TIC Irrigation Controls

Decoder based irrigation control Commercial – Golf – Landscape - Agriculture

Operating instructions and MODBUS Protocol Specification for TIC Irrigation Controls TICTT/MB/485

ModBus commanded 2 wire decoder signalling module. (RS485)

Document Version 1.06

Date 10th Mar 2014

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Revision History:-

0.9 and 0.92	Initial internal working versions
1.0	First general release.
1.01	Minor changes, images added. Reference to pushbutton removed.
1.02	Minor changes only
1.03	More minor changes.
1.04	More minor changes.
1.05	Revised for firmware V3.0 (Additional Data Registers, improved line current detection)
1.06	Added wide limits for setting current change thresholds.

GENERAL

This document draws on information contained in the following Modicon Documents: -

- *MODBUS over Serial Line – Specification and Implementation Guide V1.02 Dec 20 2006*
- *Modicon Modbus Protocol Reference Guide* ***PI-MBUS-300 Rev.J***

The functions implemented have to follow the Modicon protocol as the program within the Master has no control over the function codes used. The master controller can be a program running on a PC or firmware embedded in a PLC, or indeed any other device capable of issuing ModBus commands.

ModBus is a protocol developed for use on PLCs, and much of the terminology in the Modicon documents assumes a certain understanding of PLCs.

HARDWARE

The communication hardware specification for TICTT/MB/485 (the Encoder) is fixed RS485 running at 9600 Baud 1 Start, 8 Data, No parity, 1 Stop bit. Other baud rates and formats are available. The port is electrically isolated and +-80V fault tolerant. It will also withstand up to 15kV discharge in both direct and human body models. The isolation is intended to resolve ground loop problems, and is good for up to 80V or so, in respect of the Earth Stake potential.

TICTT/MB/485 resolves query complete by 3.5 character periods, or 750uS (which-ever is the greater for the baud rate) of line idle. We have strictly implemented this, as well as the abort during reception of a query if 1½-character periods of line idle are detected. TICTT/MB/485 does NOT respond to any message that times-out. A break of 3.5 characters / 750uS initiates the interpretation of the query received. The user therefore needs to be sure that commands are sent from the Master as single bursts of characters with no significant inter-character breaks or delays.

TICTT/MB/485 currently supports a maximum of 63 decoder stations. 2 wire '*TIC LandSwitch*' & '*UI Landscape*' Decoders are supported. Hardware V2.0 and above (with different firmware) is capable of supporting 127 station '*TIC FieldSwitch*' decoders. This option also supports legacy decoders of the "Watermation 2 wire" type, and also "Toro GTI Gemini" types (only 1 station at a time).

Optionally TICTT can be manufactured to support multiple "Toro GTI Gemini" decoders, and the 3 wire "Toro Trident" and compatibles, including the TIC '*FieldSwitch 3T*' decoder.

TICTT/MB/485 hardware will drop the line if a current greater than I_MAX (see later) is detected for more than about 1 second. Additionally it detects line short circuits and will drop the line within 20mS. Both these events set error statuses at addresses in the AUX range. An algorithm in the firmware attempts to make a decision about whether a line current fault can be attributed to a particular decoder. If it can, an error will be recorded for that decoder. Note: The 20mS short-circuit detect may not be triggered if there is significant line resistance between the encoder and the short-circuit.

The Earth Stake terminal (EST) **MUST** be connected to a properly bedded earth stake or plate (sited as close as practicable to the encoder) via a $4mm^2$ (#11AWG) or larger earth wire. This earth system is not to be regarded as an electrical safety earth. Connection of the EST to a building and/or an electrical earth is NOT permitted. If it was, a lightning strike on the field cable would be conducted into the building and/or its electrical installation!!

Firmware V3.0 onwards embodies an improved line current measuring algorithm. Prior to V3.0, current measurements were skewed by the asymmetric current drawn by decoders for their own supply. This issue was only problematic with the supply (transformer) volts in the lower parts of the allowable range. The effect was that current change seen by the encoder for the 1st station on was low, and in certain conditions insufficient for the detection of solenoid operation, unless the current change threshold was reduced below the recommended minimum value of 60mA.

The new algorithm corrects this skew by pre-calculating certain parameters whilst the line is off. Additionally a new data register is provided to scale current values between 80% and 120% of the values measured. It is not suggested that this value is altered, but is available for situations where there's excessive measurement errors due to decoder and/or other line conditions.

The encoder's ability to measure line current is only intended to be sufficient to detect successful decoder switching of solenoid loads.

TRANSFORMER

Transformer selection requires a bit of thought. Essentially the voltage should be as high as possible, with sufficient VA for the total maximum load. The limiting factor for voltage is usually the solenoids. The encoder and decoders will accept up to 40VACRMS. Solenoids don't 'see' the whole transformer voltage, with the encoder placing about ½ ohm on each of the AC lines, and the decoder about 0.6R on one side of the AC – as well as the resistance of the field cable between any given decoder and the encoder.. It is common in the UK to use 32VAC. V3.0 and above firmware now makes the consideration of transformer voltage a more simple analysis of line resistance and required field cable loading.

WIRING

TICTT/MB should be wired as follows:-

Lower edge of unit

AC and **AC** terminals should be wired to the transformer supply. Please note the transformer recommendations at the end of this document.
L1 is the Field Cable 'Live' terminal – **N.B. This is NOT a Mains Voltage connection**
L2 is the Field Cable 'Neutral' terminal - **N.B. This is NOT a Mains Voltage connection**
EST must be connected to the earth stake (see above for recommendations)
There are a further 3 terminal positions that are not used on TICTT/MB. The unit is shipped with these screws removed.

Top edge of the Unit

A, **B** are half duplex RS485 terminations. **B** is +ve and **A** is –ve during line idle conditions
COM is the ground of the isolated RS485 circuitry, and may be connected to **COM** on further TICTT/MBs and to the ground of the Master. All 3 terminals are linked with neons to EST. These neons flash-over at approx. 90V and provide a discharge path (to EST) for surges.

TICTT has 4 LEDs on the fascia. These function as follows.

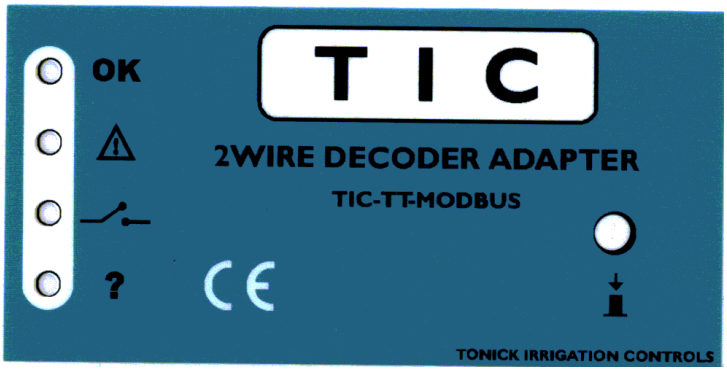

Figure 1 Top Panel Layout

Green LED 	Steady	All OK, CPU functioning, internal checks complete.
	Flash Fast (4/sec)	EEPROM Error
	Flash Slow (2/sec)	Firmware error.
	Blinks	Blinks off with RS485 activity (regardless of Slave address)
	Off	No power or fatal hardware failure
Red LED 	Steady	Error on 1 or more stations currently DESIRED ON
	Flash Slow (2/sec)	Error on 1 or more stations that have previously failed
	Off	No errors
Orange LED 	Steady	Line (Field cable) has voltage applied, i.e. "Live".
	Flash Fast	Line current overload or short detected (Line will now be OFF)
	Blink off	LED blinks off when decoder signalling occurs
	Off	Line is de-energized.
Yellow LED 	Steady	RS485 all OK, TICTT not addressed
	Blinks	Slave addressed and/or replying (Including Broadcast)
	Off	Invalid condition – Fatal error.
		Note – Broadcast not currently implemented.

ModBus Addressing

When ModBus commands are not used to set TICTT's address, the slave address is set using the DIL switch located on the underside of the CPU board. V2.0 units have a 4 position switch, and prior versions have 6 positions. Access is achieved by:-

1) Remove all connections and dismount the unit.
2) Unclip the plastic base of the unit to reveal the SIGNAL PCB. (Gently use a screwdriver in the slots provided)
3) Withdraw the signal PCB (it's on a flex cable)
4) The DIL switch is now accessible on the underside of the CPU PCB

N.B. Anti-static precautions must be employed when accessing the inside of the unit.

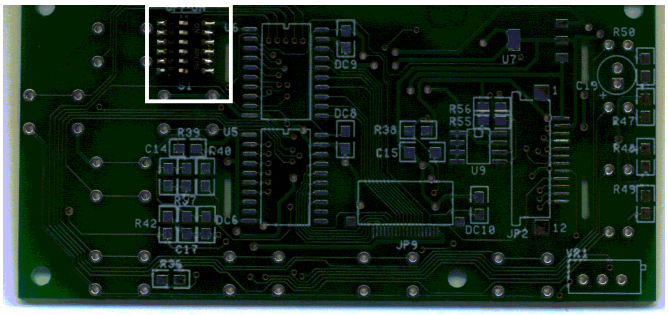

Figure 2 – Underside of CPU PCB showing DIL Switch
(N.B. Different on V2.0 hardware, but obvious nonetheless)

15 Addresses are possible (31 prior to H/W version 2.0), and are set in normal binary notation. Please note that 00 (All switches OFF) is illegal/reserved, at least one of the address switches must be ON.

Switch	Value ON	Value OFF	Device No	SW1(01)	SW2(02)	SW3(04)	SW4(08)	SW5(*) (16)
SW1	1	0	01	1	0	0	0	0
SW2	2	0	02	0	1	0	0	0
SW3	4	0	-					
SW4	8	0	14	0	1	1	1	0
SW5(*)	16	0	-					
SW6(*)	Mode select – not implemented		31	1	1	1	1	1

Note TICTT is shipped with it's slave address set to 01.

(*) Not on Hardware V2.0

See example photo below.

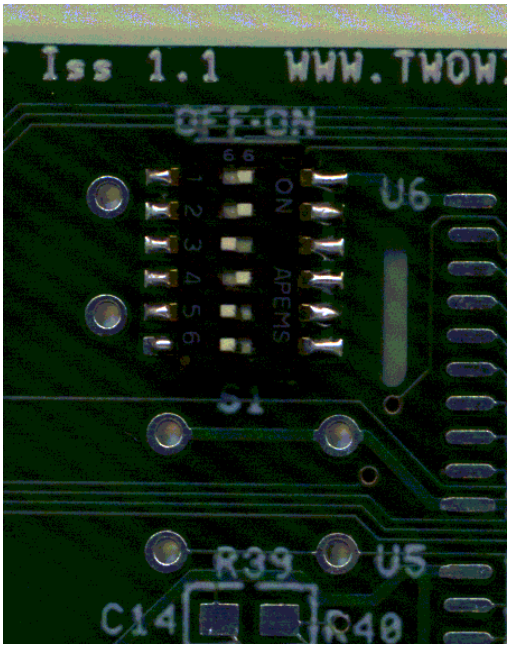

Figure 3 – Example of switch positions for address 11 decimal (0B hex)
N.B. 4 Position switch on V2.0 Hardware, but principle is the same

SOFTWARE

The ModBus protocol is implemented using RTU transmission mode (Binary). Message framing is achieved by line idle durations as described in ModBus documentation. Please refer to Modicon documents if a fuller understanding of ModBus and it's implementation on serial lines is required.

The TICTT/MB/485 implements the ModBus protocol sufficiently - such that decoders can be controlled and monitored. Decoder stations are accessed as COIL and STATUS, whilst general data values (such as line sensitivity) are accessed as data registers (Function 03).

The Function 08 diagnostics is not implemented. Slave specific comms counts and errors counts are recorded, but TICTT doesn't record successful message counts for the bus as a whole. Total message count is available at Function 11 with a busy status, and also at Function 03 along with com error counts. Com counts are reset to zero at power-up.

The ModBus standard decrees that Coil number 1 is transmitted within a ModBus messages as address 0000. The addresses discussed below are the addresses that would appear in the master program. The numbers that are transmitted within messages will be one less.

Each decoder address/station is controlled by a DESIRED coil, an ACTUAL status, a FIX coil and an ERROR status. Each range of bits has a base address starting with DESIRED at a base address of 0000. ACTUAL, FIX and ERROR addresses are then based at intervals of 1000. Each station has its own offset value - such that all addresses concerning a single station are a fixed 1000 apart.

To maintain compatibility with future developments of TICTT/MB, the user should NOT read or write to locations that are not currently implemented.

All attempted accesses to unimplemented addresses will generate an address exception.

Absolute ModBus address ranges for decoders are therefore:-
(Writes outside valid Coil address ranges will have no affect, Reads that start outside valid Status address ranges will return no data)

DESIRED Coils	=	0001	~	0200
ACTUAL Status	=	1001	~	1200
FIX Coils	=	2001	~	2200
ERROR Status	=	3001	~	3200

As an example, station 23 (ie a Decoder that has been programmed to address 23) will be controlled as follows

Desire it ON of OFF at	Coil address	0023	(0000 + 23)	(Transmitted as 0022)
Check to see it it's ON or OFF at	Status address	1023	(1000 + 23)	(Transmitted as 1022)
Fix it by turning on	Coil address	2023	(2000 + 23)	(Transmitted as 2022)
Check to see if it's had an error at	Status address	3023	(3000 + 23)	(Transmitted as 3022)

Offsets from 201 ~ 208 implement other functions. These are called AUX. They have no associated ERROR or FIX addresses. Unused ones will read as 0, and writing to them will have no effect. When addressed within this range, a maximum of 8 bits is returned. The status of the address specified is placed in the LSB of the byte, followed by the status of the next address. Any bits not implemented within the 8 at AUX, and any bits that are beyond AUX (as a result of the start address being greater than 0200) will be returned as Zeros, and writing them will have no affect.

Offset	Coil Add	Status Add	Name	Coil	Status	
201	0201	1201	Line on	Set line ON	real time line state	(Line also controlled via DESIRED)
202	0202	1202	Line off	Set line OFF	real time line status	
203	0203	1203	ERR ANY	Reset Err LED	ANY ERRORS	(*)
204	0204	1204	ERR NOW	n/u	ERROR	Reads Real Time Err status (**)
205	0205	1205	Overload	Reset overload	Reads Line o/l Status.	
206	0206	1206	Short Circuit	Resets s/c Status	Reads s/c Status.	
207	0207	1207	Busy	n/u	Reads Signalling BUSY flag	

(*) The ERR LED will begin to flash again on receipt of the next force DESIRED coil command IF there are still station addresses that have errors recorded against them). Setting of this coil is provided as means of extinguishing the LED without FIXing the failed stations. Clearly removing failed stations from DESIRED and then FIXing them is the preferred way of forcing the error LED off.

Address 0203 returns true if any station address has failed to switch ON or OFF since the last time it's FIX coil was set. Note that TICTT/MB/485 itself takes action in the event of station failing to turn OFF. The line is dropped, and then re-energised.

DESIRED is then searched from the start, and desired stations switched ON.

(**) This returns true if any station currently DESIRED to be ON has failed to switch ON. Note DESIRED stations beyond the limitation of 6 stations ON will not trigger any errors. If such stations were to be left with their DESIRED coils ON, then switching will be attempted after receipt of a command that removes ON stations at lower offsets.

NOTE Attempts to switch stations at addresses that do not exist as decoders on the line WILL be actioned, and will generate errors.

Stations that have errors recorded against them will be automatically FIXed if they are successfully switched at a later time. All stations DESIRED on will be switched (subject to the maximum number of ON channels allowed) on receipt of the next coil setting command. Channels are not removed from DESIRED when they fail, but they will only appear in ACTUAL once they have been switched. Remember that BUSY must be polled (and seen to be clear) before examining ACTUAL.

TICTT supports a maximum of 6 Stations ON at any one time (subject to total current being within limit – see specs at the end of this document). Any message received that would result in more than 6 stations becoming DESIRED ON *will* be processed, and the stations will be included into DESIRED, but any in excess of 6 will not be turned-on. The action that TICTT takes when a force coil command is received is as follows. TICTT maintains a table of all channels, in this table is information about whether a channel is currently desired ON or OFF. At the receipt of a DESIRED coil command, this table is updated. Once updated, the table is searched looking for channels that are currently ON that are now desired OFF. All channels that need to be turned OFF are then signalled, with errors recorded against any channels that don't exhibit a change in line current that meets the limits. Once this has completed, the table is then searched again for channels required to be ON. This starts at station number 1, and continues until 6 stations are ON. No signalling action is taken is respect of channels that are already ON. Status 1207 (Busy) is set to 1 on receipt of the command, and cleared when all signalling is complete. 1207 should be polled (looking for 0) before further coil commands are sent.

TICTT automatically turns the line ON if decoders are desired ON, and OFF when no decoders are desired ON. The line is also turned OFF if all decoders DESIRED ON are failed. Coils 0201 & 0202 in the AUX area will force the line ON and OFF, but only until the reception of the next message that affects DESIRED coils (even if nothing is changed).

Successful operation of a decoder station is determined by the measured change in line current as a result of the attempt at switching. All switching attempts, either ON or OFF will result in the error status being set or cleared for that channel. A channel that switches successfully having previously been in error will have its error flag cleared.

Channels that fail to switch when DESIRED ON will remain in the DESIRED table, and switching will be re-attempted (if the maximum number of ON channels has not been exceeded) on receipt of the next coil setting command. (Unless the newest command demands the channel OFF). Channels that are seen to fail to turn on, are signalled off (in case they have actually switched but didn't produce a big enough line current change)

Channels that fail to switch when DESIRED OFF will be removed from the DESIRED table. No other action is taken

The values for determining a correct change in current can be inspected and set by registers accessed through functions 03 and 16. As shipped, the unit expects a minimum change of 60mA and a maximum change of 600mA. These values are adequate for most applications.

TICTT continuously monitors line current, and will turn off the line if a current above the maximum of I_MAX is measured for more than a second or two. The capability of TICTT to supply current is determined by its transformer. This transformer should be a minimum of 24VAC and 50VA. We recommend that each TICTT be powered by it's own transformer. TICTT also monitors the line looking for a short circuit, and will drop the line within a maximum of 20mS of a short being detected.

Note. Short Circuits on the line that are many ohms (cable length) away from TICTT may not trigger this instant action, and in the event of extreme field cable lengths, may not even trigger an overload. Both Overload and Short circuit events can be polled for via status addresses in the AUX range, and also set the 'Line' LED flashing continuously.

Function Summary

Modbus Commands implemented on TICTT are :-

01 Read Coil Status – Returns the status a range of DESIRED coils. Reads in the range of FIX coils will return 0's
02 Read i/p Status – Returns a range of Status i/ps These can be ACTUAL or FAILED and includes the AUX range at offset 200
03 Read Data from Controller – Single value returned.
04 Not implemented
05 Force Single Coil – Turns individual DESIRED and FIX coils ON or OFF (Note setting a FIX to OFF does nothing)
06 Not implemented
07 Not implemented
08 Not implemented
09 Not implemented
10 Not implemented
11 Fetch Comms Event Counter – Returns busy status, and a count of successful comms receptions
12 Not implemented
13 Not implemented
14 Not implemented
15 Program multiple DESIRED, FIX and AUX coils
16 Writes Data to Controller
17 Report Slave ID – Returns the H/W code for this device, Boot s/w Ver No, and App s/w Ver No.
18 Not implemented
19 Not implemented
20 Not implemented
21 Not implemented

Please refer to *Modicon Modbus Protocol Reference Guide* ***PI-MBUS-300 Rev.J*** for details of these commands. Below is an explanation of how these commands are implemented on TICTT where such implementation is TICTT specific.

Functions outside of the range quoted above are not allowed. Hidden from the user are commands that allow the software (firmware) of TICTT/MB to be re-written with updated code. This update process used a standard PC computer with an RS485 adapter. Code releases and updates, and the PC program to perform such updates will be available from www.twowire.co.uk and via email. These firmware update commands differ in format to ModBus commands, however the user should avoid sending characters and messages that don't conform to those described in this document.

Function Detail

Fun 01 As per Modicon or not implemented

Fun 02 As per Modicon or not implemented

Fun 03 As per Modicon, reads values from internal 16 bit registers. Number of points given is ignored, and one 16 bit register only is returned. These addresses are matched to the write function (FUN16)

Addresses are:- (Any further registers will be appended at the end of this list using the next available address)

Add 0001	Switching current change threshold Upper
Add 0002	Switching current change threshold Lower
Add 0003	Total measured line Current in mA
Add 0004	Switching current change measured for last ON command (Only useful for force single coil)
Add 0005	Switching current change measured for last OFF command (Only useful for force single coil)
Add 0006	Line phase angle (Currently not implemented)
Add 0007	Read Baud Rate (Not implemented)
Add 0008	Read Coms format (Not implemented)
Add 0009	Read Message count for messages correctly rec'd for this slave
Add 0010	Read count of messages where a time-out has been detected
Add 0011	Read count of messages where a CRC error has been detected.
Add 0012	SNOOP - Value that monitors stack creep for the ModBus software loop. Any Non-zero value is a fault.
Add 0013	A>D - When the line is off, the register holds the value of the current detect A/D. Used in calibration.
Add 0014	I_MAX - The maximum line current before over-current is tripped. (Range 500 – 1800 mA)
Add 0015	ACVOLTS - Not used, defaults to 24. May be used as a general purpose non-volatile location.

Add 0016	SCALE - Will scale the detected line current between 80 and 120% - Supplied set to 100%.
Add 0017	VER_NO – Version number of the field-upgradeable firmware.
Add 0018	BVER_NO – Version number of boot load code. Current revision is V13, and should not change in the future
Add 0019	VER_HW – Encoder hardware revision. Currently 20 (V2.0)
Add 0020	BUILD – Build date. Convert to hex, upper nibble is Year - 2000, lo nibble is Month – Jan = 00, Dec = 11(0Bh)
Add 0021	SERIAL – Unit serial number

Fun 05 As per Modicon or not implemented

Fun 08 As per Modicon or not implemented

Fun 11 As per modicon – Busy status and Even count - Event count is of successful messages processed.

Fun 15 As per Modicon – Refer to coil address ranges described above.

Fun 16 As per Modicon, Sets values to internal 16 bit registers. Number of points given is ignored, and one 16 bit register only is written using the first data value supplied. Where appropriate. values are retained in Non-volatile (EEPROM) memory. See Fun 03 for location descriptions. Addresses are

Add 0001	Set switching current change threshold Upper (Range 200 ~ 1000 mA)
Add 0002	Set switching current change threshold Lower (Range 0 ~ 200 mA)
Add 0003	No effect
Add 0004	No effect
Add 0005	No effect
Add 0006	No effect
Add 0007	No effect
Add 0008	No effect
Add 0009	0000 will clear count for messages correctly rec'd for this slave. Any other value has no effect.
Add 0010	0000 will clear count of messages where a time-out has been detected. Any other value has no effect.
Add 0011	0000 will clear count of messages where a CRC error has been detected. Any other value has no effect.
Add 0012	SNOOP – Write has no effect
Add 0013	A>D – Write has no effect
Add 0014	I_MAX – Set maximum total current threshold. Range 500 to 1800mA (1400mA on pre V2.0 hardware)
Add 0015	ACVOLTS – Not implemented, any value 0 ~ 65535 can be written
Add 0016	SCALE – Sets scale factor for measured line current. Range 80 to 120%
Add 0017	VER_NO – Application version number, write has no effect.
Add 0018	BVER_NO – Boot loader version number, write has no effect.
Add 0019	VER_HW – Hardware version number, write has no effect.
Add 0020	BUILD – Build date, write has no effect.
Add 0021	SERIAL – Unit serial number, write has no effect.

Fun 17 Returns TICTT information – Serial Number, Build Date, H/W Version, App S/W Version, Boot S/W Version. Information is returned as: -

<ADD> <FUN> <COUNT> <Ser# Hi> <Ser# Lo> <Date Hi> <Date Lo> <HW Ver> <App Ver> <Boot Ver> <CRC Hi> <CRC Lo>

Maintenance & Repair

Very little maintenance is necessary. If the unit is installed in a fanned cabinet, or subject to high levels of environmental dust, then periodic checks will be necessary to remove dust from inside the unit.

External cleaning may be achieved (power off) with a soft damp cloth. Mild detergent is OK, solvents of any kind are not to be used.

The unit is adjusted at manufacture. Several parameters are stored within the CPU, and the adjustment of VR1 carried out to an approximate value before further parameters are stored in the CPU. The characteristics of the line signalling depend on these parameters, and any adjustment of VR1 will jeopardise reliable operation. The CPU and SIGNAL PCBs form at matched pair at manufacture, and difficulties may be experienced if they are mixed up.

Specification. (All specifications subject to possible change)

Supply Voltage	24 ~ 32 Vrms AC 50 or 60Hz. Absolute maximum 40 Vrms AC. (Mains grid, or pure sine wave inverter – Modified / Stepped sine wave will not work, most generators do not produce a decent sine wave, unless they're of the pure sine wave inverter type.)
Supply Current	Up to 1.9A
Output Voltage	23 ~ 31 Vrms AC
Output Current	up to 1.8A max

Note Output voltage will end up being applied (via about 1/2 ohm each side of AC) to the decoders connected to the line, and then on to the solenoids via about 0.6R on one side of the AC. Attention must therefore be given to solenoid specifications.

Line Signalling	UI Landscape 2 wire protocol. Up to 63 Decoders connected. Max 6 decoders ON (Subject to total solenoid loads)
Approvals	CE (European) marked and compliant RoHS (European) compliant & lead free WEEE (European) Compliant (Exempt)
CPU	8 bit RISC. 8MIPs . 64K flash / 4K RAM / 4K EEPROM.
Firmware	Resident boot loader in protected flash space Re-writable application in general flash space
Communications	RS485 ModBus RTU mode. Isolated and fault tolerant (+-80V fault, 15kV discharge) 9600 Baud, N,8,1 (Other formats on request) Slave address 1~15 Inclusive. (1~31 on Hardware versions pre V2.0)
Connections	AC In screw terminal x 2 Line Out Screw terminal x 3 (Use 'S' and 'N' for 2wire, 'L' is for 3wire decoder capability) RS485 Screw terminal x 3 (B is hi, A is lo during bus idle. COM is the isolated 0V) EST Screw terminal x 1 (**Must** be connected min 4mm2 wire to earth stake/array/plate) (There are 2 further unused screw terminals on the lower edge)

Environmental	General	Protect from Rain. Do not immerse. Protect from shock. Protect from excessive dust. 50mm free space clearance above and below unit. Mount conventionally (DIN Rail), with AC connections at the bottom,
	Storage	-20 to +70 Degrees Centigrade
	Operation	-10 to +60 degrees centigrade (Sufficiently ventilated environment) 20 to 90 % humidity (non–condensing)

Warranty	3 yrs from date of supply (date held in the unit) EXCLUDING lightning damage, and subject to proper EST Earthing.
	All warranty & repair work is on RTB basis. Any and all trademarks acknowledged.