CAMPBELL SCIENTIFIC®
WHEN MEASUREMENTS MATTER

UPDATE

First Quarter 2013

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When Measurements Matter

President's Message

Science is about understanding cause and effect. Metrology is the science of measurement. A metrology technique that has proven useful in electronic measuring instruments combines analog components such as a voltage reference and a thermal resistive device, and digital electronics using memory and a microprocessor. An initial calibration matrix characterizes the response of the voltage reference at different temperatures, and the characterization is stored in memory and subsequently retrieved and applied by the microprocessor to provide a temperature-corrected or compensated reference. Because most transducers are sensitive to temperature, this technique is often applied to achieve temperature-compensated measurements of such things (besides voltage) as pressure, or wind (using sonic anemometry), or even concentration of a target gas with an analyzer operating in outdoor, ambient conditions. This innovative technique, applied to instrument design and manufacture, has enabled a broader array of sensing technologies to be used for environmental measurement, and it has also enabled instruments to operate in the ambient environment that would otherwise be confined to the laboratory. Additional benefits include improved accuracy of instruments used in ambient field conditions and a lower cost for sophisticated instruments with the use of more-tolerant reference components.

"We at Campbell Scientific are pleased to offer… proven manufacturing methods that yield products that perform in the field."

The product family of pressure transducers manufactured by Campbell Scientific, Inc., (CS451 and CS456) including the new CRS451 and CRS456 featured in this newsletter, are examples of products that use the above-described temperature-compensating calibration technique. A high-precision pressure calibrator, with its own documented and maintained National Institute of Standards and Technology (NIST) traceability, is used at a stable room temperature, adjacent to a chamber containing a batch of transducers of the same pressure range being calibrated. The chamber then undergoes a temperature excursion in steps. At each temperature step, the pressure calibrator undergoes its own step change of several pressures from zero to the full scale range of the transducers being calibrated. The temperature response characterization thus generated for each unit undergoing calibration is then stored in memory of the corresponding sensor. Campbell Scientific has made a substantial investment in this process to assure integrity of instrument calibration, and to automate the process for efficiency of product manufacture.

Other benefits from this calibration process include operating time for instrument burn-in, and verification of operation and accuracy at temperature extremes. The reliability of electronics still depends on myriad connections of conductors using solder or some other form of metal-to-metal bonding, or with spring contacts. Temperature excursion exercises these conductive joints and usually exposes those prone to failure.

We at Campbell Scientific are pleased to offer, built in to our instruments, the benefits of modern metrology techniques, as well as the proven manufacturing methods that yield products that perform in the field.

Paul D. Campbell, President
Campbell Scientific, Inc.

Campbell Scientific calibrates pressure transducers in chambers that cycle through temperature concurrent with step changes from a high-precision pressure calibrator, ensuring high-quality measurements.

Recent Developments in Datalogger Operating Systems

Product Update

The CR800, CR1000, and CR3000 dataloggers continue to be the most robust, flexible, low-power data-acquisition systems on the market. One of the keys to this success is its incredibly powerful operating system (OS).

What is an OS? The OS is the collection of software that directs the datalogger internal operations. It includes measurements, time- and event-based execution of tasks, time stamping, and statistical manipulation of data. The OS also prioritizes communication tasks. The OS knows all of the resources available and, in conjunction with the user program, allocates the resources in the most economical way.

The operating system is written at Campbell Scientific. A home-grown OS promotes agile development and is one of the secrets to our success in measurement synchronization and low power consumption. The OS is shared among the CR800, CR1000, and CR3000 dataloggers, so enhancements in one OS benefit all three.

Ideas for new CRBasic instructions, telecommunication options, statistical manipulations, and measurement capabilities may come at any time, and from several sources. We are usually able to respond to those requests immediately, while maintaining backward compatibility. This allows someone who purchased a datalogger several years ago to take advantage of years of upgrades at no additional charge.

So even though Campbell Scientific dataloggers still look the same on the outside as they did when they were first released to market, they are dramatically better on the inside thanks to OS development. The timeline lists some of the noteworthy improvements.

So there you have it. Arguably the most robust dataloggers ever created, with an OS that keeps them operating beautifully and keeps them technologically young at heart.

CR1000 Upgrade Timeline

Technology Driven		Market Driven
CR1000 datalogger introduced	2004	*Modbus master and Modbus slave*
PakBus protocol		*Support CS110 Electric Field Meter*
Pipeline and Sequential modes supported		*Custom menu for CR1000KD*
Support CR1000KD		
Support CFM100 removable CF data storage	2005	*Support Li-Cor gas analyzer communications*
Auto baud detection on COM ports		*Preserve Variables*
Allow TTL logic on COM ports		
Support NL115 with TCP/IP and PPP	2006	*Added OmniSat, Argos functionality*
Web and FTP server		*Upgrades to GOES data*
Web and FTP client		*Output ETsz and Rso*
E-mail client		*Increase concurrrent communication options*
Support string data type for smart sensors		*NTCIP Support for road weather*
		FieldCal for strain gage zero and shunt calibration
		Sort Spacial, Find Spacial and Median instructions
Support smart sensors through SerialIn Record	2007	*Output statistical moment of an array*
Increase program memory from 125 kB to 512 kB		*UDP data transfer*
Increase internal data memory from 2 MB to 4 MB		*DNP3 Slave*
		Ability to hide data tables
		Support AVW200 static vibrating wire measurements
Support conditionally compiled programs	2008	*TimedControl() gives high priority to timing in pipeline mode*
Precision clock synchronization with GPS		*File encryption*
Support SC115 external mass storage device		*Multiplexer control and channel selection*
	2009	*Transport layer security (TLS) protocol*
Management of internal files and drives	2010	*AC power measurement*
Full featured web service (API)		*Support CSI EC100, EC155, IRGASON*
Support CWB100 wireless sensor networks		
Support NL200 for low power Ethernet	2011	*Solar Position instruction*
CF card size limit removed		
Support NL240 for low power wireless Ethernet	2012	*Support file compression for downloads*
		HiPriority block for PID control
FTP, HTTP and e-mail data streaming	2013	*PakBus encryption*
		DNP3 master
		Modbus ASCII
IPV6	Future	

Get the Latest OS
campbellsci.com/downloads

New Campbell Recording Sensors

New Product

Campbell Scientific is developing a powerful new line of sensors that have an integrated time-clock and memory feature. This saves money and time in standalone applications, since you often don't have to purchase a datalogger, enclosures, power supplies, or mounting hardware, and you don't spend time setting up or installing those items. Recording sensors leverage Campbell Scientific's datalogging expertise with the latest in sensor technology into an integrated unit. Recording sensors also increase the flexibility of siting sensors for optimal measurement conditions, since you only need to install the one sensor, and not the peripherals.

The new CRS451 and CRS456 are combination water-level and water-temperature sensors that feature this added recording capability. These new instruments support time-based scanning and recording, along with event-based recording. The CRS451 has a stainless-steel case, while the CRS456 has a titanium case that lets you use it in corrosive environments. They come with HydroSci software for setup, data retrieval, and data display, and they have a sealed USB connector for interfacing with a computer.

The high-accuracy transducers in the new products are the same as the ones in our CS451 and CS456 water-level sensors, and are fully temperature compensated. These new instruments are battery powered, needing no power or signal cable while deployed. Batteries should last five years at a once-per-hour logging interval. Replacement batteries are available from Campbell Scientific, and can be installed by the user.

The CRS451 and CRS456 are built to Campbell Scientific's high standards of ruggedness and innovation. The flexibility and dependability they offer will make them a valuable tool in many applications.

Learn More Here
campbellsci.com/crs451

Have You Been Trained?

Events

Campbell Scientific offers comprehensive training courses at our state-of-the-art training facility in Logan, Utah. Our list of courses includes classes on programming our dataloggers, making the best use of our software, and professional-level expertise in research methods.

Each training course is taught by experienced Campbell Scientific application engineers. Class size is limited to ensure personalized instruction and assistance. Course fees include training manuals and the use of dataloggers, computers, and sensors. Lunch is provided on all course days, and there will be a tour of Campbell Scientific's facilities as time permits.

If you have questions about which course will best meet your needs, please contact an application engineer. We can also help you arrange a self-study course or a customized course at your location.

February	
04-07	CR1000/LoggerNet
11-14	Open Path Eddy Covariance
March	
04-07	CR1000/LoggerNet
11-15	Structural & Geotechnical Instrumentation
April	
15-18	CR1000/LoggerNet
May	
06-09	CR1000/LoggerNet

To see the current schedule and to register on line, visit our website at:
www.campbellsci.com/training

Learn More Here
campbellsci.com/training

Bridge-Health Monitoring in Oregon

The Bridge Engineering Section of the Oregon Department of Transportation (ODOT) previously developed a structural health monitoring program to facilitate the maintenance and performance monitoring of selected highway bridges. This case study highlights three of those bridge projects in which ODOT contracted Engineered Monitoring Solutions (EMS) to design and install the monitoring systems.

Interstate 5 Bridge

ODOT wanted to improve its monitoring of the Interstate 5 Bridge, near Portland, during the operation of its lift span. The southbound portion of the bridge conducts traffic from Washington into Oregon over the Columbia River. The steel bridge is approximately 3,500 feet long with 16 spans.

A counterweight at each end of the southbound lift span helps raise the span for ships passing underneath. When the lift span is raised, the counterweights move vertically along guide rails. ODOT's goal was to improve its ability to monitor the lifting system's structural performance.

EMS designed and installed a monitoring system that includes a network of CR1000 dataloggers, tiltmeters, and laser position sensors to monitor the lift span and the counterweights' positions relative to the guide rails. The dataloggers are positioned on the counterweight blocks, on the lift span, and in the operator's control house. Because ac power is not available when the blocks are lowered during a lift event, the dataloggers on the blocks are solar powered.

The dataloggers collect sensor data once every five seconds during a bridge opening event, as well as once every four hours to identify any historical movement trends. The networked Campbell Scientific dataloggers communicate across the system using RF401 spread-spectrum radios. The dataloggers calculate and transmit data to a server on the ODOT computer network running LoggerNet software. Bridge engineers access and evaluate lift event data related to the lift span and counterweights, enabling them to make quick decisions regarding the need for maintenance.

Fremont Bridge

With this project, ODOT wanted to improve their understanding of the fatigue cracking of the Fremont Bridge in Portland, evidenced by the thermal strain on the tie girders. This steel-tied arch bridge spans approximately 2,150 feet and has the longest main span (1,255 feet) of any bridge in Oregon.

EMS designed and installed a monitoring system of eight CR800 dataloggers and a variety of sensors (including 64 sensors measuring strain and surface temperature) along the tie girders on both sides of the bridge. This system monitors the stress cycles in the tie girders due to thermal loading.

The networked Campbell Scientific dataloggers performed calculations on the collected data and communicated with the system via an RF450 radio network. Using an onsite CR1000 datalogger as a gateway, the tie girder data was relayed hourly to ODOT's computer network for review by bridge engineering personnel, who could then prioritize their retrofitting efforts.

Continued on page 7

Wind-Farm Monitoring in California

Case Study

CalWind Resources owns and operates a wind farm in Tehachapi, California. The wind farm has been in operation for many years, but with a new requirement to report data to the California Independent System Operator (ISO), CalWind Resources needed to procure and install new measurement and communication equipment. Campbell Scientific equipment was chosen to be installed on the wind farm to meet those needs.

The California ISO operates the wholesale power system in California, with the goal of providing higher transmission reliability while controlling costs. The California ISO acts as a key platform to achieve California's clean-energy goals. To meet its goals and manage the power grid, the California ISO requires renewable-energy generating facilities to report secure, real-time weather and power data.

For the weather data measurements, a weather station based on a Campbell CR800 datalogger was installed on a permanent meteorological tower, measuring wind speed and direction at two heights, as well as temperature, relative humidity, and barometric pressure.

A power meter located at a separate location on the wind farm is used to measure voltage, megawatts, and megaVARs.

Typically, a remote intelligent gateway (RIG) serves as the primary means for secure communication between generating facilities and the California ISO's energy management system (EMS). A CR1000 and NL200 are used in this system to provide the RIG solution. The CR1000 gathers the data from both the weather station via the PakBus protocol and from the power meter via the DNP3 protocol. The NL200 is used as a secure proxy server to provide secure DNP3 communications with the California ISO.

Due to site constraints, a wireless IP network was implemented using IP radios to communicate between the RIG, the weather station, and the power meter. Data from both the weather station and power meter are reported to the RIG, which acts as a data accumulator and as the California ISO source for all weather and power data from the site.

Learn More Here
campbellsci.com/wind-energy

High-Resolution Digital Network Camera Improvements

Product Update

For several years, Campbell Scientific has offered the CC5MPX and CC5MPXWD high-resolution digital network cameras. The cameras' ruggedness, low power consumption, and ability to operate at extreme temperatures (as low as -40°C and as high as 60°C) allow them to be used in remote, battery-powered, data-acquisition systems.

We are continually improving the cameras and adding new capabilities. Recent improvements include better motion detection and low-light performance. New PakBus commands allow the datalogger to update the still image and video so that they can be overlaid with text containing real-time data. These new commands also allow the datalogger to control the CC5MPXWD's window defroster based on measured parameters, thus saving power. PakBus Graph can now be used to remotely configure the camera.

Other new capabilities include the addition of support for SMTP TLS, allowing users to send files using popular email servers such as GMAIL. Video buffering allows the camera to store up to 30 seconds of video preceding a triggering event, so that users can better assess the circumstances surrounding the event.

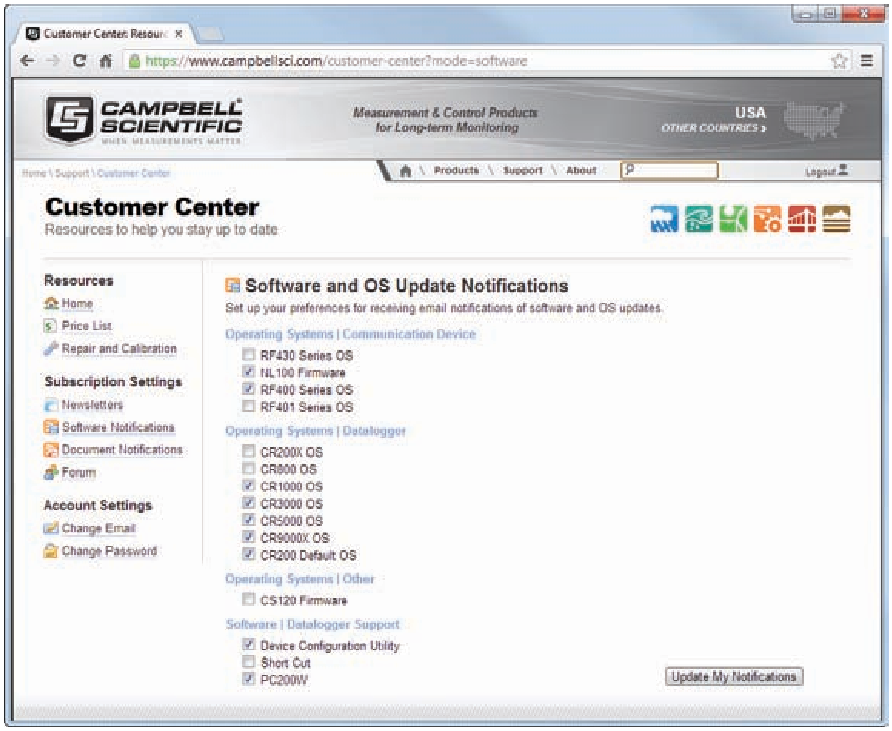
Learn More Here
campbellsci.com/cc5mpx

OS Update Notifications

Company News

We show you in this issue of the newsletter (see page 3) how we continually release new operating systems (OSs) for our dataloggers and other products, and how the new OSs improve product capabilities. Of course, you can't take advantage of a new OS unless you know it exists. A Customer Center account on our website can help you stay in-the-know. With an account, you can sign up to receive an email whenever we release a new OS that you are interested in. You'll find other helpful resources there, as well.

Right now, Customer Center accounts are available to current customers of Campbell Scientific. We hope to add broader access in the future. If you haven't taken the opportunity to register, we encourage you to do so. If you would like to register for an account, please visit our registration page at *www.campbellsci.com/register*.



Learn More Here
campbellsci.com/register

Oregon: Bridge-Health Monitoring Continued from page 5

Kamal's Bridge

Kamal's Bridge in Tualatin is a steel box-girder bridge with four spans crossing Interstate 5. ODOT sought to improve the monitoring of the bridge's structural response to changes in temperature and traffic load. This was needed because fatigue cracking appeared between the transverse cross beams and the longitudinal box girders on either side of the bridge deck.

The monitoring system designed and installed by EMS collected data regarding the strain in the box-girder and cross-beam diaphragms, as well as the rotation between them. In addition, the surface temperature of the box girders and the air temperature were monitored.

Campbell Scientific's CR9000X datalogger collected sensor data at two frequencies. Lower-frequency data was used to record the effect of temperature changes on the bridge's performance. The datalogger recorded higher-frequency data (100 times per second) in response to short-term, live-load effects based on predetermined event criteria, whereby a larger traffic load caused one or more of the strain gages to exceed its strain threshold.

The bridge's temperature and traffic load data was uploaded hourly from the datalogger to ODOT's computer network to help bridge engineers assess the effectiveness of the structural retrofits.

Learn More Here
campbellsci.com/bridge-monitoring

Tips and Tricks: DataEvent()

Tips and Tricks

How do you catch a unique bird?
You 'neak up on it.
How do you catch a tame bird?
The tame way.

Ha ha ha! That cracks me up every time. "What does that have to do with datalogging?" you ask. Most of the time data is stored on a time interval using the **DataInterval()** instruction. But, sometimes you want to store data under unique conditions. This is referred to as conditional data, and the **DataEvent()** instruction, which is a **DataTable()** modifier, is one way to accomplish it. This is what the CRBasic Editor help says:

> *The* **DataEvent** *instruction is used to conditionally start and stop storing data to a* **DataTable**. *Trigger events can be specified to determine when data storage begins and when data storage ends. Additionally, a number of records to store before and/or after the event can be specified.*

For example, let's say you are measuring and storing temperature data. You take measurements every second and store data every hour. If, in addition to these data, you also want to store every one-second measurement when the temperature exceeds a set value, you can use the **DataEvent()** instruction.

There are four arguments in the **DataEvent()** instruction: ***Records Before, Start Trigger, End Trigger,*** and ***Records After***. Let's talk first about the **Start Trigger (StartTrig)**. **Start Trigger** is a constant, variable, or expression to be evaluated for starting the data storage event. In our example, we could use an expression such as **TempC > 25**. When the variable **TempC** exceeds 25, the **StartTrig** argument is true and the data storage event starts. Likewise, the **End Trigger (EndTrig)** is a constant, variable, or expression to end the event. In our example, we could use **TempC <= 25** to stop storing data when the temperature falls below 25. The instruction would look like this:

```
DataEvent (0,TempC >25,TempC <=25,0)
```

The start and end triggers can be unrelated. You could have the start trigger based on temperature and the end trigger based on some other variable such as wind speed.

Records Before and **Records After** the event let you capture data before and after the start and end triggers are met. No, the datalogger doesn't know when an event is going to occur before it does. It sneaks up on it by keeping a buffer of the data in memory in case a data event is triggered. In our example, we'll store 30 records before, and 15 after. The complete **DataTable** may look something like this:

```
DataTable (Event,True,1000)
        DataEvent (30,TempC >25,TempC <=25,15)
        Sample (1,TempC,FP2)
EndTable
```

It is important to specify the number of records in a conditional data table: **DataTable (Event,True,1000)**. For more information, see the Data Table Memory Allocation tutorial on the web page at *www.campbellsci.com/19_1_9999_153*, and my article on compiled program details at *www.campbellsci.com/tips-details*.

Give the **DataEvent()** instruction a try when you need to catch some unique data. Use the **Records Before** argument to sneak up on it, and never miss a special event.

Uniquely yours,

Tip

Upcoming Trade Shows

Visit our website for training class schedules and additional listings.

FEBRUARY

11-15	U.S. Society of Dams	Phoenix, AZ
12-14	World Ag Expo	Tulare, CA
22-24	World Aquaculture	San Diego, CA
24-28	Waste Management Symposia	Phoenix, AZ

MARCH

08-10	38th SEATA Symposium	Atlanta, GA
11-15	Western Society of Weed Science	San Diego, CA

APRIL

01-04	Geosynthetics	Long Beach, CA
07-10	APWA Snow Conference	Charlotte, NC
16-20	SOLAR 2013	Baltimore, MD

MAY

05-08	Windpower Expo	Chicago, IL

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www.campbellsci.com
info@campbellsci.com
435.227.9000

815 W 1800 N
Logan, UT 84321