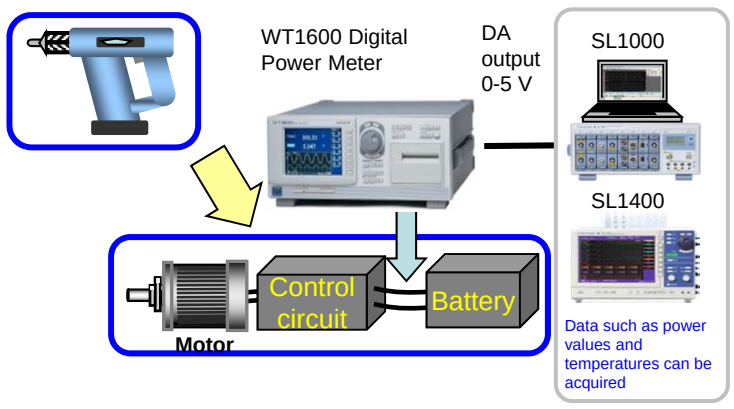
- High-precision, wide frequency measurement
- Wide-range voltage input and two types of current inputs (5A and 50A models)
- Dual screen display, such as “value + waveform” and “value + trend”
- Monitoring of changes in the voltage, current, and power values
- Capable of evaluating total current and power consumption
- Data acquisition at the maximum data update speed of 50ms (20 time per second)

Product Features

- Basic power accuracy: 0.15%
  Frequency range：DC, 0.5Hz to 1MHz
- Voltage range：1.5 V to 1,000 V
- Current range：5A input (10mA to 5A range)
  50A input (1A to 50A range)
- Not only value, trend, and waveform displays but also combination displays are possible. This is convenient because temporal changes can be visually checked while checking the values.
- Voltage, current, and power changes can be checked in the trend display screen.
- Current integral (Ah) and power integral (Wh) functions are available. Furthermore, a battery charge/discharge test can be performed by integration for each polarity.
- The data update interval can be selected from 50ms to 5 seconds.

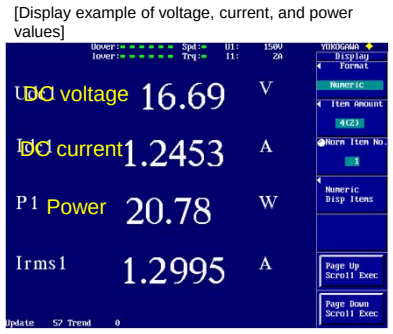
* Trend display refers to a graph display in which the horizontal and vertical axes represent a time axis and data values, respectively.

■Current ad Power Consumption Measurement of Electric Power Tool

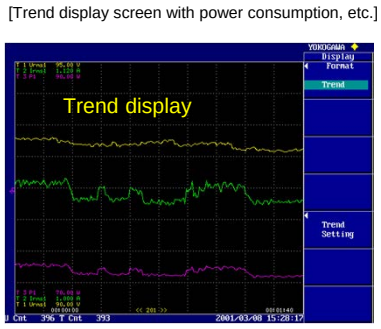


■WT1600 Display and Setting Screens

[Display example of voltage, current, and power values]



[Trend display screen with power consumption, etc.]



Resources Energy

Visual Management of Power Consumption & Energy Saving Support by Multi-Point Centralized Monitoring

Power Measurement Module
InfoEnergy Distributed Energy Monitoring System

Support from Visual Management of Waste Through to Energy Saving Measures

Conformance to an amendment to the Energy Saving Act and the ISO 14000 is a big concern in the field. On the other hand, energy saving is regarded as an effective means of cutting costs and is actively promoted. To implement energy saving measures, it is very important to visually understand activities and results, as well as waste. If locations and quantities of waste can be identified, it is easy to plan and implement measures to make improvements.

Simple Visual Monitoring

The combined use of Datum-Y Portable Data Stations and multi-circuit power modules allows operators to measure and monitor power consumption at up to 32 points. For example, the power consumption of equipment in offices and plants can be easily and precisely monitored.

- No special programming is required for data acquisition because the Datum-Y and multi-circuit power modules communicate via Modbus (RS485) communication.
- Up to 200A current measurement is possible by a clamp-type sensor.

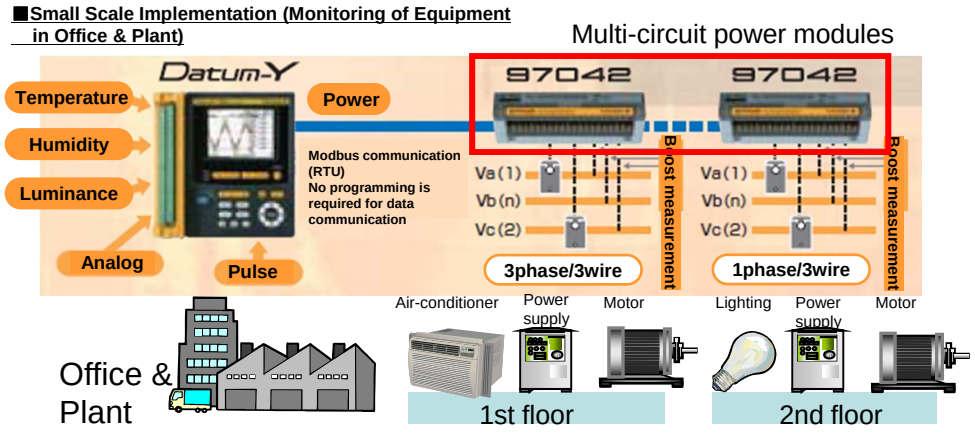
Combined Use with InfoEnergy Enables "Management & Analysis" Plus "Energy Saving Control"

Combined use of multi-circuit power modules and InfoEnergy Distributed Energy Management System allows operators to visually monitor multiple offices and plants on a large scale as well as use "analysis" and "management" functions to save energy.

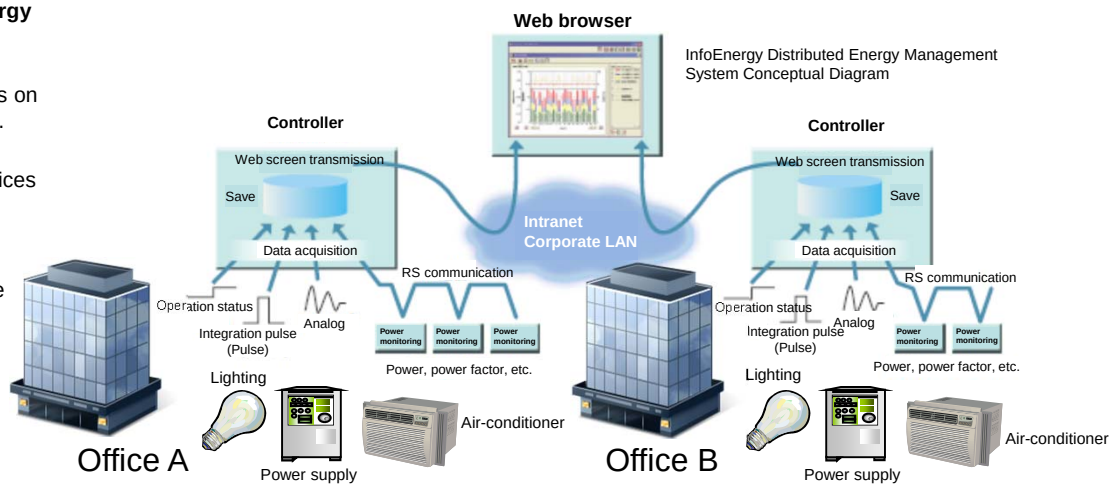
For example, by installing InfoEnergy controllers and multi-circuit power modules in offices and plants located around the country, energy consumption status in the offices and plants can be monitored anywhere and by anyone with a Web browser via an intranet. Furthermore, past power consumption trends can be analyzed to plan and implement concrete energy saving measures and check the effects in real-time.

- Integrated display of data from distributed controllers. One view of both the whole picture and details.
- Web-based system allows all staff members to share the visual data.
- Not only "visual monitoring" but also "energy saving control" are possible.

■Small Scale Implementation (Monitoring of Equipment in Office & Plant)



■Large Scale Implementation (Remote Monitoring of Multiple Offices)



Current & Power Measurement of Electric Equipment Using Clamp Probe

Power Analyzer
WT500

Application Overview

Power measurement for the maintenance of electric equipment in buildings and plants requires not only the checking of values but also the understanding of voltage and power changes through waveforms, and the making of a judgment and taking action on the spot.

Furthermore, a power measuring instrument that is able to deal with various wiring types such as single-phase, single-phase/three-wire, three-phase/three-wire, or three-phase/four wire is required on the spot.

The WT500 is able to not only display values such as voltage, current, phase angle, active power, and power factor as a clamp power meter, but also provide a scope function to observe waveforms and a harmonic bar graph function to visually check harmonic components. Furthermore, the WT500, which can record data to USB memory with high speed over a long period of time, is able to acquire data such as less frequent changes.

Application Points

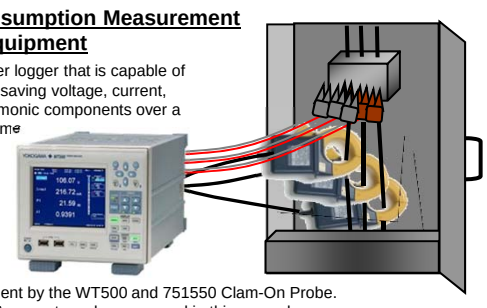
- Clamp power meter capable of measuring large current
- Easy transfer of saved image and value data to PC applications
- Power consumption data acquisition around the clock as a power logger
- Monitoring of changes in the voltage, current, and power values
- Variety of communication functions such as an Ethernet function

Product Features

- Not only direct input measurement but also large current measurement together with a clamp probe are possible.
- Screen images and measured values are saved to the internal memory or USB memory. .
  Reports and graphs can be created on a PC.
- Capable of simultaneously measuring harmonic elements and total harmonic distortion (THD), along with true RMS voltage, current, and power data, and saving up to 1GB of data to external memory such as USB memory.
- Voltage, current, and power changes can be checked in the trend display screen.
- Not only an Ethernet function but also USB and GPIB communication functions are available.

■Power Consumption Measurement of Electric Equipment

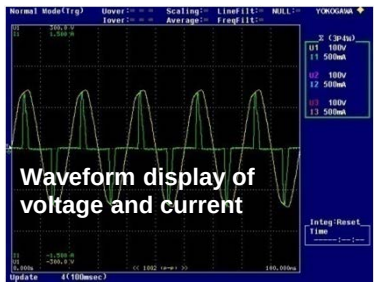
Used as a power logger that is capable of measuring and saving voltage, current, power, and harmonic components over a long period of time



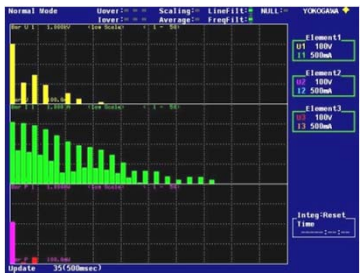
Measurement by the WT500 and 751550 Clam-On Probe.
Up to 400A current can be measured in this example.

■WT500 Display Screen

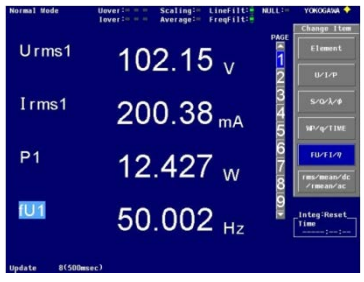
[Waveform display example]



[Harmonic bar graph screen example]



[Voltage, current, and power value display example]



[Power consumption trend display screen example]

Maintenance & Calibration of Field Equipment

Handy Cal CA150
(Yokogawa Meters & Instruments Corporation)

Application Overview

Process equipment and industrial instruments are getting more precise and have an increased number of functions. Furthermore, equipment management standards typified by the ISO and other organizations are getting stricter.

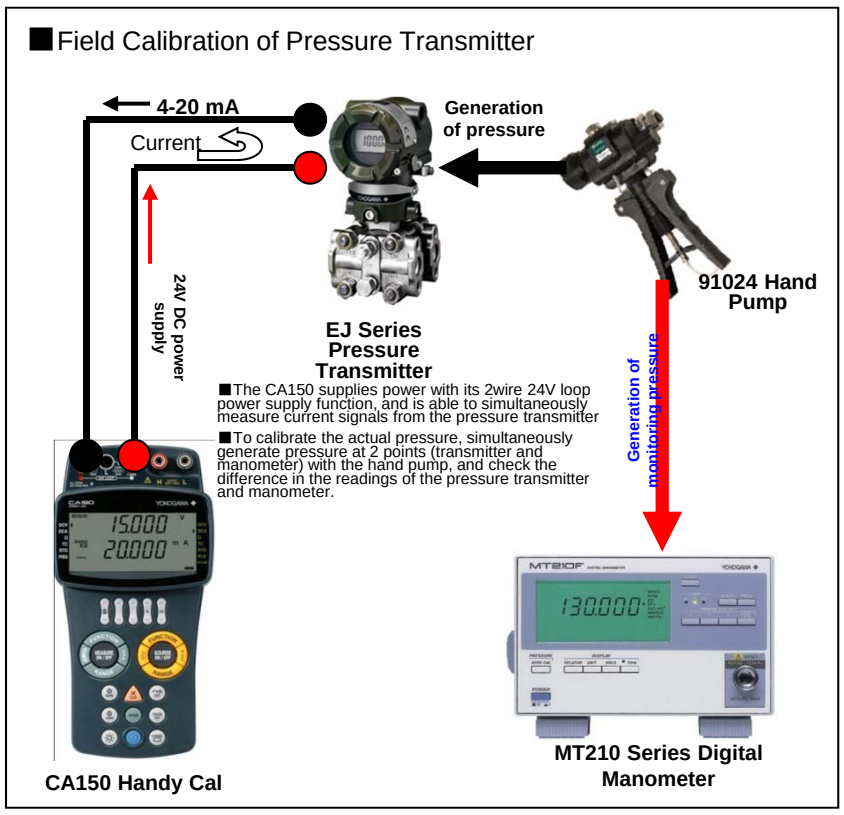
The CA150 Handy Cal is designed to inspect and calibrate equipment in the field, calibration room, or anywhere else in order to support diversified maintenance and calibration tasks.

Application Points

- Two-wire, loop powered equipment compatible
- High-precision calibration can be performed in the field.

Product Features

- Multi-functional, high-precision hand-held calibrator
- Generation/measurement: 0.02% (in the DCV/DCmA range)
- 24V DC loop power supply function, two-wire transmitter, etc. compatible
- SINK function
- Sweep function, and continuous generation function selectable from three types
  - Step sweep function
  - Linear sweep function
  - Program sweep function
- A memory function enables saving inspection and calibration data.
- Compact and portable design: 251x124x70 mm in size, and about 1 kg in weight



Simplified Maintenance of Part Processing NC Machining Center

Clamp-on Power Meter CW240
(Yokogawa Meters & Instruments Corporation)

Application Overview

The time of replacement of the cutter blade for part processing NC machining centers is judged by checking whether the load current peak value on the primary side is larger than the set value.

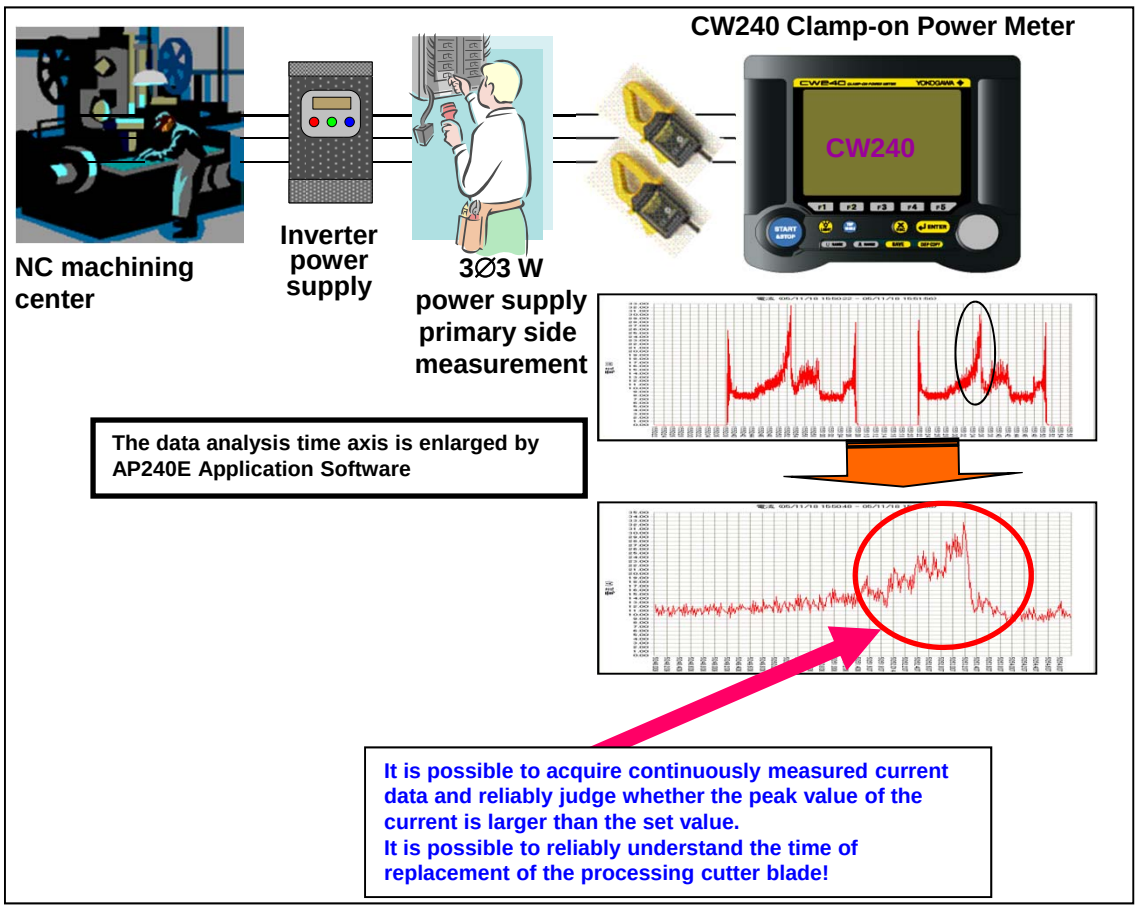
Load current on the primary side is measured and recorded using the CW240. The time of replacement of the worn cutter blade is determined by application software judging the recorded peak value of current.

Application Points

- Measurement without interrupting the circuit is favored in the field for the sake of safety.
- It is necessary to measure distorted current waveforms by continuous sampling.
- Easy-to-run application software is desirable to extract the necessary data.

Product Features

- The power consumption of the motor during processing is measured continuously from one cycle of commercial power supply.
- Current measurement is performed using a clamp.
- It is battery-driven, compact, and light, so it is easy to carry around.
- The measured data can be easily analyzed using the AP240E Data Analysis Software. This is convenient for performing macro and micro analysis.



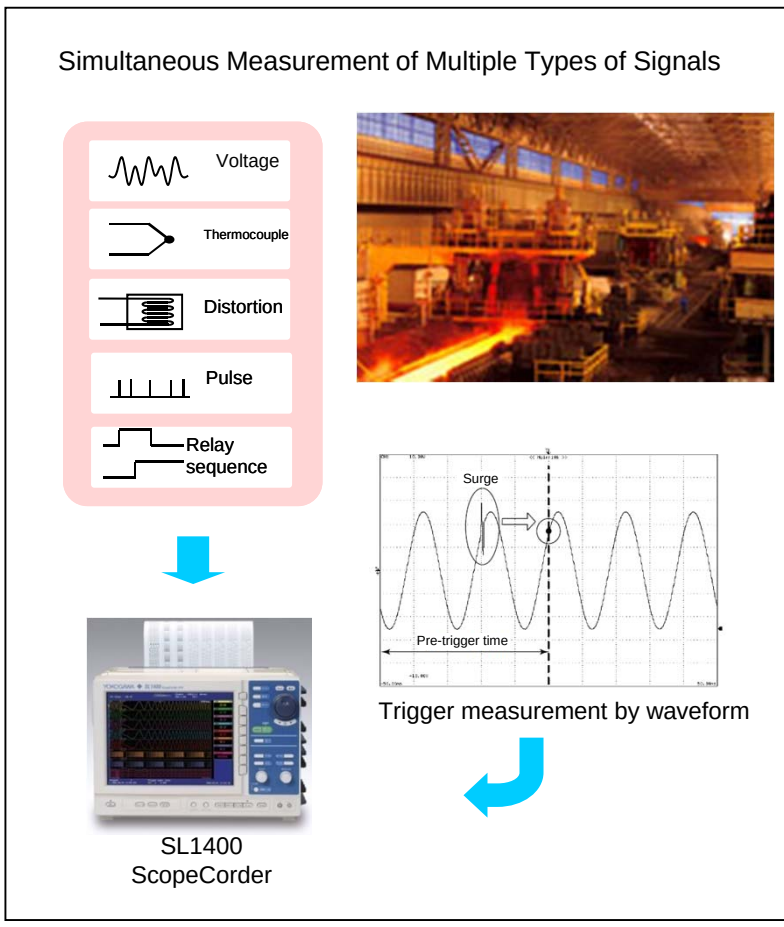
Large Equipment Maintenance

ScopeCorder
SL1400

Application Overview
To perform maintenance of large equipment such as a heat treating furnace and rolling mill, or to perform analysis when problems occur with such large equipment, many signals must be measured simultaneously, and the measurements must be taken over a long time period.

Application Points
The input is isolated, so the power voltage can be measured safely on the spot.
Modules can be selected to directly measure physical quantities such as temperature, frequency, and distortion, and to analyze the correlation between the signals. Up to 16input channels are available plus a 16bit logic input for relay sequence or similar applications.
A Wave-Wind trigger enables trigger detection by an instantaneous power failure, noise, distortion, or other event. Each signal and power supply status can be analyzed in the event of a malfunction.

Product Features
- **Total of 11 types of plug-in modules**
  Various signals such as high-speed voltage, high voltage, high-precision voltage, frequency, temperature, distortion, and acceleration can be synchronized and measured using modules for measuring these signals.
- **Simultaneous recording of chart and digital values**
  Data can be directly recorded on A-size chart paper and to the internal HDD, or saved to USB memory, a memory card. It is convenient o to check and analyze the data on the paper or process the data at a later time.
- **Wave-Wind trigger**
  Power supply waveforms can be monitored in real-time, and if an instantaneous power failure, noise, or distortion occurs, it can be detected by a trigger.



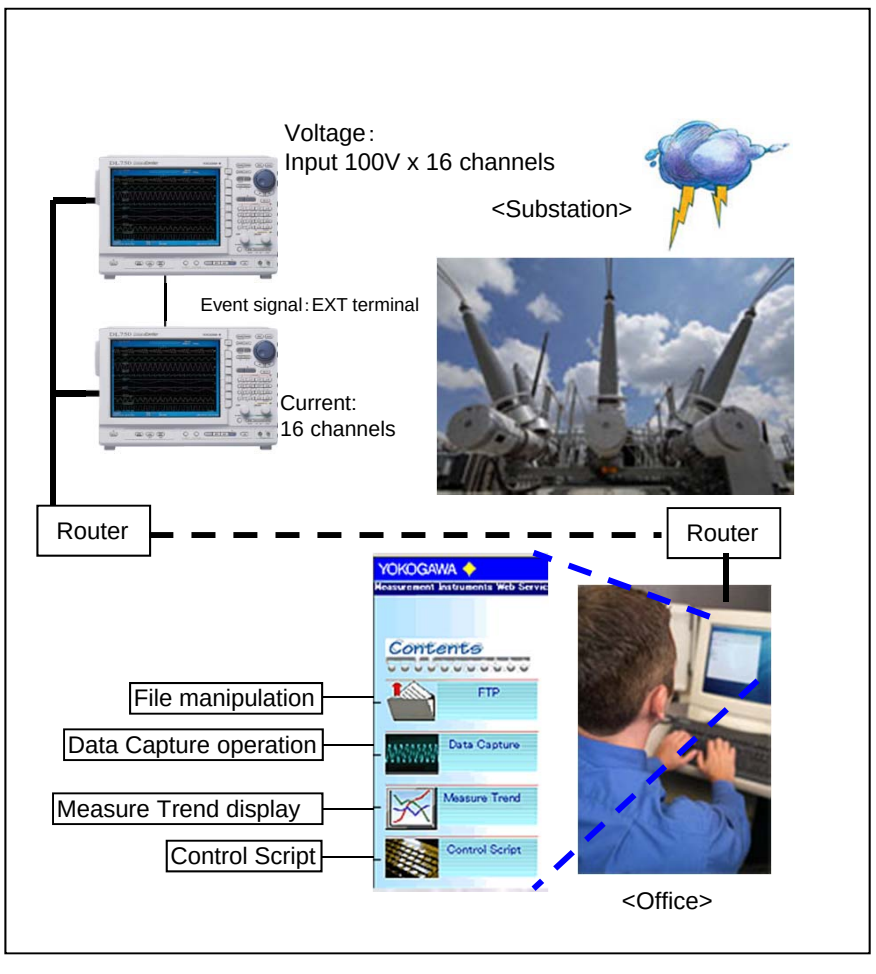
Emergency Monitoring of Major System Faults Caused by Lightning and the Like

ScopeCorder
DL750

Application Overview
System and grounding faults caused by lightning and the like may cause a power failure and affect human lives, so a fast judgment and action are required.
If a system fault occurs in association with electrical substation equipment that sometimes may be unmanned, quick analysis must be performed at a remote electric power office to understand the situation.

Application Points
- Direct isolated input of 100V line voltage
- 50 second continuous observation at 20kS/s
- Data transfer over a few kilometers
- Maintenance cost reduction

Product Features
- **11 types of isolated input modules**
  Isolated input measurement can be performed using various modules for measuring high-speed voltage, high voltage, high-precision voltage, frequency, temperature, distortion, and acceleration.
- **Multi-channel, large memory (up to 1GW)**
  Up to 16 channel input plus 16bit logic input are possible. Ultra-large memory of up to 1GW for 1 channel and up to CH 50MW for 16 channels is available (option).
- **Web Server function**
  Data can be remotely acquired and observed in a browser by connecting to routers.



Application

High-Precision Measuring Instruments Support Implementation of Innovative Power Infrastructure “Smart Grid”

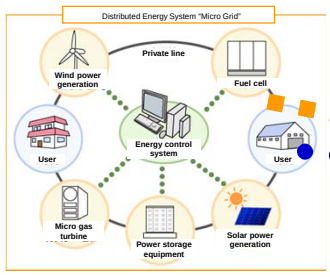
Development and installation of power generating systems using natural energy such as solar and wind power are underway toward realization of a Low-Carbon Society. A ”smart grid” aims to integrate these new power generating systems with the existing ones, and combine them with leading-edge communication technology to construct a global environmentally friendly, efficient, next-generation power grid that makes use of the advantages of both systems. The output of power generating systems using natural energy greatly changes depending on the weather conditions; therefore, to make sure power is supplied stably, it is essential to evaluate the behavior of the power grid, as well as its components, such as power generating systems and inverters. Yokogawa meets these needs with its high-precision measurement technology typified by its power meters and waveform measuring instruments, and contributes to the realization of the next-generation power grid and a low-carbon society.

WT3000
Power Analyzer

DLM2000
Mixed Signal Oscilloscope

DL750/SL1000 Series
ScopeCorder

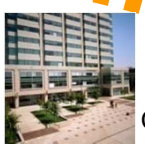
AQ7275
Optical Time
Domain Reflectometer



Pumped storage generation

Thermal power generation

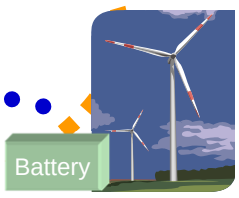
Nuclear power generation



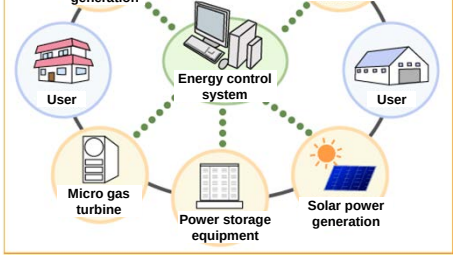
Office

Plant

Monitoring & control of power grid



Wind power generation



Home
- Solar battery
- Inverter
- Smart meter

Solar power generation

Fire Detection, Disaster Prevention, & Energy Saving

Optical Fiber Distributed Temperature Measuring Instrument
AQ8920/AQ8940

Application Overview

Taking advantage of the fire proof and corrosion resistant properties of optical fiber, an optical fiber distributed temperature measuring instrument can be used to measure the temperature distribution in a wide range of applications, including monitoring of high-temperature furnace in iron and steel plants, leakage from LNG tanks and pipelines in petrochemical plants, detection of fire in yards, belt conveyer, and tunnels, and monitoring of the power line temperature.

Furthermore, it can be used to measure the temperature distribution in rooms (e.g., in a data center) to provide information for optimizing the air-conditioning operation, thus contributing to energy-saving operation.

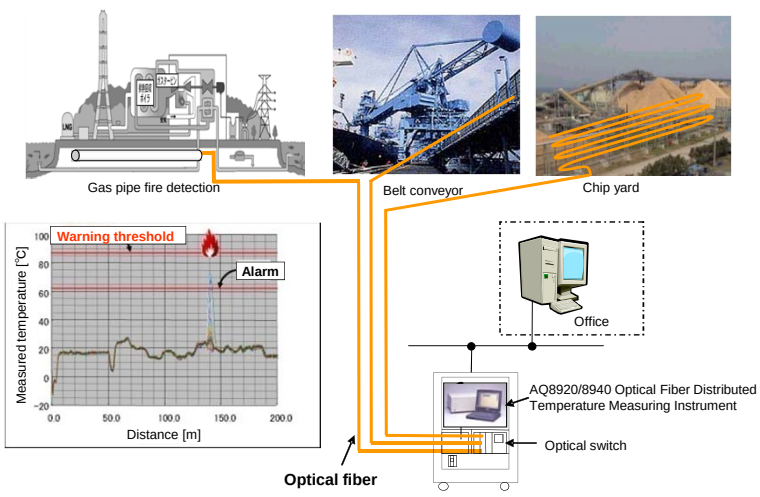
Application Points

Use of optical fiber in the temperature sensor achieves excellent fire proof and corrosion resistant properties. Measurements are not affected by lightning, and electric and magnetic fields. The AQ8920 and AQ8940 are expected to be used for the temperature control of plant equipment, and for air-conditioning applications in large buildings.

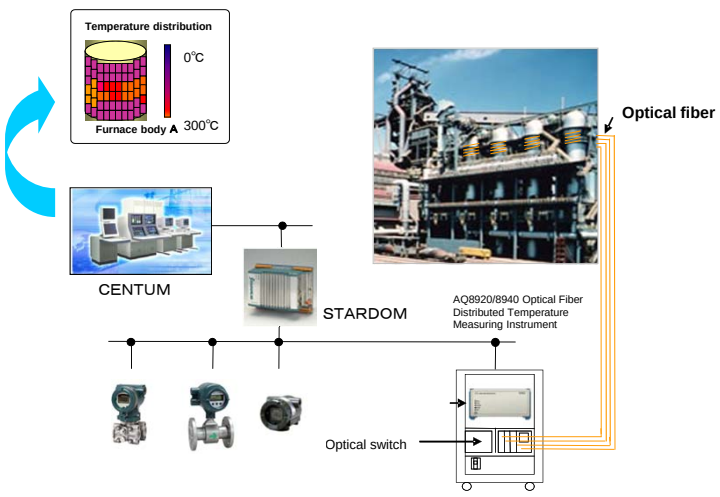
Product Features

The AQ8920 is distributed temperature measuring equipment that uses optical time domain reflectometer (OTDR) technology. Optical fiber is connected to the AQ8920 and optical pulses are input. The AQ8920 detects the backscattered light (Raman scattered light) and converts it to a temperature distribution.

- Continuous measurement of up to 2-km temperature distribution at a distance resolution of 2 m
- Measurement of up to 1-km temperature distribution at ±1°C precision
- The AQ8940 is able to continuously measure up to 10-km temperature distribution at a distance resolution of 1.5 m.



Example of Plant Fire Detection System



Example of High-Temperature Furnace Emergency Temperature Detection System

Loss Measurement & Bending Loss Detection for WDM Transmission Line

Optical Time Domain Reflectometer (OTDR)
AQ7275

With the rapidly growing popularity of broadband services, communication capacity is being increased through the use of Wavelength Division Multiplexing (WDM) transmission equipment. There are two types of WDM, Coarse WDM (CWDM) and Dense WDM (DWDM), which use the wavelengths shown in Figure 1. Installed optical fiber used for WDM is required to measure the loss at the maximum wavelength of 1625 nm, and some manufacturers guarantee a loss at 1625 nm for their optical fibers.

The transmission loss of optical fiber generally increases when the wavelength is longer than 1550 nm, which is a wavelength used for communication. Optical fiber bending loss also increases as shown in Figure 2.

Accordingly, loss measurement at 1625 nm is required for WDM, and detection of a loss caused by the bending of installed optical fiber is also useful for the fault analysis of communication problems.

Application Points

- The quality of optical fiber used for WDM can be checked by loss measurement at 1625 nm.
- Analysis to identify the location of faults in the installed fiber

Product Features

- Variety of wavelength options for Multimode and Single-mode fiber
  - ・GI50 and GI62.5：850/1300 nm
  - ・SM：1310/1490/1550/1625/1650 nm
- 0.8 m event dead zone

Detect connection points in close proximity to each other in offices, homes, etc.

- Up to 45 dB high dynamic range

Measure over 100 km ultra-long haul optical fiber cable

- Quick startup within 10 seconds

Start measurements quickly after arriving on the site.

- Multi-wavelength measurement enables continuous measurement by switching between wavelengths

Automatic switching: 1310 nm ➞ 1550 nm ➞ 1625 nm

- 8.4-inch large LCD in a compact body

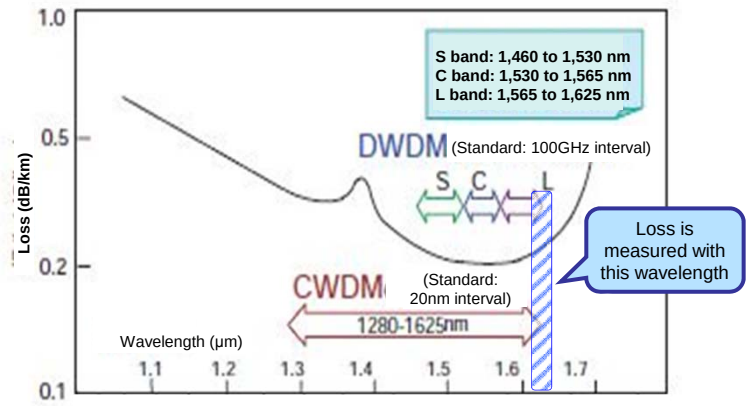


Figure 1 Wavelength Band Used for WDM and Measured Wavelength

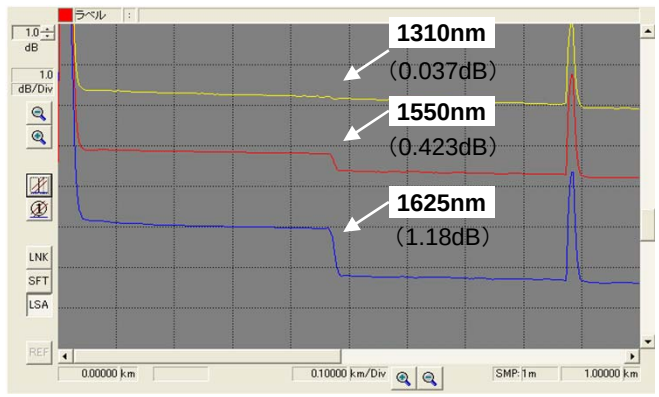


Figure 2 Bending Loss Characteristics by Wavelength
(Bending: optical fiber is turned 5 times around a 30mm diameter cylinder)

Search for Fault in Presence of Active Optical Communication Signals

Optical Time Domain Reflectometer (OTDR)
AQ7275

In PON systems such as G-PON/GE-PON, which are widely used for Fiber To The Home (FTTH), an optical signal from Optical Line Terminal (OLT) is split by the splitter to be sent to the subscribers as shown in Figure 1. Fault analysis for an optical fiber line at a subscriber home is often performed in the presence of active optical communication signals (live service) from the OLT, as shutting off the optical signals results in service disruption for other subscribers. When a standard OTDR is used in the presence of live service it is inaccurate as shown in Figure 2. Accurate measurements and proper fault identification require an OTDR with an internal filter that “cuts off” the live service signals before they enter the OTDR. The advantage of this cut filter is shown in Figure 3.

Application Point

- Search for a fault in the presence of “live service” (active optical communication signals)

Product Features

- Models with internal “cut” filter
  - 735031：1650 nm
  - 735036：1310/1550/1625 nm
  - 735037： 1310/1550/1650 nm
- 0.8 m event dead zone

Detect connection points in close proximity to each other in offices, homes, etc.

- Quick startup within 10 seconds

Start measurements quickly after arriving on the site.

- 8.4-inch large LCD in a compact body

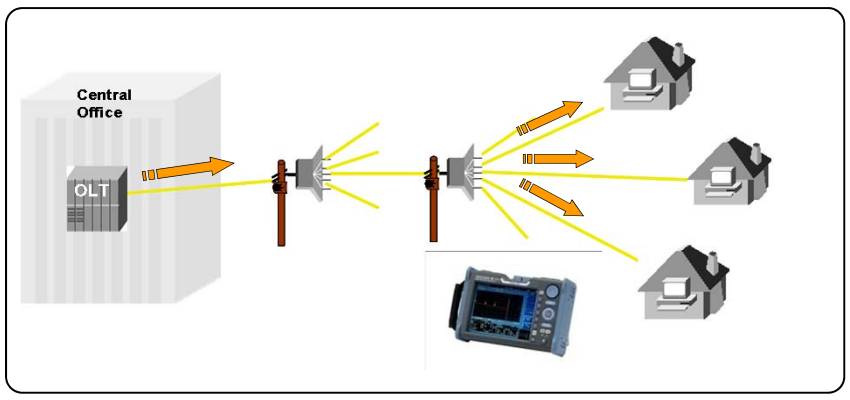
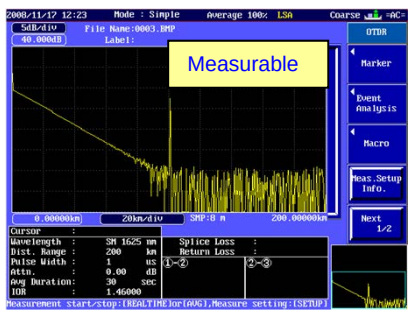


Figure 1 PON System Configuration

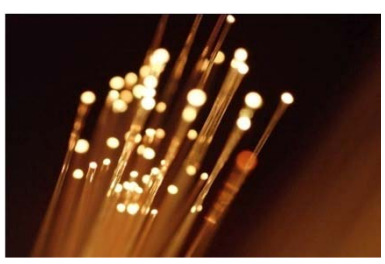
1625nm, Pw;1μs, active optical signal：-19dBm

Figure 2 Example of measurement without filter (735024)



1625nm,Pw：1μs, active optical signal：-19dBm

Figure 3 Example of measurement by a model with internal filter (735036)



Wavelength Monitoring & Wavelength Line Control of Transmission Equipment Supporting NGN

WDM Monitor WD300
Optical Channel Monitor WD30

Application Overview

Data communication traffic, including Internet traffic, increases not only in developed countries but also in emerging countries. Systems that provide a basis for transmitting and routing these large amounts of data are optical fiber communication systems. Optical fiber is a medium with low loss, so it is able to transmit a large amount of data over a long distance with high quality. Furthermore, it is easy to increase speed with optical fiber.

The figure on the right shows a basic network configuration of optical fiber communication. Wavelength Division Multiplexing (WDM) optical transmission is used as it simultaneously transmits optical signals of multiple wavelengths to increase capacity at a low cost. Photonic networks use all-optical equipment such as reconfigurable optical add-drop multiplexers (ROADMs) and optical cross connects (OXCs) to route optical signals between sub-networks without costly conversion from optical to electrical and back to optical.

The figure on the right shows a specific example of these networks. Many wavelengths are used, so it is essential to maintain the absolute precision of optical wavelengths and control optical power levels in order to ensure stable operation and high performance. The WD300 Monitor and WD30 Optical Channel Monitor are used to control these networks, maintain stability, and control optical path switching.

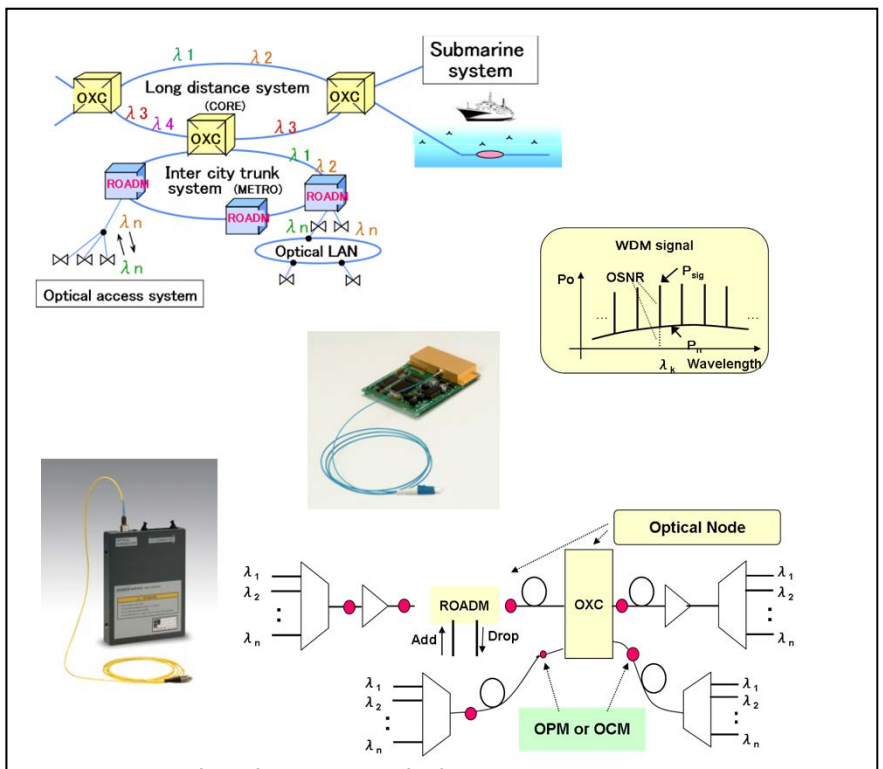
Application Points

Monitors are required to be high performance, high reliability, high-speed to control optical fiber systems and perform high-speed line switching. Furthermore, they must be compact and light because they may be incorporated in transmission equipment.

Product Features

Yokogawa developed and commercialized the WD series using key photo diode array and optical sensors technology developed and manufactured in-house. This proprietary optical design has improved environmental characteristics for temperature and polarization-dependency and employs a no-moving part method (polychromator). Yokogawa's monitors are excellent in terms of speed, performance, and reliability.

They can be used in systems with a wavelength interval of 50 GHz, and a transmission rate from 10 Gbps to 40 Gbps. The WT300 is also able to measure the optical signal-to-noise ratio (OSNR).



- WDM network performance monitoring
- Equalization and pre-emphasis of channel power
- Gain control of EDFA
- Control wavelength at transmitter

40Gbit/s Transponder Test

40G Transport Analyzer
NX4000

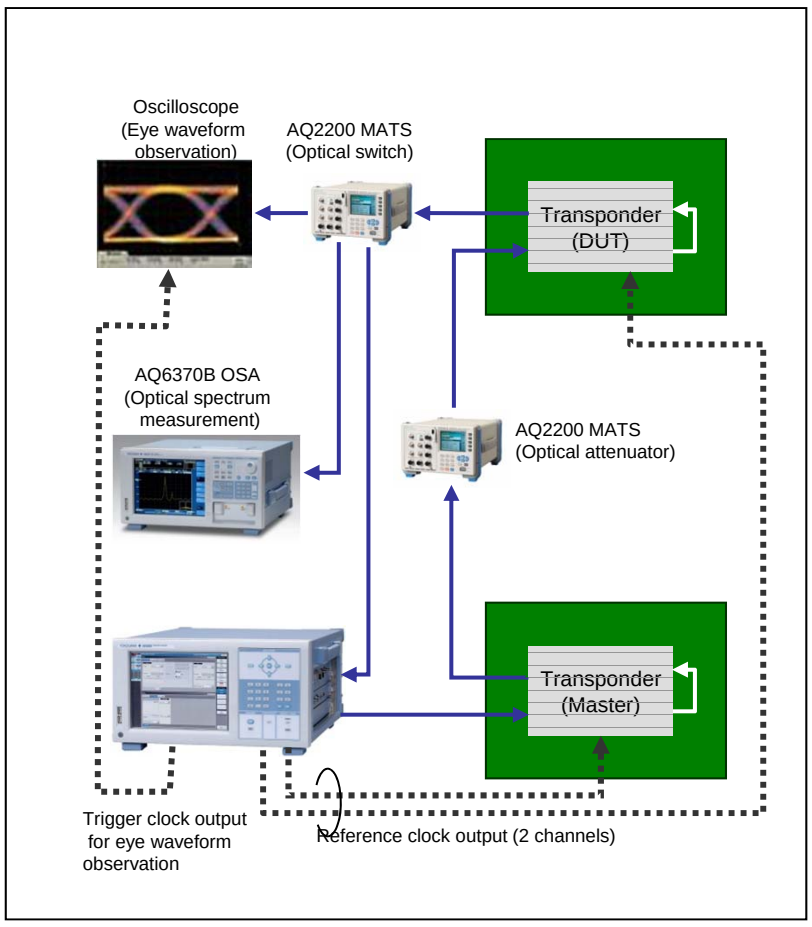
With the growing popularity of broadband communications such as Fiber To The Home (FTTH), the speed and capacity of backbone communication networks are growing by leaps and bounds. At the moment, the maximum transmission rate per wavelength has reached 40 Gbit/s (4 billion bits/s), and at the same time, research and development, and commercialization of new technologies such as optical modulation/demodulation are underway with the aim of realizing long distance transmission over a distance of a few hundred kilometers. A subsystem that integrates these leading-edge technologies and is used at the front end of systems is the 40-Gbit/s transponder. This section describes an application that tests and verifies the quality and characteristics of 40-Gbit/s transponders.

Application Points

- Non-frame testing
A simple setup capable of testing the transmission quality characteristics using a Bit Error Rate Test (BERT) with PRBS 7, 9, 10, 11, 15, 23, and 31.
- Trigger clock output for an oscilloscope
A 1/N trigger clock can be output so it is easy to observe waveforms with an oscilloscope.
- Reference clock output for a transponder
Output to each of the master transponder and transponder under test (DUT) is possible, so no external synthesizer is needed.
- Auto sync OFF function
A function to not automatically establish frame synchronization is implemented so it is possible to measure error rates as high as 1E-2.
- Total measurement solution
A modulated light spectrum can be measured in conjunction with the AQ6370B Optical Spectrum Analyzer. Also the AQ2200 Multi Application Test System (MATS) can be used for optical signal switching or as an attenuator.

Product Features

- Optical interface modules for various modulation methods are available to support NRZ (Non Return to Zero), DQPSK (Differential Quadrature Phase Shift Keying), and DPSK (Differential Phase Shift Keying).
- A Frame Edit & Monitoring function enables editing and monitoring of the overhead information of SONET, SDH, and OTN frames, as well as monitoring of payload information.
- Capable of directly mapping 10G LAN-PHY to the OTN frame (44G over-clocking).



10G XFP Optical Transceiver (XFP) Measurement System

Multi-Application Test System
AQ2200

Yokogawa's optical measuring instruments provide an efficient and accurate measurement environment for the development and manufacture of optical devices and equipment such as optical transceivers. The optical transceiver test system enables basic optical measurements using variable optical attenuators, optical switches, optical power meters, optical spectrum analyzers, etc, and can provide a total test solution for single-mode and multimode fiber transceivers when used in conjunction with a bit error tester and optical sampling oscilloscope.

Application Points

Compact space-saving plug-in module

Flexible and easy to change test system

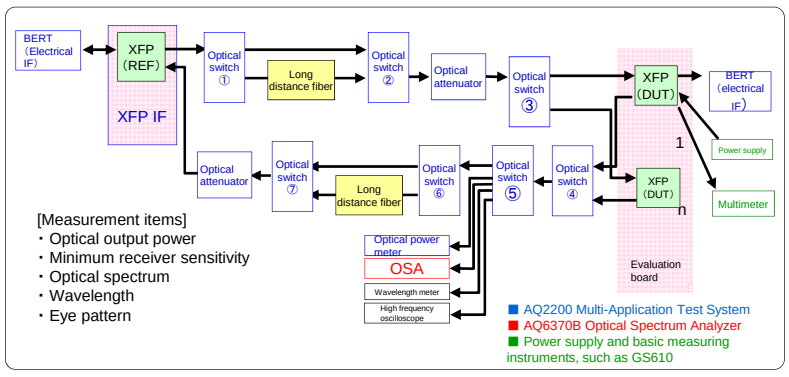
Various measurements can be integrated into one system.

Input power can be directly set by an optical attenuator with power monitor.

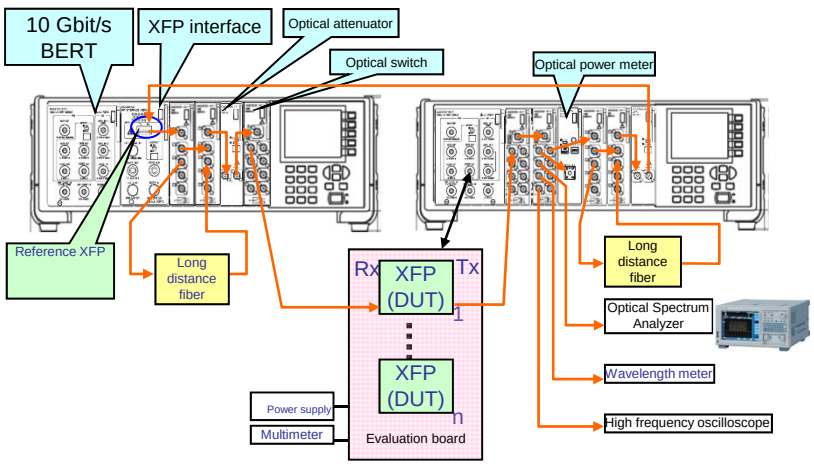
Product Features

- Compact space-saving plug-in module
Less than half the size of conventional systems
- **Flexible system building, and easy to change**
The modular platform that allows for accommodating an optical power meter, optical switch, optical attenuator and the like makes it easy to build an automatic measurement system, helping optical device manufacturing increase measurement throughput.
- **Smart attenuator can directly set an output power**
The bit rate error margin of an optical transceiver is measured by changing the receiving optical level of the optical transceiver. By incorporating an optical splitter and optical power meter into the module a compact system enables easy setting of the optical output level.
- **Optical switch allows for making various measurement configurations**
Switching between measurement paths via an optical switch module makes it possible to perform various measurements such as bit error rate measurement, optical spectrum measurement and eye pattern measurement by an oscilloscope.
- **Low cost optical bit rate measurement solution by the XFP interface module**
A low cost optical bit rate error measurement system can be constructed using a commercial XFP optical transceiver as the reference optical interface. Furthermore, the XFP interface module, which is able to control the reference XFP and supplies power, can also be used for troubleshooting by changing the transmission/receiving conditions of the reference XFP.

10G Optical Transceiver (XFP) Measurement System Configuration



XFP Measurement System Integrated into Just Two Frame Controllers



Transmission Characteristic Evaluation of Narrow-Band Optical Filter for Communication

Optical Spectrum Analyzer
AQ6370B

Optical communication systems using Wavelength Division Multiplexing (WDM) technology have many high-performance narrow-band filters such as optical multiplexers (MUX), optical demultiplexers (DEMUX), and optical bandpass filters. The performance requirement for these parts is strict in order to ensure transmission quality. Therefore, it is necessary to measure the insertion loss of the transmission and blocking bands for wavelengths in a wide wavelength range and in a high dynamic range. A tunable laser source is used to perform these measurements that cannot be performed by a conventional white light source or ASE light source.

Application Points

- Wide measurement wavelength range and wide dynamic range.
- High wavelength resolution captures even narrow-band characteristics.
- High-speed measurement

Product Features

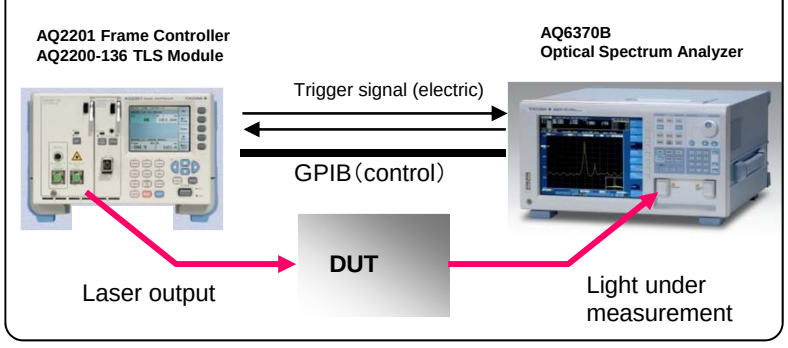
- Up to 90 dB wide dynamic range
The dynamic range can be extended by using a tunable laser that emits a very powerful beam of light. However, unnecessary light emissions such as spontaneous emission included in the laser beam interferes with achieving a high dynamic range. A high dynamic range can be achieved by shutting out those unnecessary light emissions by the filter effect of the optical spectrum analyzer.

- Maximum 200 nm wide measurement wavelength range
The tunable wavelength range of the AQ2200-136 (1440 to 1640 nm) covers the S-, C-, and L-bands of the ITU grid, which are the world standards for WDM, so an arbitrary wavelength range can be set according to the wavelength band of the device under test (DUT).

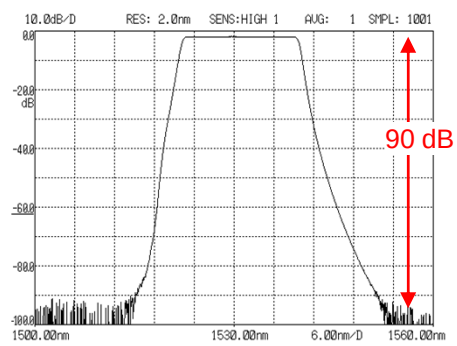
- Maximum 0.001 nm high wavelength resolution
Only the peak power of the laser at a selected wavelength is used for measurement, so a higher wavelength resolution can be achieved without being limited by the resolution of the optical spectrum analyzer (max. 0.02 nm).

- High-speed automatic measurement by synchronous sweep
The AQ2200-136 tunable laser and AQ6370B Optical Spectrum Analyzer have a synchronous sweep function that automatically performs measurement by simultaneously changing the laser and measurement wavelengths via synchronization signals. Measurement is completed in a shorter time than when controlled by an external PC.

Synchronized Sweep Measurement by Variable Wavelength Light Source and Optical Spectrum Analyzer



Measurement Example of DEMUX for CWDM



Example of measuring one port (1531nm) of DEMUX for CWDM by setting the level sensitivity to HIGH1

Measurement results were displayed on the AQ6370B screen

(A 90 dB dynamic range refers to a difference between the reference measurement line and the noise level)

Transmission & Blocking Characteristic Evaluation of Narrow-Band Optical Filter for Optical Communication

Multi-Application Test System
AQ2200

Some optical components, such as filters, need to be evaluated for rapid changes in the insertion loss characteristic for wavelengths. To measure such characteristics, it is necessary to perform measurements at a high measurement resolution by increasing the number of measurement points on a wavelength axis. A general method for this measurement is to use a tunable laser source and optical power meter to measure the optical power for each wavelength by switching between wavelengths point by point. However, this method requires about 1 second to measure one point, and the measurement time increases in proportion to the number of measurement points, thus reducing evaluation and manufacturing efficiency. High-speed measurement with high resolution can be achieved by constructing a synchronized sweep measurement system combining a tunable laser module and optical power meter module.

Application Points

- Compact and space-saving measurement configuration
- Wide measurement wavelength range and wide dynamic range
- High wavelength resolution to capture narrow-band characteristics
- High-speed measurement

Product Features

- Compact and space saving

This measurement system requires neither a control PC nor external equipment, and is completely accommodated in an AQ2201/AQ2211 frame controller, so work space can be effectively used.

- Maximum 60 dB wide dynamic range

Combined use of a tunable laser that emits a powerful laser beam of light and optical power meter with high measurement sensitivity achieves a wide dynamic range.

- Maximum 200 nm wide measurement wavelength range

The wavelength tuning range of the AQ2200-136 (1440 to 1640 nm) covers the S-, C-, and L-bands of the ITU grid that are world standards for WDM, so an arbitrary wavelength range can be set according to the wavelength band of the device under test (DUT).

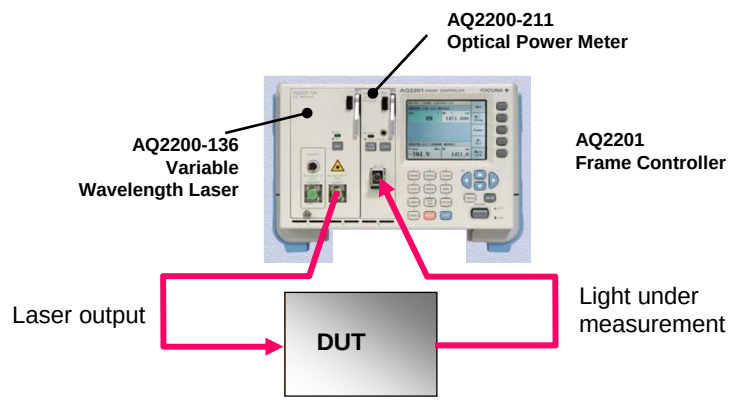
- Maximum 0.001 nm high wavelength resolution

Only the peak power of the laser at a selected wavelength is used for measurement, so a high wavelength resolution can be achieved for measurement.

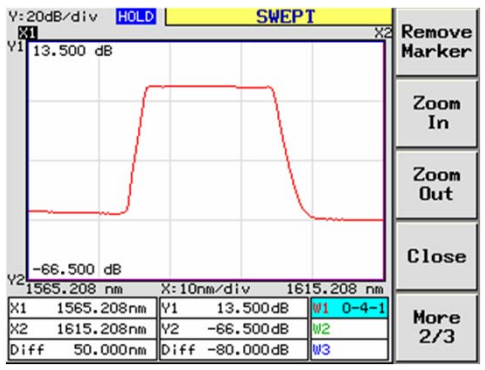
- Maximum 50nm/s High-speed synchronous sweep

The AQ2201/AQ2211 Frame Controller's standard synchronous sweep function automatically performs measurement by simultaneously changing the laser source and measurement wavelengths via synchronization signals. Measurement of the maximum 200 nm wavelength range can be completed in about 4 seconds.

System Configuration of Narrow-Band Filter Measurement



Measurement Example of DEMUX for CWDM



Example of measuring one port (1591 nm) of 8 channel DEMUX for CWDM

DUT is a multi-layered thin film filter (TFF).

The measurement results can be displayed in a graph on the AQ2201 screen.

Light-Emitting Spectrum Evaluation of DFB-LD

Optical Spectrum Analyzer
AQ6370B

Optical transceivers are optical transmitting/receiving modules indispensable to the construction of optical fiber networks. An optical transceiver consists of mainly laser diodes, and the typical laser diode device is a Distributed Feed-Back Laser Diode (DFB-LD). A DFB-LD laser has only one wavelength for the output beam of light, and its performance evaluation is performed using unique parameters that are different from other optical devices. Typical evaluation parameters of DFB-LD include a peak wavelength, peak wavelength level, side-mode suppression ratio (SMSR), spectral width, and mode spacing. These are evaluated by measuring the optical spectrum and analyzing the measured waveforms.

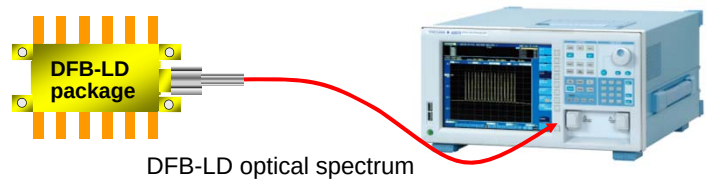
Application Points

- Separation of laser oscillation mode
- Measurement of low-level side mode
- Measurement speed
- Automatic analysis of evaluation items
- Saving of measurement results

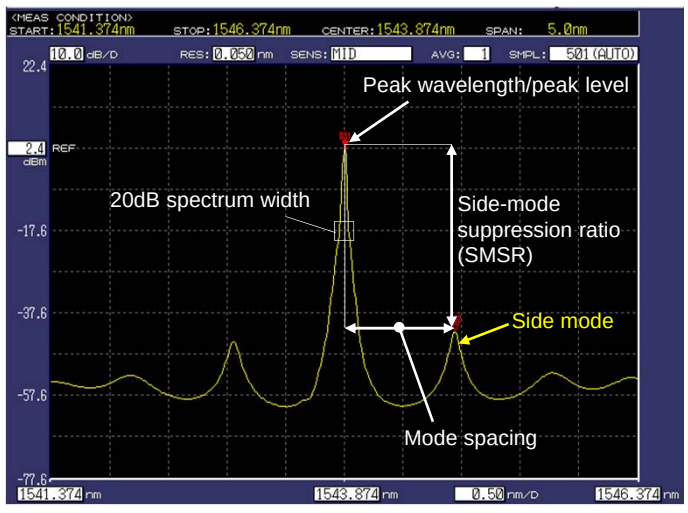
Product Features

- Laser oscillation mode is sharply separated with a high wavelength resolution (max. 0.02 nm).
- Wide measurement level range (+20 to -90 dBm) and wide dynamic range (70 dB)
- High-level main oscillation mode and low-level side mode can be simultaneously measured.
- High-speed optical spectrum measurement in 0.5 seconds
- Standard DFB-LD analysis function automatically analyzes the following evaluation items.
  - Peak wavelength (PEAK WL): Wavelength in the highest level mode
  - Peak level (PEAK LEVEL): Level in the highest level mode
  - Side-mode suppression ratio (SMSR): Obtain the difference between the highest level mode in the optical spectrum (peak) and the second-highest level mode (side mode).
  - 20 dB spectral width (SPEC WIDTH): Obtain the spectral spread.
  - Mode spacing (MODE OFFSET): Obtain the difference in wavelength between the peak wavelength and side mode.
- The measured waveforms and analysis results can be easily saved to the internal memory or external memory (USB), and edited on a PC.

DFB-LD Light-Emitting Spectrum Measurement



DFB-LD Optical Spectrum and Evaluation Items



Automatic Analysis Results

Mobile Phone Current Consumption Measurement

ScopeCorder
DL750

Application Overview
Measurement and analysis of the current consumption of mobile handsets during the standby time and connection time are essential for the development of efficient mobile handsets.
Furthermore, mobile handset chips are designed like a black box, so measurement of the current consumption of mobile handsets under the desired usage conditions is the key to the analysis of the correlation with each of the chips.

Application Points
For normal oscilloscopes that have a limitation of 8-bit vertical axis resolution, it is inconvenient to analyze the waveforms of current values whose peaks change dynamically. When the zoom function is used for detail analysis the limitation is obvious.
In addition, when the measurement sampling rate is set to about 100 kHz and the longest possible measurement is required, it is difficult for general oscilloscopes with limited memory capacity to perform the measurement.

Product Features
- **16-bit high-resolution module**

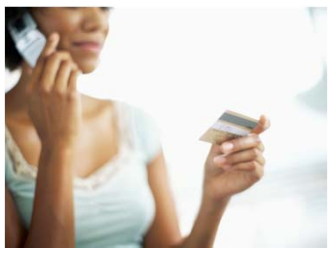
16-bit high-resolution measurement can be performed using modules for measuring various signals such as high-speed voltage, high voltage, high-precision voltage, frequency, temperature, and acceleration.

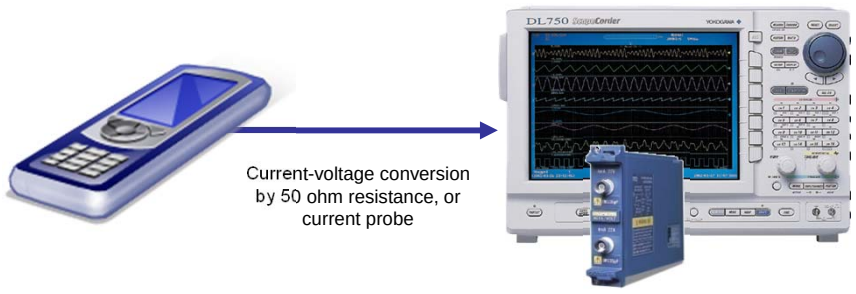
- **Multi-channel, large memory (up to 1 GP)**

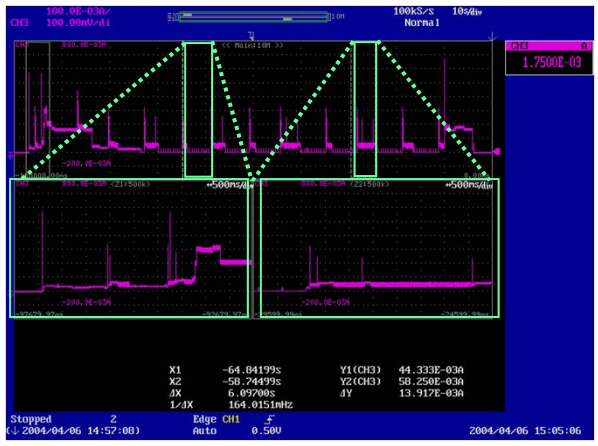
Up to 16 channel inputs with 16-bit logic is possible. Ultra-large memory with up to 1 GP storage for 1 channel and up to 50 MP for each of the 16 channels is available (option).

- **DSP channel (option)**

An individual digital signal processor (DSP) is provided for each of the channels (6 channels) and inter-channel calculation is performed in real-time while waveforms are being captured, so total current consumption can be displayed in real-time.



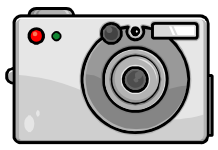




Current waveform transition over 100 seconds
from the point the power is turned on (in the upper part of the screen)
Zoomed up waveforms of the specified areas (in the lower part of the screen)

Flash Light Emission & Timing Evaluation

Digital Oscilloscope DL9000
Mixed-Signal Oscilloscope DL9740L/DLM2000



Application Overview
An automatic light-controlled flash circuit of digital cameras is required to be adjusted to get a proper exposure according to a variety of conditions.

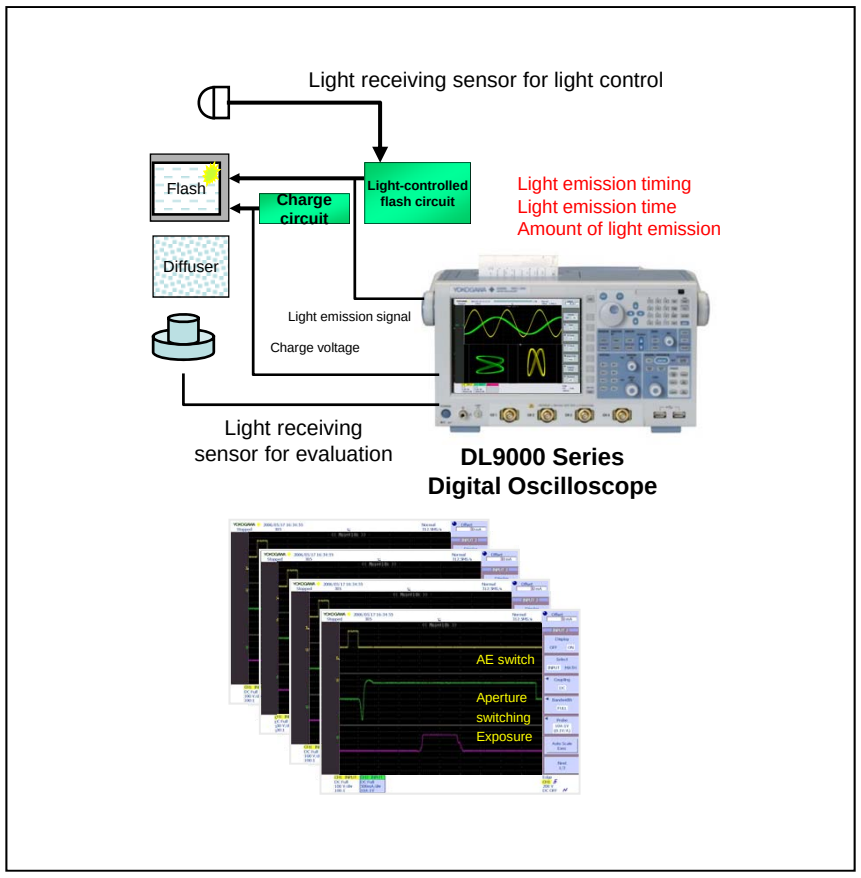
Application Points
To adjust the automatic light-controlled flash circuit properly, it is necessary to store and analyze many control and exposure signals. It is also necessary to find unusual light emission waveforms among many stored waveforms or measure the parameters at the moment of light emission for each waveform.

Product Features
- History memory function

A history memory function that holds the past waveforms acquired by each trigger captures the less frequent, unusual events.

- Statistical calculation function for history memory waveforms

Parameter calculation and statistical calculation can be performed for each of the waveform records stored in the history memory. Maximum, minimum, average, and standard deviation can be obtained for each parameter.



Drooping Characteristic Measurement of Compact AC Adapter

Source Measure Unit
GS610

Application Overview

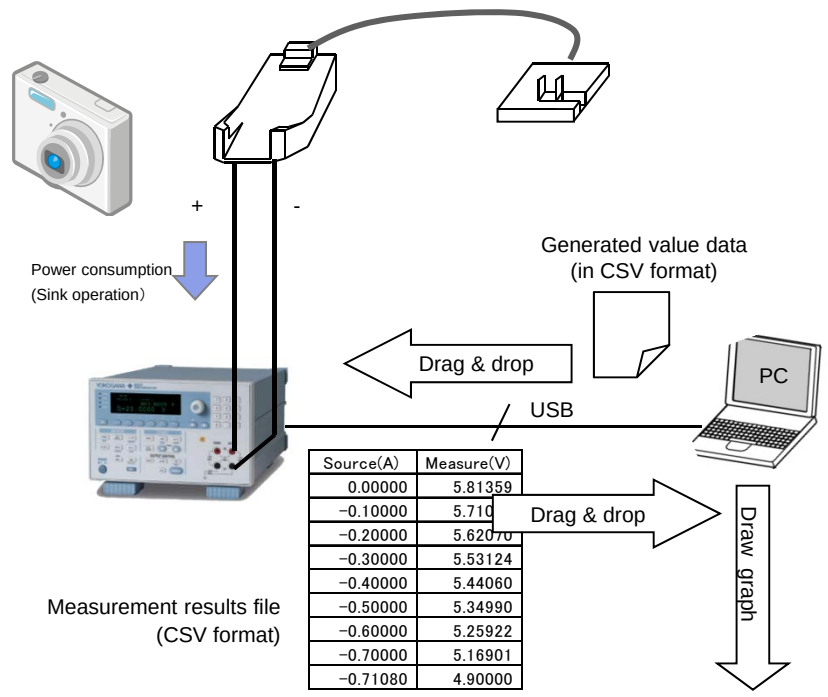
The output characteristic of compact AC adapters used in mobile phones, digital cameras etc. must be measured. To measure the output characteristic of the power supply, the load status is changed from no load (open) through to overload (short-circuit), and the relation between the load current and terminal voltage is measured and a graph is drawn. This characteristic generally exhibits a drooping curve like the constant current curve shown in the figure.

Application Points

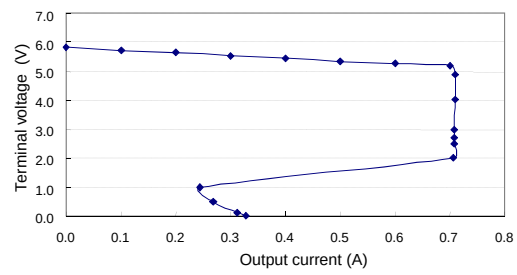
The GS610 performs a constant current or constant voltage sink operation as a load for the AC adapter and measures the drooping characteristic. The load current is sunk in the constant voltage area and the terminal voltage is measured then a load voltage is determined in the drooping area and a switch to the output current measurement operation of is made to complete the measurement.

Product Features

- Basic voltage accuracy: ±0.02%, basic current accuracy: ±0.03%
- Automatic switching of operation mode between the constant current drive and constant voltage drive
- Data acquisition and graph drawing using a general-purpose worksheet



Source(A)	Measure(V)
0.00000	5.81359
−0.10000	5.710
−0.20000	5.62070
−0.30000	5.53124
−0.40000	5.44060
−0.50000	5.34990
−0.60000	5.25922
−0.70000	5.16901
−0.71080	4.90000



Drooping Characteristic of Power Supply

Serial Signal Analysis in Firmware

Digital Oscilloscope
DL9000 Series

Application Overview

Tuners of digital TVs and slow devices are controlled by firmware via the I²C bus or SPI bus. To keep development efficient, it is necessary to be able to observe the serial bus and understand its values quickly in order to make sure the firmware operates as expected.

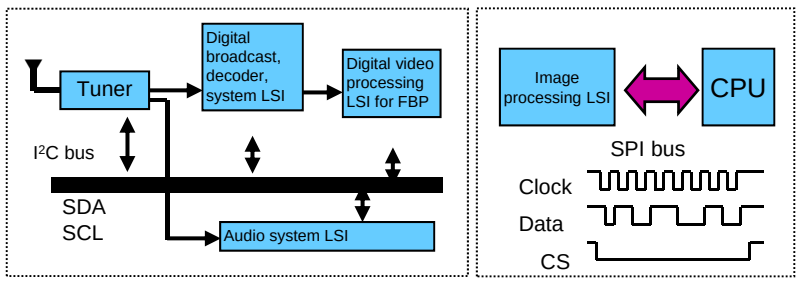
Application Points

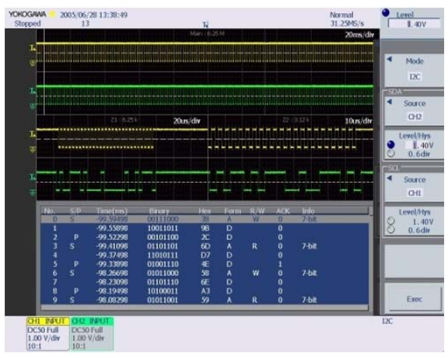
- Observation over a long time is required to control the software.
- Some systems use multiple serial bus interfaces.
- The ability to simultaneously analyze multiple serial buses increases development efficiency.

Product Features

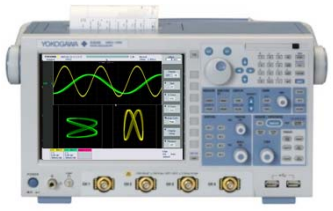
- The following serial buses are supported: I²C, SPI, UART, CAN, and LIN
- Simultaneous analysis of 2 types of buses (DL9000/SB5000/DLM2000)
- I²C, SPI, and UART triggers and analysis by logic input are possible (SB5000/DLM2000)
- Capable of performing high-speed real-time analysis
- High-speed sampling and long time measurement with large memory
Up to 125MPoints (/M2 option) large memory (DLM2000)
- HDTV, NTSC, and TV triggers available as standard
- TV trigger (NTSC/PAL, SDTV/HDTV) compatible as standard
- Special format signals can be set by user definition.

The simultaneous real-time analysis and waveform function of serial buses (I²C and SPI) improves debugging efficiency





Example of I²C analysis screen



I²C Signal Evaluation in HDMI Interface

Digital Oscilloscopes
DL1600/DL1700 Series

Application Overview

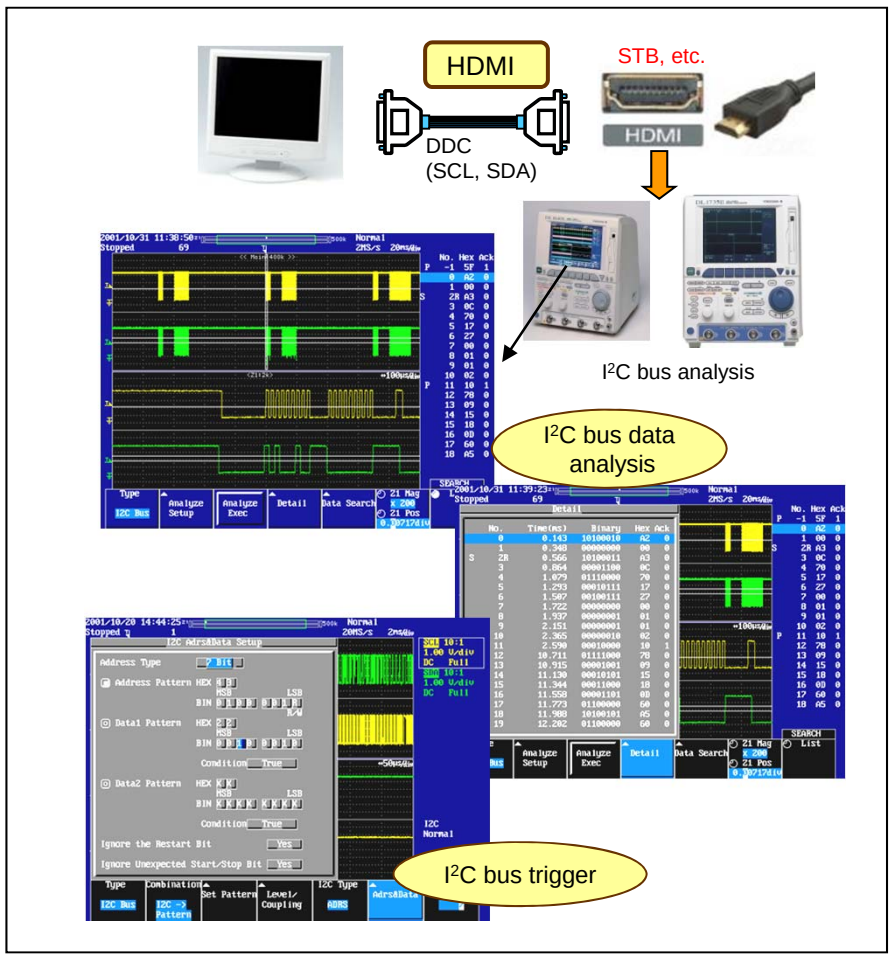
The High-Definition Multimedia Interface (HDMI) standard was developed as a next-generation digital video interface between displays and DVD players, set-top boxes (STB), etc. The HDMI standard was first developed for AV based on a Digital Visual Interface (DVI), one of the digital interface standards for displays, and is being put into practical use today. As with DVI, HDMI uses—in addition to video signals—signals for exchanging information with connected equipment on a Display Data Channel (DDC) using I²C as the data transfer method.

Application Points

- Analysis of data transferred on DDC
  An I²C data analysis function of the DL1640/DL1740E/EL is able to analyze the waveforms to check that data is transferred correctly.
- Waveform quality evaluation by cable capacity
  An I²C trigger function of the DL1640/DL1740E/EL is able to capture waveforms using a start condition, address, data or the like as a trigger point, so it is useful to evaluate the waveform quality that may be affected by extending the cable.

Product Features

- A trigger can be activated by the address pattern and data pattern of I²C.
- A parallel condition of an non-I²C analog signal and I²C pattern can be set.
- The pattern and waveform of address data can be simultaneously observed by performing the I²C analysis based on the measured data.
- A Go-NoGo function, which sets a range to the reference waveform and determines whether the range is exceeded, is able to quickly evaluate the waveform quality.
- Analysis results can be displayed in real-time (DL9000/SB5000/DLM2000)



UART Bus Signal Evaluation (Analysis, Decode, and Search)

Mixed Signal Oscilloscope
DLM2000 Series

Application Overview

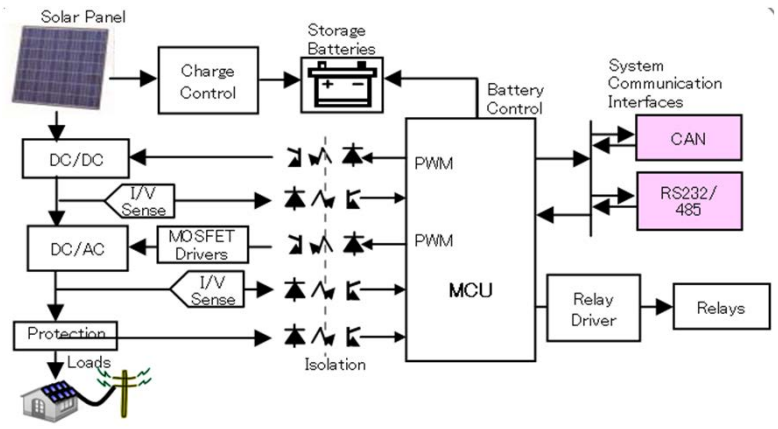
UART stands for Universal Asynchronous Receiver Transmitter, which refers to a communication circuit to convert serial signals to parallel, and vice versa. It is generally used as an interface with external equipment in conjunction with an IC that converts signals to a signal level compliant with a standard such as RS-232.
Two data lines (one transmission line and one receiving line) are used. The baud rate and signal formats (differential, single end, etc.) vary depending on the standard.

Application Points

UART signals are analyzed and the results can be shown in the decode and list displays, and a search can be performed.

Product Features

- UART signal data is analyzed and the analysis results are shown in the list display with an analysis number, time from the trigger point, data, and errors (framing and parity). Data can be displayed not only in the Hex/BIN format but also after it is converted according to the ASCII code table.
- Analysis results data can be saved to the internal memory or USB memory in CSV format.
- If you select arbitrary data from the analysis results list, the raw waveforms of UART signals corresponding to that analysis data are automatically displayed in the zoom screen (Zoom link).



Use Example of Serial Bus in Solar Power Generation System

UART Bus Analysis Screen

Evaluation & Verification of Power Line Communications (PLC) System

Traffic Tester Pro
AE5511

Power Line Communications (PLC) refers to a technology to use power lines as communication lines. Communication at data rates of a few Mbps to a few hundred Mbps is made possible by connecting a communication adapter (PLC modem) to the electrical outlet and connecting a PC to it.

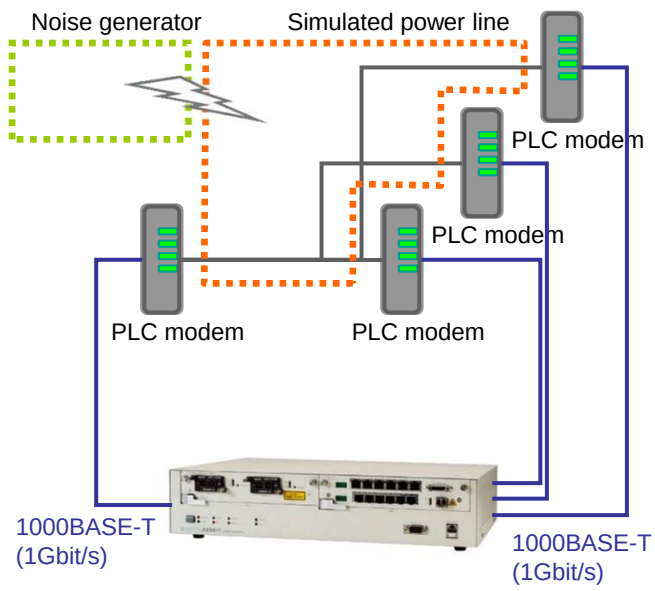
Electrical wires are already laid in homes and buildings, so it is easy to build home and local area networks using PLC, because there is no need to lay a new communication cable. Furthermore, when the power distribution grids of power companies are used for PLC, the power grids can be used as communication infrastructure and, for example, Internet connection services can be provided without any change.
This application is designed to test the transmission quality characteristics and QoS (Quality of Service) functions in various conditions of PLC systems.

Application Points

- Multi-port simultaneous throughput test
  Capable of verifying the performance, effects of interference between lines, and the like in respect to communication between one master modem and multiple slave modems.
- Frame bit error rate (BER) test
  Precisely measures the quality in the event of a transmission line error by applying disturbances such as noise to the power line.
- Latency
  Measures the delay characteristics in various conditions of power lines.
- QoS test
  Capable of testing the QoS functions of power line modems using an QoS statistical function.
- Rate change and delay change detection
  Reliably detects poorly-repeatable packet loss, delay change, and the like using an alarm log function.

Product Features

- 10Mbit/s to 10Gbit/s Ethernet compatible (up to 32 ports: 10/100BASE-TX)
- Full-wire rate traffic generation and statistical monitoring functions
- Capture function available (depending on the unit)
- Easy-to-understand displays and up to 8 multi-users



Measurement items: throughput, BER, latency, etc.

Green IT: Power Consumption Measurement in Data Center

Power Analyzer
WT500

Application Overview

With the growing interest in power consumption and environmental measures, focus is also being directed to IT equipment. For example, data centers make efforts to save energy and improve efficiency of IT equipment, power supplies (DC/AC power supplies in the range of 46 V to 600 V), lighting, and air-conditioning control. In particular, IT equipment is expected to use several times more power as communication traffic grows in the future. A growing number of companies are taking measures to reduce power consumption. Under these circumstances, industry trade associations, such as Green IT, SPEC, Green Grid, and Climate Savers, were established to promote efforts to reduce power consumption.
The WT500 is able to measure power consumption and efficiency, which are the focus of these efforts, and helps implement effective environmental measures.

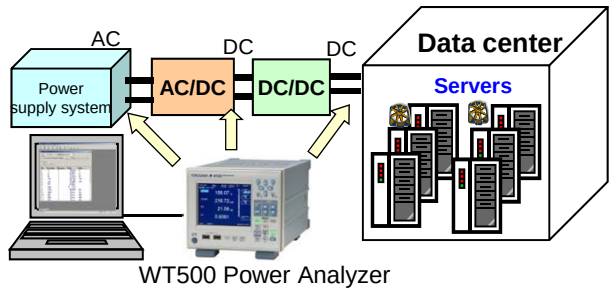
Application Points

- Measurement of voltage, current, and power changes before and after power supplies and converters
- Checking of the long time trends of power values and total power consumption
- Direct input with high-precision measurement of voltage, current, and power
- Clamp connection available for large current and simplified measurements

Product Features

- Up to 3 channels are available, so the conversion efficiency of AD/DC and DC/DC converters can be checked.
- Trend display with the maximum data acquisition interval of 10 times per second.
  Stability levels of voltage, current and power can be visually checked.
- High-precision voltage, current and power accuracy：0.2%
- Not only direct input measurement but also an input terminal for a clamp probe is available.
- Simplified measurements are also possible.

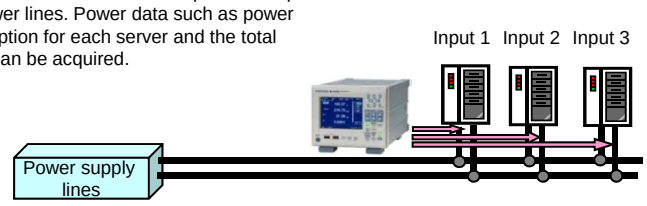
■Power Consumption Measurement in Data Center (example)



Power supplied to the data center is subject to loss during AC to DC and DC to DC conversion. This loss between input and output can be calculated and the efficiency can be displayed. When checked in the trend display, the temporal efficiency changes can also be observed. Furthermore, the measured data can be saved to USB memory.

■Power Consumption Measurement by Server

The WT500 is able to measure power for up to 3 power lines. Power data such as power consumption for each server and the total values can be acquired.



* If the current value to be evaluated is a few milliamperes, use the WT210 single-phase model or WT1600 single-phase/three-phase model (with up to 6 channel inputs).

Server Power Supply Monitoring

ScopeCorder DL750
High-Speed Data Acquisition Unit SL1000

Application Overview

Communication services industry members, including banks, telecoms and data centers, install uninterrupted power supplies (UPSs) using batteries in case the power interruptions.

UPSs monitor the power supply line from a power company and switch to the battery power supply if a failure occurs.

The battery life, instantaneous power failure time when power lines are switched, and power quality must be checked and maintained periodically to ensure the safe operation of a UPS.

Application Points

All data when the power lines are switched needs to be recorded on multiple channels.

Data before and after the switching needs to be recorded every time, over a certain period of time, to ensure quality.

Product Features

- **Total 12 types of isolated input modules (*)**

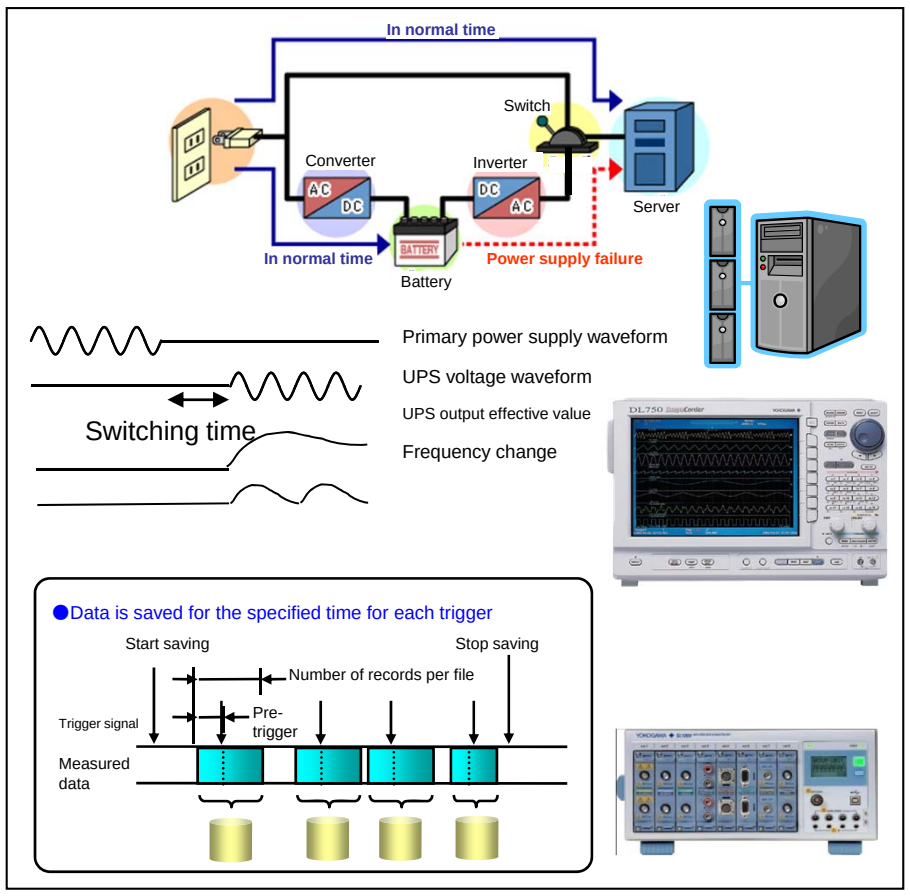
Isolated input measurement is possible using modules for measuring various signals such as high-speed voltage, high voltage, high-precision voltage, frequency, temperature, distortion, and acceleration, so a connection can be safely made while the power is on.

- **Frequency module**

Power supply frequency can be measured using a frequency input module.

- **Data save function for the specified time for each trigger**

Data for the specified period of time by each trigger can be recorded to the internal memory or HDD (option), which is useful for analysis at a later time.
(*) 11 types available for the DL750.



Current & Power Consumption Measurement for Router & Switching Equipment

Digital Power Meter
WT210

Application Overview

While the Green IT efforts are attracting attention, the Energy Saving Act for Promotion of Rational Uses of Energy for network equipment is attracting greater attention.

A Top Runner standard is applied to equipment that uses a lot of energy (and that emits a lot of CO_2) such as automobiles, air-conditioners, and refrigerators, which are required to exceed the top performance of products on the market.

The Top Runner standard will also be applied to routers and switching equipment in fiscal 2009. The power consumption and the like of this equipment will have to be checked.

The WT210 Power Meter is able to run a test to asses load factor changes caused by changes in the traffic load for network equipment, and precisely measure the power, voltage, current, etc., while the equipment is in the sleep, standby, operation, and energy-saving modes.

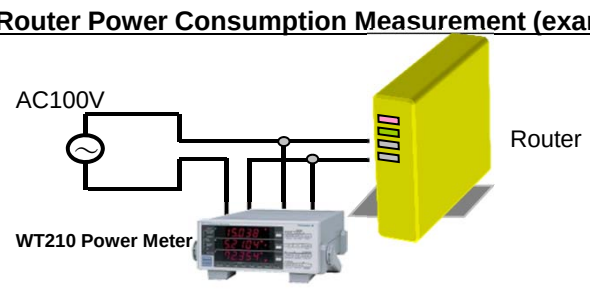
Application Points

- The signals to be measured can be directly input, so it is possible to measure high-precision current (A), power (W), integrated current (Ah) and integrated power (Wh) values.
- Wide current range from a very low to very high current available
- Compact and light, so it is easy to carry around
- Harmonic measurement function essential to checking distortion
- Data acquisition at the maximum data update rate of 100ms (10 times per second)
- Data acquisition and saving with free software.
- Power consumption changes caused by changes in the traffic load can be checked.

Product Features

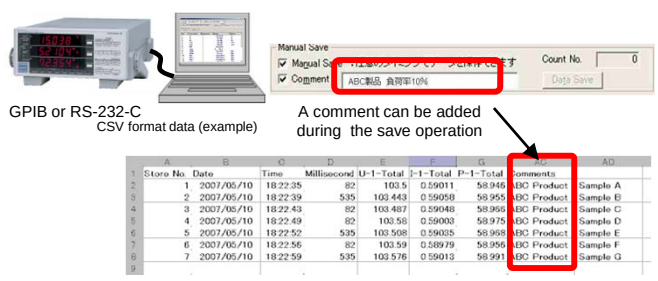
- Basic power accuracy: ±0.2%. Integrated current, integrated power, frequency, and power factor can also be measured along with voltage, current, and power values.
- Current measurement range: Direct input measurement in the range of approximately 50μA to 26A
(Current range: Wide range of 5mA to 20A)
- Compact and light (about 3kg)
- A harmonic measurement option is able to measure harmonic components up to the 50th order and distortion.
- The data update rate can be selected from 100ms to 5 seconds.
- The data measured by the WT210 can be saved on a PC using the free software WTViewer.
- The data can be converted to the CSV format and graphs can be easily created.

■Router Power Consumption Measurement (example)



■WTViewer Software (free software)
Evaluation of power consumption changes caused by load factor changes

This application software is able to transfer the value and waveform data measured by the WT210/WT230 Digital Power Meter to a PC via GPIB or Serial (RS-232-C) communication, and display and save the measured data. A Manual Save function saves the voltage, current, power, and other data for each measurement when the Manual Save button is pressed. The results of a test performed by changing the traffic load can be saved to a CSV format file and displayed in a list.



* Example of the measurement results of the WT3000
Item display and the number of digits for displayed data slightly vary depending on the product.

Energy Saving Effect Measurement of Air-Conditioner and Refrigerator

Clamp-on Power Meter
CW120
(Yokogawa Meters & Instruments Corporation)

Application Overview

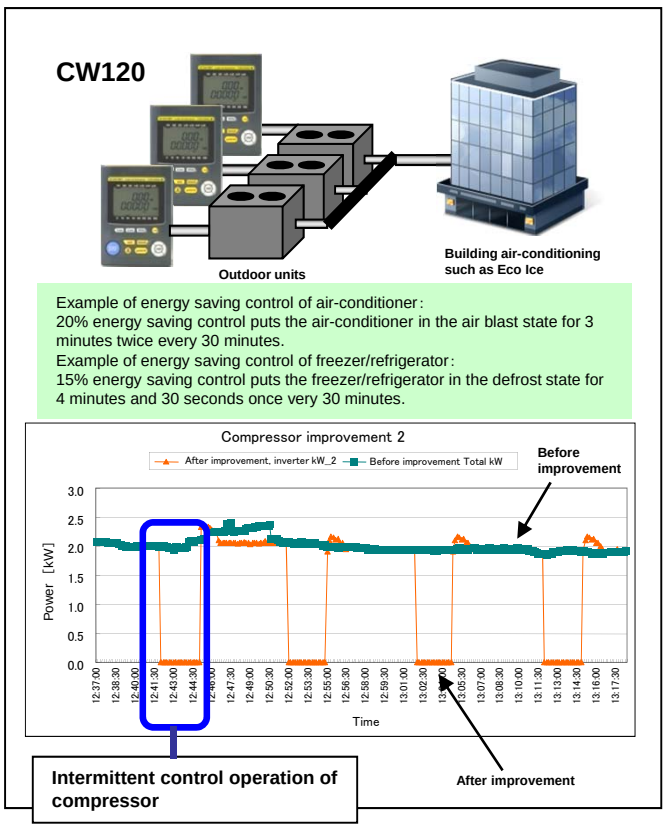
The promotion of energy saving reduces CO_2 emissions, which helps protect the global environment, and reduces energy costs, which directly contributes to the reduction of expenses, so companies and organizations are focused on reduce energy consumption. In particular, the refrigeration and air-conditioning equipment used in plants and buildings are typical of equipment for which efficiency can be improved by energy saving control. Various efforts in this regard are underway, such as operational management, efficiency management, and the use of new energy saving equipment. By measuring the power consumption and energy consumption of equipment over a certain period of time, the current energy usage and improvement effects can be checked using the value data, and the operation conditions and control characteristics of equipment can be understood in detail for energy saving efforts.

Application Points

- It is possible to evaluate the energy saving control in seconds for measurements such as a rising characteristic at the moment of starting the compressor used in refrigeration and air-conditioning equipment or intermittent control operation.
- Continuous measurement and data saving over a long period of time.
- Multiple equipment items can be simultaneously measured to understand the operation conditions.
- It is easy to analyze the measured data and output a report.

Product Features

- The data save period can be selected from 1 second.
- Measurement over a long period of time is possible with a compact flash memory card.
- An external control input signal is able to simultaneously control the start and end of integral measurement for multiple CW units.
- Up to 3-line load (with shared voltage) can be measured by the single-phase, two-wire method.
- It is easy to turn the measured data into a graph and create forms (daily and weekly reports) using the AP240E Data Analysis Software.
- Compact and portable design: body 117 (W) x161 (H) x 51 (D) mm, about 600 g
- Communication functions：Modbus, PC link, and communication protocol dedicated to a power monitor



Evaluation of Camera Drive for Digital Camera

Mixed Signal Oscilloscope
DLM2000 Series

Application Overview

The control method of a camera drive that performs the autofocus and zoom functions of digital cameras is shifting from the linear to the pulse-width modulation (PWM) drive method in order to reduce the size of the LSI chip and reduce the energy consumption of the motor.

Application Points

Real-time digital filter and pulse count functions

Product features

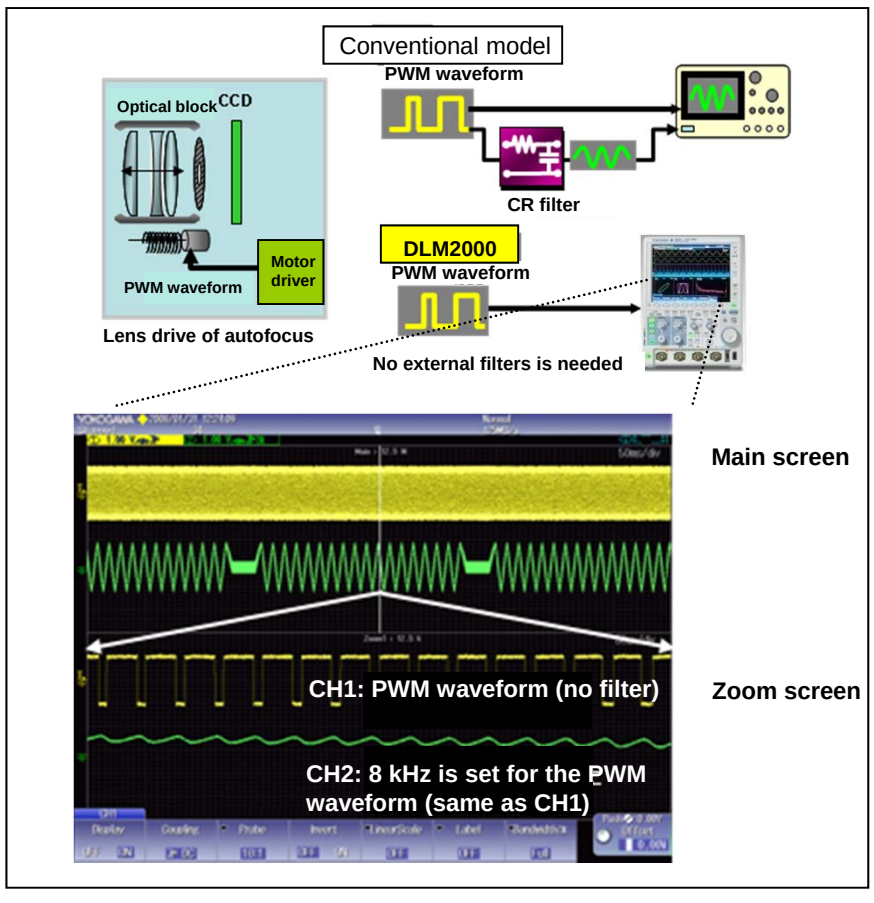
- Observation of the PWM effective value waveforms using the digital filter

Effective value waveforms (PWM demodulated waveforms) can be displayed in real-time using the internal filter function. The PWM drive signal and operation start timing of lens can be simultaneously checked. No external filter is needed. The PWM fundamental frequency can also be changed.

・Real-time preset filter：8kHz to 200MHz (14 types)
・Filter processing by calculation; 0.01Hz to 500MHz

- Pulse count function

A pulse count function is able to automatically count the pulses in the specified range. It is easy to evaluate the travel distance and the number of drive pulses when evaluating the focus adjustment. The pulse count function can be also used for the calculated waveforms after filter processing.



DC Characteristic Measurement of Two-Terminal Semiconductor Device

Source Measure Unit
GS610

Application Overview

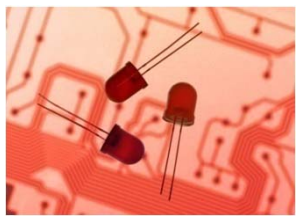
Measurement and analysis of the V-I characteristic for two-terminal semiconductor devices such as diodes and varistors. A curve tracer function included in the GS610 Source Measure Unit is able to measure the characteristic and draw a graph using a general-purpose worksheet. Neither cumbersome programming nor dedicated software are needed.

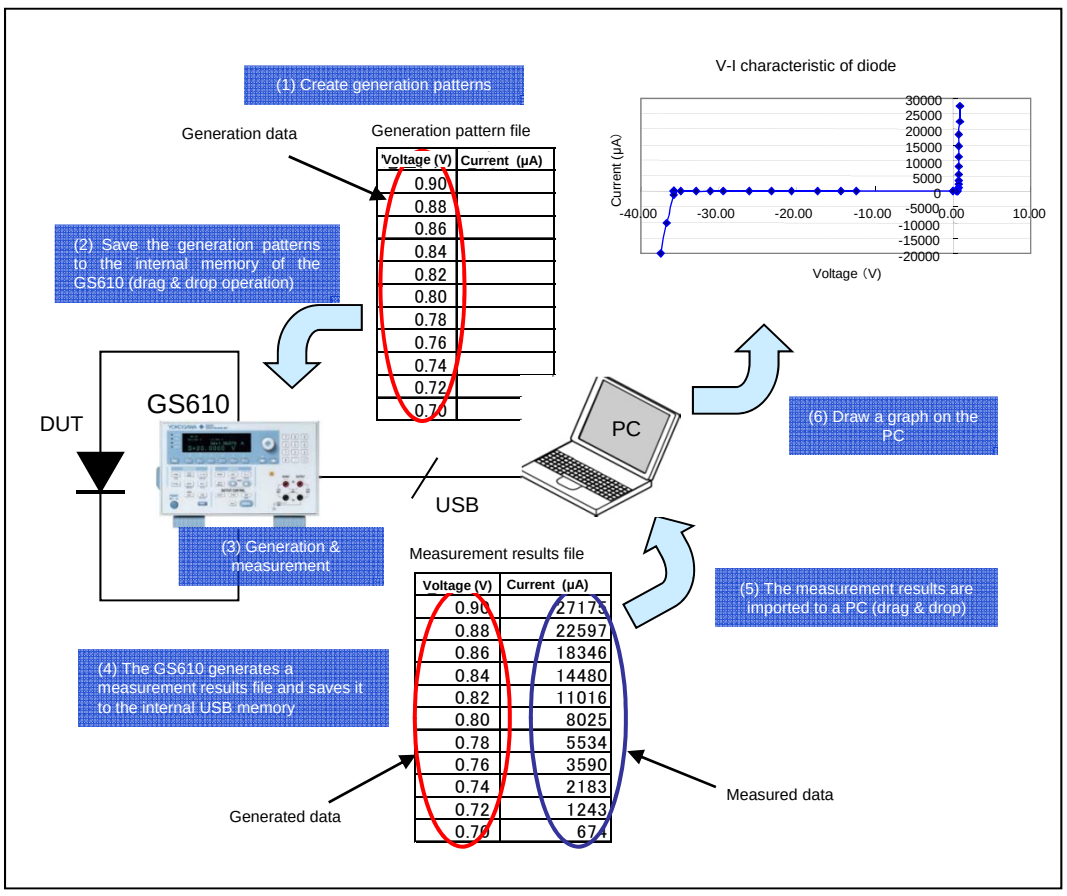
Application Points

The source & measure function included in one unit applies a voltage to the device under test (DUT) and measures the current (or applies a current and measures the voltage) in order to measure the characteristic. The measurement results are saved to the internal USB memory of the GS610 in CSV format, which then can be imported to a PC and turned into a graph, and a DC characteristic curve can be obtained as shown in the figure.

Product Features

- Easy-to-use curve tracer function using a general-purpose worksheet
- Inexpensive compared with the conventional curve tracer (about one-quarter the price of the conventional one)
- High-precision curve tracing is possible at the maximum voltage of 110V and maximum current of 3.2 A.





Wire Bonding Machine Adjustment

ScopeCorder
DL750

Application Overview

Wire bonding at the back-end process of semiconductor manufacturing is a process to bond gold or other metal wires to the IC. A wire that is kept at a high temperature is pressed and bonded while a high-speed vibration is applied to it. Proper bonding is achieved with fine adjustments of the frequency of this high-speed vibration (US oscillation) and changes in pressure of the wire.

Application Points

The front end of equipment to bond the wires is called a capillary. Since the capillary presses the wires while it vibrates very fast, it is broken off or becomes worn over time, and replacement is then required. Every time the capillary is replaced, it is necessary to perform position adjustment, vibration (US oscillation) adjustment, displacement adjustment and other adjustments.

Product Features

- **Linear scaling function**

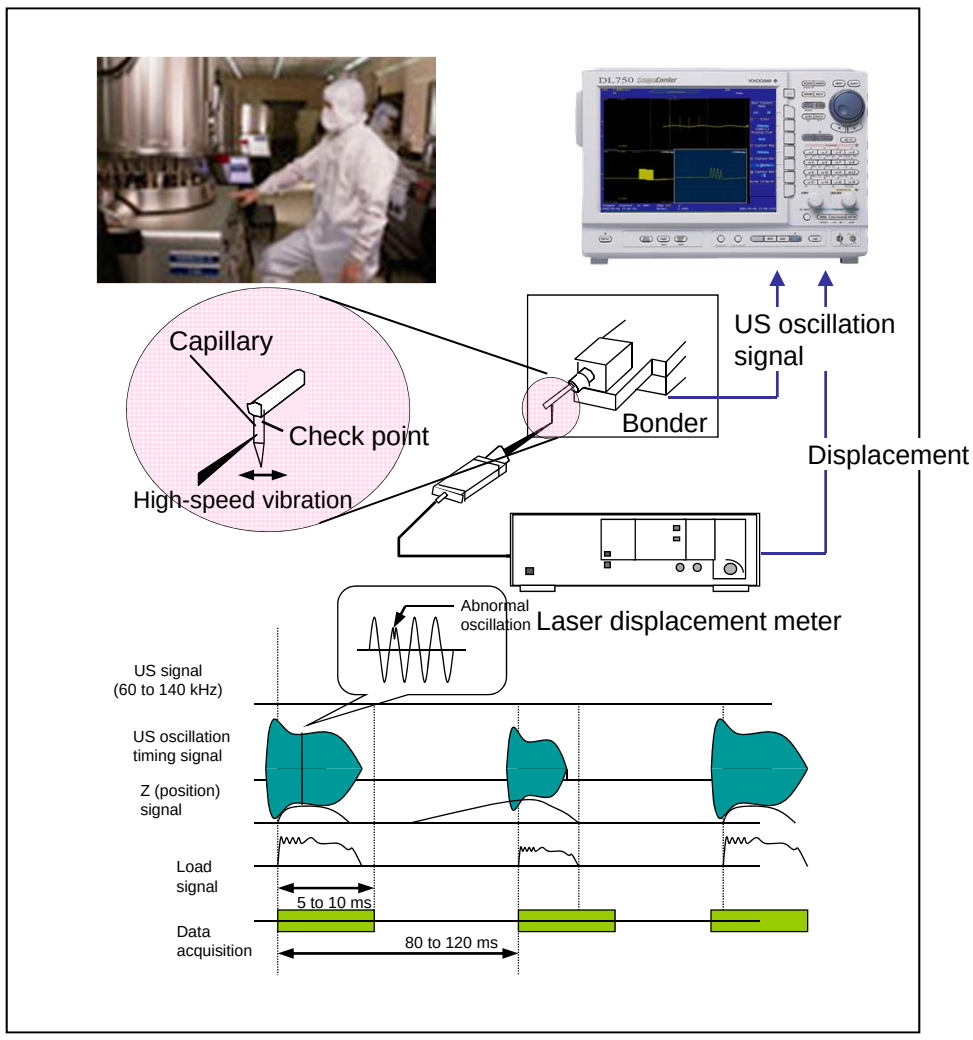
This function automatically performs a calculation for equation Y=AX+B (where A represents scaling factor A, and B the offset value). The output value can be directly read from the displacement meter.

- **Distortion module**

The load can also be measured by synchronizing to an electrical signal by using two modules, distortion NIDS and distortion DSUB modules with an internal bridge power supply.

- **Data save function for the specified time by each trigger**

Data for the specified period of time by each trigger can be recorded to the internal memory or HDD (option), which can be used for analysis at a later time.



DC Characteristic Test of Transistor by Curve Tracer

Multi Channel Source Measure Unit
GS820
Curve Tracer Software

Application Overview

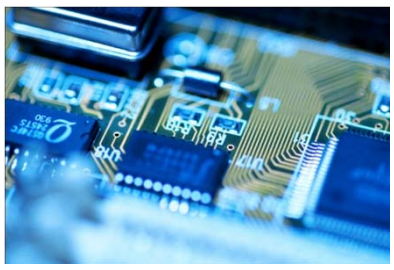
A DC characteristic (VGS-ID) of a field effect transistor (FET) is drawn. The gate-source voltage, VGS, is applied from channel 1 of the GS820, and the drain-source voltage, VDS, is swept from channel 2 to measure the drain current, ID. A real-time V-I curve tracer is implemented by controlling the GS820 with high speed and drawing the results curve with dedicated PC software.

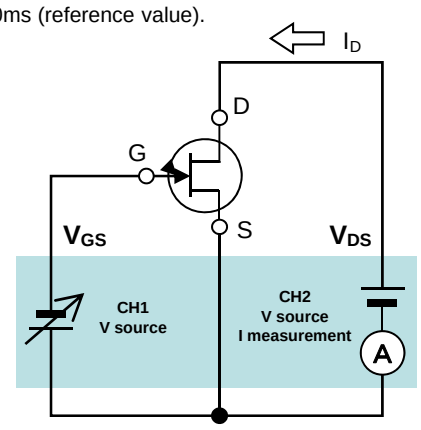
Application Points

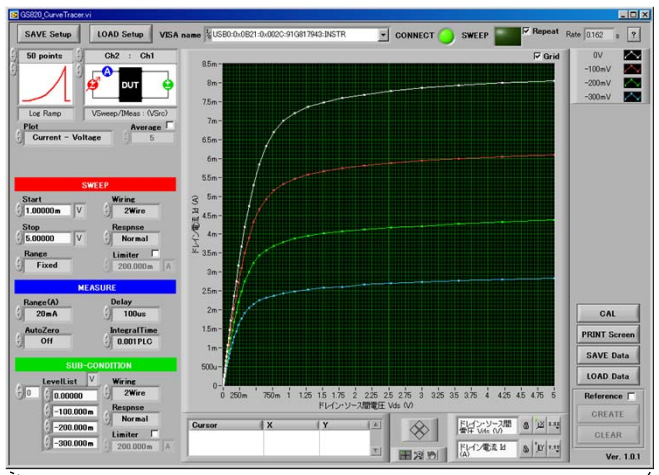
This is a simple configuration implemented by just connecting a PC and the GS820 with a USB cable. Just start the curve tracer software, select a connection model according to the characteristic you want to measure, and press the button. This solution saves the space of evaluation equipment and reduces the evaluation time. The results can be analyzed in detail by the cursor and zoom function.

Product Features

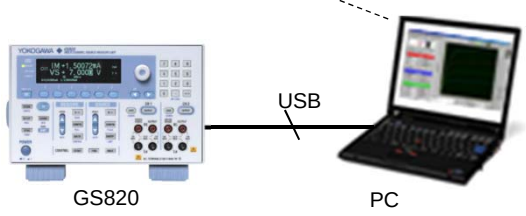
- Simple operation and crystal-clear drawing
- 12 types of connection models for various DC characteristic measurements are available.
- High-speed drawing update. 200 data records are updated at a rate of 190ms (reference value).







765670 Curve Tracer Software



Manufacturing Efficiency Improvement & Energy Saving of Semiconductor Equipment

Data Logger
Datum-Y XL120
(Yokogawa Meters & Instruments Corporation)

Application Overview

Understanding the details of the operation conditions of equipment helps understand the processing conditions of products and the actual situation, thus helping make improvements.

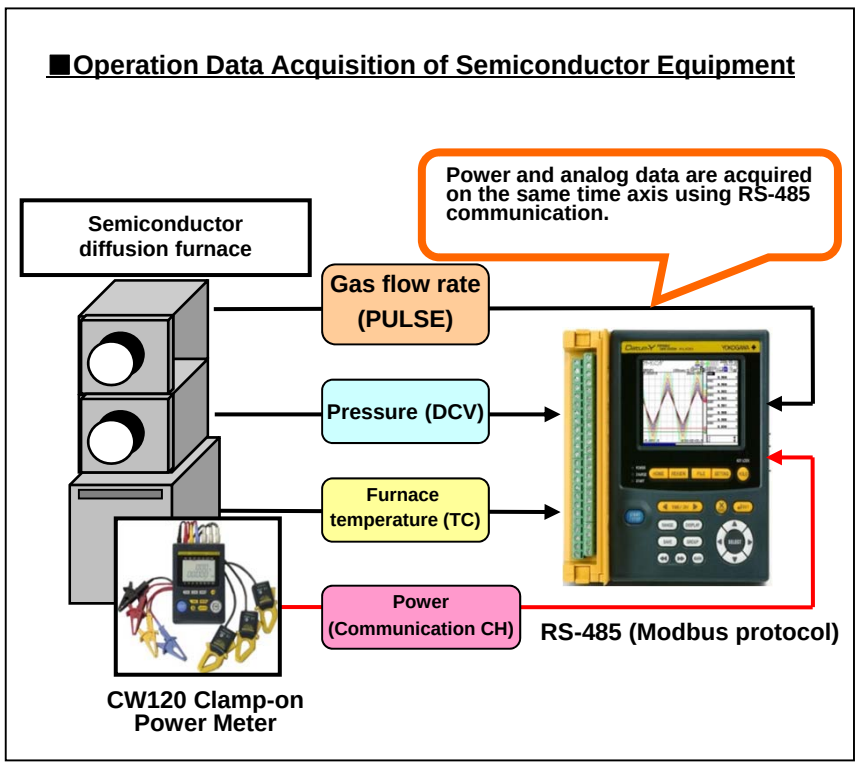
The XL120 series, which is capable of simultaneously using both the analog input and communication functions, is able to acquire data on the same time axis, and a CSV format file makes it easy to process the data on a PC.

Application Points

- Combined use of the CW120 Clamp-on Power Meter and XL121 allows for simultaneous use of both the communication and analog data to acquire the detailed operation conditions of equipment.
- The XL120 is compact, light, and battery-operated .
- Resistant to noise from inverter power supply, etc.

Product Features

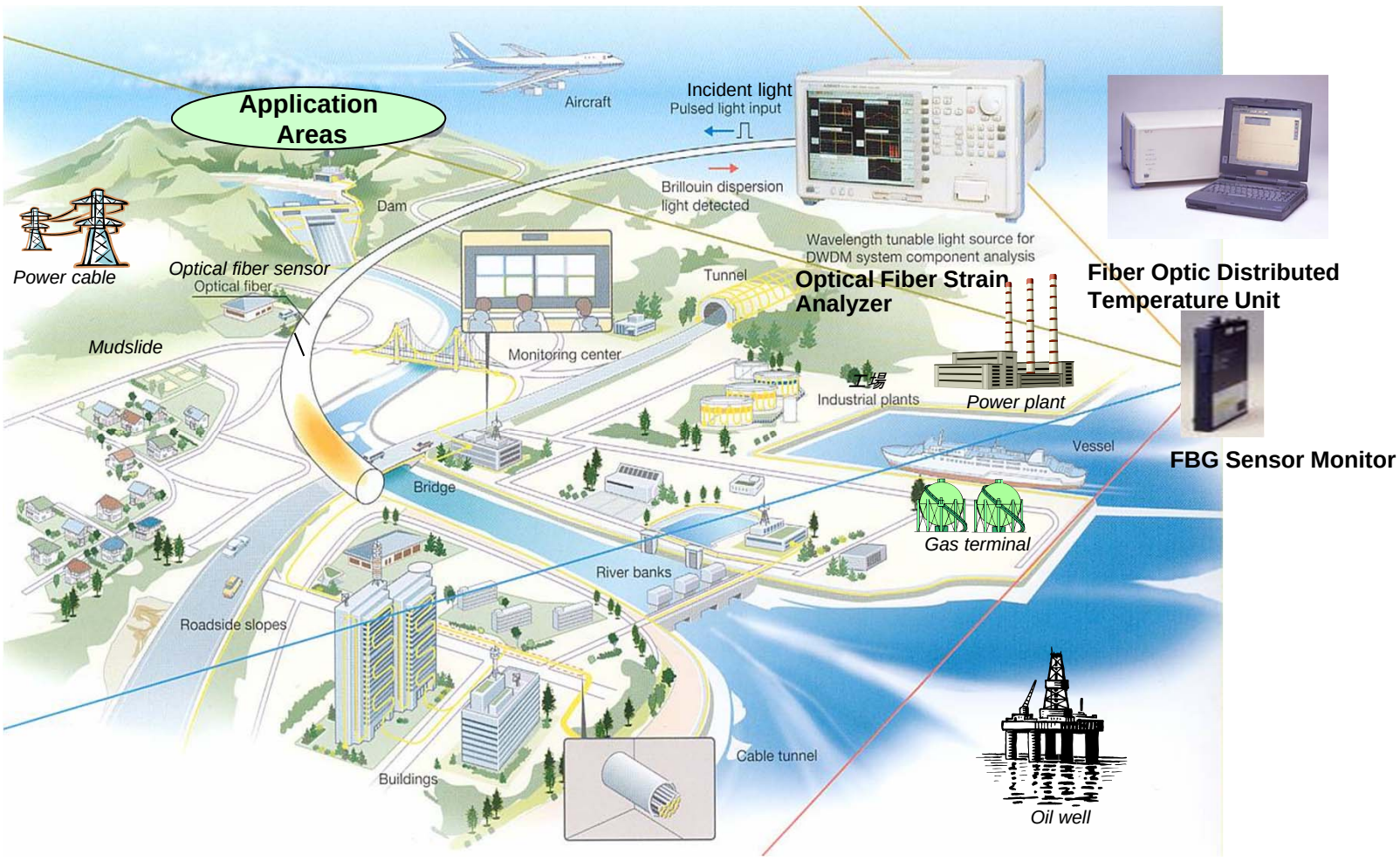
- Compact, light, noise-resistant, and isolated input on all channels (selectable from 8 or 16 channels)
- Universal input on all channels, and temperature and DCV can co-existent.
- An easy-to-read screen display and wide view-angle TFT LCD are employed.
  - Three displays of Trend, Bar graph, and Digital can be switched.
- The terminal block is removable, so switching between the 8-channel and 16-channel terminal blocks is possible.
- Convenient functions using acquired data
  - Trigger function
  - The logging review mode is able to check the past data on the spot.
  - Calculation function: four arithmetic and statistical calculations (MAX, MIN, AVE, RMS and P-P)
- Large capacity data acquisition: compact flash and other media are supported
- LAN available as standard: Data can be remotely transferred using the Web and FTP functions
- The communication channel is able to save data acquired via communication.



Wide-Area Monitoring Model Example

Optical Fiber Strain Analyzer/Optical Fiber Distributed Temperature Unit
BOTDR/ROTDR

Optical fiber sensors have advantages over conventional electrical sensors, including the ability to perform measurement over a long distance in a wide area, excellent long-term durability, resistance to electrical and magnetic field noise, needing no power supply, and the ability to perform remote monitoring. They are attracting attention as sensors for outdoor monitoring systems installed in harsh environments.



Disaster Prevention & Security

FBG Sensor Monitor
FB200

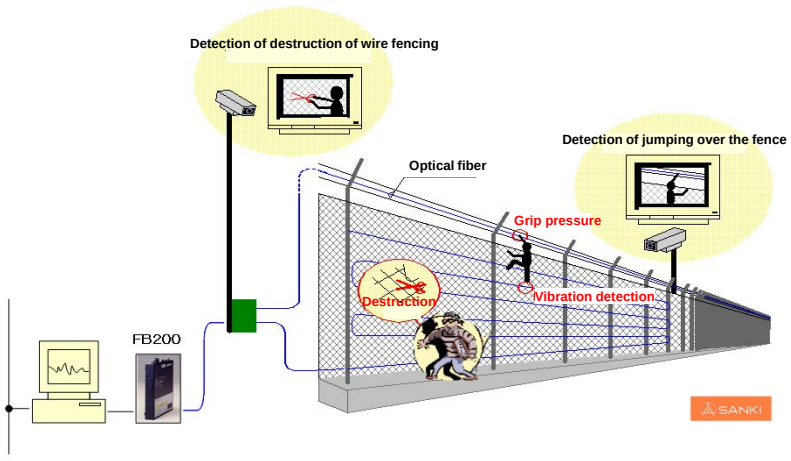
Application Overview
FBG sensors are able to perform high-speed (vibration) measurement at multiple points, and can be characterized as an optical version of a strain gage and platinum thermometer. Sensing systems using FBG sensors can be built in a wide range of areas, including health monitoring of large structures, water level monitoring of rivers and sewage systems (real-time detection of flooding caused by torrential rain), detection of flooding in a subway, underground shopping area, and basement area, and security monitoring of important facilities.

Application Points
FBG sensors are most suitable for high-speed measurement at a few points in harsh conditions (lightning, electrical and magnetic fields), and are also used in non-security applications, including the vibration measurement of structures, vibration analysis of motors, and temperature measurement inside transformers.

Product Features
A structure with no moving parts reduces the size, and increases reliability and operating speed. An approximately 1με strain resolution and approximately 0.1℃ temperature resolution are achieved at a high speed (at a 10ms period, typical). An FGB sensor can be connected to one optical fiber at multiple points, and is resistant to magnetic noise, therefore, free from the complication of electrical sensor wiring, and less load is placed on the environment.

- Number of FBG can be measured simultaneously : 40 (typical)
- Measurement wavelength range : 1527 to 1567nm or 1568 to 1607 nm
- Wavelength display resolution : 1 pm
- Measurement power range: -4 dBm to -65 dBm (0.1nm range)
- Measurement period: Min. 10ms (at a 100Hz sampling rate)

Fiber Bragg Grating (FBG) refers to an optical fiber that exhibits a periodical significant refractive-index change in a very narrow range. The FGB optical fiber has the characteristic that it reflects only the light of a particular wavelength that is in proportion to the period of a refractive-index change, and it is possible to detect a strain applied to the FBD and temperature change by using this characteristic.



Example of Security System

Unraveling Molecular Mechanism of Pathological Conditions of Metabolic Syndrome by *In Vivo* Molecular Imaging

In recent years, obese adipose tissue is attracting attention as an "active metabolic organ" that causes various diseases. Especially, visceral obesity and inflammation play a central role in metabolic syndrome. It was found that visceral obesity caused remodeling of adipose tissues based on chronic inflammation, and insulin resistance was occurred, which eventually leads to development of arteriosclerosis lesion, and cause new blood vessel events.

To elucidate the molecular mechanisms of pathological conditions consisted by the complicated and multi-cellular abnormal interactions in remodeling tissues, an "*in vivo* molecular imaging" based on the CSU system was developed.

By using this technique, it becomes possible to precisely evaluate the three-dimensional changes in the structures in living tissue, and the multi-cellular dynamics in vivo with high time and spatial resolutions.

Figure 1

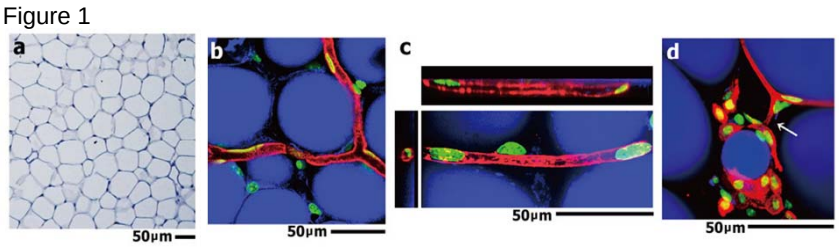


Figure 2

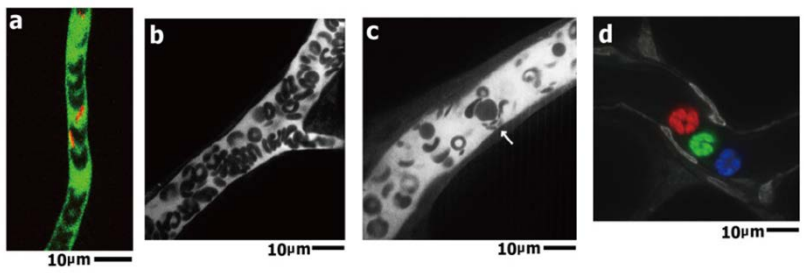


Figure 3

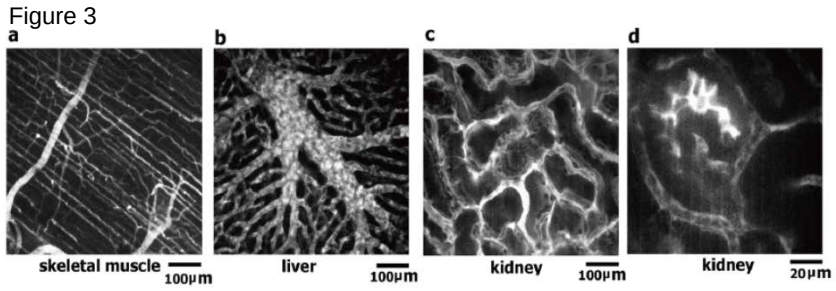


Figure 1: Images of the remodeling of adipose tissue in live animals

Successful Visualization of the remodeling of adipose tissue revealed angiogenesis is essential for the obesity, and differentiation of adipose cells occurs as a result of the interaction between macrophages and vascular endothelial cells.

a: Conventional adipose tissue specimen (lean, db/+ mouse)
b & c: Images of a white adipose tissue of an 8-week-old thin mouse (lean, db/+)
Blue: Adipose tissue, Red: Blood vessel skin, Green: Nucleus
d: Adipose tissue of an 8-week-old obese animal (obese, db/db)

Figure 2: Multi-color in vivo molecular imaging of capillary vessel blood flow

Significant increase in the rolling/adhesion to the vascular wall of macrophages and platelets in the obese animal were clearly observed. Moreover, intermittent reduction of blood flow, reduced Oxygen level were observed in obese tissues which suggests activation of the interaction among vascular endothelial cells, macrophages and platelets enhances inflammation from obesity within micro-vascular flow of adipose tissues.

a: Image of capillary vessel blood flow in the adipose tissue of a normal animal (lean, ob/+ mouse).
Deformed blood cells (red indicates a platelet) flowing in the blood vessel are clearly captured.
Green: FITC-dextran, Red: Anti-CD41 antibody
b & c: Images of venular blood flow in the adipose tissue of (b) a normal animal (lean, ob/+ mouse) and (c) an obese animal (ob/ob mouse) visualized by FITC-dextran staining.
White blood cell and platelet adhere to the blood vessel wall in the obese adipose tissue (indicted by an arrow in the center of image c)
d: Rolling of white blood cells of an obese animal (ob/ob mouse), stained with Acridine orange.

Figure 3: Application of " *in vivo* molecular imaging" on various organs
(Blood flow images of a: Skeletal muscle, b: Liver, c & d: Kidney glomeruli)

Data: Satoshi Nishimura (M.D., Ph.D) Please visit: www.invivoimaging.net, for detailed information.
Dept. of Cardiovascular Medicine, Translational Systems Biology and Medicine Initiative,
The University of Tokyo & PRESTO, Japan Science and Technology Agency

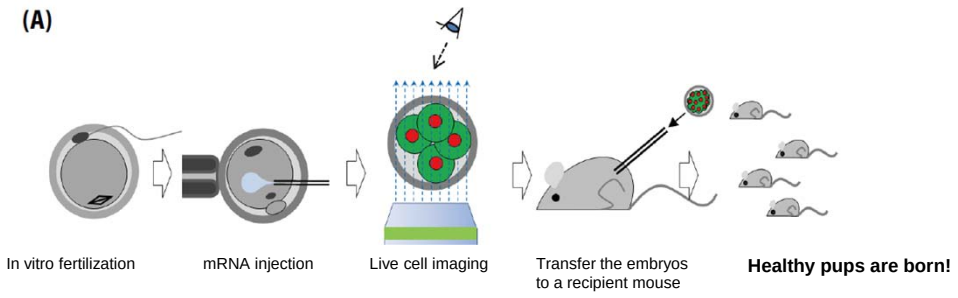
New Era in Mammalian Genetics Research; Utilize the Same Embryo After Observation

Extremely Low- Phototoxicity of the CSU Proven by Long-Time, Multi-Dimensional Imaging of Early Embryonic Development of Mouse

In the fertilization and early embryonic development process, various events are spatiotemporally controlled, and many events are connected in the cause-effect relations toward the final goal of ontogenesis. To understand the mechanism of this process, conventional experimental techniques by fixing and destruction of the cells have limitations. If this process can be observed over time and the development process can be continued after the observation, it will open a new era in the Genetics research. A mammalian developmental biology researcher, Dr. Kazuo Yamagata, established such technique by using the CSU system.

He successfully imaged mouse embryos over a long period of time, from the post-fertilization through to the blastocyst stage, to acquire approximately 60,000 of 3D confocal images. Thereafter, the embryos were transferred to a recipient mouse, and the pups were born all normally, grew healthy, and were capable of reproduction; a firm evidence that this early embryo imaging technique doesn't adversely affect the process of full-term development. The high speed image acquisition and extremely low excitation light unique for the CSU system enabled greatly reduced phototoxicity and realized intensive but damage-free long time observation. Only by using this technology which does no harm on the embryonic development, it is possible to "utilize the same embryo after intensive analysis by imaging", and thus to investigate cause- and-effect relationship of various early stage phenomena and their influence on the development.

(Figure 1)



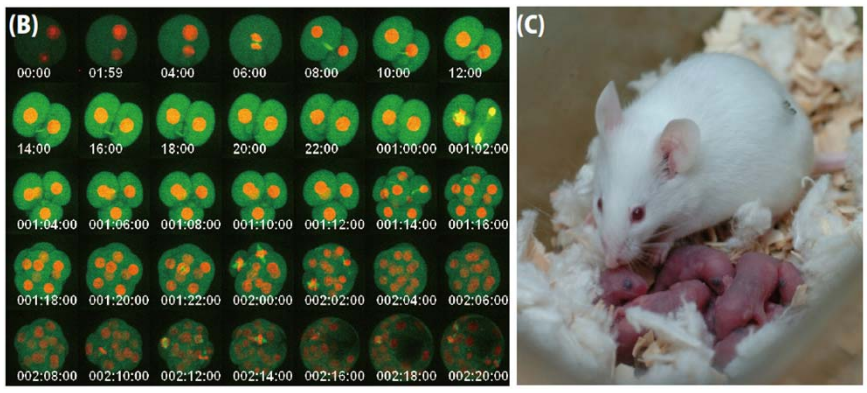


Figure 1: The long-time, multi-dimensional live cell imaging on early stage embryos does not affect the process of ontogenesis.

(A) Experimental flow

(B) Movie example: Images were acquired at 7.5minute intervals over approximately 70 hours.
This figure shows extracted images at 2hour intervals.
Each image is the maximum intensity projection of a total of 51 images in the Z-axis direction.
Green: Spindle (EGFP-α–tubulin), Red: Nucleus (H2B-mRFP1)

(C) A litter born from a recipient mouse to which the embryos were transferred after they were imaged for over 70 hours and approximately 60,000 images were taken.

Data: Kazuo Yamagata, PhD., Laboratory for Genomic Reprogramming,
Center for Developmental Biology, Riken

Interface of Plants and Atmospheric Environment Captured by Live Imaging

Stomata are pores that numerously exist especially on the abaxial side of leaves, and play roles as the gate for gas and water exchange of the plants and thus become the interface between plants and atmospheric environment. The opening/closing of the stomata is strictly regulated in response to changes in various environmental factors, such as light and humidity. Stomatal movement originates from changes in turgor pressure of the guard cells, which is under control of the mechanics of the cell wall of guard cells. That is, when the guard cell volume increases, the stoma opens, when the guard cell volume decreases, the stoma closes. Understanding of the mechanism of the stomatal movement is not only the main focus of plant cell biology but also is regarded as a basic research toward the improvement of the atmospheric environment through the carbon-dioxide assimilation of plants.

To investigate interactive dynamics of the intracellular structures and organelles in the stomatal movement through live imaging technique, a CSU system was used to capture 3-dimensional images (XYZN) and time-laps images (XYT) of guard cells.

Figure 1

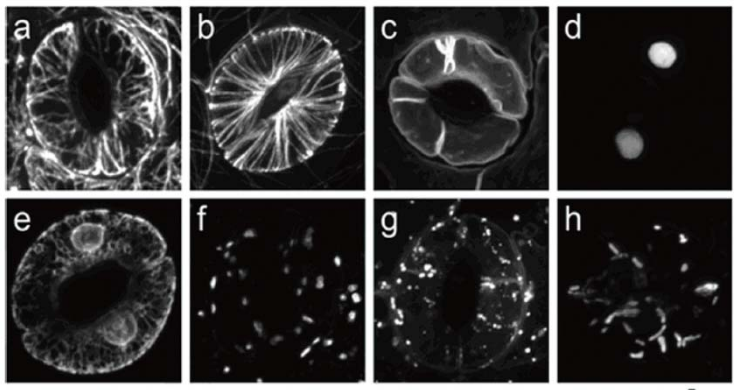


Figure 1: An example of the comprehensive live imaging of various intercellular organelles of guard cells All images are maximum-intensity projection images which were reconstructed from serial optical sections, captured from the surface to the mid-plane.

To establish standardized data to construct a comprehensive database, 50 to 500 pairs of cells were examined for each organelle. The results will be on public as LIPS (Live Images of Plant Stomata) database at http://hasezawa.ib.k.u-tokyo.ac.jp/zp/hlab.

a: Actin microfilament (GFP-ABD2), b: Microtubule (GFP-tubβ),

c: Vacuolar membrane (GFP-AtVAM3), d: Cell nuclei (HistoneH2B-tdTomato),

e: Endoplasmic reticulum (GFP-ER), f: Golgi apparatus (ERD2-GFP),

g: Endosome (ARA6-GFP), h: Mitochondria (mt-GFP)

Figure 2

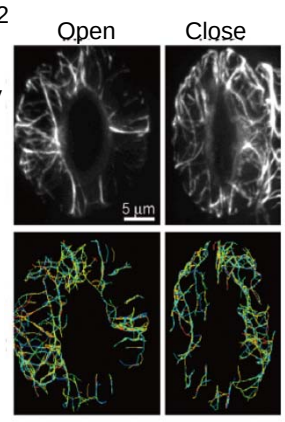


Figure 3

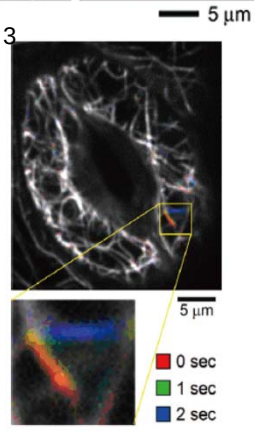


Figure 2: Three-dimensional reconstruction of the actin microfilaments at the moment of stomatal opening/closing

The orientation and bundling of actin microfilaments were found to change in response to the stomatal opening/closing.

Figure 3: Time laps observation of the dynamics of actin filaments of guard cells

Actin microfilaments were found to dynamically change the orientation by approximately 60 degrees in one or two seconds.

Data: Takumi Higaki, PhD.and Professor Seiichiro Hasezawa, Dept. of Integrated Bioscience, School of Frontier Sciences, The University of Tokyo, BIRD JST

Test for Visual Function Using MEG System

A patient who had a traffic accident had subjective symptoms of a loss of the right half visual field; However, CT or MRI test could not identify any organic failure and so could not verify the subjective complaints of the patient.

Furthermore, the visual evoked potentials of electrophysiological tests were normal in both amplitude and latency, and so the symptoms of the right half visual field could not be confirmed.

A visual stimulus test was performed using the magnetoencephalograph (MEG) system proved that there was:

・A reaction in the visual area of the right occipital region

・No reaction in the visual area of the left occipital region

Thus, diagnosis of “right homonymous hemianopsia” that was identical to the subjective complaints of the patient was objectively confirmed.

In this way, MEG is able to measure brain functions that cannot be confirmed by conventional morphological tests or electropotential test. This is an example to show that MEG functional measurement and high-spatial-resolution measurement are also useful in cases where the left and right functional areas are adjacent to each other as visual areas.

Figure 1

a b c

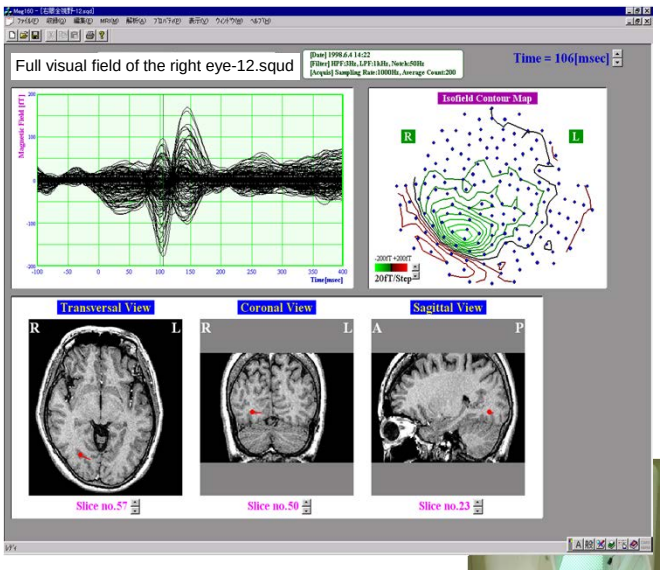


Figure 1: Measurement results using the magnetoencephalograph (MEG)

a: 160 channel superimposed MEG waveforms

b: Isofield Contour Map (The left side of the figure shows the right side of the brain)

An activity source is observed in the right occipital region, while there is no reaction in the left occipital region.

c: MEG magnetic field origins are superimposed on the MRI images

The red point indicates the functionally active part that reacts to visual stimuli.

As with the isofield contour map, the activity source is observed in the right occipital region, while there is no reaction in the left occipital region.

Figure 2: Screen mirror unit for visual stimuli

A patient is subjected to the test while lying in the supine position on a bed.

Only a visual stimulus test is performed using the screen mirror unit to reduce the burden on the patient.

Figure 2

Long-Time, 4-Color, 3-Dimensional *In Vivo* Imaging of Stromal Cell Dynamics in the Solid Tumor in Live Mouse

White blood cells are attracted to cancerous and infected regions to defend the organism. However, different types of stromal cells, including fibroblasts and variety of white blood cells, can have opposing effects on tumor progression and responses to therapy, it is important to understand how each cell type behaves in actively growing tumors, but little is unknown about their real-time behavior.
A CSU system was used to monitor behavior of various types of stromal cells inside solid tumors of a live mouse by capturing 4-color, 3-dimensional time-lapse images at five different regions repeatedly for up to 12 hours. As a result, the behavior of each stromal cell was found to be greatly varied depending on the cell type and microenvironment inside the tumor.
Long-time *in vivo* imaging at a cellular level requires high-speed imaging at high-resolution with minimal phototoxicity to the cells, for which a CSU system is the most suitable. In addition, to enable multi-position, sequential imaging in different tissue microenvironments within the same mouse, a robotic stage was used in conjunction with the CSU imaging system.

By using such system, 32,400 images (540 exposures for each of the four colors in three z-planes in five fields) were typically acquired within a 12hour experiment.

This study clearly shows the effectiveness of *in vivo* imaging at a cellular level with the CSU system, not only for the study of cancer drugs and therapy, but to understand how cells function in live organs, healthy or deceased, which may open new era for medical/pharmaceutical research.

Figure 1

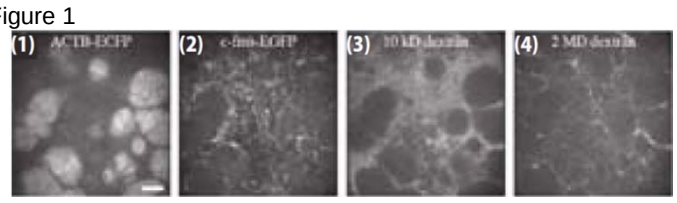


Figure 2

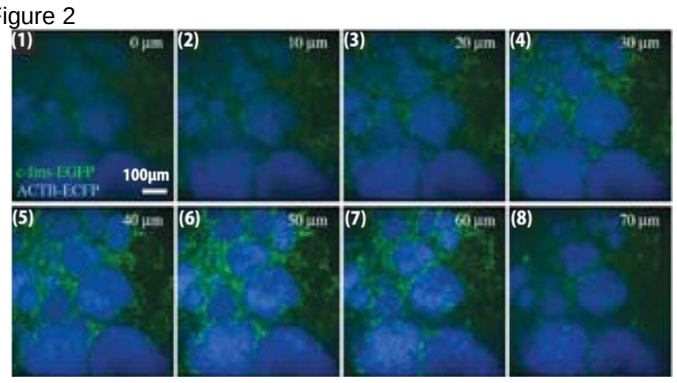


Figure 1: Individual channels from the four-color images of the same region in solid tumors in live mouse are shown in gray scale. (maximum intensity projection)
(1) ACTB-EGFP, (2) c-fms-EGFP, (3) Alexa Fluor 647-conjugated dextran, (4) rhodamine-conjugated dextran

Figure 2: The tissue penetration depth of the CSU images inside a live mouse.
Green：c-fms-EGFP, Blue：ACTB-ECFP
(1) 0 µm, (2) 10 µm, (3) 20 µm, (4) 30 µm, (5) 40 µm, (6) 50 µm, (7) 60 µm, (8) 70 µm
The CSU system clearly acquired live images up to the depth of 70 µm, in vivo.

Figure 3

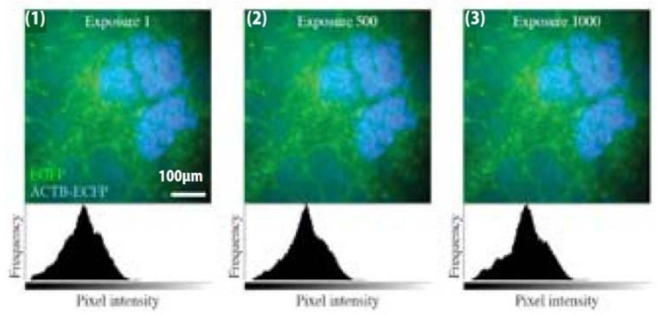


Figure 3: A single optical section of a mouse tissue was imaged 1,000 consecutive times in two colors. Pixel intensities are quantified in the curves below the images.
Green：EGFP, Blue：ACTB-ECFP, (1) 1st image, (2) 500th image, (3) 1,000th image
No significant photobleaching was observed after acquiring 1,000 images of the same region.

Data：Dr. Mikala Egeblad, Dr. Andrew Ewald, Dr. Zena Werb, the Department of Anatomy at the University of California, San Francisco

fMCI: Functional Multineuronal Calcium Imaging Technique

The neuronal network is a computing system that transforms input to output. This computation involves complex nonlinear processes through polysynaptic feedforward and feedback microcircuitry, and thus cannot be addressed either with isolated neuron responses or averaged multineuronal responses. Functional multineuron calcium imaging (fMCI) is promising to solve this problem.

The fMCI is a large-scale recording technique that simultaneously monitors the firing activity of more than a thousand neurons through their somatic Ca2+ signals.

Because of several advantages, including i) simultaneous recording from numerous neurons, ii) single-cell resolution, iii) identifiable location of recorded neurons, and iv) detection of non-active neurons during the observation period, fMCI attracts attention as a new-generation large-scale recording method.

In vitro fMCI is made more sophisticated by using multipoint illumination and scanning with the CSU in combination with low-intensity lasers and an EM-CCD (electron-multiplying charge-coupled device) camera.

This CSU system allows to achieve ultra-high-speed and high-resolution fMCI in hippocampal slices; the Ca2+ fluorescent intensity of a large number of neurons can be monitored at the speed of up to 2,000 frames per second. This is one of the applications that make best use of the high-speed performance of the CUS Confocal Scanner Unit.

Figure 1

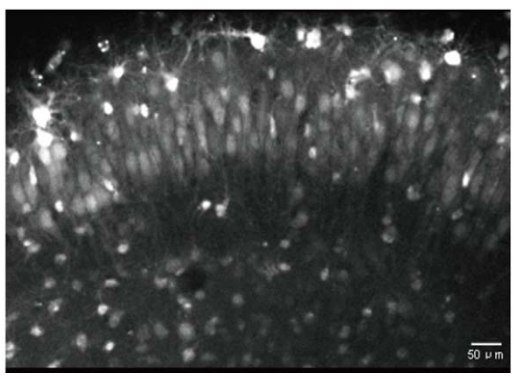


Figure 2

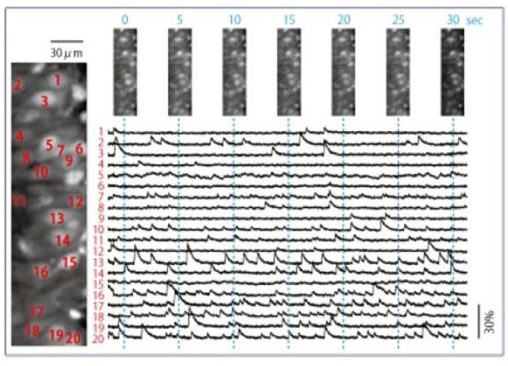


Figure 1: Spontaneous firing activity visualized as the Ca2+ fluorescence signals of a large number of neurons in a cultured hippocampal slice (CA3 region)

Figure 2: Example of a raster plot of the activity of many neurons in the CA3 region

Data：Yuji Ikegaya, PhD, Associate Professor at University of Tokyo Graduate School of Pharmaceutical Sciences http://www.hippocampus.jp/CV/

PC12 Cell Neurite Analysis

Faced with an aging society, it is critical to understand the pathological conditions and develop treatment methods for neurodegenerative diseases such as amyotrophic lateral sclerosis (ALS), Alzheimer's disease, Parkinson's disease, and Huntington's disease. Neuroscience studies are rapidly progressing and we are becoming aware that various signal transmission pathways are involved in the progression of pathological changes. The basic function of a nerve cell consisting of a cell body with a nucleus, a dendrite receiving input, and an axon performing output is as follows: A nerve cell receives a stimulus, generates an action potential, and transmits the information to another cell. There is a signaling structure made of a chemical substance called a synapse with a minute gap between the axon terminal of the former cell and dendrite of the latter cell. Neuroscience studies search for pharmacologically-active agents using the action potentials of sodium and calcium ions, and the local existence and amount of various signal transmitters as the indicators.

The CellVoyager processed the PC12 cells with nerve growth factor (NGF), analyzed the neurite extension, and was able to quantify the increase in the number of neurites that is dependent on the NGF concentration (Figure 2a). Furthermore, it is able to easily output numerical data such as neurite length, number of neurites, and number of branches of individual cells, so it is able to create not only a dose-response curve but also a graph based on the data of individual cells (Figure 2b). In this way, "neurite analysis" is able to acquire various kinds of data on neurites per well and per cell, and perform, for example, a detailed compound evaluation for neurological diseases.

Figure 1

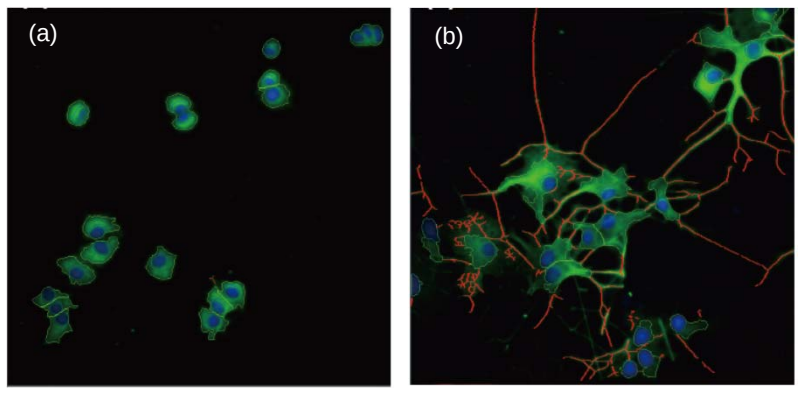


Figure 2

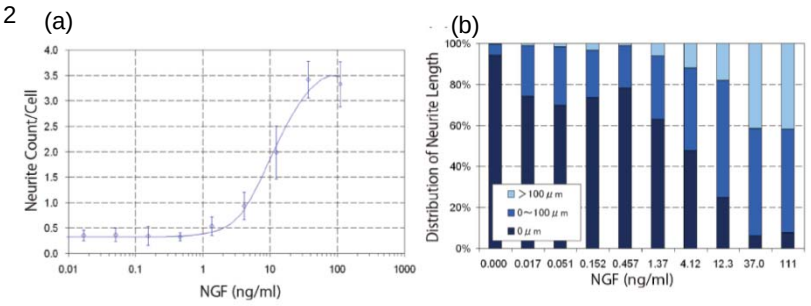


Figure 1: Images acquired using the CellVoyager

(a) Image processing result with no stimulation of NGF

(b) Image processing result after stimulating NGF (111ng/ml)

Blue：Nucleus (Hoechst33342), Green：β-Tubulin Ⅲ (Alexa488)

Figure 2: NGF concentration and neurite changes

(a) Dose-response curve of the "number of neurites per cell"

(b) Distribution based on the neurite length of each cell for each NGF concentration

Nucleus Morphological Analysis of Apoptosis

As with cell proliferation and differentiation, apoptosis (*) is one of the basic functions of cells that are controlled by genes in order to maintain the life of the individual. It undertakes important roles, including morphogenesis during ontogenesis, development of the neural network, cell turnover of mature individuals, maintenance of homeostasis regulated by the endocrine system, and development of the immune system. It has become known that abnormal apoptosis is closely related to the pathogenesis of patients who suffer from virus infectious diseases such as cancer, autoimmune disease, AIDS, and hepatitis, or neurodegenerative diseases such as Alzheimer's disease and Parkinson's disease. Apoptotic cells are morphologically and biochemically characterized by the chromatin aggregation, concentration of the nucleus and cytoplasm, DNA break, and apoptotic body separation. The nucleus of an apoptotic cell with chromatin aggregation produces bright fluorescence.

The CellVoyager was used to process a HeLa cell with staurosporine and analyzed the morphological changes of the nucleus, and fragmentation of the nucleus that is dependent on the concentration of staurosporine could be confirmed."Nucleus morphological analysis" is able to output various kinds of numerical data on nucleus morphology, and therefore is able to create graphs using various characteristic quantities as the indicators, such as the number of granules of fragmented nucleus (Figure 2a), the total area of granules of fragmented nucleus (Figure 2b), and the fluorescence intensity of granules of fragmented nucleus (Figure 2c).

* Apoptosis refers to the death of a cell that is pre-programmed in order to keep the individual in good condition. For example, excess cells in organs and tissues during the growth process, cancerous cells, and internally defective cells are removed. The tail of tadpoles that is lost during the growth process is an example of apoptosis.

Figure 1

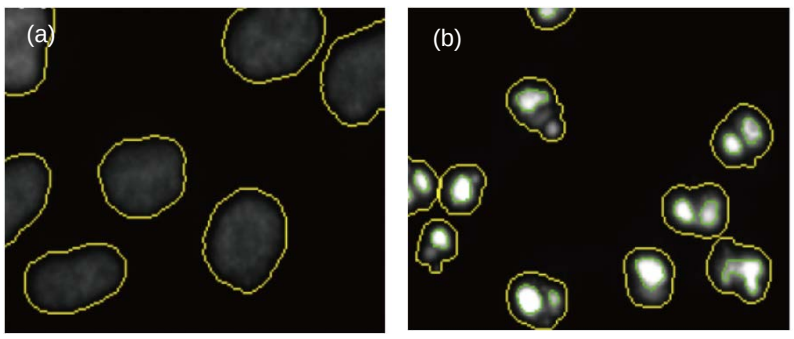


Figure 2

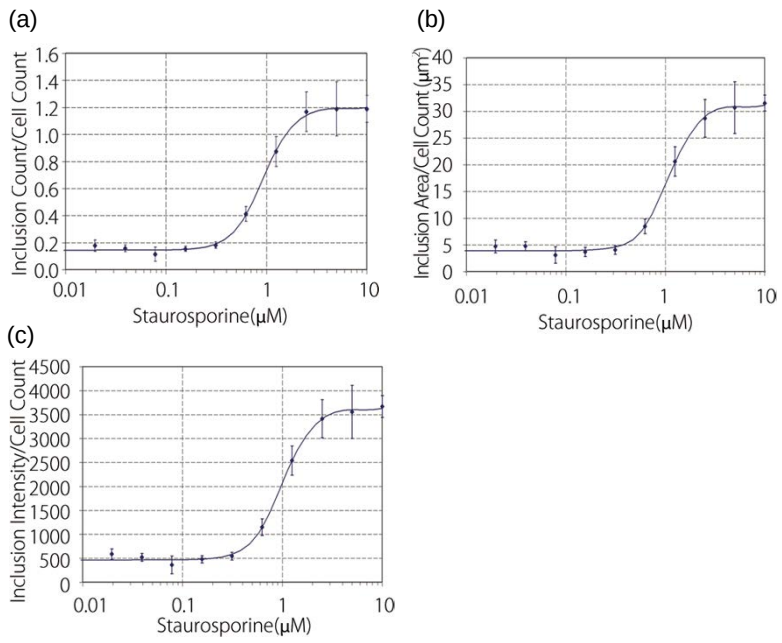


Figure 1: Images acquired using the CellVoyager

(a) Image processing result with no stimulation of staurosporine

(b) Image processing result after stimulating staurosporine (10μM)

Nucleus was stained with Hoechst33342.

Figure 2: Staurosporine concentration and nucleus fragmentation

(a) Dose-response curve of "the number of granules of fragmented nucleus per cell"

(b) Dose-response curve of "the total area of granules of fragmented nucleus per cell"

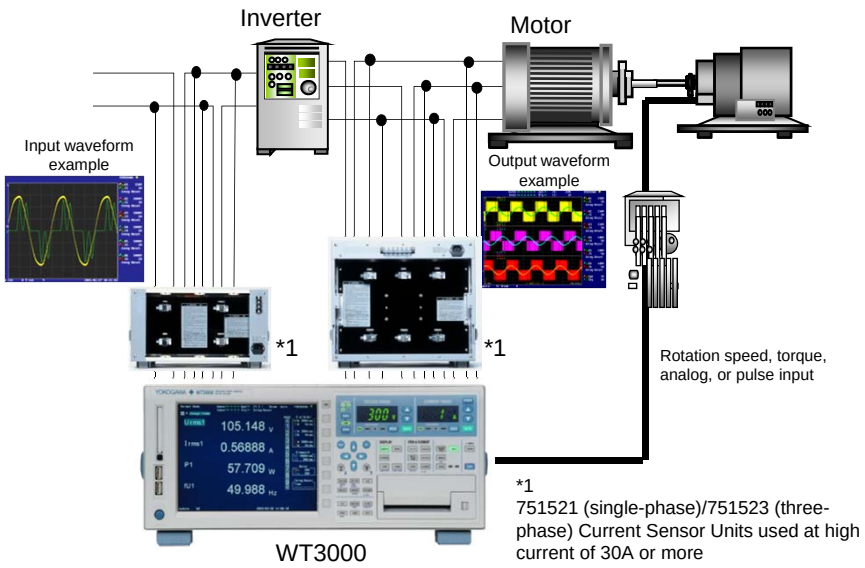
(c) Dose-response curve of "the fluorescence intensity of granules of fragmented nucleus per cell"

Main products & Contribution

WT3000 Series Precision Power Analyzer

WT3000
Power meter with world class precision and stability

- Basic accuracy (45Hz to 66Hz)
  (30A input element)
  Voltage/current: 0.01% of rdg + 0.03% of rng
  Power: 0.02% of rdg + 0.04% of rng
- Frequency band: DC, 0.1Hz to 1MHz
- Voltage direct input range:
  15/30/60/100/150/300/600/1000V
- Current direct input range:
  0.5/1/2/5/10/20/30A
  or 5m/10m/20m/50m/100m/200m/500m/1/2A
- Current sensor input range:
  50m/100m/200m/500m/1/2/5/10V



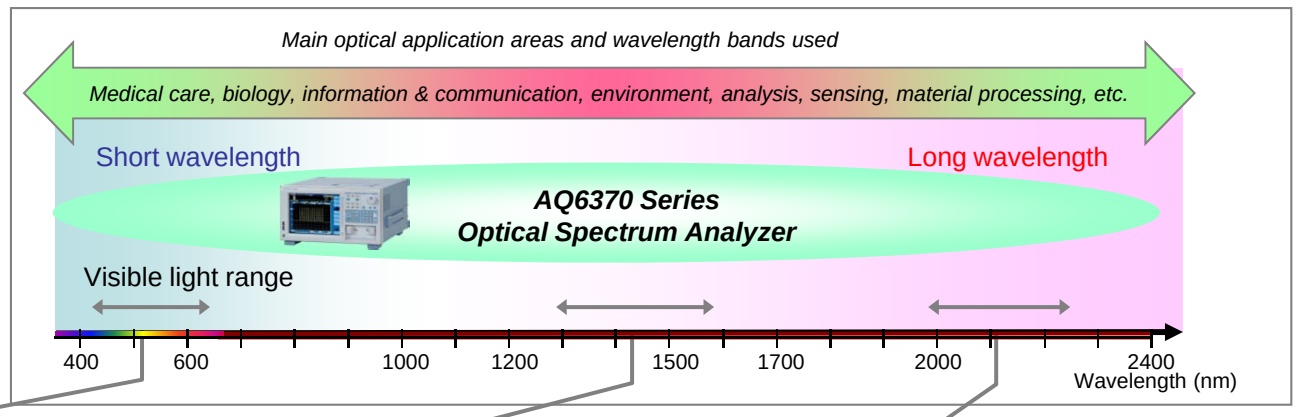
Social Contribution
The WT3000 is the most precise power meter in Yokogawa's power meter series. It meets the requirements for use as a standard instrument for calibration, or for a more precise measurement of power and conversion efficiency for power converters such as an inverter. It contributes to the improvement of evaluation and test efficiency.
Many equipment items including home appliances use a motor and inverter. In recent years, motor control is getting more complex due to the development of electronic circuit technology. On the other hand, more precise evaluation of motor and inverter control is required to meet the demand for higher efficiency that comes from social background factors including energy saving.

The WT3000 Precision Power Analyzer with the world class power accuracy of ±0.06% is able to measure up to 4 channel inputs, so it is able to test the inverter efficiency between input and output to evaluate inverters. Furthermore, a motor evaluation function (option) is able to simultaneously observe the rotation speed and torque changes, along with the observation of voltage, current, and power changes, and is able to calculate and display the mechanical power, total efficiency, and the like.

AQ6370 Series Optical Spectrum Analyzer

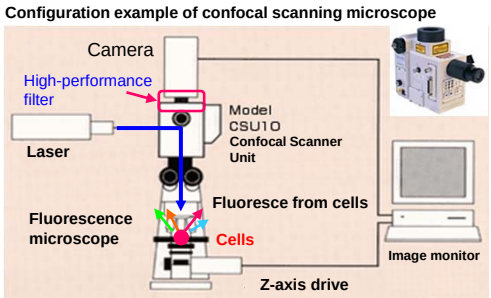
Overview
The high-speed, high-performance, cost-effective optical spectrum analyzer provides the most suitable solution to meet the optical spectrum measurement needs in various areas.

- ■ World class optical performance
  - ● High wavelength accuracy and resolution
  - ● Wide dynamic range
  - ● First measurement
- ■ Excellent functions and operation performance
  - ● Easy operation with panel keys and mouse
  - ● USB interface available
  - ● High-speed remote interface available
  - ● Various built-in analysis functions available



Biomedical area

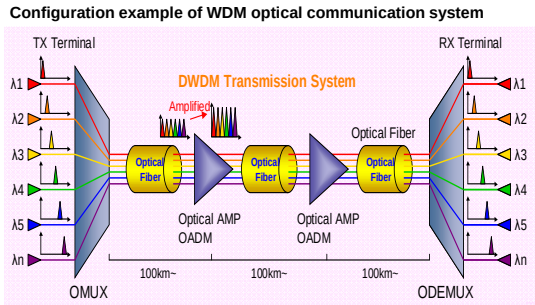
Configuration example of confocal scanning microscope



- Performance evaluation of high-performance filter for visible light laser and fluorescence extraction

Information & communication area

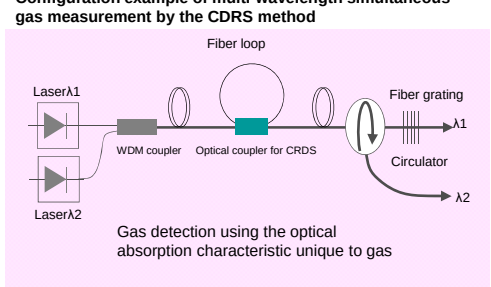
Configuration example of WDM optical communication system



- Performance evaluation of the system as a whole, as well as optical components of the system, such as laser, optical multiplexer, optical branching filter, and optical amplifier

Environmental measurement area

Configuration example of multi-wavelength simultaneous gas measurement by the CDRS method



- Performance evaluation of optical components such as laser and grating
- Evaluation of optical absorption characteristic by gas

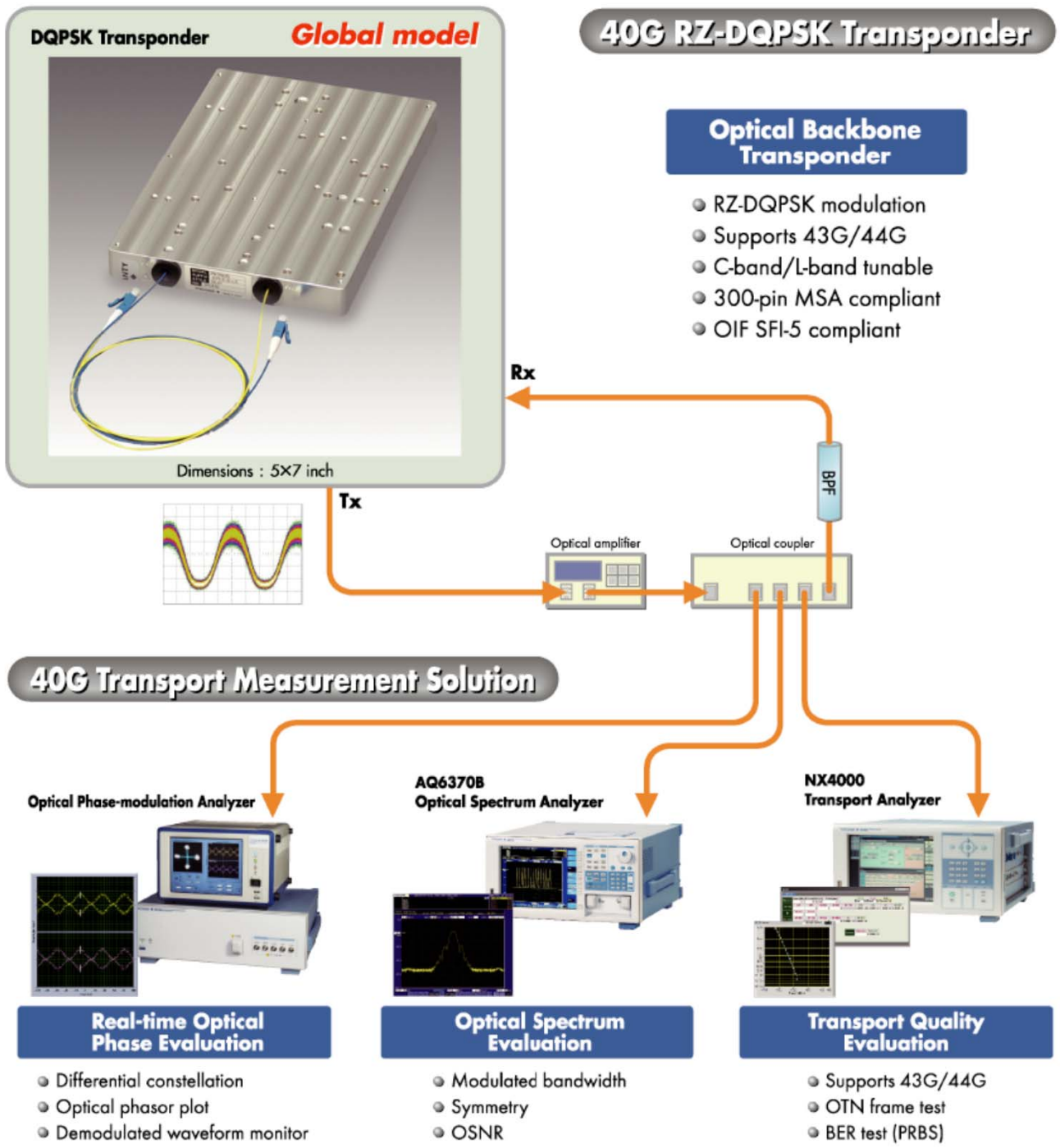
Social Contribution
The AQ6370 is an optical spectrum analyzer with world class optical performance, throughput, operation and maintenance performance. Optical technology is used not only in the information and communication area typified by the increased use of broadband, such as the Internet, IP telephony, and video streaming, but also in various areas such as biomedical and environmental measurement. Yokogawa's optical spectrum measurement technology contributes to the development of such optical application technologies.

40G Network Solution

This page describes a 40G network solution with the help of figures and photos.
40G long-distance transmission generally uses an optical phase modulation format. Which means that data is not carried by the optical amplitude (with light or no light) but by the optical phase with the optical amplitude level being kept constant. Specifically, the DPSK modulation uses two phases, while the DQPSK modulation uses four phases. Yokogawa manufactures and sells transponders (optical transceivers) used for transmission lines, and provides various measuring instruments that can be used for this optical phase modulation format. Yokogawa's RZ-DQPSK Transponders are used as communication units for transmission lines, and Yokogawa's other measuring instruments support R&D and manufacturing lines for the optical phase modulation format, thus contributing to the advancement of communication.

The RZ-DQPSK Transponder for 40Gbps long-distance backbone transmission was commercialized for the first time in the world using Yokogawa's compound semiconductor technology, high-density packaging technology, system building technology, system control technology, and the like. The RZ-DQPSK is an excellent format, because signals don't degrade significantly even when they travel over a long distance of the existing optical fiber network that is inferior in respect to dispersion and other characteristics. Furthermore, in the wavelength division multiplexing format where the light of multiple wavelengths is carried on one fiber, the occupying wavelength bandwidth is narrow so wavelength can be assigned at 50GHz spacing. Which means that the transmission capacity doubles that of the DPSK format where the wavelength is assigned at 100GHz spacing. To meet the demand for increased communication capacity, existing long-distance transmission systems with a rate of 10Gbps or less are being upgraded to 40Gbps systems. Thanks to its excellent features as described above, Yokogawa's transponder is attracting the attention of telecom carriers and system vendors, and Yokogawa is receiving orders for mass production. Yokogawa has already established mass production capacity for the transponders and is supplying them to the market in world wide. Sagamihara Factory, the construction of which was completed at end of 2006, has an integrated production line from the front-end process of compound semiconductors, the packaging thereof, through to assembly and outgoing inspection of transponders. Yokogawa owns not only semiconductor equipment for the front-end process but also equipments for the new signal format in order to meet the request for the supply of products for mass production.

Main specifications of Transponder
- Modulation format: RZ-DQPSK
- Bit rate: 43G/44Gbps
- C-band fully variable, or L-band fully variable
- 300pin MSA compatible
  5X7inch standard size
- OIF SFI-5 compliant



The figure above shows an example of a solution that combines the 40Gbps RZ-DQPSK Transponder and other measuring instruments. This configuration is often used for the demonstration of operation in exhibitions and other promotional occasions. The input and output of the transponder is back-to-back connected via an optical amplifier, and the sending and receiving status is monitored. Signals are split and connected to three measuring instruments. The instrument on the right is a NX4000 Transport Analyzer, which is able to generate and analyze optical signals on the transport layer. Furthermore, the AQ6370B is an Optical Spectrum Analyzer, which analyzes the spectrum of optical signals. In addition, the Optical Phase Modulation Analyzer is connected DQPSK signals, which are optical 4phase signals, and displays a constellation diagram. In this way, Yokogawa's RZ-DQPSK Transponder is used as a communication unit for the long-distance backbone transmission lines, and Yokogawa's other measuring instruments support the R&D and manufacturing lines for the optical phase modulation format, thus contributing to the enhancement of performance of important communication systems .

Main products & Contribution

High-Throughput Cytological Discovery System

CV6000 CellVoyager

The CV6000 was developed by integrating Yokogawa's technologies, including the confocal technology that was originally developed for the CSU, the advanced mechatronic technology typified by IC handlers and DD motors, and the control technology such as precision temperature control and FA-M3. The following shows the main features.

1. Industry-leading live cell observation function

・The confocal scanner unit uses a multi-scanning method for world-fastest image acquisition which is also effective to minimize damage to cells caused by laser radiation.

・The integrated incubator to culture the cells is able to observe temporal changes in the living cells over a long period of time.

2. Industry's fastest screening

・High throughput is achieved by integrating Yokogawa's technologies, including the high-speed positioning, high-speed autofocus, and high-speed image acquisition. Measurement of 96 well plates is completed in 1 minute (one field is taken per well).

・The high-speed performance can also be applied to primary screening (HTS).

3. Industry's first class optical technology

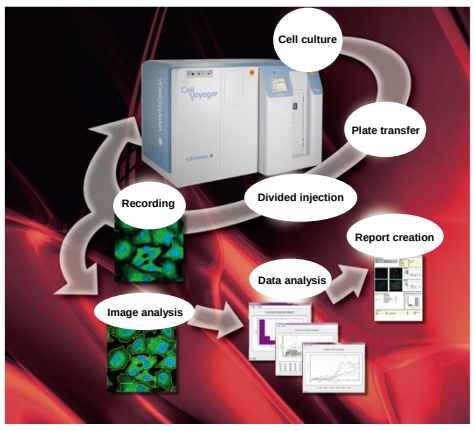
・Confocal, Epifluorescence, and Phase contrast can be switched for observation.

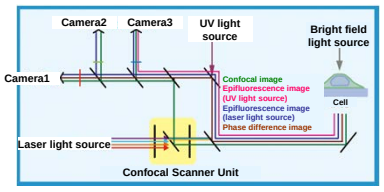
・The high-resolution real confocal method using dual Nipkow disks with microlens array is employed.

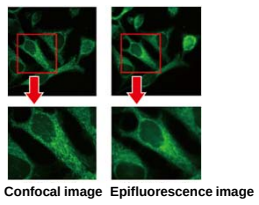
4. Multi-functional data acquisition and analysis software

・A proprietary graphical user interface makes it easy to set recording conditions and analyze images and data.

・The analysis results can be output in report form.







Social Contribution

Today, pharmaceutical industry has problems, such as the upcoming expiration of patents for blockbuster drugs and shortage of lucrative blockbuster products, so the speeding up of the development of new drugs is an urgent issue.

Furthermore, development costs increase year after year, whereas the number of approvals for new drugs remains unchanged, so it is also critical to improve development efficiency. Therefore, new drug development makes efforts to improve the development efficiency by automating and increasing the speed of the process to screen hundreds of thousands to millions of candidate compounds to identify hopeful ones. The CellVoyager High-Throughput Cytological Discovery System meets these requirements. The CellVoyager is able to automatically and with high speed run the process to input a candidate compound to a large number of cells, simultaneously record the changes in the cells with multiple cameras, and process the acquired images to check the effects of the input compound.

Cerebral Nerve Function Imaging System

PQ1160C MEGvision

1. Yokogawa's magnetoencephalograph (MEG) system that enables measurement of deep brain regions

・A first-order coaxial gradiometer is employed.

・A sensing coil with a 50mm baseline length is employed.

・Goals have been reached : " improvement MEG signal detection capability " and "noise reduction".

2. Wide-range and high-density measurement

・160 channel sensors are able to measure an extensive area of brain.

・Densely placed sensors increase the signal source estimation accuracy.

3. PC-based system integration

・Compatibility with various peripheral equipment

・Easy system management

・Adaptable to various analysis environments

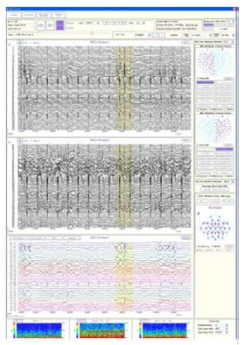
4. Running cost reduction

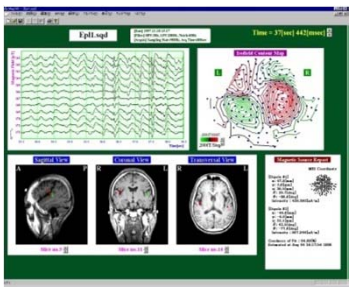
・Reduction of liquid helium consumption reduction

・Free from work to maintain the dewar vacuum

Relieved of the dewar vacuum maintenance

・Elimination of cumbersome sensor replacement





Social Contribution

Faced with an aging society with fewer children, a higher quality of medical care for a higher quality of life is required. The MEG system is widely used in the areas of brain science and medical care, because it is able to non-invasively measure the brain activity as a function with high temporal-spatial resolution instead of conventional morphological image diagnosis and invasive diagnosis.

The MEG is actively used for brain-machine-interface research in the area of brain science, and for research to early detect dementia, mental disease, and development disorder in the area of medical care. The MEG is also used in the area of basic research, such as imaging of functional activities, including signal transfer from the optic thalamus to the cortex. The MEG is a system that is able to greatly contribute to the development of brain studies.

Main products & Contribution

Direct Drive Motor

DYNASERV
- Maximum output torque：4 to 500 Nm
- Rotation positioning absolute accuracy：±15 to ±150 arc-sec
- Rotation positioning repeatability accuracy： ±1 to ±5 arc-sec
- Maximum resolution：425,984 to 4,096,000 pulses/rotation

LINEARSERV
- Maximum thrust：40 to 400 N, Rated speed：0.16 to 2 m/s
- Absolute positioning accuracy：10μm or less (Stroke length: 1,000 mm or less)
- Maximum encoder resolution：0.05 to 0.5μm/pulse
- Repeated positioning accuracy：0.1 to 1μm
- Stroke length：50 to 1,800mm

Driver
Communication interface
- Serial, contact I/O, CC-Link, PROFIBUS-DP

PLANESERV
Slider：3-axis (XYθ) hybrid plane motor
High precision
- Resolution: 27 nm
- Repeatability accuracy: ±100 nm (XY), ±0.2 arc-sec (θ)

High-speed response
- Setting time: 20 ms (with a setting width of 1μm and at a position control bandwidth of 40 Hz)
- Pneumatically floated so no mechanical parts and no friction

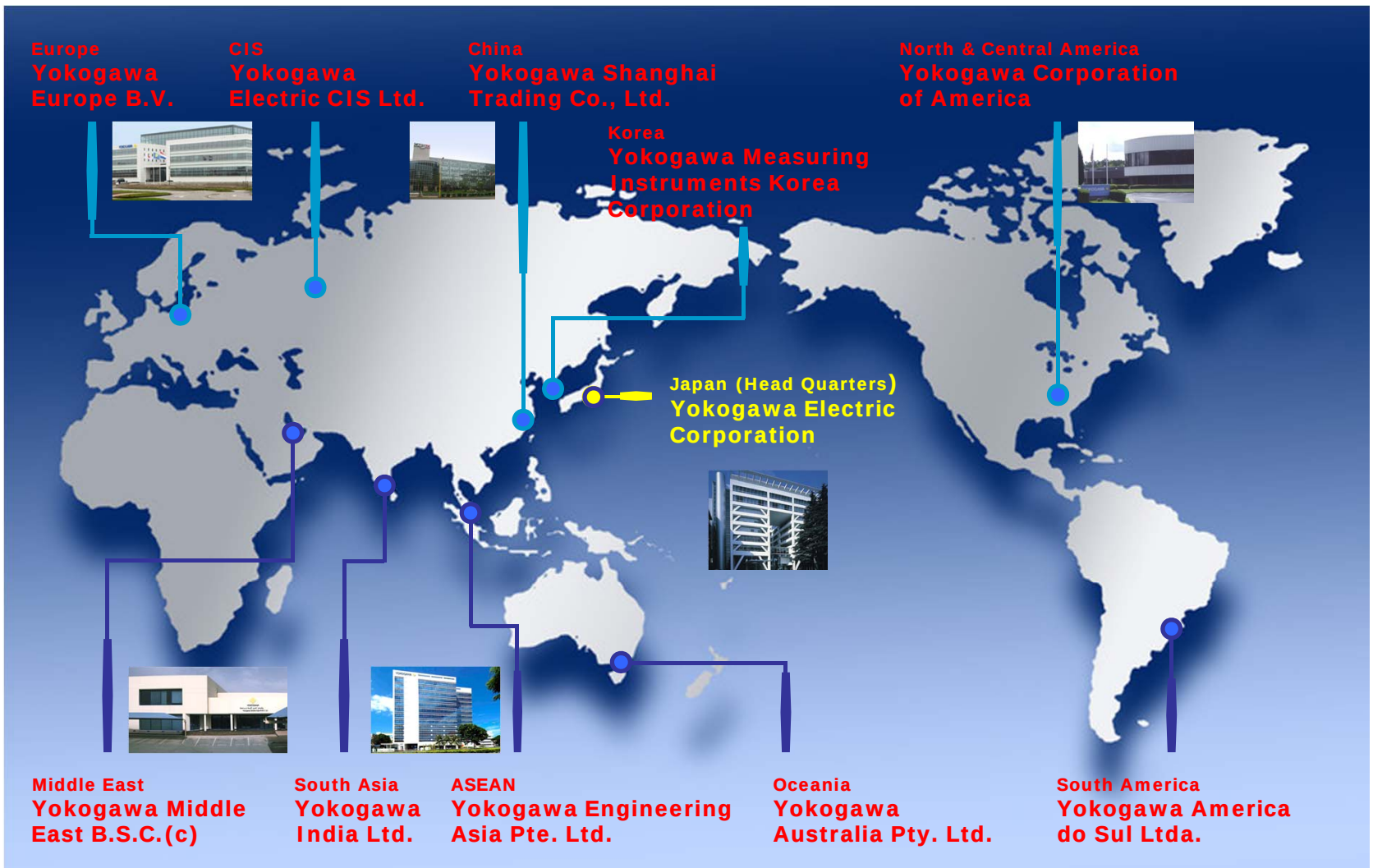
Solar cells

Social Contribution
DYNASERV and LINEARSERV do not need any mechanical parts such as gears and ball screws, and are able to perform startup adjustment and maintain precision over a long period of time, thus contributing to the saving of energy and resources.
Furthermore, the high servo stiffness and precision enable customers to perform minute positioning in their equipment, help increase their production process quality, and reduce the failure rate.
The high precision positioning with high speed helps customers improve the production capability, including the improvement of tact time and the number shots. With respect to solar cells that are attracting attention and are driven by the demand for energy saving these days, DYNASERV and LINEARSERV are used in manufacturing equipment for crystal solar cells to perform high-precision positioning to miniaturize electrode patterns, thus contributing to the improvement of power generation efficiency of solar cells. In the thin film application, DYNASERV and LINEARSERV meet the requirements, for example, for the precision of laser processing. In addition, the high-speed and short-cycle drive of DYNASERV and LINEARSERV enable stable mass production and contribute to the supply of high-quality solar panels to the market.

Worldwide Business Operations

Yokogawa's Global Network

68 subsidiaries and 2 affiliates outside Japan
(As of March 31, 2009)



Yokogawa Corporation of America	
Head Office	
Address:	2 Dart Road, Newnan, Georgia 30265-1094, United States
Tel:	(1)-800-888-6400 or (1)-770-253-7000
FAX:	(1)-770-251-6427
URL:	www.yokogawa.com/us/
Remark:	US customers may also call us toll-free at 1-800-888-6400 extension 5212 (8:00 to 17:00 Eastern).

Yokogawa Engineering Asia Pte. Ltd.	
Head Office & Factory	
Address:	5 Bedok South Road, Singapore 469270
Tel:	(65)-62419933
FAX:	(65)-62412606
URL:	www.yokogawa.com/sg/

Yokogawa America do Sul Ltda.	
Sales branch office	
Address:	Av. Ceci, 1500 Tamboré - Barueri - SP, CEP-06460-120, Brazil
Tel:	(55)-11-5681-2400
FAX:	(55)-11-5681-4435
URL:	www.yokogawa.com.br

Yokogawa India Ltd.	
Head office	
Address:	Plot No.96, Electronic City Complex, Hosur Road, Bangalore 560 100, India
Tel:	(91)-80-2852-1430/2852-1450
FAX:	(91)-80-2852-0625/1363
URL:	www.yokogawa.com/in/

Yokogawa Europe B.V.	
Regional Support Office for Europe	
Address:	Euroweg 2, 3825 HD Amersfoort, The Netherlands
Tel:	(31)-88-4641000
FAX:	(31)-88-4641111
URL:	www.yokogawa.com/eu/

Yokogawa Shanghai Trading Co., Ltd.	
Head Office	
Address:	4F Tower D Cartelo Crocodile Building, No.568 West Tianshan Road, Changning District, Shanghai, China
Tel:	(86)-21-6239-6363
FAX:	(86)-21-6880-4987/3005/9254
URL:	www.yokogawa.com/cn-ysh/

Yokogawa Electric CIS Ltd.	
Address:	Grokholskiy per 13, Building 2, 4th Floor, 129090, Moscow, Russia
Tel:	(7)-495-737-7868
FAX:	(7)-495-737-7869
E-mail:	info@ru.yokogawa.com
URL:	www.yokogawa.ru/

Yokogawa Measuring Instruments Korea Corporation	
Head Office	
Address:	Room 405-9, City Air Terminal Bldg,, #159-6 Samsung-dong, Kangnam-ku, Seoul, Korea
Tel:	(82)-2-551-0660
FAX:	(82)-2-551-0665
URL:	www.yokogawa-yik.co.kr

Yokogawa Middle East B.S.C.(c)	
Address:	P.O. Box 10070, Manama, Building No. 577, Road 2516, Busaiteen 225, Muharraq, Bahrain
Tel:	(973)-17358100
FAX:	(973)-17336100
URL:	www.yokogawa.com/bh/

Yokogawa Australia Pty. Ltd.	
Head Office	
Address:	Tower A, 112-118 Talavera Road, Macquarie Park NSW 2113, Australia
Tel:	(61)-2-8870-1100
FAX:	(61)-2-8870-1111
URL:	www.yokogawa.com/au/

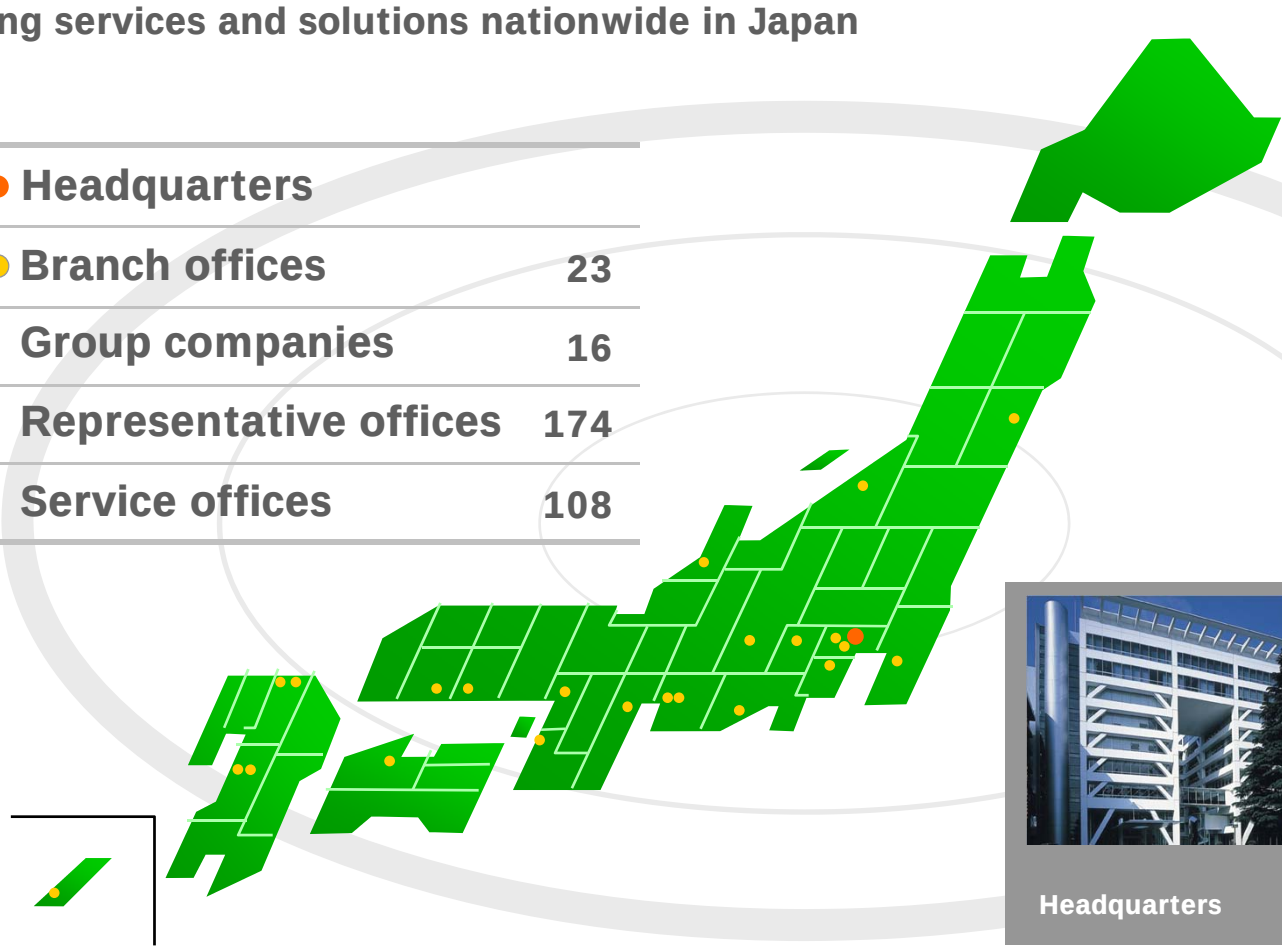
Yokogawa Electric Corporation	
Communication & Measurement Business Headquarters	
Address:	9-32, Nakacho 2-Chome, Musashino-shi, Tokyo, Japan
Tel:	(81)-422-52-6768
FAX:	(81)-422-52-6624
E-mail:	tm@cs.jp.yokogawa.com
URL:	www.yokogawa.com/tm/

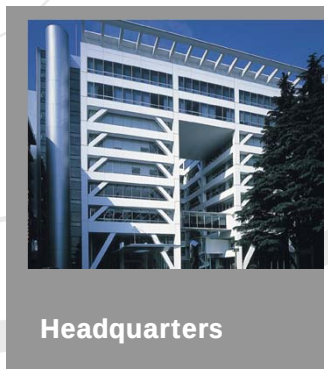
■ Some of products is handled by other channels.

Network

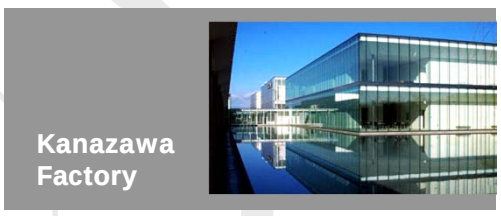
Providing services and solutions nationwide in Japan

● Headquarters	
● Branch offices	23
Group companies	16
Representative offices	174
Service offices	108

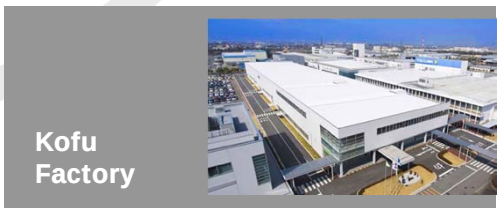



Headquarters


Komine Factory


Kanazawa Factory


Sagamihara Factory


Kofu Factory

Yokogawa Electric Corporation Measurement business Headquarters

Test & Measurement Products (DL,WT,GS,AQ etc.)

Test & Measurement
Adress: 9-32, Nakacho 2-chome, Musashino-shi, Tokyo, 180-8750, Japan
TEL: **Sales Department** : +81-422-52-6614 / 5609
Marketing Department : +81-422-52-5627
URL: http://tmi.yokogawa.com/

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C&M HQ Communication Equipment Division
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TEL: +81-42-770-6811 (Sales Department) E-Mail: photonicsinfo@cs.jp.yokogawa.com

Actuator (DYNASERV etc.)

Motion Control Center
Address: 9-32, Nakacho 2-chome, Musashino-shi, Tokyo, 180-8750, Japan
TEL: +81-422-52-4474

Bio Analitical Product

Bio Analitical Center
Address: Kanazawa Office: 2-3 Hokuyoudai Kanazawa-shi Ishikawa, 920-0177, Japan
Tokyo office: 9-32, Nakacho 2-chome, Musashino-shi, Tokyo, 180-8750, Japan
CSU&CellVoyager products: TEL: +81-76-258-7028 (Kanazawa) , +81-422-52-1283 (Tokyo)
E-mail: csu@csv.yokogawa.co.jp
MEG products: TEL: +81-422-52-8062 (Sales Department)

Yokogawa Digital Computer Corporation (Bus Analyzer, Data Generator etc.)

Address: 6th floor, J-Tower, 1-1 Nikko-cho, Fuchu-shi, Tokyo, 183-0044, Japan
TEL: +81-42-252-5698 E-mail: info-ovs@yokogawa-digital.com
URL: http://www.yokogawa-digital.com/en/

Yokogawa Meters & Instruments Corporation (General measuring instruments)

International Sales Division
Address: 6-1-3 Sakae-cho, Tachikawa-Shi, Tokyo, 190-8586 JAPAN, Tachihi BLD. No2 2nd Floor
TEL: +81-42-534-1413 E-mail: isd@mcc.yokogawa.co.jp
URL: http://www.yokogawa.com/mcc/mcc-businesstop-001-en.htm

■ The contents of this booklet are as of October 2009.
■ Subject to change without notice.