4010 - 4 Port Input Expansion Card

Technical Notes

Firmware Version 20

Author –Steve Brennan

Last Updated - 7 March 2012

Introduction

The 4010 4 Port Input Expansion Card provides four discrete input ports for iNTELLiTROL telemetry systems. The card has been designed to provide a cost effective expansion to other 4xxx cards using the RS485 communications interface or to provide basic input functions on a cabled network (PC controlled) iNTELLiTROL telemetry system.
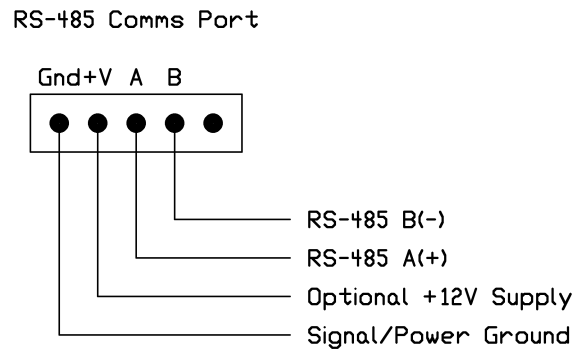
Data from a maximum of 16 sensors may be recorded on any single logger. If multi-sensor probes are utilized (totaling more than 16 channels) the board can be programmed to produce "Virtual Loggers" (additional module numbers for the same board). Refer to the iConfigure Technical Note for further details. The 4010 board supports up to six virtual loggers.

The card does not include facilities for standalone data logging, direct radio connection to the board or solar panel battery charging. Charging of a battery (if fitted) must be derived from power supplied via the RS-485 communications cable.
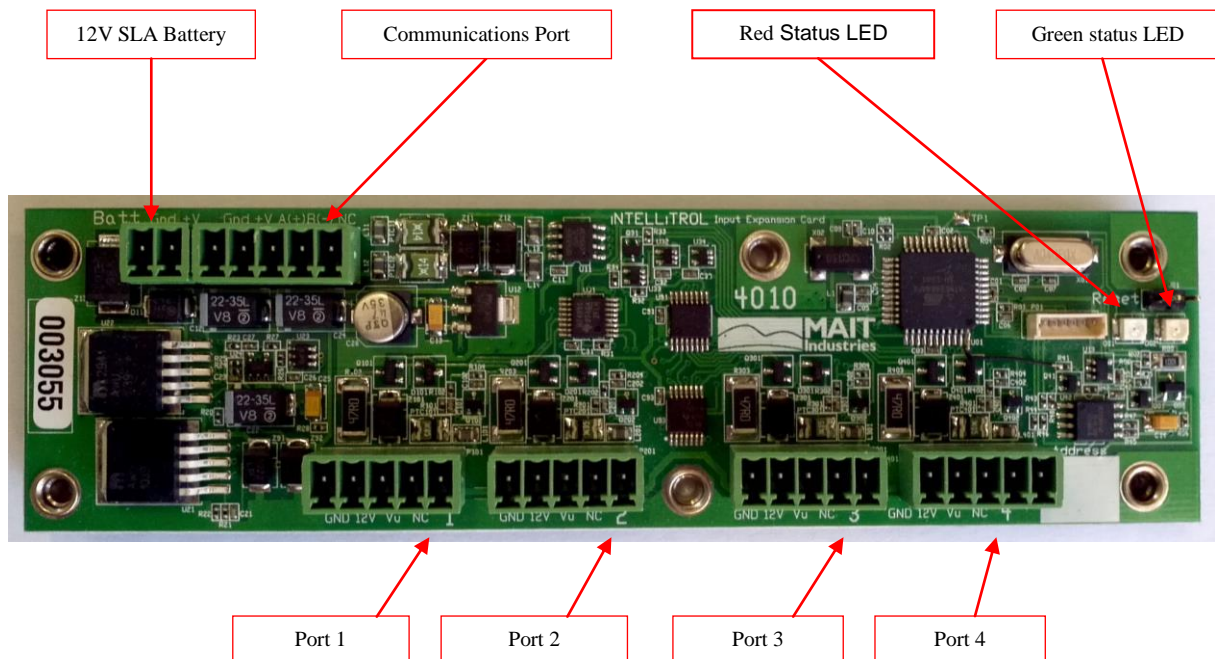
Communications Interface

The communications port is designed to connect to the standard iNTELLiTROL RS-485 communications bus. This may be a cable or radio telemetry system or an installation where many boards are attached to the one radio/modem/laptop/PC. The five pin Phoenix connector located adjacent to the battery connector is used for the RS-485 communications interface.

```
            RS-485 Comms Port

            Gnd +V  A   B
           ┌─────────────────┐
           │ ●   ●   ●   ●   ● │
           └─────────────────┘
             │   │   │   │
             │   │   │   └──────────── RS-485 B(-)
             │   │   └──────────────── RS-485 A(+)
             │   └──────────────────── Optional +12V Supply
             └──────────────────────── Signal/Power Ground
```

Power Connections

Power is normally derived from the Communications Interface. A 12V Sealed Lead Acid battery can be fitted to maintain power during sampling of the probes. This is useful when the power source is some distance from the card.

On board linear voltage regulators supply a user settable voltage (Vu) and 12V to power the attached sensors. Note that the 12V sensor voltage will only be achieved if the Communications Interface or battery voltage is greater than 12.5V. At lower supply voltages, the power to the probes will be marginally lower than the supply voltage. These supplies are limited to a maximum of 1A and have protection against short circuits and thermal overload.

Connecting a Solar Panel or Plug Pack DC Power Supply

Solar panels and plug packs should not be connected directly to the board. If they must be used at this board location, an optional solar charger board may be fitted. Alternatively, they should be connected to other boards incorporating a charger facility such as the 4020 or 4270 boards.

Port (Sensor) Connectors

The 4010 module has four physical I/O ports. These are spread across four Phoenix connectors located at the bottom of the board.

+12V and Vu (User Defined) Supplies

The four sensor connectors each supply both 12V regulated and Vu (user defined) regulated power. However, it must be noted that these two power supplies are common to all four connectors. The 12V and Vu supplies are switched independently of each other and may be "Permanently Off", "On When Sampling" or "Permanently On". (Because the supplies are common to all ports, whatever switching option is selected for one port will apply to all ports.)

Port Configuration

Ports 1 through 4 are identical, providing the following I/O options:

- Digital Output - 50 ohm source impedance to ground when ON, high impedance when OFF
- Digital Input – weak pull-up option and/or external pull-up resistor required
- Voltage Input (0-1V)
- Voltage Input (0-2.5V)
- Voltage Input (0-3.5V)
- Current Loop Input (0-20mA)
- Current Loop Input (0-50mA)
- Pulse Width Measurement (seconds)
- Asynchronous Counter (counts pulses to ground from devices such as tipping buckets and flow meters)
- SDI-12 serial protocol
- EnviroPro on 3 loggers (refer to the iConfigure Technical Note for further details)
- Aquaspy
- Modbus (ASCII 1200,E,7)
- Garmin 17x GPS

Note:

All "logic-level" inputs (digital, pulse width, asynchronous and serial protocols) use a schmitt-trigger to condition the input signal. As such, the input voltage should be less than 0.5V to be recognised as a "low" level and greater than 2V to be recognised as a "high" level. Voltages between 0.5V and 2V are not guaranteed to be read as any particular state.
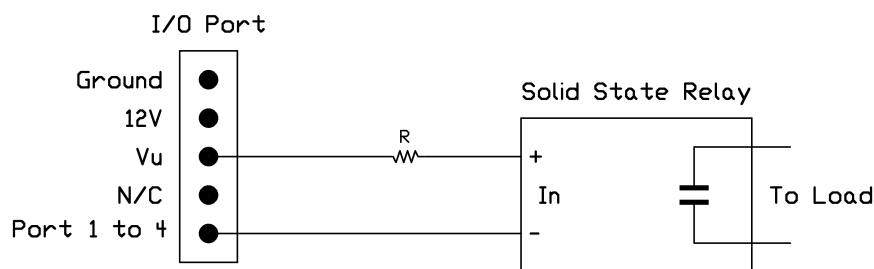
Port *Connections*

Ports 1, 2, 3 and 4 are provided on separate five pin Phoenix connectors. The pinout for these connectors is as follows:

1   Ground

2   +12V (switched)

3   Vu (2-12V switched)

4   No Connection (may be used for terminating external circuits)

5   I/O Port

Digital Outputs

The digital output functionality on Ports 1 to 4 is achieved by enabling the 47 ohm current sense resistor. When OFF, the output is high impedance. When ON, the output provides a 47 ohm connection to Ground. The 47 ohm source impedance limits what can be connected to these outputs. Generally they would be used to drive optically isolated (solid state) relays whose outputs were rated for the particular control application.

The positive side of the optical relay must only be taken to a supply of 5V or less. **Do not connect to 12V.** The Vu voltage may be used for this purpose provided it is set to "Permanently On" and <=5V.
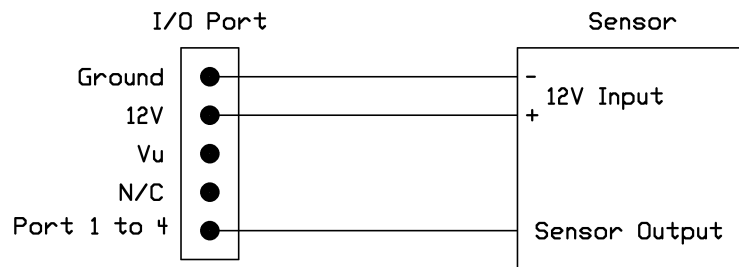

Typical output connection (Ports 1 to 4)

When the port turns on, the negative terminal of the solid-state relay is connected to ground via the internal 47 ohm resistor. This turns on the solid state relay. When the output turns off, the ground connection is removed, disabling the relay.
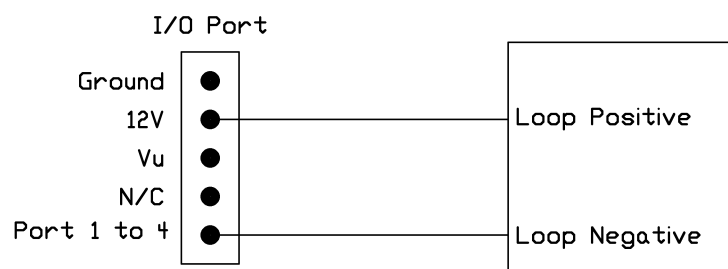
Note that the maximum current that can be drawn is just over 100mA (i.e. 5V/47R) less any voltage drop across the relay. An external resistor (R) will generally be required to reduce the current to acceptable levels.
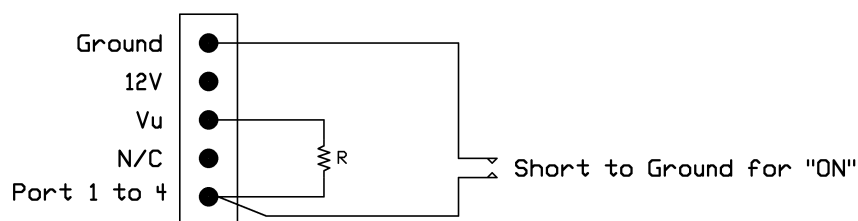
Inputs

Most sensors require 12V to operate and provide a variety of output signals. While many only require the 12V to be present while performing the sample, others require the 12V to be permanently applied. Remember that whatever 12V switching option is selected, it will apply to all ports. In addition, if one or more of the ports is used as a digital output then the Vu (5V) supply will need to be permanently enabled.

```
         I/O Port                      Sensor

Ground    ●  ─────────────────  -
 12V      ●  ─────────────────    12V Input
  Vu      ●                     +
 N/C      ●
Port 1 to 4 ● ─────────────────  Sensor Output
```

Typical Sensor Connection for Analogue and SDI-12

```
         I/O Port

Ground    ●
 12V      ●  ─────────────────  Loop Positive
  Vu      ●
 N/C      ●
Port 1 to 4 ● ─────────────────  Loop Negative
```

Typical Loop Powered (2 Wire) Current

```
Ground    ●
 12V      ●
  Vu      ●
 N/C      ●        R
Port 1 to 4 ●              Short to Ground for "ON"
```

Connecting switch contacts for Digital Inputs, Pulse Width or Pulse Counting (Asynchronous) measurements

Digital and Pulse Inputs – General Information

Most digital and pulse type sensors provide a reed-switch or relay contact at their output. Others provide "open-collector" style electronic signals while, in rarer cases, the sensors provide a voltage output that swings between ground and some defined voltage (e.g. 5V).

Pull-Up Resistors

For switch/relay contacts and open-collector outputs, a pull-up resistor is required for correct operation. The purpose of the pull-up resistor is to provide a voltage greater than 2V (typically 5V) to the input when the contacts are open. A pull-up resistor to 12V may be used but will result in current being drawn by the input protection circuits and is not ideal.

For Digital Inputs and Pulse Width measurements, an optional internal pull-up resistor (typically 20k-50k) is available. Where this is not sufficient, an external pull-up resistor (typically 1k-10k), shown as "R" in the above circuit, may be wired between the input and Vu (set to +5V). In such cases Vu must be set to "On When Sampling" or "Permanently On".

Note that the internal pull-up is not available for Asynchronous Pulse Count inputs. For asynchronous pulse counting the external pull-up (typically 10k) is required to provide a pull-up to Vu (+5V). For asynchronous inputs, power must be set to "Permanently ON" as "ON When Sampling" will result in a false count!

Internal Filters

The 4010 board has internal filters that may be optionally selected to filter out "contact bounce" or to smooth the signal in electrically noisy environments. With the filter applied, pulses less than 15ms duration will not be detected. This allows measurement of signals up to around 60 pulses per second.

Unless circumstances dictate the opposite, the input filters should always be applied when measuring Digital, Pulse Width and Asynchronous signals.

Note: For Asynchronous Count Inputs, pulse rates exceeding 500 pulses per second may cause incorrect operation of the 4010 board. It is the users responsibility to ensure that pulse rates in excess of this limit are not applied to the inputs.

Digital Inputs

Digital Inputs simply measure if a sensor is ON or OFF. In this case, an input voltage of <0.5V is considered to be ON and >2V is OFF. Voltages between 0.5V and 2V are undefined. In simple terms, when the switch contact is open, the logger will read +5V (OFF). When the sensor contacts close they apply a ground to the input pin and the logger will read 0V (ON).
The sampled value will be "1" for ON (Ground or < 0.5V) and "0" for OFF (> 2V).

Voltage Inputs

When configured as a voltage input these ports are capable of measuring voltages in the range 0 to +3.5V. The range can be configured for 0-1V, 0-2.5V or 0-3.5V with highest resolution at the lowest voltage range. Larger voltages (up to 15V) may be applied without damaging the input circuitry but readings over 3.5V will be highly inaccurate. Power to the sensor may be derived from the Vu or +12V supplies.

The input voltages should not exceed +15V or go negative as the input protection circuits may draw excessive current from the external device. The sampled value is expressed in Volts.

Current Loop Inputs

Current measurements are performed by passing the current through an internal 47 ohm resistor to ground and measuring the developed voltage. While this input is generally used for sensors that generate 4-20mA signals, any current from 0 to 50mA may be measured.

Currents in excess of 70mA should be avoided as damage may occur to the 47 ohm current sense resistor.

The sampled value is expressed in milliAmps.

Duration Counter (Pulse Width) Inputs

The duration counter is used to measure sensors with low frequency outputs, typically from around 20 pulses per second (1200 pulses per minute) down to 6 pulses per minute. The resolution of 1ms begins to cause noticeable errors at frequencies higher than 20pps. This input is useful for measuring older Aquaflex moisture sensors that produce 10 pulses per minute when dry and 130 pulses per minute when saturated.

If the incoming pulse duration is <1ms then an error value (-999.999) will be returned. Similarly, if a full pulse is not received during the sample period (gate time) then the same error value will be returned. The gate time is user definable and can be up to 25s.

The sampled value is expressed in seconds.

The following table provides a cross reference between the pulse width (in seconds) and the pulse rate.

Pulse Width (s)	Pulses per Second	Pulses per Minute
0.01 (10ms)	100	6000
0.02 (20ms)	50	3000
0.05 (50ms)	20	1200
0.1 (100ms)	10	600
0.2 (200ms)	5	300
0.462 (462ms)	2.167	130 ("Aquaflex" maximum)
0.5 (500ms)	2	120
1	1	60
2	0.5	30
5		12
6		10 ("Aquaflex" minimum)
10		6

Relationship between Pulse Width Values (seconds) and Pulse Rate

Note that the pulse duration can be measured across the entire waveform or just the positive or negative portion. If measured across the positive or negative portion only, the previous table is not valid.

Asynchronous Counter Inputs

The Asynchronous Counter inputs count random pulses as may be generated by Tipping Rain Buckets, ET Gauges, Flow Meters, etc. The input pulses are counted as they arrive at the input pin. When the logger takes a sample, the total count is stored and the counter cleared in preparation for the next sample period.

The sensor may provide a voltage output, simply be a set of contacts or have an open collector type output. Choose the appropriate wiring diagram and remember that an external pullup resistor is required to be connected to these ports to facilitate "dry contact" and "open collector" types of connections. The external pullup resistor is connected to the Vu (+5V) supply and the supply set to "Permanently On".

An internal filter may be applied to the signal to remove the effect of contact bounce for mechanical contacts. Without the filter, frequencies of up to 400 pulses per second may be measured. If the filter is applied then this is reduced to around 50 pulses per second. For contact bounce > 1ms duration an external RC filter may be required.

The maximum number of pulses that may be counted between sample periods is 2,097,151. Values greater than this, will return 2,097,152. There is no minimum value (no pulses will simply return "0").

The sampled value is expressed as the number of pulses received since the last sample.

Asynchronous Pulse Rate

The 4010 board has an additional feature that calculates the highest rate of pulses received within each logging period. This is useful for measuring the highest "wind gust", for example, along with the average wind speed for the measurement period. Other variable such as the highest rate of rain fall may be similarly measured.

Pulse rate measurements are obtained by allocating a second channel to the specific port.

Two options are available for pulse rate measurements. For pulses that arrive continuously and frequently (e.g. a flow meter) the board counts the number of pulses that arrive every minute and then keeps track of the highest count. For infrequent or erratic pulses (e.g. rain buckets) the board measures the time between each consecutive pulse and keeps track of the minimum interval. It then converts this time into pulses per minute.

A minimum of one pulse per minute is required for this feature. A maximum pulse rate of less than one pulse per minute will return a value of zero.

SDI-12 Inputs

SDI-12 is an intelligent serial sensor interface protocol that has been adopted by many sensor manufacturers. Using the standard wiring diagram, most SDI-12 enabled sensors may be read. All three SDI-12 data sampling methods are supported (i.e. Normal, Concurrent and Continuous). Sampled values are expressed in whatever units of measurement are employed by the sensor.

General Information

Error Values

The logger will store error values in place of sensor values when certain error conditions are detected. Numeric values in the range -900 through -1000 are currently reserved for the logging of these errors. Current error values are:

-999.999   Sensor Out of Range Error

-980.000   Divide by Zero Error

-950.000   SDI-12 Communications Error

Numeric Restrictions

The iNTELLiTROL data communications specification limits numeric values to between -2,147,483.648 and +2,147,483.647 with a maximum of 3 decimal places. The 4020 module has conformed to this specification. Thus, the smallest absolute value that can be stored is 0.001 with a resolution of 0.001.

Formulas

Simple formulas (second order polynomials, inverse functions and simple divisions) can be embedded into the logger to convert the sampled value into engineering units. The use of single precision floating point numeric processing places limits on the accuracy of such calculations. While the accuracy of the 4010 formula calculations is better than the accuracy of most sensors, conversions should be performed at the PC level, if possible.

If any formula results in a divide by zero then the "Divide by Zero" error value will be returned.

A further restriction is that the results of the application of any formula must not exceed +/- 1,073,741. As it is extremely unlikely that this condition will ever occur in this product's target market, this is not deemed to be an issue.

Logging Functions

The 4010 board is capable of holding 4096 samples. At a sample rate of 1 hour this equates to approximately 170 days or nearly 6 months of storage. The minimum and maximum sample rates are 1 minute and 24 hours respectively. At 1 minute sampling the logger will hold a bit more than two days and 20 hours of data.

Real Time Clock

A hardware Real Time Clock (RTC) is not provided. The software RTC is set by the controlling PC to keep the date/time correct. In the case of RTC failure and the loss of power, when power is restored the logger clock will be set to the date/time of the last sample.

Status LEDs

The two status LEDs (green and red) provide information regarding the status of the 4010.

Power On Sequence

Upon power up the red LED will illuminate for 1s during which time the green LED will flash twice. The micro-controller now tests the RTC and logger memory. If an error is detected with the RTC or logger memory then the red LED will illuminate.

In addition, applying power will also raise an alarm ("Power On Reset"), this alarm can be removed by resetting the board by applying a brief short across the two reset pins located above the green LED or clearing the alarm in the iConfigure Control screen (F1). The red LED will then extinguish. Current alarms may be viewed in the iConfigure Control screen.

Normal Operation

At completion of the power up sequence the green LED will flash once per second. If an error was detected during the power up sequence the red LED will also flash.

Communications

The green LED (and red LED, if an error condition exists) will illuminate every time data is received and transmitted providing visual indication of data communications.

Fault Conditions

Occasionally a situation will arise where neither LED is flashing (i.e. solid on or solid off). If neither LED is on then it is most likely a loss of power. Check the battery fuse and power supply from the RS485 cable.

On rare occasions the 4010 board may "lock up", indicated by a lack of LED activity. This can happen under certain disturbances such as local lighting. The board has a built in "watchdog" to recover from these situations. However, in the rare situations where the watchdog has failed to detect or rectify the condition, the issue can be resolved by simply resetting the board.

Occasionally the green LED will flash erratically. As stated previously, the LED flashes in the presence of RS-485 communications. However, continual erratic flashing may be an indicator of noise on the communications line. An oscilloscope will be required to investigate this condition.

4010 Errors

The following errors will cause the red LED to flash every second, along with the green LED.

> Power On Reset
>
> Watchdog Reset
>
> Real Time Clock not set correctly
>
> Error reading from or writing to the logger memory

Configuring the 4010 with iConfigure

The standard module configuration program iConfigure.exe is used to configure:

1. Network and Module Addresses,
2. Each of the four I/O ports,
3. Sensor power options,
4. Logging functionality, and
5. Embedded formulas.

Refer to *Technical Note - iConfigure* for full details of each application, testing the inputs and outputs & adding formulae (F1) and viewing logged data & clock (F4).

Following is a typical example for configuring a 4010 (F2) .

Connect to the Board

Using the configuration cable, connect the board to a PC COM port. Start iConfigure, select the correct COM Port and click [Connect]. Ensure "Web" is selected in the Command Type group box.

If only one board is connected to the cable, click [Interrogate All]. Otherwise enter the correct Network and Module Addresses and click [Select]. If communications is successful the board will appear in the list in the lower portion of the window.
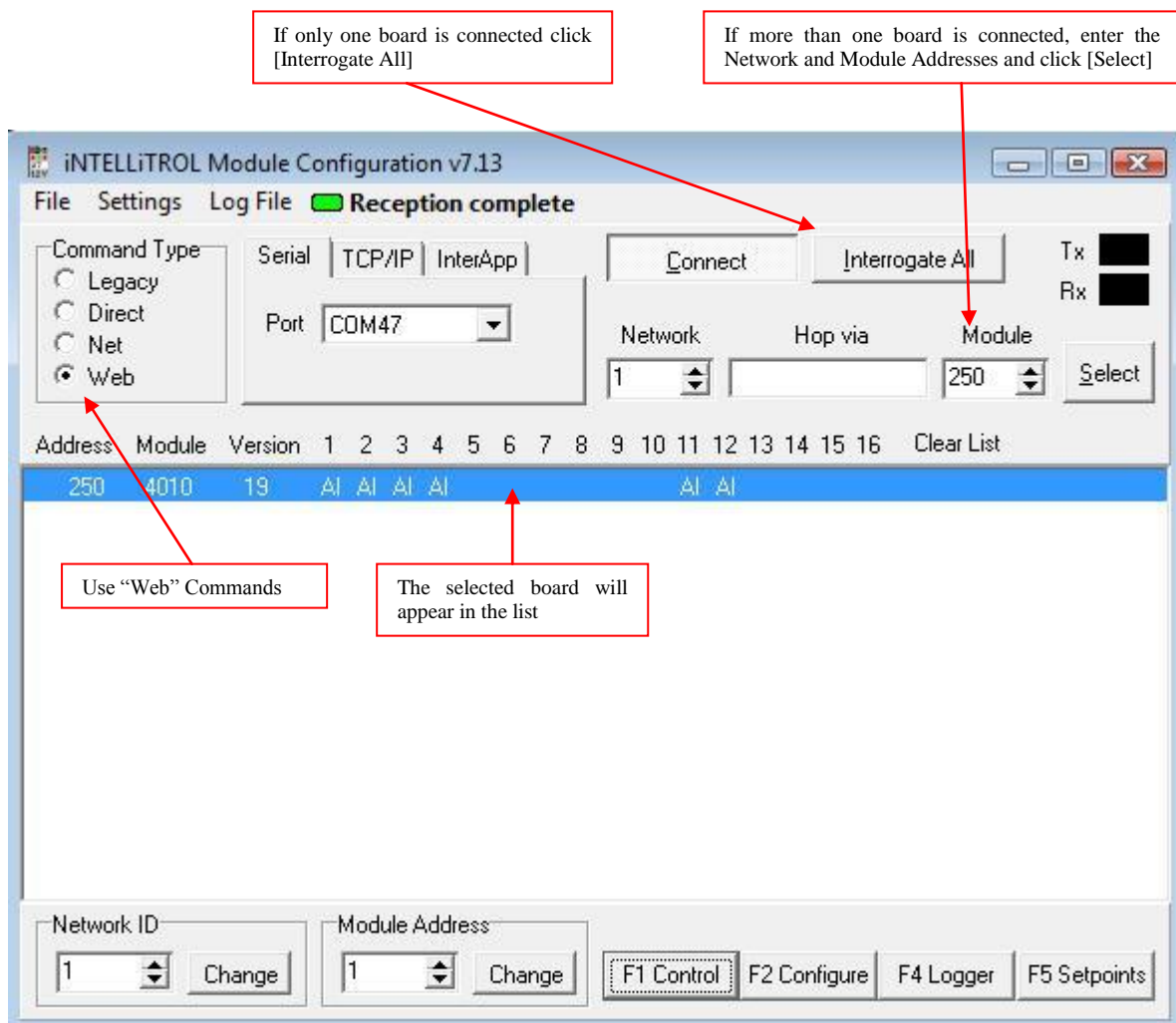
Configuring the Ports

Highlight the appropriate entry in the list and press <F2> or click on the "F2 Configure" button at the bottom of the window. This allows changing of:

1. The Network and Module addresses,

2. Port I/O type, gate times, pull-up resistors and input filters,

3. The number of channels allocated to each port, and

4. Sensor voltage options and warmup times.

Initialise Configuration

This option restores the 4010 to its factory default settings. When a 4010 board is delivered it will have had the firmware loaded (flashed) and its configuration initialized. However, if incorrect or undesired configuration changes are made, or the board is being reused in a different application, then this feature may be used to reset the board to a known state.

Notes:

If the 4010 is reflashed with a new firmware version, the existing configuration is normally retained. I.e. by default, reflashing the board does not erase the configuration EEPROM.

After performing an "Initialise Configuration" the Network ID will be set to "1" and the Module ID to "250".

After initialisation, the 4010 will need to be "re-interrogated" to read it's new configuration into iConfigure.

Once initialised, close the configuration screen, re-interrogate the board, ensure the correct line is highlighted and then tap <F2> or click on the "F2 Configure" button. The default configuration will now be loaded and the board may be set up as required.

Ports and Channels

There are four physical I/O Ports on the 4010 module. The logger firmware can log data for 16 channels. One of the primary functions of the configuration screen is to map data from each of the four I/O ports to one of more of the logger channels. If each Port has one sensor then the Ports can be mapped 1:1 (i.e. Port 1 = Channel 1, etc. through to Port 4 = Channel 4).

However, some sensors (e.g. SDI-12) use one physical port but provide data for many sensors. Therefore, 1:1 mapping is no longer suitable. For each Port in the configuration screen there is a drop down box that allows the user to specify the number of channels that will be allocated to this port.

e.g.

Port 1   1 Channel   Channel 1

Port 2   9 Channels   Channels 2-10

Port 3   1 Channel   Channel 11

Port 4   1 Channel   Channel 12

If a Port has no Channels allocated to it then the sensor will not be sampled. Similarly, if a 10 sensor SDI-12 probe has only 6 channels allocated, then only the first 6 sensors will be logged.

The 4010 board can also be programmed to extend the channel availability by using virtual loggers; see *Technical Note - iConfigure* for details. Virtual loggers are only available to serial probes (SDI, Modus, etc.)

If virtual loggers are used then one port is mapped to one (or more) virtual loggers. That is, a virtual logger is never shared between two or more ports.

Reserving Channels

Multiple channels may be allocated to any port even if the probe only provides one value. Channels may also be allocated to an "Unused" port. This has the effect of "reserving" these channels for later use.

Changing Port/Channel Allocation

To change the Port/Channel allocation at a later stage, while possible, is not desirable and must be handled carefully to avoid corruption and/or loss of data. As such, care should be exercised when initially allocating Channels to Ports. As a rule unused Ports should reserve one or more Channels (if possible) for later use.

If the Port/Channel allocation is changed then the PC configuration must also be changed to reflect the new settings. The PC database will also need to be modified to ensure the old data is transferred to the new channel numbers.

Configuration Example

The following example is provided as an aid to understanding the various configuration options of the 4010 module.

In this configuration the Network ID and Module Address have been set to "1" and "250" respectively.

Port 1 has a temperature sensor attached that provides a 4-20mA output. One channel has been allocated to this port (in this case, **Channel 1**). The option exists to effectively calibrate a sensor at one measurement value by providing a trim to the current measurement using the "Analogue trim %". This could be useful when changing a sensor that returns a slightly different value for the same quantity measured, such as changing a frost sensor. The "Instantaneous" option provides one value at the time of the sample, ignoring other values that may exist between samples.

Port 2 has a pressure sensor attached that provides a 4-20mA output. The "Stats (Avg, Max, Min) option allocates 3 channels (provided at least 3 channels have been allocated) to provide these values measured during the sample interval, set by the sample rate of the logger clock. Nine channels have been allocated, so this reserves **Channels 5 through 10**.

Port 3 has been configured to measure the width of an incoming pulse. One channel has been allocated (in this case **Channel 11**). The "Gate Time" has been set to 10s. This means that the logger will wait 10s for the incoming pulse. If a complete cycle does not arrive within this time an error value (-999.999) will be returned. The whole cycle is to be measured (i.e. both the positive and negative portions). The input filter has not been activated probably because the signal source is unlikely to have contact bounce.

Port 4 is configured to count random (asynchronous) pulses which may arrive at any time between logger samples (e.g. Tipping Rain Buckets). One channel has been allocated (**Channel 12**) and, as the signal is presumably coming from a reed switch, the input filter has been activated to eliminate contact bounce. The option "Count only" provides 1 value of the number of pulses received during the sample interval. A further option of "Count, Max pulses/min (erratic)" or "(fast)" provides values of both counts during the sample interval and maximum rate of pulses/min, provided that the channel allocation is more than 1. If two channels had been allocated to this port then Channel 13 would return the maximum rate of pulses/min. The "erratic" option would apply to slow random pulses such as a tipping bucket, the maximum value being determined by measuring the shortest period between any 2 pulses that arrived during the sample interval. The fast option should be used for faster pulses that could exceed 10 pulses per second, the maximum value is determined by counting the maximum number of pulses received within any 1 minute interval during the sample interval.

Sensor Power

In this configuration, both the 12V and User (Vu) supplies will be turned on during the sample period and turned off again at completion of sampling. This assumes that none of the devices (including the rain bucket) require continuous power and that the rain bucket does not require a pull-up resistor.

The "Warmup Time" of 2s means that power will be applied to the sensors for at least two seconds before any sampling is performed. This gives time for the sensors to initialise themselves, take their readings and apply the correct values to the signal lines before the values are sampled and logged. The maximum warmup time is 25s.

The User (Vu) voltage may be set between +2 and +12V, this voltage can also be trimmed using the "Trim" option. The "Set Voltage" can be used whilst measuring the Vu output to aide quick adjustment. If possible it is best to use the "On When Sampling" option for two reasons, to reduce power, and to avoid permanent DC voltages along the cables. This becomes an issue if the cable is punctured allowing water to seep in. Damage due to electrolysis will be greatly accelerated with the presence of a permanent DC voltage.

Writing the Configuration

Once the correct configuration has been entered simply click the "Write Config to Board" button to write the new configuration to the logger.

If the Network or Module Addresses are changed then a Dialog Box will be displayed reminding the user to re-interrogate the module. In any case, the board will usually need to be re-interrogated to ensure that iConfigure is loaded with the correct information.