

# SDI-12 and the Aquacheck Sub-Surface Soil Moisture Probe



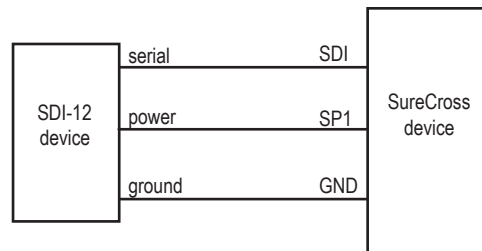
## Technical Note

### DX80DRM-H12 MultiHop Series SDI-12 Enabled Radio

Use the manufacturer's cable to connect the SDI-12 sensor to the computer. Use the manufacturer's software to change the sensor's SDI-12 address. Most manufacturers ship their sensor/probe units with an address of 0. The DX80DR9M-H12 radios are, by default, set to communicate with SDI-12 address 1 because address 0 is reserved as a broadcast method. Reference the sensor's instruction manual to determine how to read your sensor/probe address, adjust it, and determine readings.

### Sensor Wiring

- DC+ = Brown (SP1)
- DC- = Green/Yellow (GND)
- Data = Blue (SDI)



### Configuring the Banner DX80DR9M-H12 with SDI-12 Protocol

The DX80DR9M-H12 MultiHop radio ships from the factory with the noted default register values. This allows you to connect one SDI-12 probe to the radio (refer to the radio's datasheet for the complete wiring of the sensor/probe). The radio queries the sensor/probe based on its default parameters. The radio can communicate with up to five probes (only one SDI-12 command per probe) or a combination of single/multiple probes (with multiple SDI-12 commands). Although the radio can communicate with up to five devices or provide five commands to a single or multiple devices (such as the xM!), by default the radio communicates with only one SDI-12 address or generates one M! command. Change the number of devices or commands enabled by modifying the "Enabling SDI-12 Section" in the registers list below.

For each of the five probes or five commands, there are up to twenty-four results registers (each result register has two 16-bit registers for a total potential number of registers of 24). Only results registers 1 through 9 are enabled since Mx! commands only support nine results. When using the DXM150 Controller, use the 32-bit floating point local registers as the destination for the radio's results. The 32-bit floating point local registers in the DXM150 controller range from 1001 to 1499.

## Example — Five Aquacheck Sub-Surface Probes to One Radio

To connect up to five probes with one sensor type or command (such as soil moisture) reporting back, set the values in the enabling registers to M! (verify this with the probe manufacturer's documentation). Enable the radio to read the additional SDI-12 devices (all the settings are preset according to tables below) and modify the addresses of the probes to represent SDI-12 addresses 1 through 5.

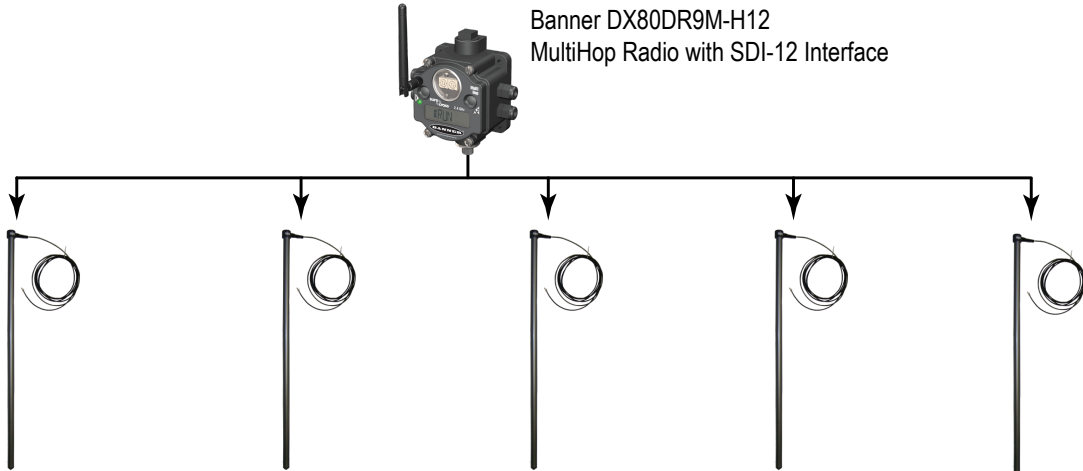


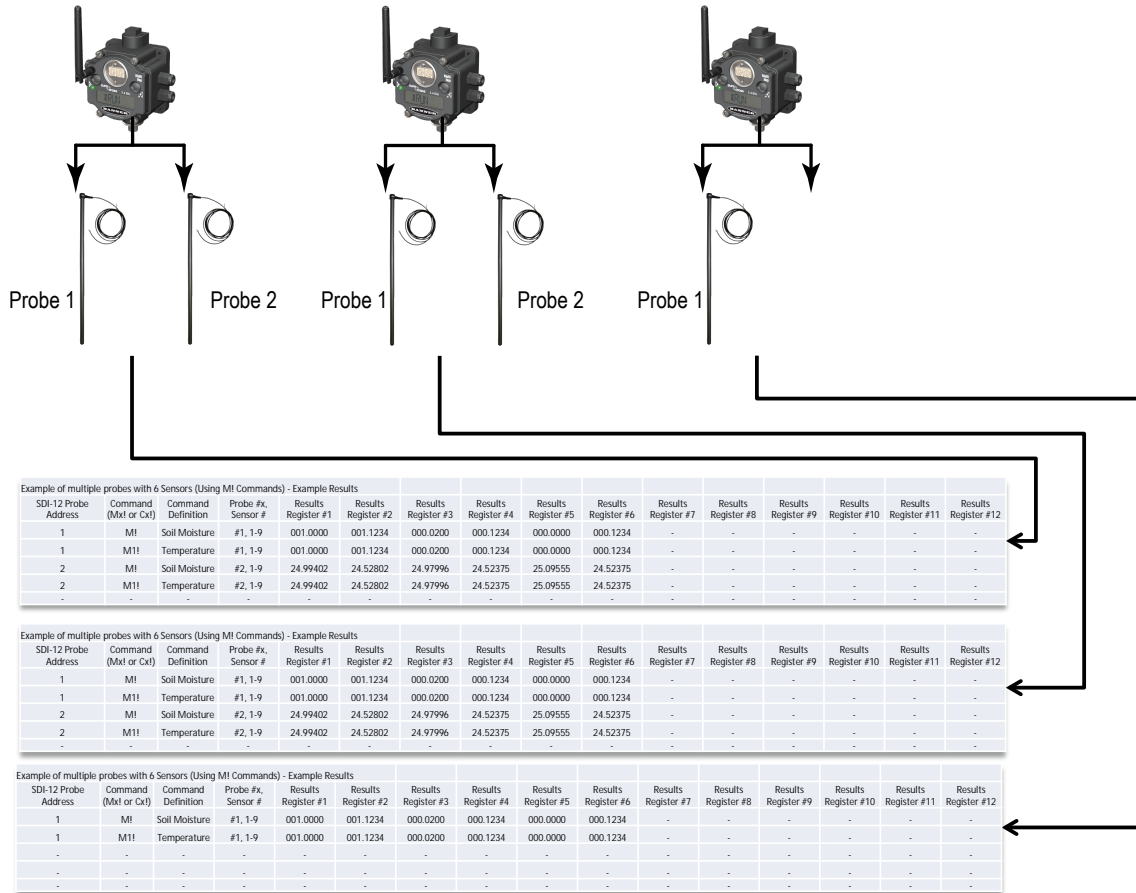
Table 1: Example of multiple probes with 6 Sensors (Using M! Command) - Example Results

| Probe Address | Command    |               | Probe #x, Sensor # | Results Registers |        |       |         |         |         |   |   |   |    |    |    |
|---------------|------------|---------------|--------------------|-------------------|--------|-------|---------|---------|---------|---|---|---|----|----|----|
|               | Mx! or Cx! | Definition    |                    | 1                 | 2      | 3     | 4       | 5       | 6       | 7 | 8 | 9 | 10 | 11 | 12 |
| 1             | M!         | Soil Moisture | #1, 1-6            | 1                 | 1.1234 | 0.02  | 0.1234  | 0       | 0.1234  | - | - | - | -  | -  | -  |
| 2             | M!         | Soil Moisture | #2, 1-6            | 1                 | 1.1234 | 0.02  | 0.1234  | 0       | 0.1234  | - | - | - | -  | -  | -  |
| 3             | M!         | Soil Moisture | #3, 1-6            | 24.994            | 24.528 | 24.98 | 24.5238 | 25.0956 | 24.5238 | - | - | - | -  | -  | -  |
| 4             | M!         | Soil Moisture | #4, 1-6            | 24.994            | 24.528 | 24.98 | 24.5238 | 25.0956 | 24.5238 | - | - | - | -  | -  | -  |
| 5             | M!         | Soil Moisture | #5, 1-6            | 24.994            | 24.528 | 24.98 | 24.5238 | 25.0956 | 24.5238 | - | - | - | -  | -  | -  |

The DX80DR9M-H12 can poll each of the five probes with the aM! command. The M-H12 can measure up to 12 soil moisture points per probe. With this arrangement, you cannot request more data using additional aM! commands because all the SDI-12 addresses or command registers are used.

## Example — Five Aquacheck Sub-Surface Probes to Three Radios

When both soil moisture and temperature data is required from each of the five probes, you must use more than one M-H12 radio. Modify the default settings to acknowledge the addresses of the probes and to make the proper commands.



The DX80DR9M-H12 radio can poll each of the five probes with the aM! and aM! command. The data radios can store up to 12 soil moisture points or temperature points per probe. In this arrangement, use additional M-H12 radios to gather the results from the probes because the number of SDI-12 address and/or commands is too many for a single data radio to store.

## Example — One Aquacheck Sub-Surface Probe to One Radios

Using a single AquaCheck probe connected to a single MultiHop radio, the probe only reports back soil moisture and temperature readings using the aM!



| Probe Address | Command    |               | Probe #, Sensor # | Results Registers |        |      |        |   |        |   |   |   |    |    |    |
|---------------|------------|---------------|-------------------|-------------------|--------|------|--------|---|--------|---|---|---|----|----|----|
|               | Mx! or Cx! | Definition    |                   | 1                 | 2      | 3    | 4      | 5 | 6      | 7 | 8 | 9 | 10 | 11 | 12 |
| 1             | M!         | Soil Moisture | #1, 1-6           | 1                 | 1.1234 | 0.02 | 0.1234 | 0 | 0.1234 | - | - | - | -  | -  | -  |
| 1             | M!!        | Soil Moisture | #1, 1-6           | 1                 | 1.1234 | 0.02 | 0.1234 | 0 | 0.1234 | - | - | - | -  | -  | -  |
|               |            |               |                   | -                 | -      | -    | -      | - | -      | - | - | - | -  | -  | -  |

The DXM Configurator Tool Register View screen list the results registers for the probe. In the example probe, there are six (6) sensors and each sensor has two (2) registers in the DX80DR9M-H12 (please reference the Results Register list referenced later in this document). The values represented are in floating point format.

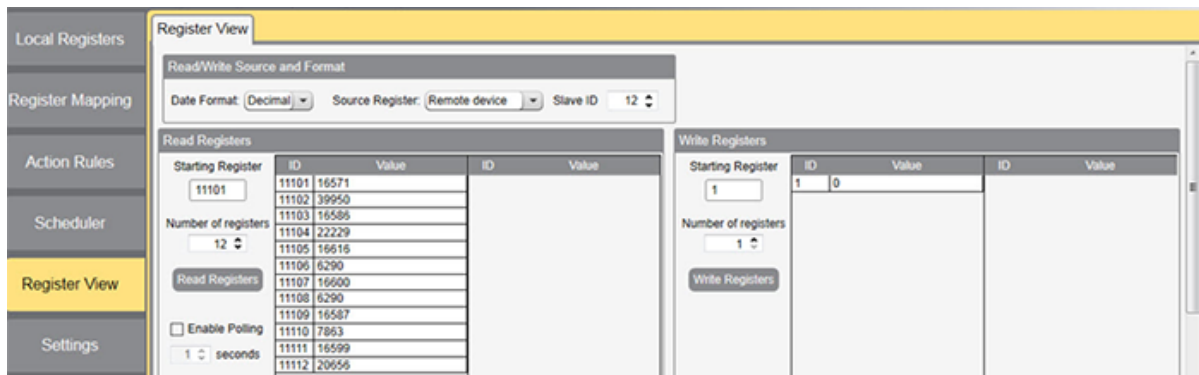


Figure 1. AquaCheck Results Registers using the DXM Configurator Tool

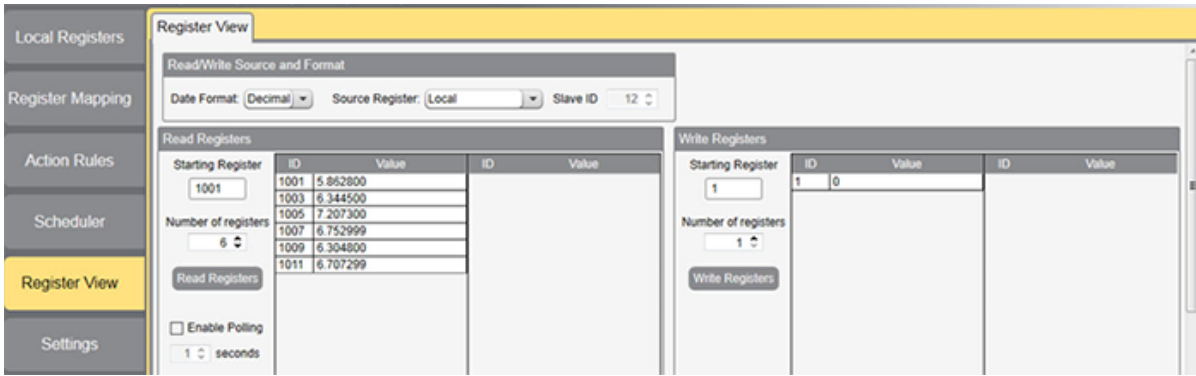


Figure 2. AquaCheck Local Registers using the DXM Configurator Tool

To compare values to the SDI-12 reader results or to view/store the value in a controller other than Banner Engineering's DXM150 Controller, convert the decimal values to hexadecimal values (via the "Data Type" field in the upper left corner) using a basic conversion tool. One example conversion tool is: <http://babbage.cs.qc.cuny.edu/IEEE-754.old/32bit.html>.

## Excerpts from the M-H12 Datasheet

The following tables are included in the DX80DR9M-H12 datasheet. Refer to the datasheet for complete product information.

| Register (4xxxx) | Input # | Inputs                | Units | I/O Range  |            | Holding Register Representation |             | Terminal Block Labels |
|------------------|---------|-----------------------|-------|------------|------------|---------------------------------|-------------|-----------------------|
|                  |         |                       |       | Min. Value | Max. Value | Min. (Dec.)                     | Max. (Dec.) |                       |
| 1                | 1       | Discrete IN 1         | -     | 0          | 1          | 0                               | 1           | DI1                   |
| 2                | 2       | Discrete IN 2         | -     | 0          | 1          | 0                               | 1           | DI2                   |
|                  | ...     |                       |       |            |            |                                 |             |                       |
| 5                | 5       | Analog IN 1 *         | mA    | 0.0        | 20.0       | 0                               | 65535       | AI1                   |
| 6                | 6       |                       |       |            |            |                                 |             |                       |
| 7                | 7       | Analog IN 2 *         | mA    | 0.0        | 20.0       | 0                               | 65535       | AI3                   |
| 8                | 8       | Thermistor *          | °F    | -1638.3    | 1638.4     | -32768                          | 32767       | AX2                   |
| 9                | 9       |                       |       |            |            |                                 |             |                       |
| 10               | 10      |                       |       |            |            |                                 |             |                       |
| 11               | 11      |                       |       |            |            |                                 |             |                       |
| 12               | 12      | SDI-12 Device/CMD 5 * |       |            |            |                                 |             | SDI                   |
| 13               | 13      | SDI-12 Device/CMD 4 * |       |            |            |                                 |             | SDI                   |
| 14               | 14      | SDI-12 Device/CMD 3 * |       |            |            |                                 |             | SDI                   |
| 15               | 15      | SDI-12 Device/CMD 2 * |       |            |            |                                 |             | SDI                   |
| 16               | 16      | SDI-12 Device/CMD 1   |       |            |            |                                 |             | SDI                   |

\* The factory default setting for SDI-12 devices 2 through 5, analog inputs 1 and 2, and the thermistor are disabled.

| Register (4xxxx) | Output # | Outputs        | Units | I/O Range  |            | Holding Register Representation |             | Terminal Block Labels |
|------------------|----------|----------------|-------|------------|------------|---------------------------------|-------------|-----------------------|
|                  |          |                |       | Min. Value | Max. Value | Min. (Dec.)                     | Max. (Dec.) |                       |
| 501              | 1        | Discrete OUT 1 | -     | 0          | 1          | 0                               | 1           | DO1                   |
| 502              | 2        | Discrete OUT 2 | -     | 0          | 1          | 0                               | 1           | DO2                   |
| 503              | 3        | Switch Power 1 |       |            |            |                                 |             | SP1                   |
| 504              | 4        | Switch Power 2 |       |            |            |                                 |             | SP2                   |

The Modbus configuration registers are listed. All registers are defined as Modbus holding registers. The factory default values are shown in parentheses. All values are in decimal, unless noted otherwise.

| Device/CMD Configuration | Registers (Default Value) |                         |                |
|--------------------------|---------------------------|-------------------------|----------------|
|                          | Enable                    | Device Address          | Device Command |
| SDI-12 Device/CMD 1      | 1751 (1)                  | 11001 (49) <sup>1</sup> | 11002 (10)     |
| SDI-12 Device/CMD 2      | 1701 (0)                  | 11201 (50)              | 11202 (10)     |
| SDI-12 Device/CMD 3      | 1651 (0)                  | 11401 (51)              | 11402 (10)     |
| SDI-12 Device/CMD 4      | 1601 (0)                  | 11601 (52)              | 11602 (10)     |
| SDI-12 Device/CMD 5      | 1551 (0)                  | 11801 (53)              | 11802 (10)     |

| Device / Cmd Configuration | Registers (Default Value) |                         |                |           |              |             |            |
|----------------------------|---------------------------|-------------------------|----------------|-----------|--------------|-------------|------------|
|                            | Enable                    | Device Address          | Device Command | Sample Hi | Sample Low   | Warmup Time | Voltage    |
| SDI-12 Device/CMD 1        | 1751 (1)                  | 11001 (49) <sup>2</sup> | 11002 (10)     | 1752 (0)  | 1753 (22500) | 1755 (50)   | 1756 (148) |
| SDI-12 Device/CMD 2        | 1701 (0)                  | 11201 (50)              | 11202 (10)     | 1702 (0)  | 1703 (22500) | 1705 (50)   | 1706 (148) |
| SDI-12 Device/CMD 3        | 1651 (0)                  | 11401 (51)              | 11402 (10)     | 1652 (0)  | 1653 (22500) | 1655 (50)   | 1656 (148) |
| SDI-12 Device/CMD 4        | 1601 (0)                  | 11601 (52)              | 11602 (10)     | 1602 (0)  | 1603 (22500) | 1605 (50)   | 1606 (148) |
| SDI-12 Device/CMD 5        | 1551 (0)                  | 11801 (53)              | 11802 (10)     | 1552 (0)  | 1553 (22500) | 1555 (50)   | 1556 (148) |

Device Address. Each SDI-12 device must have a unique device address. This parameter is the ASCII code for the device address. Valid device addresses are 0–9 and a–z that map to ASCII codes 48–57 and 97–122, respectively. The factory default addresses are:

- SDI-12 Device 1 uses ASCII code 49
- SDI-12 Device 2 uses ASCII code 50
- SDI-12 Device 3 uses ASCII code 51
- SDI-12 Device 4 uses ASCII code 52
- SDI-12 Device 5 uses ASCII code 53

| Supported M! Commands |                | Supported C! Commands |                |
|-----------------------|----------------|-----------------------|----------------|
| SDI -12 Command       | Register Value | SDI -12 Command       | Register Value |
| xM!                   | 0 or 10        | xC!                   | 1 or 20        |
| xM1!                  | 11             | xC1!                  | 21             |
| xM2!                  | 12             | xC2!                  | 22             |
| xM3!                  | 13             | xC3!                  | 23             |
| xM4!                  | 14             | xC4!                  | 24             |
| xM5!                  | 15             | xC5!                  | 25             |
| xM6!                  | 16             | xC6!                  | 26             |
| xM7!                  | 17             | xC7!                  | 27             |
| xM8!                  | 18             | xC8!                  | 28             |
| xM9!                  | 19             | xC9!                  | 29             |

<sup>1</sup> The default device addresses 49 through 53 are in ASCII.

<sup>2</sup> The default device addresses 49 through 53 are in ASCII.

## SDI-12 Device Result Registers

The result registers store all information received from the SDI-12 devices.

The registers are 16-bit registers and require two registers to store a 32-bit value. The factory default configuration defines the result registers as 32-bit registers, floating point format, and the first nine result registers are enabled for use. A host system reads the SDI-12 device data from these registers.

| Result Registers                 | Register 1 | Register 2 | Register 3 | Register 4 | Register 5 | Register 6 |
|----------------------------------|------------|------------|------------|------------|------------|------------|
| SDI-12 Device/CMD 1 Result Upper | 11101      | 11103      | 11105      | 11107      | 11109      | 11111      |
| SDI-12 Device/CMD 1 Result Lower | 11102      | 11104      | 11106      | 11108      | 11110      | 11112      |
| SDI-12 Device/CMD 2 Result Upper | 11301      | 11303      | 11305      | 11307      | 11309      | 11311      |
| SDI-12 Device/CMD 2 Result Lower | 11302      | 11304      | 11306      | 11308      | 11310      | 11312      |
| SDI-12 Device/CMD 3 Result Upper | 11501      | 11503      | 11505      | 11507      | 11509      | 11511      |
| SDI-12 Device/CMD 3 Result Lower | 11502      | 11504      | 11506      | 11508      | 11510      | 11512      |
| SDI-12 Device/CMD 4 Result Upper | 11701      | 11703      | 11705      | 11707      | 11709      | 11711      |
| SDI-12 Device/CMD 4 Result Lower | 11702      | 11704      | 11706      | 11708      | 11710      | 11712      |
| SDI-12 Device/CMD 5 Result Upper | 11901      | 11903      | 11905      | 11907      | 11909      | 11911      |
| SDI-12 Device/CMD 5 Result Lower | 11902      | 11904      | 11906      | 11908      | 11910      | 11912      |

| Result Registers                 | Register 7 | Register 8 | Register 9 | Register 10 | Register 11 | Register 12 |
|----------------------------------|------------|------------|------------|-------------|-------------|-------------|
| SDI-12 Device/CMD 1 Result Upper | 11113      | 11115      | 11117      | 11119       | 11121       | 11123       |
| SDI-12 Device/CMD 1 Result Lower | 11114      | 11116      | 11118      | 11120       | 11122       | 11124       |
| SDI-12 Device/CMD 2 Result Upper | 11313      | 11315      | 11317      | 11319       | 11321       | 11323       |
| SDI-12 Device/CMD 2 Result Lower | 11314      | 11316      | 11318      | 11320       | 11322       | 11324       |
| SDI-12 Device/CMD 3 Result Upper | 11513      | 11515      | 11517      | 11519       | 11521       | 11523       |
| SDI-12 Device/CMD 3 Result Lower | 11514      | 11516      | 11518      | 11520       | 11522       | 11524       |
| SDI-12 Device/CMD 4 Result Upper | 11713      | 11715      | 11717      | 11719       | 11721       | 11723       |
| SDI-12 Device/CMD 4 Result Lower | 11714      | 11716      | 11718      | 11720       | 11722       | 11724       |
| SDI-12 Device/CMD 5 Result Upper | 11913      | 11915      | 11917      | 11919       | 11921       | 11923       |
| SDI-12 Device/CMD 5 Result Lower | 11914      | 11916      | 11918      | 11920       | 11922       | 11924       |