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APPLICATION NOTE

Shaft Encoders for Water Resources Applications

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Shaft Encoders for Water Resources Applications

This application note describes using shaft encoders with Campbell Scientific dataloggers. Shaft encoders discussed in this note are the Campbell Scientific CS410, Stevens PG-III, Handar 436A and 436B, Synergetics 501A, and Enviro-Systems SE-104P, SE-107, SE105(S), and SE-109. Compatible dataloggers include our CR23X, CR10(X), CR510, CR500, BDR320, and BDR301. Electrical connections and datalogger programming are provided. For information about selecting pulleys, floats, counter weights, tape, or beaded lines, contact our Water Resources Group through water@campbellsci.com.

Shaft Encoder Descriptions

Shaft encoders monitor fluctuations in water level and the position of water control gates by converting shaft rotation to electronic signals that are measured by the datalogger. A selection of shaft encoders that are compatible with Campbell Scientific dataloggers are described below.

Campbell Scientific CS410 — Includes an onboard QD1 decoder to generate two pulse strings—one indicating clockwise and the other counter-clockwise rotation.

Campbell Scientific SSR100 — Is a pre-programmed system that consists of our CS410 shaft encoder and CR510 datalogger housed in an environmental enclosure. It also includes an alphanumeric display. A High Data Rate GOES satellite transmitter, tipping bucket rain gage, and SDI-12 sensor can be added to the system. Designed as a replacement for the USGS Automated Data Recorder (ADR), the SSR100 mounting bracket has the same footprint as the old ADRs allowing the SSR100 to be mounted where the ADRs functioned. Because the SSR100 is preprogrammed, the SSR100 is not mentioned in the programming sections of this application note.

Stevens PG-III — Uses switch closures to generate electronic pulses. The switch closures are decoded internally by electronic logic circuits. The electronic logic circuits determine the direction the shaft is rotating and produce two pulse strings—one indicating clockwise and the other counter-clockwise rotation.

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Handar 436A — Incorporates a 50-pole magnet that's fixed to its shaft and sensed by a pair of Hall Effect devices that produce two square waves. One wave is half a wave-length out of phase with the other. Reversing the shaft rotation reverses the phase which indicates a change in shaft direction. A Campbell Scientific QD1 decoder is required to convert the square waves to two pulse strings—one indicating clockwise and the other counter-clockwise rotation.

Synergetics 501A — Produces square waves similar to the Handar 436A, and like the Handar 436A, the Synergetics 501A requires a Campbell Scientific QD1 decoder.

Enviro-Systems SE-104 and SE-107 — Provide several options for output signals. The output option that's often preferred produces two pulse trains (i.e., up and down counts like the PG-III). The SE-104P provides this output option. The dual pulse train option does not require additional interfaces or signal conditioners. The quadrature output option requires a Campbell Scientific QD1 decoder.

Handar 436B and Enviro-Systems SE-105(S) and SE-109 — Both encoders include an internal microprocessor that communicates using the SDI-12 digital protocol (for details, see http://www.sdi-12.org/). The internal microprocessor counts the shaft rotations (up and down) and transmits a number to the datalogger on a single, three-conductor cable.

The outputs of the SE-105(S) and SE-109 are programmable. This allows you to match the output and resolution to specific pulley circumferences and units. When using the SE-105(S) or SE-109, if you don't know how it was programmed, you need to determine the output ratio empirically by operating the shaft encoder.

The Handar 436B output units are feet if a 1 foot circumference pulley is used.

NOTE

The CR23X, CR10(X), CR510, CR500 are compatible with all of the shaft encoders listed, both pulse and SDI-12 output. The BDR301 and BDR320 are only compatible with the SDI-12 encoders. The CR10 must have its OS10-1.1 or OS10-2.1 PROM installed.

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Using Short Cut

Short Cut is the easiest, and typically the preferred, method for programming a CR23X, CR10(X), CR510, or CR500 datalogger. Short Cut is not compatible with the BDR320, BDR301, and Synchronous Devices for Measurement (SDMs). Short Cut creates programs for applications requiring only sensor measurement and data output.

When using Short Cut, you:

- Choose the shaft encoder model number, such as the CS410 or 436B, or choose QD1 for shaft encoders that require the QD1.
- Enter the pulley diameter and the current water level reading.
- Select the data and output processing.
- Save the program.
- Send the program to the datalogger.

After you have saved the program, Short Cut automatically creates a wiring table that shows how to connect the shaft encoder to the datalogger.

The remaining text discusses wiring and programming for Edlog or PC300 users. Short Cut users can stop reading now.

Using Edlog or PC300W

Wiring

Below are wiring examples. Multiple configurations are possible (i.e., where the wire connects to C1, you could connect it to any other datalogger control port). Unless stated otherwise the connections are for the CR23X, CR10(X), CR510, and CR500 dataloggers.

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Campbell Scientific CS410

CS410	Datalogger
Black	GND
Red	5V
Green	P2
White	P1
Shield	GND

Stevens PG-III

PG-III	Datalogger
Red	12V
Green	P1
White	P2
Black	GND
Clear	GND

NOTE

When using a CR10, a 10 KΩ pull-up resistor is required to bridge each pulse channel to the 5 V terminal. The resistor is not required when using a CR23X, CR10X, CR510, or CR500.

PG-III	SDM-INT8
Red	12V
Black	G
Green	CH6
White	CH7
Shield	G

NOTE

Use 10 KΩ resistors to jump from 12 V to CH6 and 12 V to CH7. Interface between a CR23X or CR10(X) and the SDM-INT8 is shown in the SDM-INT8 manual. The CR510 and CR500 are not compatible with SDM devices.

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Handar 436A

436A	QD1
Pin A	N/C
Pin B	N/C
Pin C	5V
Pin D	S2
Pin E	S1
Pin F	GND

QD1	Datalogger
GND	GND
5V	5V
P2	P2
P1	P1

Handar 436B

436A	CR23X, CR10(X), CR510, or CR500
Pin A	C1
Pin B	12V
Pin C	GND
Pin D	N/C

436A	BDR301
Pin A	SDI-12 Pin A
Pin B	SDI-12 Pin B
Pin C	SDI-12 Pin C
Pin D	N/C

436A	BDR320
Pin A	SDI
Pin B	12 V
Pin C	GND
Pin D	N/C

Synergetics 501A

501A	QD1
Pin A	GND
Pin B	S2
Pin C	N/C
Pin D	GND
Pin E	S1
Pin F	N/C

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QD1	Datalogger
GND	GND
+5	5V
P2	P2
P1	P1

Enviro-Systems SE-104P or SE-107

Dual Pulse Output Option:

SE-104P or SE-107	Datalogger
Pin F	GND
Pin D	5V
Pin A	P1
Pin B	P2

Quadrature Output Option:

SE-104P or SE-107	QD1
Pin F	GND
Pin A	S1
Pin B	S2
Pin D	5V

QD1	Datalogger
GND	GND
+5	5V
P1	P1
P2	P2

Enviro-System SE-105(S) or SE-109

SE-105(S) or SE-109	CR23X, CR10(X), CR510, or CR500
Pin A	C1
Pin B	N/C
Pin C	N/C
Pin D	12 V
Pin E	N/C
Pin F	GND
Pin G	N/C

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SE-105(S) or SE-109	BDR301
Pin A	SDI-12 Pin A
Pin B	N/C
Pin C	N/C
Pin D	SDI-12 Pin B
Pin E	N/C
Pin F	SDI-12 Pin C
Pin G	N/C

SE-105(S) or SE-109	BDR320
Pin A	SDI
Pin B	N/C
Pin C	N/C
Pin D	12 V
Pin E	N/C
Pin F	GND
Pin G	N/C

Programming

Shaft encoders with a pulse output are measured with Instruction 3. The SDI-12 sensors are measured with Instruction 105 when using a CR23X, CR10(X), CR510, or CR500. For the BDR320 and BDR301, use PC300's prompt programming.

Multiplier for Instruction 3

The multiplier is based on the wheel circumference and the shaft encoder counts per revolution:

$$\text{MULTIPLIER} = \frac{\text{WHEEL CIRCUM. (in desired units)}}{\text{COUNTS/REV}}$$

Stevens PG-III: 300 counts/revolution

Campbell Scientific CS410, Handar 436A, and Synergetics 501A: 100 counts/revolution

Examples:

A Stevens PG-III with a 1-foot circumference wheel:

MULTIPLIER = 1/300 = 0.00333
(measures in feet)

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Our CS410 with a 12-inch circumference wheel:

MULTIPLIER = 12/100 = .12
(measures in inches)

Multiplier for Instruction 105 or BDR Prompt Programming

When the measurement and the wheel circumference are in the same units, the multiplier is typically one. For example if you want the measurement units returned in feet and a 1-foot circumference wheel is used, the multiplier is one. Use the multiplier in the program instruction to convert the wheel circumference to the desired units. For example, if you want to measure in meters and you're using a 1-foot circumference wheel, a multiplier of .3048 is required since 1 foot equals .3048 meters.

Offset

When shaft encoders power up, they reference the wheel position to zero. An offset may be required to reference the actual water level height, as indicated by a known reference such as a staff gauge. On-site you can enter the offset value into the program by using a portable computer or keyboard/display (computer only for the BDR320 or BDR301).

Edlog Program for our CS410, Stevens PG-III, Handar 436A, or Synergetics 501A

This is a portion of a CR23X, CR10(X), CR510, or CR500 program that measures a CS410, 436A, 501A, SE-104P, or SE-107 with a one foot circumference pulley. The program has a five minute measurement interval and the desired units are feet. Please note that this is only a portion of a program. A complete program would require output processing instructions to place the data in final storage. The data must be in final storage to transfer the data to a storage module or to retrieve the data via a telecommunications link.

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```
*Table 1 Program
  01:    300          Execution Interval (seconds)

;5-minute scans
;Input Instructions
;Up-counts connected to P1 measure an increase in level

1:  Pulse (P3)
  1:       1          Reps
  2:       1          Pulse Channel 1
  3:       0          High Frequency, All Counts
  4:       1          Loc [COUNT_UP]
  5:        .01       Mult
  6:       0          Offset

;Down counts connected to P2 measure a decrease in level

2:  Pulse (P3)
  1:       1          Reps
  2:       2          Pulse Channel 2
  3:       0          High Frequency, All Counts
  4:       2          Loc [COUNT_DWN]
  5:        .01       Mult
  6:       0          Offset

; Processing instructions add the number of counts to a running total

3:  Z=X+Y (P33)
  1:       1          X Loc [COUNT_UP]
  2:       3          Y Loc [STAGE_FT]
  3:       3          Z Loc [STAGE_FT]

4:  Z=X-Y (P35)
  1:       3          X Loc [STAGE_FT]
  2:       2          Y Loc [COUNT DWN]
  3:       3          Z Loc [STAGE_FT]
```

Edlog Program for Handar 436B or Enviro-Systems SE-105(S) or SE-109

This is a portion of a CR23X or CR10(X) program that measures a 436B, SE-105(S), or SE-109 with an 18 inch circumference pulley. (A CR510 or CR500 program would be the same except Instruction 105's entry for parameter 3 must be either 1 or 2.) The program has a ten minute measurement interval and the

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desired units are feet. Please note that this is only a portion of a program. A complete program would require output processing instructions to place the data in final storage. The data must be in final storage to transfer the data to a storage module or to retrieve the data via a telecommunications link.

```
*Table 1 Program

01:     600         Execution Interval (Seconds)

1:  SDI-12 Recorder (P105)
  1:      00        SDI-12 Address
  2:      00        SDI-12 Command
  3:       1        Port
  4:       1        Loc [STAGE_FT]
  5:     1.5        Mult
  6:       0        Offset
```

PG-III using an SDM-INT8 and a CR10(X)

Below are the instructions for using an SDM-INT8 and processing the data. To make this a complete program, you need Instruction 3 to measure the up and down counts and output processing instructions to place the data in final storage.

```
1:  SDM-INT8 (P101)
  1:      00        Address
  2:    0220        Input Config:  Channels 8, 7, 6, 5
  3:    0000        Input Config:  Channels 4, 3, 2, 1
  4:    0770        Function:  Channels 8, 7, 6, 5
  5:    0000        Function:  Channels 4, 3, 2, 1
  6:      0--       Output Options
  7:       1        Loc [UP          ]
  8:    0.01        Mult
  9:       0        Offset

2:  Z=X+Y (P33)
  1:       1        X Loc [UP]
  2:       3        Y Loc [STATE_FT]
  3:       3        Z Loc [STAGE_FT  ]

3:  Z=X-Y (P35)
  1:       3        X Loc [STAGE_FT]
  2:       2        Y Loc [DOWN]
  3        3        Z Loc [STAGE_FT    ]
```

BDR320/BDR301 Prompt Program

This program measures an SE-105(S) or SE-109 with a 308 mm circumference pulley. It has a 15-minute measurement interval and the desired output units are feet.

$$\text{Multiplier} = \frac{1\ \text{ft}}{308\ \text{mm}} = 0.003247$$

Input Table Number 01
Measurement Interval mins 0015

Loc	Name	Units	Type	Chn	Mult	Offset
01	Level	CM	SDI	001	0.003247	+0.0000
02			OPT			