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Networking Guide - Modbus

SMARTSTART 6000 Series

Ethernet

Modbus RS485

IMPORTANT – Read this first !

Ensure every device on the Modbus RS485 serial bus has a unique address. Otherwise abnormal behaviour of the whole bus can occur, potentially inhibiting communication with all devices.

Only one network TCP client must control and/or configure a Smartstart® 6000 at any given time. Otherwise conflicts in register writes can arise which may result in unexpected behaviour. Network security must be in place to ensure Smartstart® 6000 behaviour cannot be compromised by unauthorised network clients.

On changeover between local and network control and vice versa, the motor may start or stop depending on the state of the new command source (local or network). This may result in an unintentional operation on change of a configuration parameter or on change of state of the "Local" input. The local and network control system (e.g. PLC) must to be designed and configured to satisfy the system's safety and operational requirements. Start Logic (A53) and/or 3-wire control can be configured to help avoid unintentional motor starts.

Essential Services Override (ESO) request via network should only be used as backup to the normal local ESO request. Contact Zener for more information on the ESO operation and associated risks.

This manual must be read in conjunction with the SMARTSTART 6000 Instruction manual.

PLEASE NOTE:
Current Firmware (Revision 1.20) or earlier does not support
the changing of parameters via communications.

Contents

1 Introduction

The Smartstart® 6000 includes the following networking features:

- **Modbus RTU over RS485 via embedded interface** (2 wire cabling – screw terminals)
- **Modbus over TCP via Ethernet option board** (CAT5 cabling – RJ45 connector)
- Control and monitoring of the SmartStart® via network
- Motor stops on a network timeout error (soft-stop or trip options)
- A programmable input ("Local") can be configured to facilitate local override
- Easily configured via the "Network" menu
- Network access permissions are configurable
- Display provides comprehensive network diagnostic information

1.1   References

[1]   Smartstart® 6000 Series User Manual, IMI0042, Zener Electric (Newcastle)
[2]   Smartstart® 6000 Series Modbus Address Map, APPENDIX A
[3]   Modbus Application Protocol Specification V1.1b3 (www.Modbus.org)
[4]   Modbus over Serial Line Specification and Implementation Guide V1.03 (www.Modbus.org)
[5]   Modbus Messaging on TCP/IP Implementation Guide V1.0b (www.Modbus.org)
[6]   Basics of the RS-485 Standard, Technical Article, B&B Electronics (www.bb-elec.com)
[7]   RS-422 and RS-485 Applications eBook v1.0, B&B Electronics (www.bb-elec.com)

1.2   Definitions

AOK	All Okay
AR	Auto Reset /Restart
CAT5	Category 5 (or 5e) cabling for Ethernet over twisted pair
CIDR	Classless Inter-Domain Routing (IP address format #.#.#.#/#)
Client	A device (e.g. PLC or SCADA) that initiates requests (also see master)
Coast	Free-wheel stop
Common	The signal common in the EIA/TIA standards
CRC	Cyclic Redundancy Check (detects communication errors)
Device	Electronic component connected to network (client or server)
DHCP	Dynamic Host Configuration Protocol
ESO	Essential Services Override
FC	Function Code (Modbus definition)
FE	Framing Error (invalid stop bit)
IP	Internet Protocol
LAN	Local Area Network (e.g. TCP/IP over Ethernet with CAT5 cabling)
LEN	Length (e.g. length error – packet to short or broken up)
Local	A programmable input to force local control (or a general reference to local control)
Master	Legacy term for client (e.g. RS485 terminology)
N/C	Normally Closed
Net	Network (or bus)
N/O	Normally Open
OR	Over Run (character overrun error)
PC	Personal Computer
PE	Parity Error
PLC	Programmable Logic Controller (network client/master)
Req	Request (from client to server)
Rsp	Response (from server back to client)
RTU	Remote Terminal Unit or a reference to the Modbus binary transmission mode
SCADA	Supervisory Control And Data Acquisition
Server	A device (e.g. Smartstart®) that sends responses back to client (also see slave)
Slave	Legacy term for server (e.g. RS485 terminology)
TCP	Transmission Control Protocol
T/O	Timeout
Unit ID	Modbus TCP header field used to address serial line slave devices via gateway
XC	eXception Code (Modbus definition)

2 Installation

2.1 Prepare

Prepare for commissioning by filling in the following check list.

Category	Item / Description		Setting / Notes
CONFIGURE	Set protocol to suit type of network used. Options: Disabled; Modbus/RS485 or Modbus/TCP.		N01 Net Protocol =
	Set operation on network timeout. Options: Disabled; Stop On T/O or Trip On T/O. Where Net Control (N02) is enabled, consider need for a force "Local" override input.		N02 Net Control =
	Set network control timeout to suit system safety requirements (0.1 to 60.0s).		N03 Net Timeout =
	Allow configuration / parameter changes over network. THIS IS NOT CURRENTLY AVAILABLE.		N04 Net Config = [NOT AVAILABLE]
	MB / RS485	Address (1 to 247)	N10 RS485 Addr =
		Speed/Baud (4800 to 38400 bps)	N11 RS485 Speed =
		Format (8e1, 8o1, 8n1 or 8n2)	N12 RS485 Format =
	Modbus / TCP	Set required static IP Address. Set IP Address to 0.0.0.0 for automatic address assignment (via DHCP). When editing the IP Address, the [RESET] key can be used to zero current value	N20 IP Address = ___.___.___.___
		Set IP Mask Bits to number of 1's in subnet mask (per CIDR).	N25 IP Mask Bits = /___
CONNECT	Are site schematics or network cabling guidelines available?		
	Phone number for SCADA control centre (if applicable).		
	Modbus / RS485	Have suitable RS485 line terminators been installed at each end of line?	
		Have suitable RS485 line polarisation resistors been installed?	
PROVISION	Who will program and configure the network client (e.g. PLC) to work with the Smartstart®?		

2.2   Configure

It is preferable to configure the Smartstart® before connecting it to a live network as incorrect settings could disrupt the network. Press [ENTER] to access the menu system to set and review parameters as per the check list. Press [ESC] to exit the menu system. New settings take effect after menu exit and motor off. Older units may require control supply to be cycled for an IP address change to take effect.

2.3   Connect

Before wiring the Smartstart®6000, make sure the requirements for shielding, twisted pairs, signal common, line termination and line polarisation are understood (see "Specifications" section). The Smartstart®6000 provides following network terminals.

Smartstart® Terminal	Modbus Name [5]	EIA-485 Name	Recommended Wire Colour [5]	Description
17: SCREEN	-	-	Shield	Protective ground
22: RS485 DATA+	D1	B/B'	Yellow	High when bus idle (Note 2)
23: RS485 DATA-	D0	A/A'	Brown	Low when bus idle (Note 2)
24: RS485 COM	Common	C/C'	Green	Signal common (isolated)
ETHERNET PORT	-	-	CAT5 cable	RJ45 on RHS of Smartstart®

Procedure:
1. Inform system control of task activity (e.g. possible alarms or disruptions)
2. Isolate the Smartstart®6000 (control and power circuits)
3. Wire network cabling to Smartstart®6000 terminals per above table (Notes 2 and 3)
4. Turn Smartstart®6000 on and check Net status on "Clock & Network" screen (e.g. Idle or Live)
5. Inform system control of task completion (e.g. ready to provision for new Smartstart®)

Notes:
1. Incorrect configuration can disrupt the network (e.g. address must be unique).
2. Some vendors use A/B naming opposite to the EIA-485 standard.
3. Unplugging the Modbus RS485 connector also breaks the motor thermistor circuit.

2.4   Provision

The Smartstart®6000 is provisioned into a system by programming and configuring the network client (e.g. PLC). Information is this guide is provided to assist this process. Once provisioned, check the "Clock & Network" screen to confirm Smartstart® is communicating correctly (e.g. Net status shows RxOk or Ctrl).

3 Network Diagnostics

3.1   Network Status Summary

The network status summary is shown on the "Clock & Network" dashboard screen:

```
 17:25:45  Net*
14 Apr 2013 RxOk
```

Status text is shown under "Net" and the top RH corner (*) shows a clockwise rotating event wheel which indicates the approximate rate of network transactions.

Status Text	Status Description	Possible causes / solutions
Off	Networking is disabled	Networking has not been configured. Check setting of N01 Net Protocol parameter.
Boot	Network adapter is initialising	Network adapter option board (e.g. Ethernet) is initialising.
Idle	Network is idle (no activity)	Smartstart® is not connected; network client is not connected or not running.
Live	Network active, but Smartstart® NOT addressed	A network client is not programmed and/or not provisioned to address the Smartstart®. The Smartstart® network address is not set correctly.
FLT!	Network adapter fault	Network adapter (e.g. Ethernet option board) not detected or faulty (warning alarm also raised).
BRK!	Communication break condition	Network wire is broken, short-circuited or reverse polarity. Check suitable line terminators and biasing resistors are installed. Check network wiring.
ERR!	Communication error occurred Message corrupt (discarded)	Data link settings are incorrect (baud, parity, stop bits, etc.), faulty cabling (wiring, termination, screening) or significant signal interference. Note 1.
BAD!	Processing exception occurred Request invalid (discarded)	The Smartstart® is being addressed okay (no data link errors), but request is invalid. Check network client (e.g. PLC) programming. Note 1.
RxOk	Request processed normally	Smartstart® is processing requests normally (note that "Ctrl" will override "RxOk").
Ctrl	Control via network is enabled and online	Smartstart® is receiving and acting on control command requests. Note 2.

Notes:
1. The Network Diagnostic menu can be used to further diagnose communications errors (ERR!) and request exceptions (BAD!). See next section for more information.
2. The "Ctrl" status text indicates Smartstart® is being controlled by a network client (Net Control Online). The "Ctrl" message is disabled when the "Local" input is asserted irrespective of received requests (e.g. back to "RxOk" message). See section "Smartstart® Control" for more information.

3.2   Network Diagnostic Menu

The "Network Diag" menu provides comprehensive network diagnostic information including the diagnostic counters as defined in the Modbus specification [5]. Press the [RESET] key to clear the counters. Use this menu to diagnose network communication and/or measure transaction rate.

Network Diagnostic Screen	Description
`Net Status Ctrl *` `Diag Flags 003Ah`	Network status text and event wheel as per "Network Status Summary". Network Diagnostic Flags (in hex) as per Smartstart® Modbus map [2].
`C0: ReqsAok 12345` `C1: BusMsgs 12345`	Count of requests processed normally. Note 2. Count of error-free bus messages. Note 4.
`C2: BusErrs 12345` `FE PE OR LEN CRC`	Count of bus messages with a communication error. Note 4. Shows "No comms errors" or lists the type of errors detected. Note 5.
`C3: ReqsBad 12345` `A001 FC016 XC002`	Count of bad requests received. Shows "No exceptions" or the last exception (bad request). Note 6.
`C4: ReqsRxd 12345` `A001 FC023 okay`	Count of requests received (with or without exceptions). Shows "No requests" or the last function code. Note 6 and 7.
`C5: ReqCast 12345` `C6: RspNaks 12345`	Count of broadcast requests received. Count of exception responses sent.
`C7: RspBusy 12345` `C8: OvrRuns 12345`	Count of busy responses sent (always zero for Smartstart®). Count of messages detected with a character overrun error.

Notes:
1. Press [RESET] to clear all diagnostic registers and counters (only when in this menu).
2. C0 is the event counter described in [4] for FC 11 "Get Comm Event Counter".
3. C1 to C8 correspond to the serial line diagnostic counter numbering as defined in [5].
4. Regarding C1 & C2, the Smartstart® does not error check messages to/from other devices.
5. Errors shown: framing, parity, overrun, length and CRC (FE, PE, OR, LEN & CRC).
6. Shows device address (A) & function code (FC). If applicable exception code (XC) is shown. A000 indicates a broadcast request. Meanings of exception codes (XC) are listed in [4].
7. For Modbus/TCP, the device address (A) is the "Unit Identifier" from the Modbus/TCP header.

4 Modbus Application Protocol

The Modbus application protocol is defined in [4]. Modbus communications can be used to monitor, and control the Smartstart®. The ability to configure via the network is currently not available. Modbus/RS485 and Modbus/TCP share the same application layer protocol and functionality.

4.1 Functions

Supported Modbus Functionality	Supported Modbus Function Codes
Read 16-bit registers	FC 03, 04 & 23
Write 16-bit registers	FC 06, 16 & 23

Notes:
1. A full list of supported function codes is given in "Specifications".
2. Input registers overlap and Holding registers (i.e. FC 03 and 04 are equivalent).
3. FC 23 (read & write) can be used to efficiently monitor and control the Smartstart®.

4.2 Exceptions

Code	Name	Meaning
XC 01	Illegal Function	Request contained an unsupported function code
XC 02	Illegal Data Address	Request referenced an undefined register address (i.e. not in [2])
XC 03	Illegal Data Value	Error in request format (e.g. implied length is incorrect). Note 1.
XC 11	Gateway target device failed to respond	The Smartstart® did not respond to a Modbus/TCP request. Check Net Protocol is set to Modbus/TCP.

Notes:
1. XC 03 does NOT cover range error of data written to registers. The client should read back values where data validation is required.

4.3 Address Map

The Smartstart® Modbus Address Map is fully defined in [2]. The address space consists of:

Group Name	Access	Data Type	Comments
Device Identification	Read Only	Static	Product information.
Trip Log	Read Only	Persistent	Log of last 10 trips.
Operation History	Read Only	Persistent	Counters, meters, etc.
Operation Status	Read Only	Dynamic	Live status of Smartstart® operation.
Network Diagnostics	Read Only	Dynamic	Network diagnostic flags and counters
Device Control	Read/Write	Dynamic	See section "Smartstart® Control". Note 3.
Device Configuration	Read/Write	Dynamic / stored	See section "Smartstart® Configuration". THIS FEATURE IS CURRENTLY NOT AVAILABLE

Notes:
1. Any attempt to access an undefined register returns an exception response (XC 02).
2. Any attempt to write to a read-only register returns an exception response (XC 02).
3. Some registers can be write-protected (e.g. by configuration and/or Local input asserted). Attempting to write to a protected register returns a normal response even though data is discarded. The client can read back register values when validation is required. FC 23 can be used to write and read in a single request for efficient validation of changes.
4. To avoid unexpected behaviour, ensure only one Modbus client writes to registers.
5. Ensure network security is in place to prevent writes from unauthorised clients.

5   Device Monitoring and Control

The Smartstart®6000 can be monitored and/or controlled via a network. For information on local monitoring and control, see [1] and [3].

5.1   Status Registers

A network client can read registers (as defined in [2]) to monitor the status of Smartstart® at any time, irrespective of Net Control (N02) setting or Force Local mode. The register space includes device identification, trip log, operation history, operation status and network diagnostics. A network client can use status information to assist with the control of the Smartstart®6000 and/or other system devices.

5.2   Control Command Flags Register

A network client can control the Smartstart®6000 by regularly writing to the Control Command Flags register (see [2]). The following control flags are supported.

Flag	Description
Reset	0->1 = Attempts to reset trip alarm. Motor may start.
Enable	1 = enables start and run of motor; 1->0 = initiates motor stop
Start	1 = start motor (provided Enable on and other conditions permit start)
Coast	1 = force free-wheel stop
ESO	1 = Essential services override request (overrides protection). Note 4.

Notes:
1. Acceptance of Start flag is per Start Logic (A53) setting (level or edge sense).
2. Enable and Start can be logically coupled for simple run/stop control. Keeping the Enable and Start flags asserted makes system highly available (when set for level sense start logic) and motor will auto start whenever conditions permit (e.g. network restoration, trip reset, restoration of line supply, activation of local enable input, etc.).
3. Where unintentional start must be avoided, review Start flag PLC logic, Start Logic (A53) setting and/or Net Control (N02) setting (e.g. trip on network timeout).
4. ESO is only available when a programmable input has been configured for ESO (Inputs menu). Network ESO request requires: Enable=1, Start=1, Coast=0 and ESO=1. Network ESO request should only be used as a backup of the local ESO request. ESO operation overrides all starter and motor protection and can void Smartstart® warranty.

5.3   Network Control Permission

Network control of the Smartstart® is only permitted when ALL of the following are satisfied:
- "Net Control" parameter is set to enable network control (i.e. not "Disabled")
- "Local" input (D1 or D2) is NOT asserted (or not configured) to force local control.
- Enable (EN) input is asserted; AND
- Network client (e.g. PLC) is regularly writing to the Control Command register.

5.4   Network Control Methods

There are number of terminal wiring options to support network control with or without Force Local support (override network control). The following is applicable when Net Control (N02) is enabled.

Control Method	Inputs Used	Description
Network Only	Enable (bridged)	Enable is bridged to +24VDC. Motor start and stop are only controlled by the network client. Local control is not available.
Network with Local Stop	Enable (switched)	Enable is to N/C switch to provide local stop control. There is no provision to force local start. Closing switch may initiate a motor start (where PLC logic asserts Enable and Start flags).
Network with Simple Override	Enable & Local	Enable and Local are wired to a three (3) position changeover switch (e.g. RUN/STOP/AUTO).This is simplest way to Force Local control of motor start and motor stop.
Network with Classic Override	Enable, Local & Start	Enable and Local are wired to a three (3) position changeover switch (e.g. LOCAL/OFF/REMOTE). Start is wired to N/O [START] button. Start input is only functional in Force Local mode ("Local" asserted).

5.5   Network Control Timeout and Restoration

The motor stops when writes to the Control Command Flags register cease for Net Timeout (N03). The stop behaviour (normal stop or trip) is defined by the Net Control (N02) parameter. On restoration of network communications, the motor may automatically start (when network Enable and Start flags are on). This can be avoided by having PLC logic use a pulse timer for motor start, setting Start Logic (A53) to edge sense, and/or setting Net Control (N02) to Trip on T/O. After a NET TIMEOUT trip and after network restoration, the PLC can toggle the reset bit to clear the trip alarm.

5.6   Operating Motor when Network is down

If it is necessary to be able to run a motor when the network (or network client) is down, the Smartstart® will need to change to a "Local Only" mode. Be aware that the motor may start on changeover. Options to change over to a local control mode are:
- Operate a changeover switch to "Force Local" (assert the "Local" input); or
- Change the "Net Control" parameter to "Disabled" to permit local control.

5.7   Local/Network Changeover

Changing the state of the "Local" input (Force Local mode) or the Net Control (N02) setting can change the control source. Bump-less transfer is supported when control signals are same as previous source. Depending on the state of the new control signals (Enable, Start, Stop & Coast), the motor may start or stop on changeover.

6 Device Configuration

The current firmware does not support the configuration or the changing of Soft Starter parameters via the network. If this feature is required contact Zener for more details .

7 Specifications

7.1 Specifications – Modbus Application Layer

Item (Note)	Description	Notes
Function Codes	FC 03 Read Input Registers (max 125) FC 04 Read Holding Registers (max 125) FC 06 Write Single Register FC 16 Write Multiple Registers (max 123) FC 23 Read/Write Multiple Registers (max 121)	
Exception Codes	XC 01 Illegal Function XC 02 Illegal Data Address XC 04 Illegal Data Value XC 11 Gateway target device failed to respond (Modbus/TCP only)	
Reachable Registers	Defined in document: "Smartstart® 6000 Modbus Map"	
Diagnostics	Available on display: status text, event wheel, diagnostic flags (including communication errors), diagnostic counters (per Modbus specification), last function code & last exception code.	

7.2 Specifications – Modbus over RS485

Item	Description	Default / Notes
Implementation Class	All "basic" requirements. Most "regular" requirements (excludes ASCII transmission mode and 4 wire cabling).	
Addressing	0 to 247	0, Note 1
Baud Rate (bps)	4800, 9600, 19200 & 38400	19200
Parity	ODD, EVEN, NO (8o1, 8e1, 8n1 & 8n2)	EVEN, Note 2
Configurable	Yes (address, baud rate and parity)	
Broadcast	Yes	
Transmission Mode	Binary RTU only	
Electrical Interface	RS485 2 wire cabling (1 twisted pair plus Common)	Note 3
Connector Type	Screw terminals (Data+, Data-, Common & Screen)	
Grounding	Common is isolated (ground/screen terminal available)	Note 4
Line Isolation	Yes (internal isolated RS485 transceiver)	
Line Termination	Not provided	Note 5
Line Polarisation	Lightweight only (internal 10K pull up/down resistors)	Note 6

Notes:
1. When address is set to zero (default), only broadcast requests are processed.
2. The 10 bit character format (8n1) is not compliant with the Modbus specification [5], but is supported for compatibility with other systems.
3. Shielded cable with two twisted pairs is recommended. Use one pair for circuit "Common" and other pair for balanced data lines. Connect shield of each cable segment to protective ground at one end only.
4. The "Common" circuit must be connected to all devices on the bus and connected directly to protective ground (at one point only, typically near the master device). "Screen" terminal provides a local protective ground (e.g. for cable shield).
5. It is required to place a Line Terminator near each of the two ends of the bus [5]. A capacitor (1nF) in series with a resistor (120 Ohms) is recommended for both Line Terminators [5].
6. Line polarisation (450 to 650 Ohms pull up and pull down) is recommended [5], typically near the master device.

7.3 Specifications – Modbus over TCP

Item	Description	Default / Notes
Implementation	Modbus TCP/IP server	
Addressing	Static IP address or assigned via DHCP. Standard Modbus TCP port 502. Accepts any Unit Identifier. Note 1.	
Configurable	Yes. IP address and subnet mask bits. Set IP Address to 0.0.0.0 to enable assignment via DHCP.	0.0.0.0/24 (DHCP)
Network Interface	RJ45 Ethernet 10Base-T or 100Base-TX (auto-sensing)	
LEDs	Ethernet Link Activity (on RJ45 connector)	
Isolation	Yes (via Ethernet magnetics)	
Diagnostics	Net "Boot" displayed while Ethernet adapter boots up. Net "FLT!" and warning "W08 ETH PORT FLT" displayed on boot failure. Other diagnostics as per Modbus application layer.	Check correct option board is fitted
Exception Codes (unique to Modbus/TCP)	XC 11 Gateway target device failed to respond. This indicates that Modbus/TCP client connected the Ethernet adapter okay, but the Smartstart® is not responding.	Check "N01 Net Protocol" is set correctly

Notes:

1. The Smartstart®6000 is addressed by IP address and will respond irrespective of value in the Unit Identifier field (Modbus header).

8   APPENDIX A: Modbus Map

Classic Number	Hex. Address	Decimal Address	Bit No.	GROUP NAME / Data Item Name	Reg. Count	Data Type	Units	Comment
				DEVICE IDENTIFCATION				**Static/constant data (read only)**
41025	0x0400	1024		Product Identifer	1	UINT16		0x5560 for SMARTSTART 6000
41026	0x0401	1025		Firmware version number	1	UINT16	0.01	100 to 999 (version 1.00 to 9.99)
41027	0x0402	1026		Firmware revision letter	1	ASCII[1]		32 (' ') for none, 65 to 90 ('A' to 'Z')
41028	0x0403	1027		Product Series	1	ASCII[2]		"6E", "6R", "6V" etc (e.g. 0x3652 for "6R")
41029	0x0404	1028		Product Rating (full load current)	1	UINT16	0.1A	e.g. 30 to 8300 for 3A to 830A models
41030	0x0405	1029		Product Option Flags . . .	1			See below . . .
		"	0	/ Custom Model		BOOLEAN		1 = Special customised model
		"	1	/ Six Wire Support		BOOLEAN		1 = Model supports 6 wire installation
		"	2	/ Reserved (to bit 15)		BOOLEAN		
41031	0x0406	1030		Reserved	2			
				TRIP LOG				**Persistent data (read only**)**
41033	0x0408	1032		Trip Log 1: Trip Info . . .	1	. . .		Information about last trip (most recent) . . .
		"	0..7	/ Operating State		UINT8 (low)	ENUM	Operating state at time of trip
		"	8..15	/ Trip Code		UINT8 (high)	code	Cause of trip (see T## codes in user manual)
41034	0x0409	1033		Trip Log 1: Trip Date (month & day)	1	BCD16	mmdd	Date of trip (e.g. 0x1231 for December 31st)
41035	0x040A	1034		Trip Log 1: Trip Time (hour & minute)	1	BCD16	hhmm	Time of trip (e.g. 0x2359 for 23:59 = 11:59 PM)
41036	0x040B	1035		Trip Log 2	3	As above		L02 trip info, date and time
41039	0x040E	1038		Trip Log 3	3	"		L03 "
41042	0x0411	1041		Trip Log 4	3	"		L04 "
41045	0x0414	1044		Trip Log 5	3	"		L05 "
41048	0x0417	1047		Trip Log 6	3	"		L06 "
41051	0x041A	1050		Trip Log 7	3	"		L07 "
41054	0x041D	1053		Trip Log 8	3	"		L08 "
41057	0x0420	1056		Trip Log 9	3	"		L09 "
41060	0x0423	1059		Trip Log 10	3	"		L10 " (oldest trip)

NOTE: The trip log has entries for the last 10 trips. Trip log 1 (L01) is the most recent trip (i.e. last trip), while trip log 10 (L10) is the oldest trip. Each entry has the same format (3 registers each). If a trip has not been logged, the log registers read as zero. The "Trip Info" register includes the operating state at the time of trip and cause of trip (see "Operating State" and "Trip Code" registers for more information). Trip date and time are encoded in binary coded decimal. The trip log can be cleared using the "Commands" menu.

Classic Number	Hex. Address	Decimal Address	Bit No.	GROUP NAME / Data Item Name	Reg. Count	Data Type	Units	Comment
				OPERATION HISTORY				**Persistent data (read only**)**
41063	0x0426	1062		Energy Meter (kWh)	2	UINT32	0.1 kWh	Rollover after 99999999.9 (9 digits)
41065	0x0428	1064		Operating Meter (hrs)	2	UINT32	0.1 hr	"
41067	0x042A	1066		Start Counter	2	UINT32	count	Rollover after 999999999 (9 digits)
41069	0x042C	1068		Trip Counter	2	UINT32	count	"
				NOTE: Meters and counters are viewable via the dashboard screens and can be cleared via the "Command" menu.				
				OPERATION STATUS				**Dynamic data (read only)**
41071	0x042E	1070		Protection Threshold Flags . . .	1			. . .
		"	0	/ Starter Thermal Hot		BOOLEAN		1 = starter too hot to start (Ts > reset temp.)
		"	1	/ Motor Thermal Hot		BOOLEAN		1 = motor too hot to start (i2t TOL > reset level)
		"	2	/ Motor Overtemp Hot		BOOLEAN		1 = motor too hot to start (thermistor > ~1k6 ohms)
		"	3	/ Alarm Input D1 Detect		BOOLEAN		1 = trip input prewarning (e.g. low pressure)
		"	4	/ Alarm Input D2 Detect		BOOLEAN		1 = trip input prewarning (e.g. low flow)
		"	5	/ Acceleration Overtime Detect		BOOLEAN		1 = accel timer expired AND NOT up to speed
		"	6	/ Current Imbalance Detect		BOOLEAN		1 = imbalance deteteced (prewarning)
		"	7	/ Motor Stall Detect		BOOLEAN		1 = stall current detected (prewarning)
		"	8	/ Motor Overcurrent Detect		BOOLEAN		1 = heavy load detected (prewarning)
		"	9	/ Motor Overtorque Detect		BOOLEAN		1 = heavy load detected (prewarning)
		"	10	/ Motor Undercurrent Detect		BOOLEAN		1 = light load detected (prewarning)
		"	11	/ Motor Undertorque Detect		BOOLEAN		1 = light load detected (prewarning)
		"	12	/ Voltage Imbalance Detect		BOOLEAN		1 = imbalance deteteced (prewarning)
		"	13	/ Reserved		BOOLEAN		
		"	14	/ Reserved		BOOLEAN		
		"	15	/ Other Alarm Detect		BOOLEAN		1 = Another alarm input condition is active
				NOTE: Above can be used for prewarning indication (e.g. threshold exceeded)				
41072	0x042F	1071		Protection Warning Flags . . .	1			. . .
		"	0	/ Starter Thermal Warning		BOOLEAN		1 = thermal level above "Warn Level"
		"	1	/ Motor Thermal Warning		BOOLEAN		1 = "
		"	2	/ Motor Overtemp Warning		BOOLEAN		1 = near trip point (Rt > ~1k6 ohms)
		"	3	/ Alarm Input D1 Warning		BOOLEAN		1 = trip timer greater than "Warn Delay"

Classic Number	Hex. Address	Decimal Address	Bit No.	GROUP NAME / Data Item Name	Reg. Count	Data Type	Units	Comment
		"	4	/ Alarm Input D2 Warning		BOOLEAN		1 = "
		"	5	/ Acceleration Overtime Warning		BOOLEAN		1 = "
		"	6	/ Current Imbalance Warning		BOOLEAN		1 = "
		"	7	/ Motor Stall Warning		BOOLEAN		1 = "
		"	8	/ Motor Overcurrent Warning		BOOLEAN		1 = "
		"	9	/ Motor Overtorque Warning		BOOLEAN		1 = "
		"	10	/ Motor Undercurrent Warning		BOOLEAN		1 = "
		"	11	/ Motor Undertorque Warning		BOOLEAN		1 = "
		"	12	/ Voltage Imbalance Warning		BOOLEAN		1 = "
		"	13	/ Reserved		BOOLEAN		
		"	14	/ Reserved		BOOLEAN		
		"	15	/ Other Alarm Warning		BOOLEAN		1 = Another alarm warning (see Warning Code)

NOTE: Above gives pre-trip warning indication ("Warning Code" gives highest priority warning)

Classic Number	Hex. Address	Decimal Address	Bit No.	GROUP NAME / Data Item Name	Reg. Count	Data Type	Units	Comment
41073	0x0430	1072		Protection Trip Flags . . .	1			. . .
		"	0	/ Starter Thermal Trip		BOOLEAN		1 = starter thermal overload/overtemp trip
		"	1	/ Motor Thermal Trip		BOOLEAN		1 = motor i2t thermal overload trip
		"	2	/ Motor Overtemp Trip		BOOLEAN		1 = motor overtemp (Rt reached 3k ohms)
		"	3	/ Alarm Input D1 Trip		BOOLEAN		1 = external trip input timeout
		"	4	/ Alarm Input D2 Trip		BOOLEAN		1 = external trip input timeout
		"	5	/ Acceleration Overtime Trip		BOOLEAN		1 = timeout waiting for motor to get up to speed
		"	6	/ Current Imbalance Trip		BOOLEAN		1 = imbalance timeout
		"	7	/ Motor Stall Trip		BOOLEAN		1 = motor stalled
		"	8	/ Motor Overcurrent Trip		BOOLEAN		1 = heavy load timeout
		"	9	/ Motor Overtorque Trip		BOOLEAN		1 = heavy load timeout
		"	10	/ Motor Undercurrent Trip		BOOLEAN		1 = light load timeout
		"	11	/ Motor Undertorque Trip		BOOLEAN		1 = light load timeout
		"	12	/ Voltage Imbalance Trip		BOOLEAN		1 = imbalance timeout
		"	13	/ Reserved		BOOLEAN		
		"	14	/ Reserved		BOOLEAN		
		"	15	/ Other Alarm Trip		BOOLEAN		1 = Another alarm has tripped (see Trip Code)

NOTE: Above is a subset of trip conditions. Other trip conditions can be decoded by testing the "Trip Code" register.

Classic Number	Hex. Address	Decimal Address	Bit No.	GROUP NAME / Data Item Name	Reg. Count	Data Type	Units	Comment
41074	0x0431	1073		Input/Output Flags . . .	1			. . .
		"	0	/ Control Supply Healthy		BOOLEAN		1 = on; 0 = PSU dip/brownout
		"	1	/ Line Supply On		BOOLEAN		1 = three phase line supply on (L1, L2, L3)
		"	2	/ Line Rotation 123 (Fwd)		BOOLEAN		1 = line on with forward rotation sequence
		"	3	/ Line Rotation 321 (Rev)		BOOLEAN		1 = line on with reverse rotation sequence
		"	4	/ Enable Input (EN)		BOOLEAN		1 = on/closed (local start/stop control)
		"	5	/ Digitial Input 1 (D1)		BOOLEAN		1 = on/closed (programmable input)
		"	6	/ Digitial Input 2 (D2)		BOOLEAN		1 = on/closed (programmable input)
		"	7	/ Thermistor Input		BOOLEAN		1 = okay/closed/cold (Rt < ~1k6 ohms)
		"	8	/ Current Sensed		BOOLEAN		1 = CTs sensing current
		"	9	/ Motoring (+ve power)		BOOLEAN		1 = power going to motor
		"	10	/ Regenerating (-ve power)		BOOLEAN		1 = power returning to line supply
		"	11	/ Reserved		BOOLEAN		
		"	12	/ Relay Output 1		BOOLEAN		1 = on/closed (programmable relay)
		"	13	/ Relay Output 2		BOOLEAN		1 = on/closed (programmable relay)
		"	14	/ Relay Output 3		BOOLEAN		1 = on/closed (programmable relay)
		"	15	/ Relay Output 4		BOOLEAN		1 = on/closed (programmable relay)
41075	0x0432	1074		Programmable Input Flags . . .	1			. . .
		"	0	/ Trip Input		BOOLEAN		1 = trip request (e.g. low oil pressure)
		"	1	/ Reset Input		BOOLEAN		1 = reset trip request (e.g. panel keyswitch)
		"	2	/ Start Input		BOOLEAN		1 = start request at terminals (e.g. start button)
		"	3	/ Stop Input		BOOLEAN		1 = stop request at terminals
		"	4	/ Coast Input		BOOLEAN		1 = coast request at terminals
		"	5	/ Local Input		BOOLEAN		1 = request "Force Local" (disable net ctrl & cfg)
		"	6	/ ESO Input		BOOLEAN		1 = local ESO request (overrides protection!)
		"	7	/ Reserved (to bit 15)		BOOLEAN		
41076	0x0433	1075		Programmable Signal Flags . . .	1			. . .
		"	0	/ Trip Signal		BOOLEAN		1 = post delay signal
		"	1	/ Reset Signal		BOOLEAN		1 = post delay signal

Classic Number	Hex. Address	Decimal Address	Bit No.	GROUP NAME / Data Item Name	Reg. Count	Data Type	Units	Comment
	"	2		/ Start Signal		BOOLEAN		1 = post delay signal
	"	3		/ Stop Signal		BOOLEAN		1 = post delay signal
	"	4		/ Coast Signal		BOOLEAN		1 = post delay signal
	"	5		/ Local Signal		BOOLEAN		1 = post delay signal
	"	6		/ ESO Signal		BOOLEAN		1 = post delay signal
	"	7		/ Reserved (to bit 15)		BOOLEAN		
41077	0x0434	1076		Active Alarm	1			Highest priority active alarm
	"		0..7	/ Alarm Code		UINT8 (low)	code	Alarm code (0..99). See codes in user manual
	"		8..15	/ Alarm Type		UINT8 (high)	ENUM	Alarm type. 0=interlock; 1=warning & 2=trip.
41078	0x0435	1077		Special Mode Flags . . .	1			. . .
	"	0		/ Reserved		BOOLEAN		
	"	1		/ Reserved		BOOLEAN		
	"	2		/ Torque Control Active		BOOLEAN		1 = torque control active (accel or decel)
	"	3		/ Voltage Control Active		BOOLEAN		1 = voltage control active (kick, accel or decel)
	"	4		/ Current Limiting Active		BOOLEAN		1 = current limiting active (accel or decel)
	"	5		/ ESO Request		BOOLEAN		1 = ESO request (local or via network)
	"	6		/ ESO Proof		BOOLEAN		1 = ESO request, motor on and current sensed
	"	7		/ Any Trip Override		BOOLEAN		1 = starter on with any trip alarm (ESO)
	"	8		/ Starter Trip Override		BOOLEAN		1 = starter on with "starter" trip overriden (ESO)
	"	9		/ Starter Stressed (persistent flag)		BOOLEAN		1 = starter has been over stressed (void warranty)
	"	10		/ AR Pending		BOOLEAN		1 = automatic trip reset is pending (could restart)
	"	11		/ AR Lockout		BOOLEAN		1 = AR lockout on final trip (after AR Attempts)
	"	12		/ Reserved (to bit 15)		BOOLEAN		
41079	0x0436	1078		Auxiliary Status Flags . . .	1			. . .
	"	0		/ Prewarning		BOOLEAN		1 = protection threshold exceeded
	"	1		/ Warning		BOOLEAN		1 = warning alarm (see Warning Code)
	"	2		/ Tripped		BOOLEAN		1 = latched trip/fault alarm (see Trip Code)
	"	3		/ Standby		BOOLEAN		1 = standing by for line power-up start (local only)
	"	4		/ Ready		BOOLEAN		1 = only waiting for Enable/Start command
	"	5		/ Local Control Only		BOOLEAN		1 = force local control or net control disabled

Classic Number	Hex. Address	Decimal Address	Bit No.	GROUP NAME / Data Item Name	Reg. Count	Data Type	Units	Comment
	"		6	/ Local Enable Command		BOOLEAN		1 = local control enable conditions
	"		7	/ Local Start Command		BOOLEAN		1 = local start request
	"		8	/ Net Control Only		BOOLEAN		1 = net control enabled AND NOT force local
	"		9	/ Net Control Online		BOOLEAN		1 = network control command accepted
	"		10	/ Net Enable Command		BOOLEAN		1 = network control enable conditions
	"		11	/ Net Start Command		BOOLEAN		1 = network start request
	"		12	/ Wait Delay (cooling)		BOOLEAN		1 = motor off delay or waiting to cool (mtr|str)
	"		13	/ Start Delay Active		BOOLEAN		1 = start requested, but start is being delayed
	"		14	/ Reserved (to bit 15)		BOOLEAN		
41080	0x0437	1079		Operating Status Flags . . .	1			. . .
	"		0	/ Line Control		BOOLEAN		1 = external line contactor on/close command
	"		1	/ Reserved		BOOLEAN		
	"		2	/ Fan Control		BOOLEAN		1 = internal fan on/run command
	"		3	/ Operating		BOOLEAN		1 = motor on/energised (SCRs or bypass)
	"		4	/ Ramping		BOOLEAN		1 = regulating conduction (kick, accel or decel)
	"		5	/ Starting		BOOLEAN		1 = ramp up active (starting, includes kick start)
	"		6	/ Kick Start		BOOLEAN		1 = kick start boost active
	"		7	/ Overtime		BOOLEAN		1 = accel timer expired and NOT Up To Speed
	"		8	/ Up To Speed		BOOLEAN		1 = at operating speed (continuous or bypass)
	"		9	/ Run Mode		BOOLEAN		1 = Up To Speed AND accel timer expired
	"		10	/ Bypass Control		BOOLEAN		1 = bypass contactor on/close command
	"		11	/ Continuous		BOOLEAN		1 = SCRs continuously firing
	"		12	/ Reserved		BOOLEAN		
	"		13	/ Stopping		BOOLEAN		1 = ramp down active (stopping/decel)
	"		14	/ Reserved (to bit 15)		BOOLEAN		
41081	0x0438	1080		Last Warning Code	1	UINT16	code	Cause of last warning (see W## codes in manual)

NOTE: Warning conditions do not inhibit starter operation. The value indicates the cause of the last warning and corresponds to the "W##" value shown on the display (see SMARTSTART User Manual). When there are multiple warnings, the highest priority warning is given. This code can be used to identify specific warnings not covered by "Protection Warning Flags".

Classic Number	Hex. Address	Decimal Address	Bit No.	GROUP NAME / Data Item Name	Reg. Count	Data Type	Units	Comment
41082	0x0439	1081		Last Trip Code	1	UINT16	code	Cause of last trip (see T## codes in user manual)
				NOTE: Above indicates the cause of the last trip and corresponds to the "T##" value shown on the display (see SMARTSTART User Manual). This code can be used to identify specific trips not covered by "Protection Trip Flags".				
41083	0x043A	1082		Operating State	1	UINT16	ENUM	Current operating state
				Val : (op code) Name and description				
				0 : ('O') Off. Line off AND enable off.				
				1 : ('S') Standby. Line off AND enable on (waiting for line supply).				
				2 : ('R') Ready. Line on AND enable off (waiting for start request).				
				3 : ('Y') Start request/delayed (cooling or min off time active).				
				4 : Reserved = ('H') Heating. Preheating				
				5 : ('K') Kick start.				
				6 : ('A') Accelerating (acceleration timer active)				
				7 : ('U') Up To Speed (acceleration timer active)				
				8: ('V') Acceleration oVertime (acceleration timer expired)				
				9 : ('C') Continuous. Run mode with continuous conduction.				
				10 : Reserved = ('E') Energy save mode. Eco run mode.				
				11 : ('B') Bypass. Run mode with bypass contactor closed				
				12 : ('D') Decelerating				
				13: ('w') Wait/Deflux delay (~3s, "Motor Off" displayed)				
				14 : ('W') Wait/Cooling delay (min off time active and no start request)				
				15 : ('T') Tripped. Cause of trip given by "Trip Code".				
				16 : ('P') AR Pending. Tripped, but and automatic trip reset is pending.				
				17 : ('L') AR Lockout. Final trip after all AR attempts exhaused.				
				18 : ('Z') Shutdown. Control PSU shutdown detected (normal on power down).				
				19 : ('z') Brownout. Persistent control PSU under voltage condition (fault).				
				Note: The op code listed above is printed to logger and shown in trip log.				
41084	0x043B	1083		AR Counter	1	UINT16	count	Counts trips. Indicates # for next restart attempt.
41085	0x043C	1084		AR Delay	1	UINT16	s	Delay to next auto trip reset (0 = anytime)
41086	0x043D	1085		Ramp Progress Timer	1	UINT16	0.1 %	Ramps up to 1000 (accel) and down to 0 (decel)
41087	0x043E	1086		Motor Current (A)	1	UINT16	0.1 A	Current (from line CTs)
41088	0x043F	1087		Motor Current (%)	1	UINT16	0.1 % In	Current as % of motor rating

Classic Number	Hex. Address	Decimal Address	Bit No.	GROUP NAME / Data Item Name	Reg. Count	Data Type	Units	Comment
41089	0x0440	1088		Output Torque (%)	1	INT16	0.1 % Tn	Power/torque as % of motor rating (signed)
41090	0x0441	1089		Input Power (W, 32 bit)	2	INT32	1 W	Measured active input power (signed 32 bit)
41092	0x0443	1091		Input Power (%)	1	INT16	0.1 % Pn	Real input power as % of motor rating (signed)
41093	0x0444	1092		Power Factor	1	INT16	0.001	Power factor (cos phi, signed)
41094	0x0445	1093		Motor Thermal Capacity	1	UINT16	0.1 %	Thermal capacity remaining (trips at 0%)
41095	0x0446	1094		Motor Thermistor Resistance	1	UINT16	1 ohm	Value above 10k ohms indicates open circuit
41096	0x0447	1095		Starter Heatsink Temperature	1	UINT16	0.1 K	Measured heatsink temperature
41097	0x0448	1096		Starter Thermal Capacity	1	UINT16	0.1 %	Thermal capacity remaining (trips at 0%)
41098	0x0449	1097		Ambient Temperature	1	UINT16	0.1 K	Ambient temperature (0 K = not available)
41099	0x044A	1098		Line Voltage (V)	1	UINT16	0.1 V	Line voltage
41100	0x044B	1099		Line Voltage (%)	1	UINT16	0.1 %	Line voltage
41101	0x044C	1100		Line Frequency	1	UINT16	0.1 Hz	Line frequency
41102	0x044D	1101		Current Imbalance	1	UINT16	0.1 %	Current imbalance
41103	0x044E	1102		Phase L1 Current	1	UINT16	0.1 A	Phase current
41104	0x044F	1103		Phase L2 Current	1	UINT16	0.1 A	Phase current
41105	0x0450	1104		Phase L3 Current	1	UINT16	0.1 A	Phase current
41106	0x0451	1105		Voltage Imbalance	1	UINT16	0.1 %	Voltage imbalance
41107	0x0452	1106		Phase L12 Voltage	1	UINT16	0.1 V	Phase to phase voltage
41108	0x0453	1107		Phase L23 Voltage	1	UINT16	0.1 V	Phase to phase voltage
41109	0x0454	1108		Phase L31 Voltage	1	UINT16	0.1 V	Phase to phase voltage
41110	0x0455	1109		Reserved	3	UINT16		
				NETWORK DIAGNOSTICS				**Dynamic data (read only)**
41113	0x0458	1112		Network Diagnostic Flags . . .	1			. . .
		"	0	/ Listen Only Mode		BOOLEAN		1 = special network diagnostic mode (LOM)
		"	1	/ Bus Active		BOOLEAN		1 = bus activity detected (Live, not Idle)
		"	2	/ Broadcast Request Received		BOOLEAN		1 = broadcast request received (no errors)
		"	3	/ Normal Request Received		BOOLEAN		1 = addressed request received (no errors)
		"	4	/ Normal Response Sent		BOOLEAN		1 = normal response sent
		"	5	/ Control Write Accepted		BOOLEAN		1 = control write accepted (Net status = "Ctrl")
		"	6	/ Config Write Accepted		BOOLEAN		1 = config write accepted
		"	7	/ Reserved		BOOLEAN		

Classic Number	Hex. Address	Decimal Address	Bit No.	GROUP NAME / Data Item Name	Reg. Count	Data Type	Units	Comment
		"	8	/ Communication Error		BOOLEAN		1 = data error detected (FE, PE, OR, LEN, CRC)
		"	9	/ Framming Error		BOOLEAN		1 = invalid stop bit detected (FE)
		"	10	/ Parity Error		BOOLEAN		1 = invalid parity bit detected (PE)
		"	11	/ Character Overrun		BOOLEAN		1 = receive buffer overrun error (OR)
		"	12	/ Length Error		BOOLEAN		1 = unexpected msg length (LEN) short, split etc.
		"	13	/ CRC Error		BOOLEAN		1 = cyclic Redunancy Check failed (CRC)
		"	14	/ Bad Request Received (exception)		BOOLEAN		1 = exception occurred processing request
		"	15	/ Exception Response Sent		BOOLEAN		1 = exception response sent (after bad request)
				NOTE: Most of the above flags auto-clear every 10 seconds.				
41114	0x0459	1113		Good Requests Received (AOK)	1	UINT16		C0:ReqsAok = Modbus "Comm Event Counter"
41115	0x045A	1114		Bus Message Count (total on bus)	1	UINT16		C1:BusMsgs = Bus messages without data errors
41116	0x045B	1115		Bus Comms Error Count	1	UINT16		C2:BusErrs = Bus messages with data errors
41117	0x045C	1116		Server Exception Error Count	1	UINT16		C3:ReqsBad = Bad requests (exceptions)
41118	0x045D	1117		Server Message Count	1	UINT16		C4:ReqsRxd = Requests received (good & bad)
41119	0x045E	1118		Server No Response Count	1	UINT16		C5:ReqCast = Broadcast requests rxd (no rsp)
41120	0x045F	1119		Server NAK Count (response sent)	1	UINT16		C6:RspNaks = Exception responses sent (neg ack)
41121	0x0460	1120		Server Busy Count (response sent)	1	UINT16		C7:RspBusy = Server busy exception rsps sent
41122	0x0461	1121		Character Overrun Count	1	UINT16		C8:OvrRuns = Messages with overrun error
				NOTE: See "Serial Line Diagnostic Counters" in Modbus specification for definitions.				
				DEVICE CONTROL				Write access when "Net Control" Enabled
42049	0x0800	2048		Control Command Flags	1			. . .
		"	0	/ Reset		BOOLEAN		0->1 = attempt to reset trip condition
		"	1	/ Enable		BOOLEAN		1 = allow start/run; 0 = stop/decel motor
		"	2	/ Start		BOOLEAN		1 = start motor (pulse to latch)
		"	3	/ Coast		BOOLEAN		1 = force a freewheel stop
		"	4	/ ESO		BOOLEAN		1 = ESO request (requires Enable+Start+!Coast)
		"	5	/ Reserved (to bit 15)		BOOLEAN		