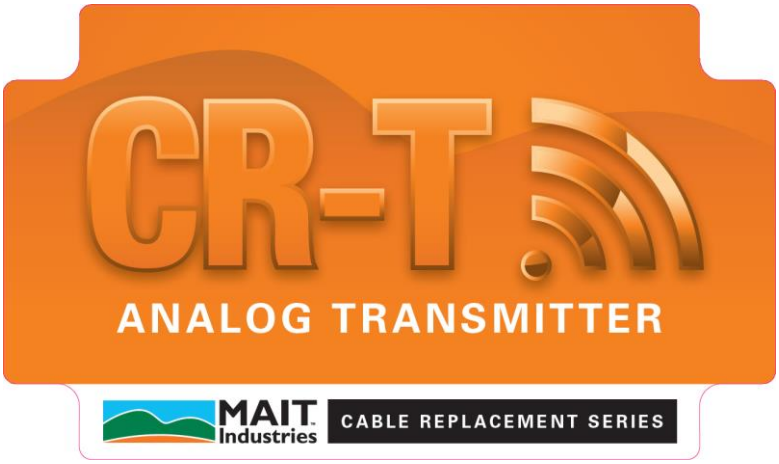
Cable Replacement Series
CR-T and CR-R
Analog Transmitters and Receivers



Specifications

Revision 4

03/07/2020

Introduction

The CR-T and CR-R Analog Transmitters and Receivers are members of the MAIT Industries "CR" series of cable replacement units. The CR-T transmits analog or digital signals to a CR-R which faithfully reproduces these signals at its outputs.

Transmitter Inputs

The CR-T Analog Transmitter is able to read 4-20mA signals, asynchronous pulses and/or digital contacts (switches, relays, etc.) Each CR-T transmitter has two channels that align with two channels on the receiver. Any of the three input types may be independently selected for either channel.

Alternatively, two CR-Ts may be paired with a single CR-R with one CR-T transmitting on channel 1 and the other transmitting on channel 2.

Receiver Outputs

Each CR-R has two analog outputs that provide 4-20mA (or voltage) signals and two digital outputs that reproduce the asynchronous pulses or digital signals. The digital outputs are capable of driving 12VDC relays (or solenoids) or can be wired as "NPN open collector" outputs for connection to a PLC or other controller.

N.B. Do not connect the outputs to devices that reference voltages greater than the supply voltage – typically 12VDC. I.e. relays, solenoids and pullup resistors must not be tied to a voltage greater than the CR supply voltage.

Voltage Output

A set of jumper pins toward the bottom center of the CR-R allow selection of either "mA" or "Volts" as the output signal. If "Volts" is selected then a proportional voltage in the range 1-5V will be presented at the output socket rather than the 4-20mA signal. Note that, depending on the particular hardware version, some boards may produce 2-10V rather than 1-5V. Use a voltmeter to confirm which voltage range is implemented to ensure correct operation of the connected equipment.

Range

Sensor values may be transmitted over distances of several kilometers line-of-sight. Repeaters (type CR-V) may be used to extend this distance if required.

Revision History

Revision 2 – Firmware v22 – 7 Nov, 2014

Introduced ability for CR-T and CR-R to send and receive continuous transmissions.

Revision 3 – Firmware v25 – 6 Mar, 2018

Added five minute auto-off functionality to CR-R (digital signals only).

Updated flash sequences for easier interpretation of faults and pairing states.

Revision 4 – 2 Jul, 2020

No firmware changes. Modified the document to better describe the flashing sequences of the red and green diagnostic LEDs.

Electrical Specifications

Maximum Ratings

Battery Terminals (w.r.t. Gnd) [Note 1] (V_{Batt})		-15V to +15V (9350, 9351) -21V to +21V (9352)
CR-T	Sensor Supply Voltage [Note 1]	0V to +15V
	Sensor Supply Output Current [Note 2]	400mA
CR-R	Analog Output Current	Continuous short circuit
	Digital Port Output Voltage	0V to V_{Batt}
	Digital Port Output Current	2A (continuous)
	Open Collector Pullup Voltage	0V to V_{Batt}

Typical Operating Conditions

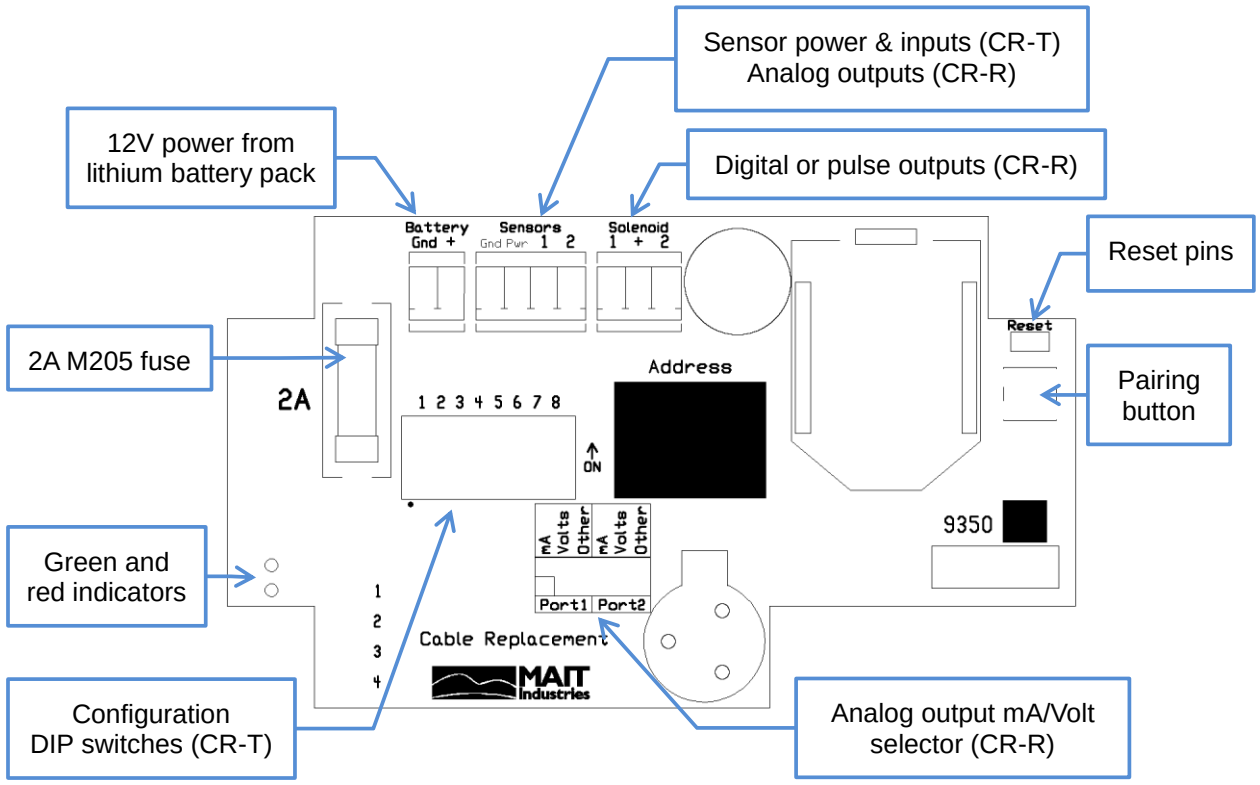
Battery Voltage		+9V to +14V
Operating Current (Approx.) (12V supply, inputs open circuit, outputs off) Additional current with 12V Sensor Power operating in "unregulated" mode (CR-T)		0.3mA (Radio sleeping, 12V sensor power disabled) 10mA (Radio awake, idle) 55mA (Radio transmitting) 4mA
CR-T	Sensor Input Voltage [Note 3]	0V to 3.3V
	Sensor Output Voltage [Note 4]	12V
	Current Loop Resistance	47 Ohms
	Current Loop Range	0 to 23mA
	Asynchronous Pulse Rate	Zero to 20 pulses per second
CR-R	Digital Port Output Current [Note 5]	3A pulsed <500mA continuous
	Analog Output Accuracy	Better than +/-1% FS (4-20mA, 1-5V, 2-10V)

Notes:

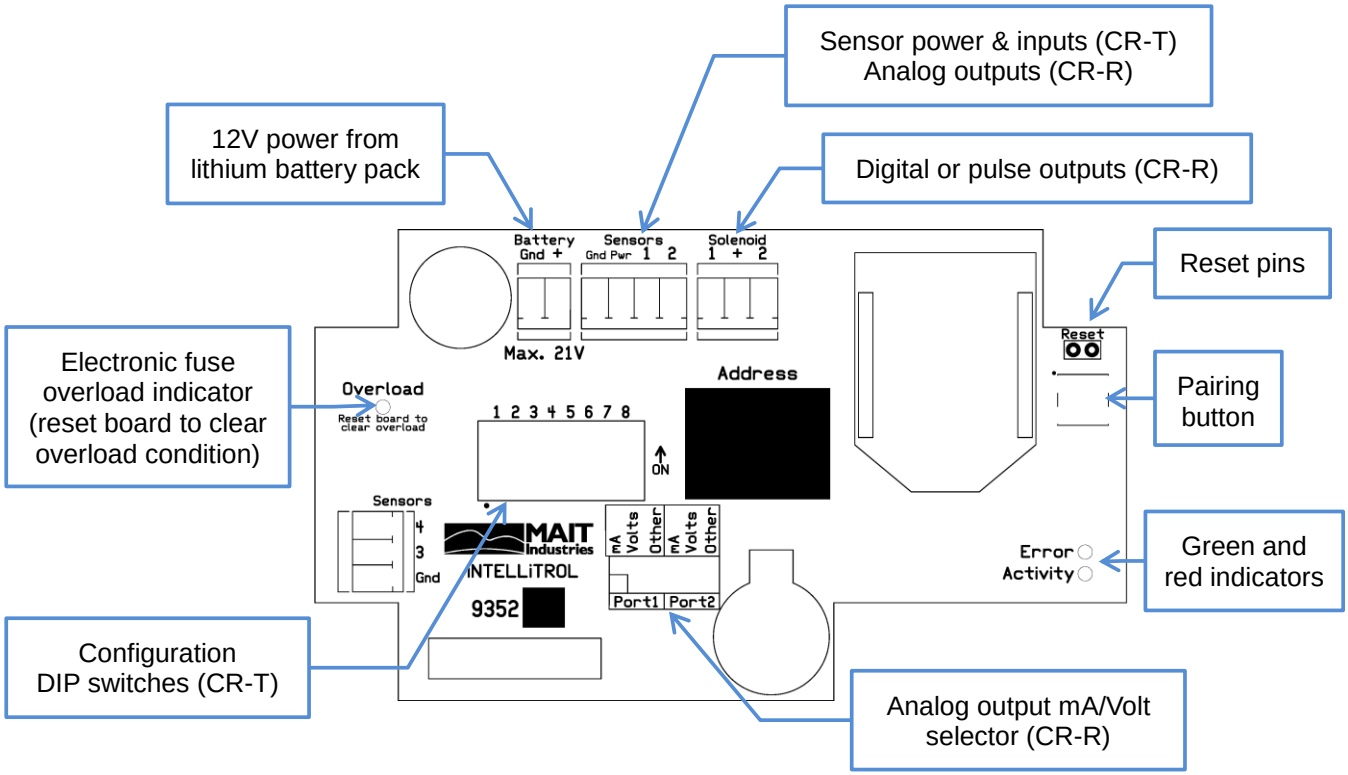
1. Inputs are clamped for surge protection. Continuous DC inputs outside these extremes will cause overheating and possible destruction of the clamp diodes.
2. The sensor output voltage is current limited and able to withstand a continuous short circuit.
3. Applying a voltage outside these limits will cause the input protection diode to conduct, placing approx. 1k resistance between the input and ground.

   When "Digital Inputs" are enabled, each sensor input has a 10k pull-up resistor to +3.3V. This represents the OFF condition. The input is typically shorted to ground through a voltage free contact to represent an ON condition.
4. The sensor output voltage is derived from the CR supply voltage and, therefore, will always be less than the CR supply voltage. It is limited to a maximum of 12V.
5. The charge current into the standard Lithium battery pack is limited to 1A. Regardless of the charging source, drawing a total of more than 1A of continuous current will cause the batteries to have a net discharge.

Board Layout 9350/9351 (Standard Fuse)



Board Layout 9352 (Electronic Fuse)



Power Supply

The CR-Ts and CR-Rs are powered from a nominal 12VDC power source. Typically this would be the standard in-built, 3AH, rechargeable lithium battery pack. This pack is generally kept charged via a 15VDC 1A regulated plug pack. Where mains power is not available a 12V solar panel (5 or 10W) may be used but care must be taken to ensure the panel is able to supply sufficient charge to maintain the power requirement of the boards and all connected components.

12V power for the sensors on the CR-T may be obtained from the sensor connector. Power for the current loop outputs on the CR-R is supplied by the board. As such, the target sensors and devices are not required to supply power to the unit.

Note: If the lithium pack is used, the voltage from the battery may vary between 9.5 and 12.5VDC. Caution must be exercised when selecting relays to ensure they operate reliably over this range.

For higher power applications a 12V 7AH Sealed Lead Acid battery may be used, also charged from a suitable source.

The CR units may be powered directly from a **12VDC** plug pack if mains power is reliable and battery backup is not required. The power rating of the plug-pack must be sufficient to handle the maximum load, including the CR unit and any attached devices.

If the attached output devices continuously draw significant current (i.e. >100mA) then an external power source, rather than the lithium battery pack, is recommended.

Operation

The CR-R has two digital and two analog outputs. These outputs are controlled by data received from paired Analog Transmitters.

Digital and asynchronous pulse signals on the transmitter inputs will be replicated on the digital output ports. Analog signals (current loop) on the transmitter inputs will be replicated on the analog output ports. The analog output ports are configured with jumpers for 0-20mA or 0-5V (0-10V) signals. *Note: Even though most sensors use the range 4-20mA, the CR boards will operate down to 0mA, though relative accuracy is reduced at lower current and voltage levels.*

Update Rates

The output values on the CR-R are updated whenever a transmission is received. This rate is determined by DIP switches on the CR-Ts and can be 60 seconds, 10 seconds or “continuous”.

If “continuous” is selected then the values are transmitted at a rate of 1 to 1.5 seconds. The reason for the variation is to mitigate the interference that may occur if two or more CR-Ts transmit “continuously”.

Acknowledgements

Sensor readings from the CR-T are grouped into a “packet” and sent to the CR-R. The CR-R will acknowledge receipt of this packet with a response transmission. The CR-T will check for this acknowledgement and, if not received, will retransmit the packet up to ten times at random intervals of between 1 and 2.4 seconds. The random retry delay is, again, used to mitigate interference.

Note: In “continuous” mode, the CR-R does not issue an acknowledgement and a packet is never repeated. Rather, a new packet is sent with every transmission.

Auto-Off Functionality

CR-R firmware version v25 (Revision 3) introduced five minute auto-off functionality for digital signals.

Consider the situation where the CR-T is configured for digital signals (i.e. on/off conditions) and has turned the CR-R output on. If the CR-T loses power, or communication fails for any reason, the CR-R output will never be switched off.

This situation could lead to pumps running continuously causing overflow of tanks or dams.

To circumvent this problem, if the CR-R fails to receive a signal from the CR-T within five minutes, it will automatically turn the output off.

Implications of Missed Transmissions

Generally is it not an issue if a transmission is lost as it will be repeated up to ten times. Even if all ten retries fail to get through (resulting in a lost packet), the next packet will be sent within a short period of time – a maximum of one minute – depending on the CR-T sample rate.

However, if the CR-T is configured to send asynchronous pulses and a packet is lost then those pulses will never be reproduced by the CR-R.

Thus, for asynchronous pulse systems it is vital that the radio path is robust. It is also good practice to not use continuous mode for asynchronous pulse counting as the receiver does not provide acknowledgements and missed transmissions will not be repeated, resulting in lost packets.

Fuse

A blown fuse is identified by the red LED flashing slowly (on for one second, off for one second.

Only the output driver circuits are fuse protected. If the fuse blows then the board will continue to function normally but the outputs will not operate.

Earlier boards (9350 & 9351) have a 2A M205 (20mm x 5mm) glass fuse.

To ensure continued protection, replace the fuse only with the same type and rating.

Later boards (9352) have an electronic fuse. If this fuse "blows" then an Overload LED will light. The overload condition may be cleared by resetting the board. *(The board is reset by shorting the two gold pins marked "Reset" with a screw driver or some other metallic object.)*

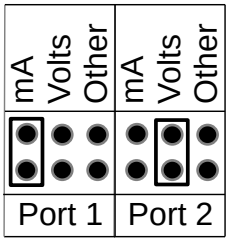
Indicator Lights

The green "Activity" LED provides an indication that the CR unit is performing some operation. When idle, the LED will flash briefly once per second. The green LED will also flash erratically whenever sensors are being sampled or radio communications are occurring.

Under normal operation, the red "Error" LED should be extinguished. This LED indicates an abnormal condition of some description. Refer to the section Indicator Lights on page 11 for more information.

CR-R Jumper Settings

Two jumpers are used to select either current or voltage signals for the two analog output ports.



This example shows 4-20mA selected for channel 1 and 1-5V selected for channel 2.

CR-T DIP Switch Settings

There are eight DIP switches that allow the user to define the operation of the CR-T. These switches are defined in Table 1.

DIP switches are enabled (turned on) by pushing the switch "up" as indicated on the board. In the following table ・ represents off (down) and ↑ represents on (up).

Switch	Function	
1 **2** ・ ・ ↑ ・ ・ ↑ ↑ ↑	**Port 1 Input Type** Unused (Channel is not sent to the CR-R) Digital Input Current Loop Asynchronous Pulse Counter	
3 … **4** ・ ・ ↑ ・ ・ ↑ ↑ ↑	**Port 2 Input Type** Unused (Channel is not sent to the CR-R) Digital Input Current Loop Asynchronous Pulse Counter	
5 ・ ↑	**12V Sensor Voltage** On when sampling Permanently on	**Continuous Mode** CR-T units supplied after 7/11/2014 will be shipped with firmware version 22 or higher. This version allows "continuous" transmissions (approx. one transmission per second) if DIP switches 5 through 8 are all turned ON. This implies that power will be permanently applied to the sensor and the radio does not sleep. Due to the higher power requirements, solar power is not recommended. The CR-R receiver must also have firmware v22+ to use this mode.
6 ・ ↑	**Sensor Warmup Time** 2 seconds 6 seconds	
7 ・ ↑	**Sample Rate** 1 minute 10 seconds	
8 ・ ↑	**Radio Sleep Mode** Radio sleeps when not transmitting Radio is always awake	

Table 1: DIP Switch Settings

Power Considerations for Solar Installations

Reducing Power Consumption

In solar powered installations, reducing power consumption should be considered a priority.

CR-T Sensor Power

The CR-T provides a 12V 400mA power source from which any attached sensors may be powered. This power is sourced from a linear regulator and can never produce more voltage than the input supply. (In the case of the lithium battery pack, this could be as low as 9.5V.) When the input voltage drops below approx. 12.5V the linear regulator is no longer capable of supplying a regulated 12V and runs in its "unregulated" mode. In this mode, current consumption increases considerably.

If 12V sensor power is not permanently required then it is recommended that it be set to "On when sampling".

When set to "On when sampling" the DIP switches also provide an option for either 2s or 6s warmup time. This defines the number of seconds to wait after applying 12V power to the sensors before the sensors are sampled. If the sensors are ready to be sampled within 2s of being powered up then choosing a 6s wakeup time is wasteful of power.

CR-T Radio Sleep

The radio normally sleeps between transmissions. Permanently enabling the radio is useful for diagnosing faults with specialist test equipment and is not recommended for normal operation. Keeping the radio awake considerably increases power consumption.

CR-T Sample Rate

The CR-T may be configured to sample once per minute, once every ten seconds or continually. Power consumption is higher during the sample period and the subsequent transmission. If possible, reduce the sample rate to one minute to keep power consumption as low as possible.

If the CR-T is set to "continuous" mode then both the radio and the sensor voltage will be permanently enabled. This should be avoided in solar powered installations.

CR-T Power Reduction Summary

The minimum power consumption for the CR-T is obtained by setting the;

- sensor power to "On when sampling" with 2 second warmup,
- sample rate to one minute, and
- radio to sleep when not transmitting.

CR-R

With the CR-R, the radio is permanently enabled to allow reception of data that could arrive at any time. As such, the only means to reduce power consumption is to consider the output.

It is unlikely that a CR-R will be used to reproduce analog signals in a solar situation. In the rare event this does occur, check to see if the target device can be configured to accept 1-5V (or 2-10V) signals rather than 4-20mA signals. The card can then be configured for voltage operation which could, potentially, save up to 20mA per port.

If driving relays then select relays with the smallest operating current. With the addition of latching solenoid driver boards, latching relays may be used so that power is only consumed during the latching phase.

Pairing Units

The CR-R Analog Receiver must be paired with one or two Analog Transmitter units (CR-T) or, if extended range is required, one or two repeater units (CR-V).

CR-T — Paired → **CR-R** *Pair the CR-T with the CR-R*

CR-T — Paired → *CR-V* — Paired → **CR-R** *Pair the CR-V with one unit. Then pair the CR-V with the second unit.*

Port 1 Enabled **CR-T** — Paired
Port 2 Enabled **CR-T** — Paired
→ **CR-R**

Pair the CR-R with one CR-T. Then pair the CR-R with the second CR-T.

Multiple Pairing

If two CR-Ts are paired with a single CR-R then Port 1 of one transmitter should be disabled and Port 2 of the other transmitter should be disabled. If both ports on the transmitters are enabled then the receiver will receive values from both transmitters and constantly toggle between those values.

A repeater may be added to either transmitter without affecting the other transmitter. If both transmitters require repeaters then two separate repeaters must be used. Two transmitters cannot use the same repeater.

Port 1 Enabled **CR-T** — Paired
Port 2 Enabled **CR-T** — Paired → *CR-V* — Paired
→ **CR-R**

In any order:
Pair the CR-V with the CR-R.
Pair the CR-V with the appropriate CR-T.
Pair the CR-R with the remaining CR-T.

Steps for Pairing Devices

1. On the first unit, press and hold the pairing button for at least five seconds. The red and green indicator lights will start flashing alternately to indicate "pairing mode". Release the pairing button.
2. Within three minutes, press and hold the pairing button on the second unit for at least five seconds. The red and green indicator lights will start flashing alternately to indicate "pairing mode". Release the pairing button.

If radio communications is acceptable the units will pair within a few seconds indicated by the red and green indicators flashing at a rate of four times per second, simultaneously, for a period of five seconds.

The units will retain the pairing information even if power is removed and/or the board is reset.

For repeaters and analog receivers (if two transmitters are employed), the process is performed a second time to pair with the second unit. For CR-Ts, the last pair will be remembered and all others discarded. For CR-R and CR-Vs the last two paired units will be retained in the unit's memory.

Un-pairing Devices

When installing a new system with units that may have been used elsewhere, it is prudent to clear any pairing information. This is particularly relevant for CR-Rs which will keep the last two paired devices in memory.

The "un-pairing" procedure is as follows:

1. Hold down the pairing button.
2. While the pairing button is held down, reset the unit by shorting the two pins just above the pairing button.
3. Keep the pairing button pressed until the green and red LEDs flash in unison.

After the initial flashing sequence, the two lights will stay solid for one second and then flash in unison six times. Once the lights start flashing, the unit is "un-paired" and the pairing button may be released.

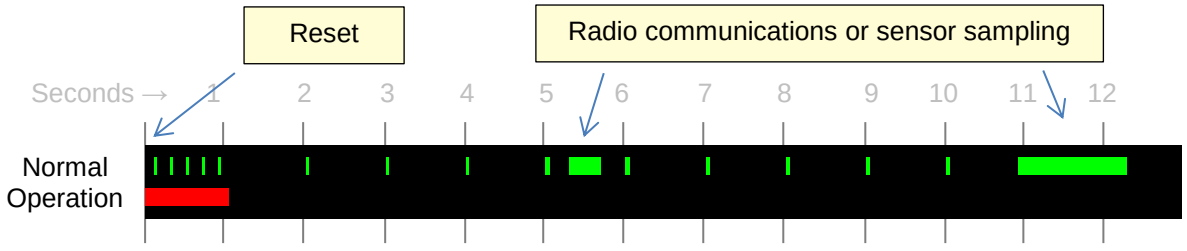
Indicator Lights

Two LEDs (green and red) provide indications as to the operational state of the CR units.

If a unit is reset (by shorting the two gold "reset" pins with a metallic object) the red LED will illuminate for approximately 1s while the green LED flashes five times. This indicates normal startup.

After startup, the red LED should extinguish. The green LED then provides an indication of the unit's "activity". The CR unit will generally wake up every 1s and flash the green LED briefly. This indicates the unit is idle and will be the normal condition for most of the time.

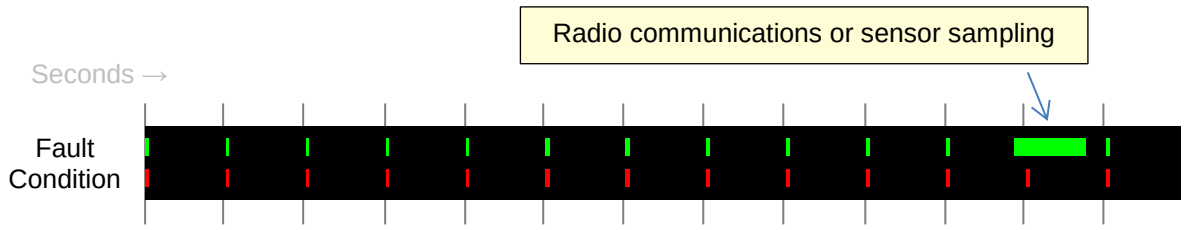
The green LED will also flash erratically whenever sensors are being sampled or radio communication is occurring.



Fault Conditions

A flashing red LED indicates various fault conditions. Fault conditions include:

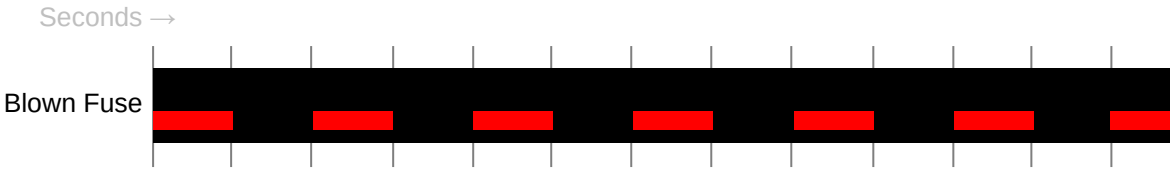
- Abnormal reset (brown-out or watch-dog).
- No response (or error response) from paired unit.



In the case of a fault condition, resetting the unit (shorting the "reset" pins with a metal object) will clear the error condition. Following a reset, if the red LED re-appears after 10 to 20 seconds seconds, then it is most likely the paired unit is not responding.

Blown Fuse

If the board detects a blown fuse it will flash the red LED in a slow blinking fashion. The green LED will be extinguished.



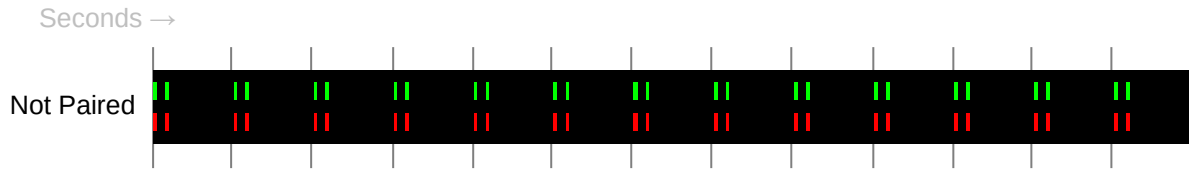
Older style boards have a physical fuse. To ensure continued protection, replace the fuse with the same type and rating:

2A M205 (20mm x 5mm) glass

Newer boards have an electronic fuse. A separate "Overload" LED will also illuminate when this fuse has tripped. An overload condition may be cleared by resetting the board.

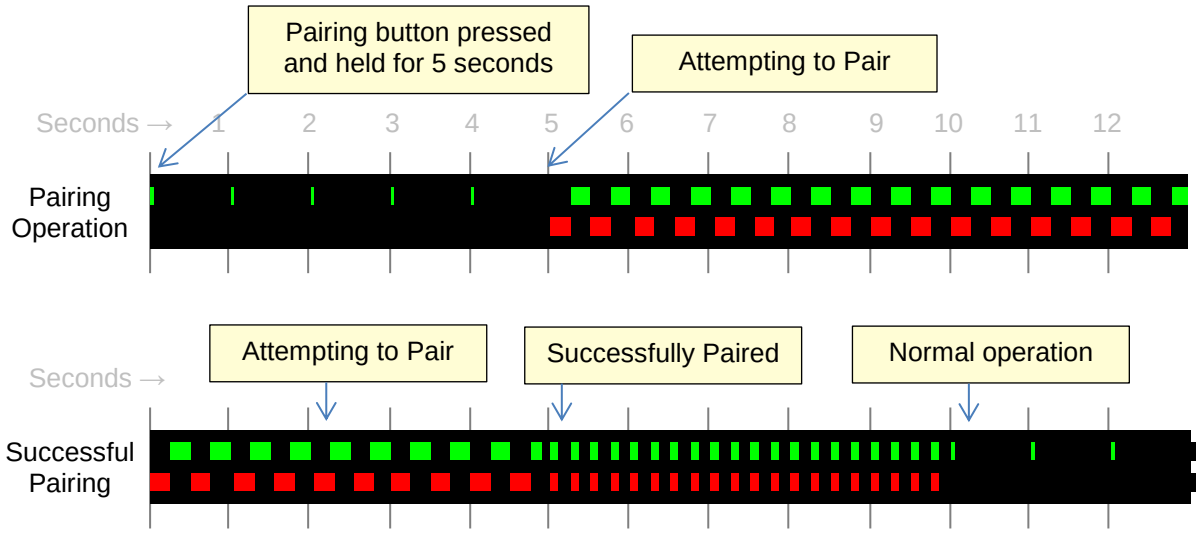
Not Paired

The "Not paired" sequence consists of two brief flashes of both LEDs every second. It will only occur if the unit has never been paired or has been specifically "un-paired". If a unit cannot communicate with its paired unit then it will **not** flash the un-paired sequence. Rather, a fault condition will be indicated.



Pairing Sequences

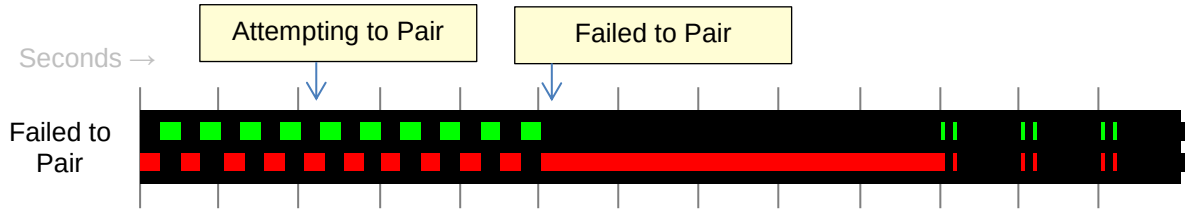
(See previous section for notes on how to pair CR units.)



Failure to Pair

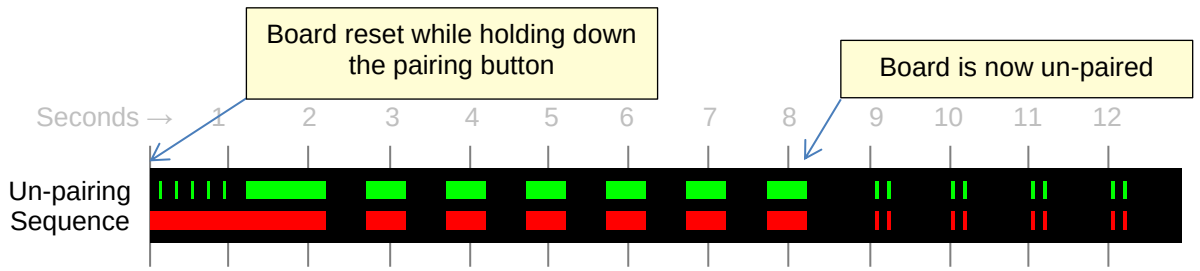
If pairing is attempted and the pairing attempt fails then one of two conditions will exist:

- If the unit was previously paired then the previous pairing will be retained. In this case, the flashing sequence will revert to “Normal operation”.
- If the unit was not previously paired then the unit will remain un-paired and flash the “Unpaired” sequence.



Un-Pairing

Once paired, the only means of un-pairing a unit is to use the un-pairing procedure described on page 11. The following LED sequence illustrates the un-pairing operation.

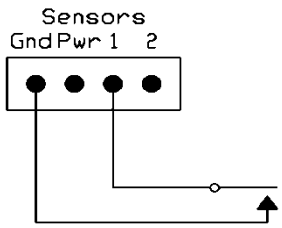


Application Notes

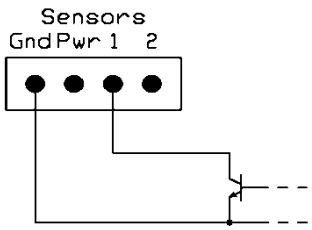
CR-T (TRANSMITTER)

Digital and Asynchronous Inputs

The digital input ports are pulled to +3.3V via an internal 10k resistor. Typically they would be left floating in the OFF state and pulled to ground in the ON state. They may be pulled to ground through a switch or relay contact or by an NPN open collector output from a sensor (such as a flow meter).



Switch or relay



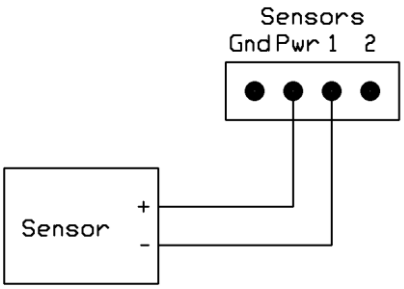
Open Collector

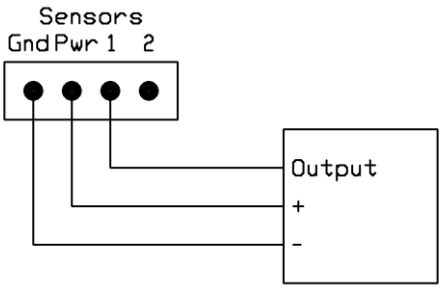
A voltage may be applied to the inputs providing it is within the specified limits. The input state is determined as follows:

<1V	ON
1 to 2V	Undefined
>2V	OFF

Current Loop Inputs

Two wire current loop sensors (loop powered) simply require 12V from the Sensor Power terminal wired to the positive (+) pin and the sensor output (-) wired into the appropriate input port.



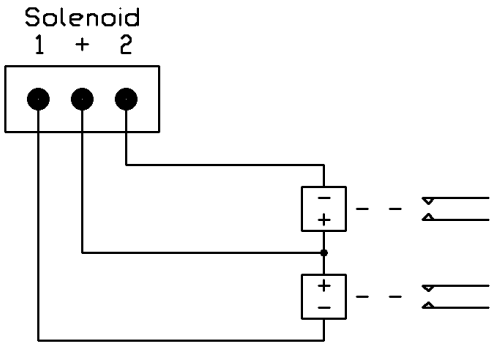


Three wire current loop sensors require power and ground connections to provide power to the sensor. The sensor output is wired to the appropriate input port.

CR-R (RECEIVER)

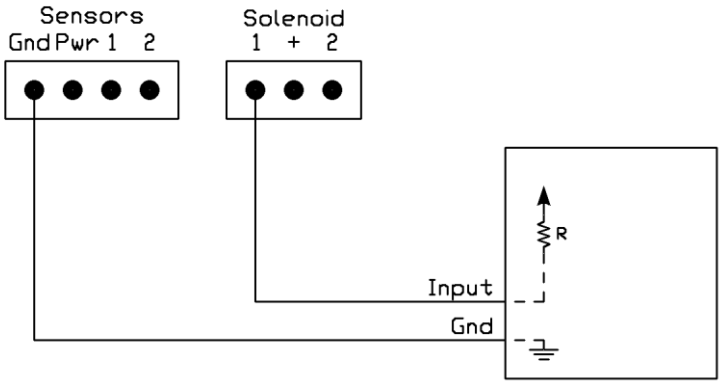
Digital Outputs and Asynchronous Pulses

The digital output ports will switch on and off depending on the state of the digital inputs of the corresponding transmitter. If the transmitter is set up for asynchronous pulse counting the receiver outputs will pulse on and off to reproduce the asynchronous signal.



Outputs 1 and 2 are normally high impedance. They are taken to ground when the output is turned on. A relay may be referenced to the center + pin which provides fused 12VDC directly from the battery.

Alternatively, the digital outputs may be used as "NPN open-collector" drivers with pullup resistors provided by the attached device. The pullup resistor must not be taken to a voltage higher than the battery voltage of the CR unit.



Current Loop and Voltage

Power for the current loop (or voltage) is provided by the CR-R. As such, only ground and signal connections are required to connect the analog output to another device such as a logger, controller or PLC.