CR7 Measurement and Control System

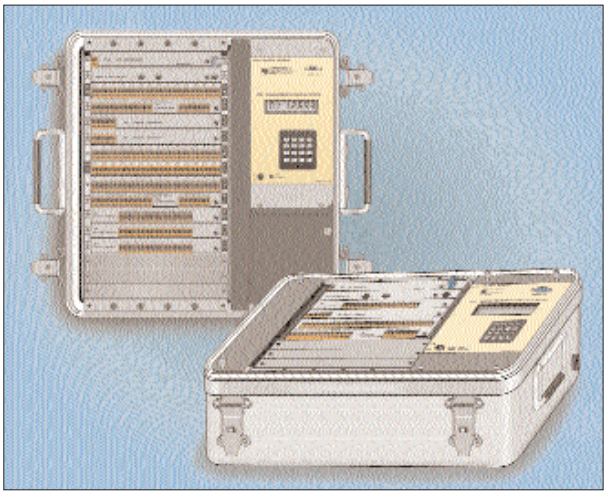
Ultimate Precision in a Rugged, Expandable System

Extremely Sensitive: 50 nanovolt resolution at 20 channels per second throughput.*

Broad Input Range: 16-bit precision on 8 software-selectable ranges (±5 V to ±1.5 mV); input ranges up to ±50 V are possible with the 726 card.

Signal Conditioning Typically Not Required: Most thermocouples, RTDs, pressure transducers, humidity sensors, thermocouple psychrometers, soil moisture blocks, magnetic pulse flow transducers, and pulse transducers are measured directly.

Battery Operated: With the CR7 active 10% of the time (typical application), fully-charged sealed rechargeable batteries power the system for about 5 days. Charging circuitry is included for solar panels, 12 volt vehicle power, or AC.



Most applications use a seven card slot system, but larger applications may require a fourteen card system.

Isothermal Design and Transient Protection: Input terminals in the I/O module are spark gapped to copper bars. The copper bars, together with aluminum panels between each I/O card, minimize thermal gradients.

Analog and Digital Control Outputs: Continuous analog outputs are available for strip-chart recording or proportional control. Digital outputs can be used with relays to control external devices, activate alarms, or provide process control.

Expandable: Seven or fourteen card slot modules are available. Expansion is also possible with SDMs, multiplexers, and slaved I/O modules.

Remote Programming and Data Retrieval: Programs and commands are entered from the CR7's keyboard or from a computer with an appropriate communications link. Data are stored in internal memory (up to 280K data points) for transfer to a storage module, printer, modem, or computer.

Operation in Harsh Environments: Specifications are valid from -25° to +50°C. On special order, CR7s are tested over a -40° to +70°C range. The ENC 7F or ENC 7XL enclosures provide protection from humidity and contaminants.

Internal Processing: Programmable instructions include algebraic, statistical, and transcendental functions.

Portable: In most field applications, a rugged fiberglass enclosure houses the system. System weight is ~40 lbs.

Warranty: 3-year warranty covering parts and labor.

*Throughput rate includes similar measurements on adjacent channels, conversion to engineering units, and storage in Final Memory. Additional processing decreases given rate. The time between signal conversions on adjacent input channels is the *Input Sample Rate* and is given in the Specifications.

Environmental Applications

Growth Chambers, Greenhouse Monitoring and Control

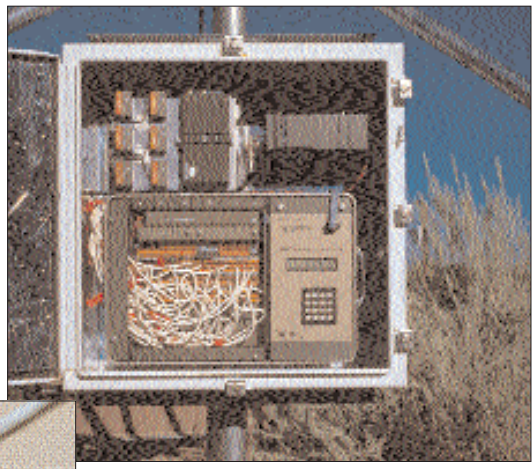
The CR7 can measure large numbers of distributed air temperature, relative humidity, soil temperature, and solar radiation sensors. Coupled with its ability to monitor and control HVAC systems, AC power, and water flow, the CR7 is an ideal instrument for controlled-environment applications. The CR7 can be programmed to maintain measured parameters within preset limits and sound alarms if monitored systems fail.

Peltier Psychrometers

Psychrometric water potential measurement of soil, plant leaves, or other porous media requires measurement of the wet-bulb depression of a thermocouple housed inside a small chamber. The junction is Peltier-cooled below dew point and the wet-bulb temperature is measured as the water evaporates. Wescor, Inc. (Logan, UT) markets the CR7 in conjunction with their psychrometers.

Other Applications

- Multi-level meteorologic towers
- Eddy covariance experiments
- Soil temperature profiles
- Lysimeters



A CR7 measures the soil water potential across a research plot with dozens of thermocouple psychrometers. Results are transmitted via UHF radio to the researcher's computer. Green Canyon, UT.

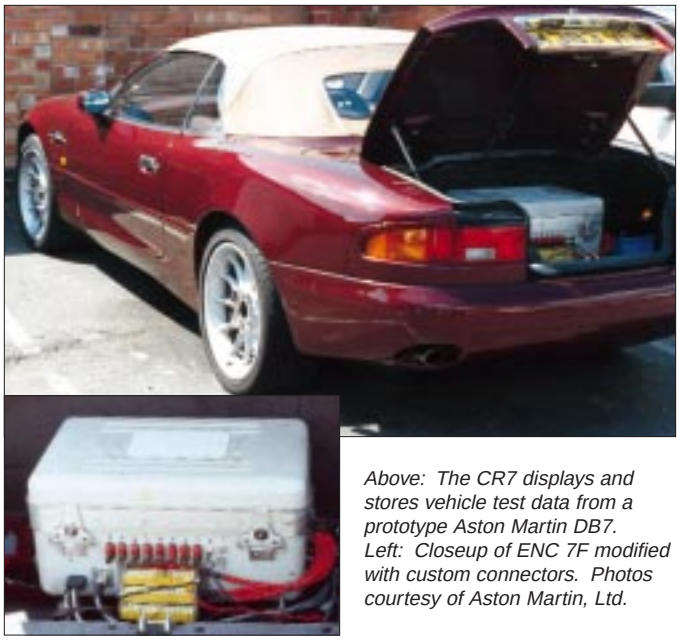
Cover photos At left: CR7 Measurement and Control System. From top right: *Automotive* Electric vehicle monitoring, Waterbury, VT; *Process Control* Respiration measurements on woodchips at Silsoe Research Institute, Bedford, England; *Agricultural/Meteorology* USDA/ARS lysimeter installation, Bushland, TX; *Agricultural Research* NASA CELSS Research Lab, Utah State University, Logan, UT.

Industrial Applications

Vehicle Test

The CR7's wide operating range (-40° to +70°C, extended), portability, ruggedness, and expandability make it a useful tool in vehicle testing applications. In automobiles, locomotives, tractors, helicopters, and other vehicles, the CR7 can measure temperature, pressure, velocity, acceleration, engine RPM, force, displacement, and electrical system load.

Most sensors can be connected directly to the CR7 without the use of external signal conditioning. The CR7 is also SDM-OBDII compatible allowing the user to monitor, record, and compare data from the vehicle's onboard computer with the CR7's sensors.



Above: The CR7 displays and stores vehicle test data from a prototype Aston Martin DB7. Left: Closeup of ENC 7F modified with custom connectors. Photos courtesy of Aston Martin, Ltd.

The CR7 is typically housed in an ENC 7F enclosure and interfaced to the DSP4 Heads Up Display for real-time display. The SM192/716 Storage Modules or CSM1 Card Storage Module provide additional data storage. Real-time data can be downloaded via cellular phone or RF link.

HVAC & Utilities

Measured parameters include:

- Voltage
- Current
- Power
- Temperature
- Relative humidity
- Pressure
- Flow

The CR7 is usually panel-mounted in a NEMA enclosure. HVAC applications typically require input/output channel expandability. Options include:

- 720XL I/O modules
- AM416 multiplexers
- Up to four remote I/O modules

Systems can monitor and control pumps, fans, and starter motors. Proportional control of dampers is also possible.

Remote I/O modules or multiplexers can greatly simplify cabling from remote sensor arrays by sending data or signals over a few common lines.

Process Control

The CR7 can monitor ongoing production allowing operators to discard items that don't meet specifications. Real-time measurements can be displayed for operators and stored for review by quality control personnel. Both product and assembly line status can be monitored simultaneously, providing on-line quality control while minimizing production downtime.

Process and control applications include:

- Maintaining oven/dryer temperature
- Monitoring conveyor/belt speed
- Sounding alarms for out-of-specification conditions or equipment malfunction
- Maintaining liquid or gas levels

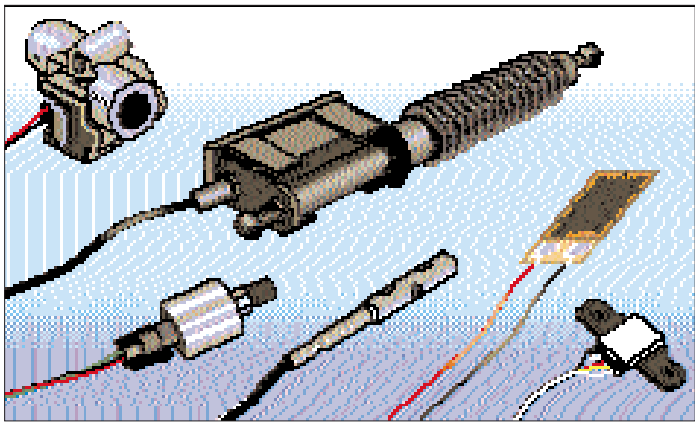
Measurement Examples

Thermocouples

The CR7's input offset error of less than 100 nV allows inexpensive thermocouples to be used for precision temperature measurements. Type T, E, K, J, S, R, and B thermocouples connect directly to a 723 or 723T card; the signal voltage is then linearized relative to a user-specified reference junction. Measurements of type E thermocouples can be resolved to 0.001°C at throughput rates of 20 channels per second, 0.0125°C at 100 channels per second.

RTDs, Strain Gage Pressure Transducers and Load Cells

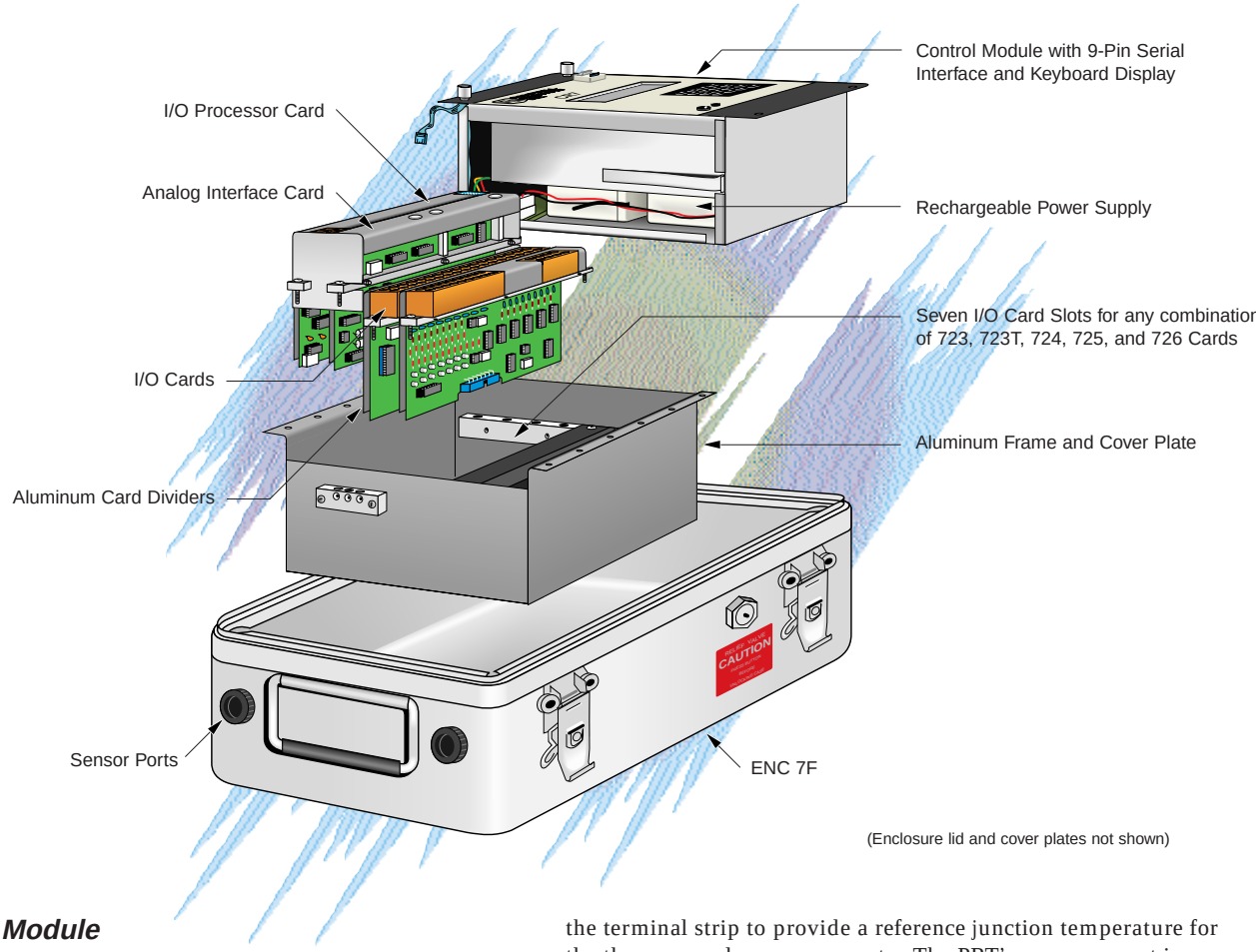
Strain gages and RTDs are measured as the ratio of bridge signal to excitation voltage. Consecutive measurements with reversed excitation polarity eliminate errors due to thermal emfs in connectors and sensor junctions. The CR7's measurement precision allows bridge excitations to be reduced, eliminating self-heating errors (e.g., a 100 ohm RTD with a 0.5 mA excitation current resolves to within 0.00025°C at 15°C).



One CR7 can measure large numbers of flow meters, LVDTs, pressure transducers, thermocouples, strain gages, and accelerometers.

System Description

The CR7 features a modular, multiple-processor design that provides precision measurement and control capability in a rugged, battery-operated system.



(Enclosure lid and cover plates not shown)

700X Control Module

Control Module functions include task initiation, processing, data storage, and telecommunications. The control module contains the CPU with 24K bytes of system PROM and 40K bytes of RAM, the serial interface for peripheral communication and connection of up to four I/O modules, the keyboard/display, and the optional memory expansion card. The system's 2.5 Amp-hour sealed-rechargeable batteries and AC-charging circuitry are also in this module.

709 512K Memory Card: Provides RAM storage for an additional 262,126 data values. Maximum of one per 700X Control Module.

720 & 720XL I/O Module

The I/O module performs all measurement and control functions; it consists of a processor card, a precision analog interface card, and seven card slots. Model 720 has seven I/O card slots; model 720XL has 14 slots (ENC 7XL required). The processor card provides regulated power for analog and digital functions from the unregulated 12-volt supply. The analog interface card contains a 16-bit A/D converter and a precision voltage reference. All I/O module connections are transient protected with spark gaps.

723 Analog Input Card: Contains 14 differential or 28 single-ended inputs. Differential measurements reverse the input polarities for a second conversion to reduce thermal emfs. Input ground terminals connect to a heavy copper bar, which reduces single-ended measurement offsets to less than five microvolts.

723T Analog Input Card With RTD: Identical to the 723 Card except a platinum resistance thermometer (PRT) is centered below the terminal strip to provide a reference junction temperature for the thermocouple measurements. The PRT's measurement is accurate to ±0.1°C over a -40° to +60°C range.

724 Pulse Counter Card: Provides four pulse counting channels for switch closures, low-level AC, or high-frequency pulse signals.

725 Excitation Card: Provides eight switched analog excitations for resistance measurements, two continuous analog outputs, and eight digital control outputs. All continuous analog outputs and digital control ports can be active simultaneously; only one switched excitation output can be active at a time.

726 50 Volt Analog Input Card: Provides 8 differential or 16 single-ended inputs for full-scale ranges of ±50 and ±15 VDC. Accuracy is ±0.2% FSR; common mode range is ±50 VDC; maximum sustained input voltage without damage is ≤ ±160 VDC.

Enclosures

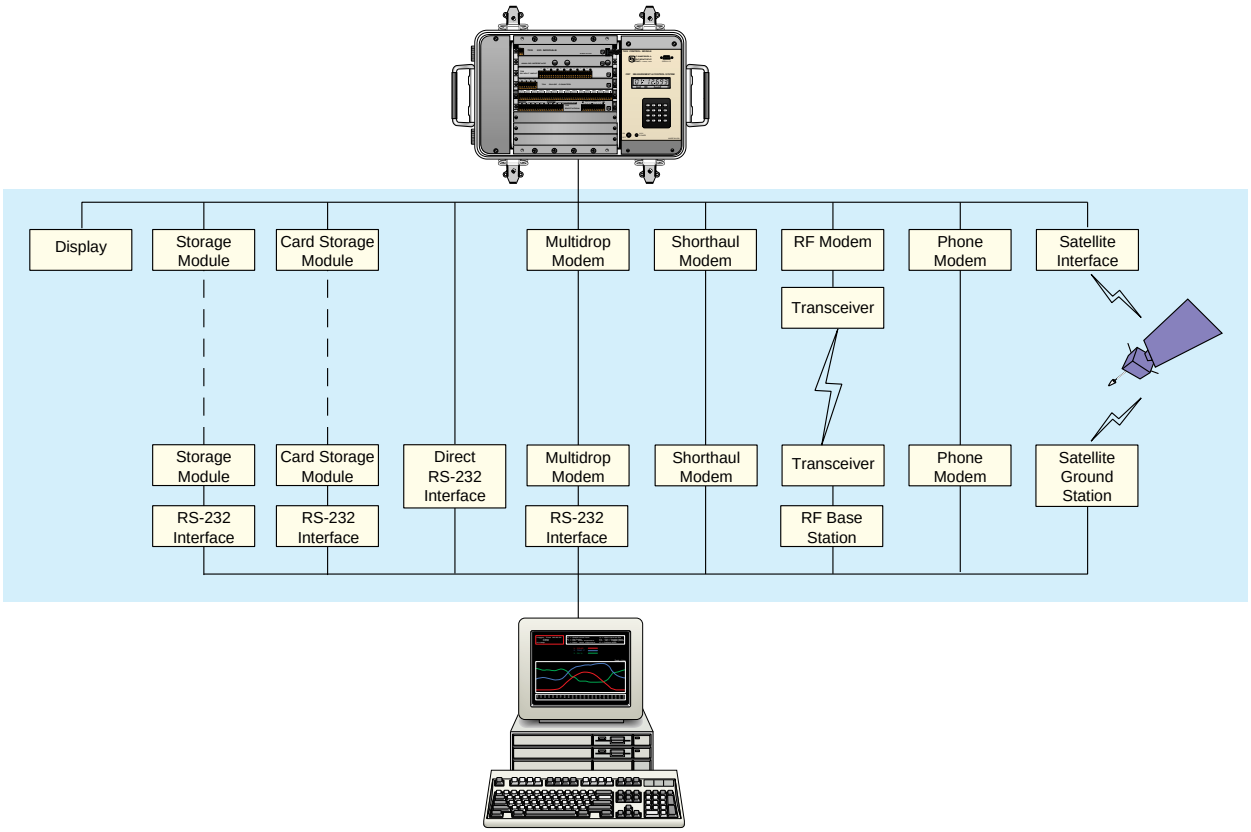
ENC 7F Environmentally Sealed Enclosure (cover photo): 20" x 13" x 10" fiberglass enclosure for harsh environments. Accommodates the 700X control module and 720 I/O module. It has two sensor ports that fit #14 shell size circular connectors. A gas-tight connector option is also available.

ENC 7L Aluminum Frame for Lab: 17" x 12" x 6"; provides a housing for benchtop use. 19" rack mounts and NEMA enclosures are also available.

ENC 7XL: 19" x 19" x 10" fiberglass enclosure for harsh environments. Accommodates 700X and 720XL modules.

Data Storage and Transfer

Up to 18,800 (expandable to 280K) raw or processed data points can be stored in the CR7's memory. Data are transferred to a computer via telecommunications or on-site data retrieval options.



Software

We offer Windows or DOS-based datalogger support software that provides telecommunications, programming, data transfer, data processing, and graphical display functions. With an appropriate communication link, the software supports two-way communication between the CR7 and IBM-PC or compatible computers.

Display

The CR7's keyboard / display provides on-site review of data and programs. Annotated datalogger programs and labeled data values can be displayed on a computer monitor. The DSP4 Heads Up Display provides a dashboard-mounted luminescent display for vehicle test applications.

Storage Modules

Rugged, battery-backed RAM SM192 or SM716 Storage Modules (96K or 358K data values, respectively) can be left connected to the CR7 or carried to the field to retrieve data from the CR7's memory. Two storage modules can be connected to one CR7. Operational temperature range is -35° to +65°C (extended range available). The SC532 Interface is used to transfer data and / or programs between the storage module and a PC.

Card Storage Module

The CSM1 Card Storage Module is a read / write module that either remains with the CR7 or is transported to the datalogger site. Battery-backed RAM memory cards are inserted into the CSM1 for data and / or program transfer. The system operates over a -20° to +50°C range (extended range available).

Direct Line Options

Direct Datalogger-to-Computer Interface

The SC32A RS-232 Interface supplies an optically isolated connection between the CR7 and a computer over distances up to 50 ft.

Short Haul Modems

The SRM-6A short haul modems provide local communication between the CR7 and a computer with an RS-232 serial port. The modem transmits data up to 11.2 miles over a four-wire unconditioned line (two twisted pairs).

Coax Network

The MD9 Multidrop Interface links a central computer to over 200 dataloggers on a single coaxial cable. Total coax cable length can be up to three miles.

Radio Frequency (RF) Communication

Campbell Scientific's RF communication system uses the RF95 modem and a low-powered transceiver at the remote station(s) with a transceiver connected to an RF232 Base Station at the computer site. Up to 255 stations can be interrogated over a VHF or UHF frequency.

Telephone Networks

Telephone communication links require a DC112 modem at the CR7 site and a Hayes-compatible modem at the calling end. Cellular communications are supported with our COM100 transceiver. Phone-to-RF and phone-to-MD9 networks are also available.

Datalogger Support Software

We offer Windows- and DOS-based software packages that simplify the exchange of data, programs, and commands between the CR7 and a computer.

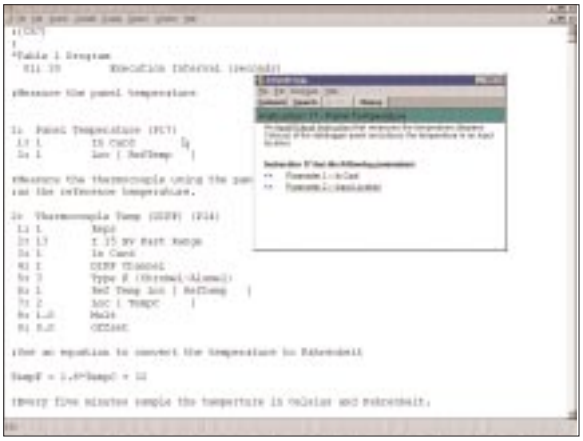
Creating a CR7 Program

EDLOG software allows you to create an application-specific program. If application requirements change, the program can be easily modified. EDLOG helps you create or edit a CR7 program by providing:

- Select-from-a-list and fill-in-the-blank programming sequences
- Annotated instructions, parameters, and labels
- Automatic checking of program structure and syntax when program is compiled
- Extensive on-line help
- The ability to enter algebraic expressions directly into the program and insert comments for documentation

Once programmed, the CR7 automatically:

- Measures sensors at specified scan rate(s)
- Processes data using arithmetic operators, math functions, spatial functions, and time-series functions
- Stores measurements and processed data
- Makes logic decisions based on time or data
- Controls external devices



EDLOG is a powerful software program for creating and editing CR7 programs.

Communicating with the CR7

Our DOS-based PC208E or Windows-based TCOM software will:

- Place a call to the CR7 via one of our telecommunications links
- Transfer a program to the CR7
- Monitor and display real-time measurements in tabular or graphical form
- Collect CR7 data on demand or schedule; integrity is ensured during transmission

TCOM also provides:

- New network capabilities that simplify interactions with the CR7
- Log files that track communications with the CR7
- The ability to run while other Windows software is active (also depends on operating system and computer)
- Simultaneous data collection via multiple COM ports

The Windows-based TCOM graphs real-time data from the CR7.

Processing and Splitting Data Files

Reports can be generated by using Split software. Split allows you to:

- Split large data files into smaller, more easily analyzed files
- Sort and combine data based on time or conditions
- Process data using arithmetic operators, math functions, spatial functions, and time-series functions
- Create output files that are compatible with spreadsheet programs

Communicating with a Storage Module

We offer Windows- and DOS-based software packages that handle storage module communication. The packages support:

- Use of solid-state and card storage modules
- Transfer of CR7 programs to and from storage module and cards
- Retrieval of all or part of a storage module or card's data
- The ability to reset, clear, and configure storage modules or cards

SMS (Windows-based) also provides:

- The ability to view data before storing it on disk
- The choice of appending data to an existing file or creating a new file

The Windows-based SMS displays the status of a solid-state storage module.

Specifications

Electrical specifications are valid for over a -25° to +50°C range unless otherwise specified.

Analog Inputs

(723T or 723 Card specifications below; 726 ±50 V Card specifications discussed in *System Description*)

Voltage Measurement Types: Single-ended or differential.

Range and Resolution: Ranges are software selectable on any input channel.

Full Scale Input Range (mV)	*Resolution Differential*	*Single-ended*
±5000	166 µV	333 µV
±1500	50 µV	100 µV
±500	16.6 µV	33.3 µV
±150	5 µV	10 µV
±50	1.66 µV	3.33 µV
±15	500 nV	1000 nV
±5	166 nV	333 nV
±1.5	50 nV	100 nV

Accuracy of Voltage Measurements:

Differential: ±0.02% FSR (±0.01%, 0-40°C) (e.g. ±0.02% FSR = ±2.0 mV for ±5 V range)

Positive single-ended: ±0.02% FSR (±0.01%, 0-40°C) ±5 µV

Negative single-ended: ±0.03% FSR (±0.015%, 0-40°C) ±5 µV

Input Sample Rates: Fast A/D conversions are integrated over 250 µs. Slow A/D conversions are integrated over 16.67 ms for 60 Hz AC rejection or optionally, 20.0 ms for 50 Hz AC rejection. Differential measurements include two conversions, one with reversed input polarity, to reduce thermal offset and common mode errors. The following intervals do not include the self-calibration measurement which occurs once per instruction.

	Input sample rates ms/channel	*Typical input noise nV/RMS*
Fast Single-ended	2.9	350
Fast Differential	4.7	250
Slow Single-ended	22.0	43
Slow Differential	43.0	30
Fast Differential (TC)	7.9	250

Common Mode Range: ±5 V

Common Mode Rejection: > 140 dB (DC to 100 Hz)

Normal Mode Rejection: 70 dB (60 Hz with slow differential measurement)

Input Current: 100 pA max

Input Current Noise: 9 pA RMS (slow differential)

Input Resistance: 2.5 GΩ typical

Sustained Input Voltage without Damage: ≤ ±16 VDC

Pulse Counters

(724 Card)

Pulse Counters per Card: 4

Maximum Counts per Interval: 32,767 (with overrange detection)

Modes: Programmable modes are switch closure, high frequency pulse, and low level AC.

Switch Closure Mode

Minimum Switch Closed Time: 1 ms

Minimum Switch Open Time: 4 ms

Maximum Bounce Time: 1.4 ms open without being counted.

High Frequency Pulse Mode

Minimum Pulse Width: 2 µs

Maximum Input Frequency: 250 kHz

Voltage Thresholds: The count is incremented when the input voltage changes from below 1.5 V to above 3.5 V.

Maximum Input Voltage: ±20 V

Low Level AC Mode

This mode is used for counting the frequency of low voltage, sine wave signals.

Input Hysteresis: 11 mV

Maximum AC Input Voltage (RMS): 20 V

Frequency Range:

Minimum AC Input Voltage (mV RMS)	*Range (Hz)*
15	1 to 100
25	1 to 1,000
50	1 to 3,000
160	1 to 10,000

Digital Control Outputs

(725 Card)

Each card includes 8 digital control outputs.

Output Voltages (no load):

High: 5.0 V ±0.1 V

Low: < 0.1 V

Output Resistance: 400 Ω

Analog Outputs

(725 Card)

Each card contains 8 switched and 2 continuous analog outputs.

Switched: Provides a precision voltage for resistance measurement, then switches off (high impedance). Only one switched output can be active at a time.

Continuous: A preset voltage is held until updated. Voltage degrades 0.17 mV every 7 seconds. All continuous analog outputs (and digital control ports) can be active simultaneously.

Range: ±5 V

Resolution: 166 µV

Accuracy: Same as voltage measurements.

Output Current: 25 mA at ±5 V, 50 mA at ±2 V

Resistance and Conductivity Measurements

(Combination of 723 and 725 Cards)

Accuracy: ±0.01% of full scale bridge output provided the matching bridge resistors are not the limiting factor.

Measurement Types: 6-wire and 4-wire full bridge, 4-wire, 3-wire, and 2-wire half bridges. High accuracy, low impedance bridge measurements are made ratiometrically with dual polarity measurements of excitation and output to eliminate thermal emfs. AC resistance and conductivity measurements use a 750 µs excitation pulse with the signal integration occurring over the last 250 µs. An equal duration pulse of opposite polarity is applied for ionic depolarization.

Transient Protection

All input and output connections to the I/O Module are protected using spark gaps that are rated to 10,000 A. The spark gaps are connected directly to a heavy copper bar on each input card with no more than 2 inches of 20 AWG copper wire.

Control Module

Processor: Hitachi 6303

Memory: 24K ROM; 40K RAM, 709 Card provides an additional 512K RAM.

Data Storage: 18.8K values, standard; 280K values, expanded.

Display: 8 digit LCD (0.5" digits).

Peripheral Interface: 9-pin, D-type connector on the Control Module panel for connection to storage module, card storage module, multidrop interface, modem, printer, or RS-232 adapter. Baud rates selectable at 300, 1200, 9600, and 76,800.

I/O Module Interface: Optically isolated current loops allow connection of up to 4 I/O Modules. I/O Modules can be separated from the Control Module by up to 1,000 feet.

Clock Accuracy: ±1 minute per month.

Maximum Program Execution Rate: System tasks can be initiated in sync with real-time up to 80 Hz.

System Power Requirements

Voltage: 9.6 to 15 VDC

Typical Current Drain: 3.5 - 6 mA (minimum system) quiescent, 16 mA during processing, 100 mA during analog measurement.

Internal Batteries: Sealed rechargeable with 2.5 Ahr capacity per charge.

Charging Circuit: Requires DC or rectified AC voltage from 15 to 25 V. Thermal compensation is included to optimize charging voltage according to ambient temperature.

External Batteries: Any 12 V external battery can be a primary power source; internal batteries provide a backup while the external batteries are changed.

Operation from AC Sources: An AC operated battery charger is included with the enclosure to maintain full charge on the batteries where AC power is available. In the event of power failure, the internal batteries will keep the system operational for up to 5 days in most applications.

Physical Specifications

Size:

ENC 7L	17" x 12" x 6"
ENC 7F	20" x 13" x 10"
ENC 7XL	19" x 19" x 10"

Weight: ~40 lbs (ENC 7F with 700X, 720, & seven I/O cards).

Warranty

Three years against defects in materials and workmanship.

Additional Information

Assurance of Quality

Campbell Scientific has produced research-grade dataloggers for more than twenty years. The workmanship and design of our CR7 demonstrates our commitment to quality.

If repair is required, our professional staff of technicians will repair and recalibrate the CR7 to original specifications.

Every CR7 is calibrated and thoroughly tested to ensure consistent, dependable performance. The CPU, system components, and all I/O connections are tested.

The results are calibrated against a standard traceable to the National Institute of Standards and Technology (NIST). A test report and calibration certificate including NIST traceable numbers are shipped with each CR7.

Warranty and Repair

The CR7 has a three-year warranty covering parts and labor. The Mean Time Between Failures (MTBF) of the CR7 is more than 24 years.

For More Information

Pricing and ordering information is provided by our:

- Price lists
- Order Entry Staff

Technical information on our products is provided by our:

- Product Literature
- Product Configuration Guide
- World Wide Web site at http://www.campbellsci.com
- Applications Engineers
- Authorized representative in your area (for a list of representatives, visit our web site or contact us by e-mail, phone, or fax)
- Training sessions

Customers may also contact our U.S. factory via e-mail or phone:

- Environmental group: enviro@csius.com or 801-750-9691
- Industrial group: industrial@csius.com or 801-750-9692

Campbell Scientific's U.S. factory is located in Logan, Utah.

Please call us today. We would like to discuss your application needs with you.

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