USING SDI-12 TO ACQUIRE HYDROLOGIC DATA

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Abstract. This paper describes SDI-12, which is a standard to interface battery powered data recorders with micro-processor based sensors. SDI-12 stands for serial/digital interface at 1200 baud. SDI-12 has several advantages for sensors and data recorders. It is battery powered with minimal current drain, a data recorder can interface with multiple sensors on a single cable, and complex calibration algorithms can be done in the sensor. This paper discusses these advantages, describes SDI-12, and gives an example of using SDI-12 to help acquire water quality data such as dissolved oxygen, conductivity, and temperature. Vendors that manufacture SDI-12 data recorders and SDI-12 sensors are listed in this paper.

INTRODUCTION

This paper describes the SDI-12 interface and explains how it is used by battery powered data recorders and sensors to acquire hydrologic data such as stream stage and water quality. SDI-12 is a communications protocol for interfacing data recorders with micro-processor based sensors. This interface provides a means to transfer measurements taken by an intelligent sensor to a data recorder. An intelligent sensor typically takes a measurement, makes computations based on the raw sensor reading, and outputs the measured data in engineering units. For example, an SDI-12 pressure sensor may take a series of pressure measurements, average them, and then output pressure in psi, inches of mercury, bars, millibars, or torrs. The sensor's microprocessor makes the computations, converts sensor readings into the appropriate units, and uses the SDI-12 protocol to transfer data to the recorder.

SDI-12 stands for Serial-Digital Interface at 1200 baud and is used in applications with the following requirements:

- battery powered operation with minimal current drain
- use of one data recorder with multiple sensors on a single cable
- use with microprocessor-based sensors that perform complex calibration algorithms or make internal computations[1]

These requirements are necessary to acquire hydrologic data at remote sites. SDI-12 equipment is now used to measure and record stream stage at stream gauging stations throughout the United States. Most sites use battery powered data recorders to operate for long and unattended periods of time.

MULTI-DROP AND MULTI-PARAMETER

SDI-12 is a multi-drop interface that can communicate with multi-parameter sensors. Multi-drop means that more than one SDI-12 sensor can be connected to a data recorder. Figure 2 illustrates this. The SDI-12 bus is capable of having ten sensors connected to it. Having more than ten sensors, however, is possible. Some SDI-12 users connect more than ten sensors to a single data recorder.

Multi-parameter means that a single sensor many return more than one measurement. For example, some water quality sensors return temperature, conductivity, dissolved oxygen, pH, turbidity, and depth.

The maximum number of sensor readings a sensor can take in response to a single command is nine. The data recorder tells the sensor to take a measurement and the sensor responds by measuring up to nine different phenomena. The sensor may also measure one attribute, and determine other attributes as a function of the measured attribute. For example, a water quality sensor may measure conductivity and calculate total dissolved solids, salinity, and resistivity as a function of conductivity. All four measurements are then returned to the data recorder.

The SDI-12 command set is flexible and powerful. SDI-12 has a set of commands used to tell the sensor to take different measurements. One command (M1!) may instruct a sensor to measure temperature; another command (M2!) may instruct a sensor to measure pressure. SDI-12 has ten commands used to start measurements. Because each command can result in up to nine measurements, SDI-12 sensors can theoretically take up to 90 different measurements. To comply with SDI, however, a sensor is only required to respond to one measurement command, returning a single data value.

INTELLIGENT SENSORS

SDI-12 facilitates the use of micro-processor based sensors. A micro-processor in the sensor may calibrate the sensor, control sensor measurements, take a series of measurements, and convert raw sensor readings into engineering units. The micro-processor also controls the SDI-12 interface. It accepts and decodes instructions received from the data recorder, starts the measurements, controls all timing, and uses the SDI-12 protocol to communicate with the data recorder.

ADVANTAGES OF SDI-12

SDI-12 has many advantages for hydrologic data collection:

- The interface between all SDI-12 sensors and SDI-12 data recorders is identical.
- Personnel trained in SDI-12 have skills to work with any combination of SDI-12 sensors and recorders.
- Sensors can be interchanged without reprogramming the data recorder.
- Power is supplied to the sensor through the interface.
- Data recorders can be designed and produced independently of sensor technology.[4]

APPLICATIONS FOR SDI-12 SENSORS

SDI-12 is used in water resource research and management, industry, government, and agriculture. For example, the U.S. Geological Survey uses over 4,000 SDI-12 sensors in its data collection networks.[5] SDI-12 sensors are available that measure the following:

- bridge scour
- conductivity
- dissolved oxygen
- distance
- groundwater level
- petroleum hydrocarbons in water
- pH
- pressure
- redox (ORP)
- tank level
- temperature
- tide and sea state
- turbidity
- water velocity
- weight of snow and ice on a snow pillow

SDI-12 IS A COMMUNICATIONS PROTOCOL

SDI-12 does not measure stream stage, water quality, or any environmental attribute. Each SDI-12 sensor employs some type of sensor technology to sense the phenomena to be measured. For example, a shaft encoder counts the number of turns on a wheel as a float rises and falls with water lever, submersible water level sensors use a pressure transducer to sense water pressure, ultrasonic sensors use sound waves to measure distance, etc. This is independent of the SDI-12 protocol. SDI-12 is the interface between sensors and data recorders. The SDI-12 protocol specifies a command set, a serial-digital format, timing requirements, and the electrical interface. It does not specify a sensing technology. For this reason, compliance with the SDI-12 protocol does not guarantee the quality of the data measured by the sensor.

HOW SDI-12 WORKS

SDI-12 uses three wires to interface SDI-12 sensors with SDI-12 data recorders. This is called the SDI-12 bus. The three wires are:

1) a serial data line
2) a 12-volt line
3) a ground line

The serial data line is a bi-directional line used to transit and receive data. Serial transmission means that data is transmitted and received as a sequence of bits. Bi-directional means that communications are done in two directions, but not at the same time. A single wire is used by the data recorder to transmit instructions to the SDI-12 sensor. The sensor, in turn, uses the same wire to return its response to the data recorder.

The 12-volt line provides power to the sensor. One battery typically provides power for several SDI-12 sensors on the SDI bus.

Figure 1 shows the SDI-12 bus with one sensor connected to a data recorder. Figure 2 shows the SDI-12 bus with multiple sensors connected to a data recorder.

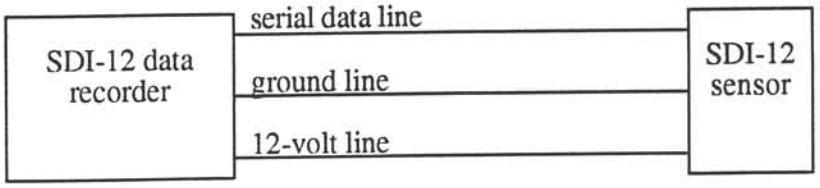

Figure 1. The SDI-12 Bus

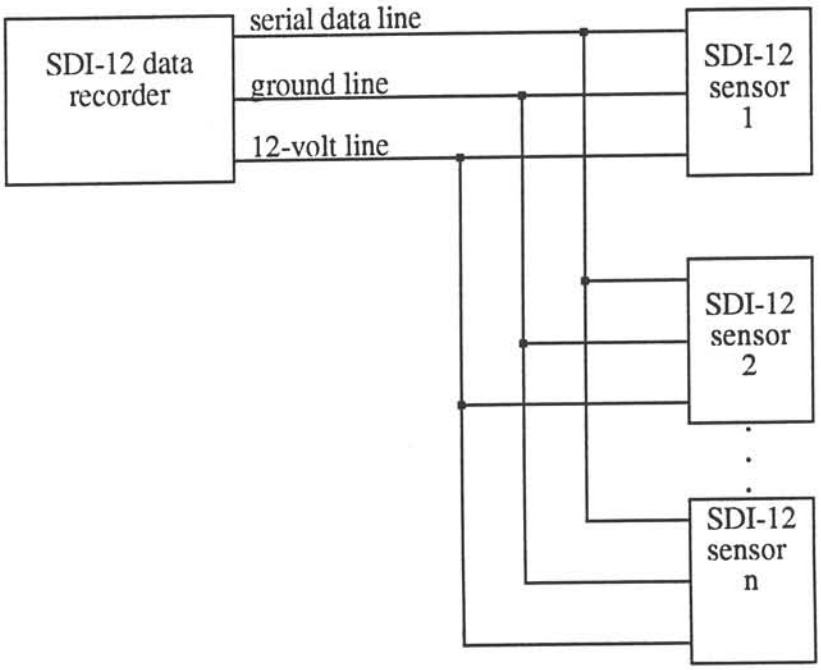

Figure 2. The SDI-12 Bus with Multiple Sensors

SDI-12 data recorders and sensors communicate by an exchange of ASCII characters on the data line.[2] A recorder/sensor measurement sequence proceeds as follows:

1) The data recorder wakes all sensors with a condition known as a break.

2) The recorder transmits a command to a specific, addressed sensor, instructing it to take a measurement.

3) The addressed sensor responds, within a specified time period, returning the maximum number of seconds until data will be ready and the number of data values it will return. All other sensors on the bus return to a low power, stand-by mode.

4) If the measurement is ready immediately, the recorder transmits a command to the sensor instructing it to return the measurements(s). If the measurement is not ready, the data recorder waits for the sensor to send a request to the recorder, which indicates that the data are ready. The recorder then transmits a command to request the data.

5) The sensor responds, returning one or more measurements.[3]

Example

The following is an example of a recorder/sensor measurement sequence:

0M!00053<CR><LF>
0<CR><LF>
0D0!0+3.14+2.718+1.414<CR><LF>

0M! a command transmitted to the sensor by the data recorder, telling the sensor to take a measurement

- 0 the address of the specified sensor
- M tells the sensor to take a measurement
- ! terminates the command

00053<CR><LF> transmitted from the sensor to the data recorder, in response to the command

- 0 the sensor's address
- 005 time until the data are ready (in seconds)
- 3 the number of measurements that sensor will make
- <CR><LF> carriage return/line feed to terminate the response

0<CR><LF> a signal (called a service request) from the sensor to the data recorder, telling it that the data are ready

0D0! a command transmitted to the sensor by the data recorder, telling it to return the measured data

0	the sensor's address
D0	tells the sensor to return its data
!	terminates the command

0	the sensor's address
+3.14	the first measurement
+2.718	the second measurement
+1.414	the third measurement
<CR><LF>	carriage return/line feed to terminate the response

THE SDI-12 SUPPORT GROUP

SDI-12 was designed in 1988. Over 30 companies now produce and market SDI-12 products. Some make SDI-12 sensors, some make SDI-12 data recorders, and others make both. (A list of companies that produce SDI-12 products is listed at the end of this paper.) Once SDI-12 was accepted as a robust and workable interface between sensors and recorders, the SDI-12 Support Group formed to support the standard. This is an association of companies that produce and use SDI-12 products. The mission of the SDI-12 support group is to maintain the backward compatibility of SDI-12, maintain the SDI-12 specification, contribute to the technical longevity of the SDI-12 architecture, and support and educate the environmental monitoring industry on the use of SDI-12.

The SDI-12 Support Group reviews proposed changes to the standard, holds a yearly meeting to discuss the status of SDI-12, and publishes a newsletter. For more information on the SDI-12 Support Group or to obtain a copy of the SDI-12 Standard, call or write the SDI-12 Support Group at:

SDI-12 Support Group
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REFERENCES

1) SDI-12. A Serial-Digital Interface Standard for Microprocessor-Based Sensors. Version 1.1. NR Systems, Inc., Logan, Utah and Campbell Scientific, Inc., Logan, Utah. July 1994.

2) Ibid.

3) Ibid.

4) Ibid.

5) SDI-12 Support Group News. Fall 1994.