Sigma 2 Load Bank

Modbus Register Manual

Document Number: FP1046-001 – rev 2.5

Revision Date: Oct 2022

1. Introduction

The Modbus RTU (Remote Terminal Unit) interface provides a means of integrating the Sigma 2 load bank controller with generator test cell automation or building supervisory and monitoring systems.

Modbus is an industry-wide serial communications protocol standard supported by many PLC and industrial controls manufacturers. A Modbus RTU network has one Client and one or more Servers, in this system the Sigma 2 Controller is the Server. For more information on Modbus protocol refer to the Modbus Protocol Reference Guide, available from the www.modbus.org website.

This document details the Modbus protocol implementation on the Sigma 2 load bank controller. Implemented using an RS232 serial port (or optional RS232/Ethernet or RS232/RS485 converter). Modbus provides not only a means of monitoring both operation and instrumentation on a single load bank, but also load control.

WARNING
The Modbus/TCP protocol is inherently unsecure and therefore should be used with care to avoid sensitive information disclosure and unauthorized access. To mitigate the risks associated with weaknesses in the Modbus/TCP protocol, users should set up network segmentation and implement a firewall to block all unauthorized access.

1.1. Physical Connection

The physical connection will be via the fitted RS232 serial port.

Each load bank has a unique 8-bit Device Address, this will be set at the factory prior to delivery.

The Modbus RTU communication parameters will be as follows:

Settings	Sigma 2 Module
Device Address	1 (*)
Baud (bps)	19200
Data bits	8
Stop Bits	1 (*)
Parity	None (*)
Flow Control	Hardware RTS/CTS

** These values are the factory defaults configured at the factory and can be custom set to your requirements.*

A minimum break of 50ms is recommended between messages or retries to detect correct framing. The pin out of the RS232 serial port is as follows:

Description	Signal	Direction	Sigma 2 Connector
Transmit Data	TxD	Out	H1
Receive Data	RxD	In	H2
Ready To Send	RTS	Out	H3
Clear to Send	CTS	In	H4
Ground	GND		H5

The Sigma 2 load bank has an opto-isolated RS232 port and acts as a server in the Modbus protocol, only responding to messages received from the Modbus client on the given Modbus Station Number (Device Address).

1.2. Function Codes

A subset of the Modbus protocol is implemented with the following function codes supported:

- 03 – Read one or more output/holding register.
- 16 – Preset one or more single-point output/holding registers.

1.3. Holding Registers

A contiguous block of holding registers can be read at any time using a function 03 message.

Registers are addressed starting at zero: register 40001 is addressed as 0.

A single-point holding register is 16 bits.

Bits are numbered starting at bit 0, which is the least significant or right most bit in the field of 16 bits found in a Modbus register. The bit order is big-endian, and the first byte is the MSB, and first bit is bit 15.

Single-point writes using Function Code 16 are mandatory when writing to a holding register.

1.3.1. Example - Reading a Single Holding Register

With the device address set as 1, the following is a sample message interaction to read a single instrumentation register at 41001 (Address 0), ***VL1N***, using function 3 (03h).

Send request:

Device Address	Function Code	Start Address Hi	Start Address Lo	Number of Registers Hi	Number of Registers Lo	CRC Hi	CRC Lo
01h	03h	03h	E8h	00h	01h	04h	7Ah

Note the address offset in the message request as specified in the Modbus standard.

Response:

Device Address	Function Code	Byte Count	Data Byte Hi	Data Byte Lo	CRC Hi	CRC Lo
01h	03h	02h	6Ch	1Bh	D5h	4Fh

Multiple contiguous registers can be read in one block.

1.3.2. Address Error Response

Exception responses are provided for illegal address and inconsistent data. There will be no response for unsupported function calls.

If an exception error occurs, then an Address error (Error Code 02) is sent back. The packet may contain an Invalid number of registers from the address, or the wrong function code.

An example of an invalid packet is:

Device Address	Function Code	Start Address Lo	Start Address Hi	Number of Registers Hi	Number of Registers Lo	CRC Hi	CRC Lo
01h	03h	03h	E8h	00h	64h	C4h	51h

Will result in an Address Error being returned from the slave:

Device Address	Function Code	Exception Code	CRC Hi	CRC Lo
01h	83h	02h	C0h	F1h

1.3.3. Example – Writing a Single Point Holding Register

Write to one single 16-bit register using as a Single Point Holding register.

Send request using the function code 16 (10h) to obtain Modbus Control using the preset register 41701:

Device Address	Function Code	Start Address Hi	Start Address Lo	Number of Registers Hi	Number of Registers Lo	Byte Count
01h	10h	06h	A4h	00h	01h	02h

Data Hi	Data Lo	CRC Lo	CRC Hi
80h	00h	<*nn*>h	<*nn*>h

Note the address offset in the message request as specified in the Modbus standard.

Response:

Device Address	Function Code	Start Address Hi	Start Address Lo	Number of Registers Hi	Number of Registers Lo	CRC Hi	CRC Lo
01h	10h	06h	A4h	00h	01h	<*nn*>h	<*nn*>h

2. Sigma 2 Load Bank

Connect to the load bank using the Sigma Setup program and upload the load bank information. On the Configuration page, enable Modbus and select the Modbus Device Address. The default RTU Framing interval is 10ms.

Connect Modbus to the RS232 serial port on the load bank module as described in the Physical Connection section of this document.

2.1. Load Bank Registers

This section defines the output holding registers used for data exchange with the load bank.

The Instrumentation registers provide high speed full 3-phase instrumentation of the supply on test and can be used for monitoring or display on a Human Machine Interface. Further status information is available in the Operating Voltage and Frequency and the Load Selected and Applied registers. I/O information is available in the Input and Output registers. Controlling the Load is described in the Next Section.

Register Address	Description	Function	Length
41001	Instrumentation	Read Only	24
41101	Load Bank Status	Read Only	14
41201	Load Capacity	Read Only	6
41301	Operating Voltage and Frequency	Read Only	3
41401	Load Bank ID	Read Only	14
41501	Inputs and Outputs	Read/Write	7
41601	Load Select and Apply	Read Only	12
41701	Load Control	Read/Write	11
42001	System	Read Only	120
42201	Global Counters	Read Only	14
42301	Contactor Counters	Read Only	84
42401	Contactor On-Time	Read Only	84
42501	Contactor Type & State	Read Only	42

The following sections provide a detailed description of the data and control registers.

2.1.1. 41001 Instrumentation

Monitoring load bank Voltage, Current and Frequency is achieved using the 22 holding registers starting at register 41001. The contents of these registers are continuously updated from the load bank instrumentation.

Address	Type	Tag	Bit Size	Scaling	Description
41001	UINT16	Tick	16		Timestamp (in 10ms increments) for the instrumentation data
41002	UINT16	VL1Np	16	See below	L1N Peak Phase-to-Neutral Voltage
41003	UINT16	VL1N	16	See below	L1N Phase-to-Neutral Voltage
41004	UINT16	VL2N	16	See below	L2N Phase-to-Neutral Voltage
41005	UINT16	VL3N	16	See below	L3N Phase-to-Neutral Voltage
41006	UINT16	VL1L2	16	See below	L1L2 Phase-to-Phase Voltage
41007	UINT16	VL2L3	16	See below	L2L3 Phase-to-Phase Voltage
41008	UINT16	VL3L1	16	See below	L3L1 Phase-to-Phase Voltage
41009	INT16	AL1a	16	See below	L1 Active Current
41010	INT16	AL2a	16	See below	L2 Active Current
41011	INT16	AL3a	16	See below	L3 Active Current
41012	INT16	AL1r	16	See below	L1 Reactive Current
41013	INT16	AL2r	16	See below	L2 Reactive Current
41014	INT16	AL3r	16	See below	L3 Reactive Current
41015	UINT16	Hz	16	*100	L1L2 Frequency
41016	UINT16	AL1	16	See below	L1 Apparent Current
41017	UINT16	AL2	16	See below	L2 Apparent Current
41018	UINT16	AL3	16	See below	L3 Apparent Current
41019	INT16	kW	16	See below	Total Active Power
41020	INT16	kVAr	16	See below	Total Reactive Power
41021	INT16	kVA	16	See below	Total Apparent Power
41022	UINT8	PF	8	*100	Power Factor
	BOOL	Lead	1		Leading Power Factor (Capacitive)
	UINT	Spare	7		Not Used
41023	INT16	pkVL1N	16	See below	Peak VL1N Voltage
41024	INT16	pkVL1L2	16	See below	Peak VL1L2 Voltage

All instrumentation voltages, currents and powers require division by the load bank specific scaling factor (normally 10). Load banks below 2MW in size will normally have the voltage scaled in tenths of a Volt and the current scaled in tenths of an Amp. The resultant power will be scaled in tenths of a kVA (or kW). The voltage and current scaling factors can be read from the load bank ID message (register 41401).

There are seven voltage registers with Phase to Neutral voltages in the ***VL1N***, ***VL2N*** and ***VL3N*** registers and Phase-to-Phase voltages in ***VL1L2***, ***VL2L3*** and ***VL3L1*** registers. The ***VL1Np*** register provides peak voltage on the **VL1N** phase, and can be used to calculate Crest Factor.

The current registers show the three phase current vectors (***AL1***, ***AL2*** and ***AL3***) for both the Active and Reactive Currents and the overall Apparent Current.

The Power is returned in the ***kW***, ***kVAr*** and ***kVA*** registers and frequency are measured from the L1L2 voltage. Power Factor, ***PF***, is returned as a byte value and requires dividing by 100 to return a value between 0.00 and 1.00.

2.1.2. 41101 Load Bank, Fan status and Error Messages

Load bank status is returned in registers 41101 and 41102. The status registers show the operational state of the load bank, such as fans running, voltage on the bars and error conditions.

The LED status register 41103 returns the value as displayed on the LED of the Load bank Module. The Fan Status can be read from 41104 – 41105, giving the Fan voltage, Frequency and Phase Rotation. The Load Step Status bit fields can 41106 to 4113 returns the status of the faulty or disable load steps.

Tags are described in the order of MSB to LSB.

Address	Type	Tag	Bit Size	Description
Load Bank Status				
41101	UINT16	Spare	3	Not Used
		VoltageOK	1	Stable Voltage on Busbars
		FrequencyOK	1	Stable Frequency on Busbars
		PhaseRotation	2	Supply Phase Rotation: 0 - Failed 1 – Forward 2 – Reversed 3 – Single Phase
		SupplyOK	1	Supply Status data is Valid
		ModuleTemp	8	Module Temperature ^{O}C
41102	UINT16	FanRunning	1	Fan Running
		Spare	2	Not Used
		EmStop	1	Load bank in Emergency Stopped State
		ConfigError	1	Configuration Error
		DuctError	1	Cooling Duct Closed Error
		Spare	2	Not Used
		CommsError	1	Communications Timeout Error
		OverVoltError	1	Over Voltage Error
		SupplyFailError	1	Supply Failure Error
		AirFlowError	1	No Air Flow Error
		OverTemError	1	Over Temperature Error
		FanSupplyError	1	Fan/Control Supply Error – Voltage and/or Frequency is out of limits
		FanRunError	1	Fan Not Running Error
		FanTripError	1	Fan Trip Error
LED Status				
41103	UINT8	EmergencyStop	1	Emergency Stop Active
		Running	1	Load bank running
		LoadOn	1	Load On

Address	Type	Tag	Bit Size	Description
		FansRunning	1	Fans Running
		Communications	1	Load bank remote control
		SetupMode	1	Setup Mode
		Warning	1	Warning Message available
		Error	1	Error Message available
	UINT8	Message	8	Warning or Error Message
Fan Status				
41104	UINT16	FanState	16	Fan Phase Status: 1 – Forward, Correct Rotation 2 – Reversed 3 – Single Phase
41105	UINT16	FanVoltage	16	Fan Voltage
41106	UINT16	FanFrequency	16	Fan Frequency
Load Step Status				
41107	UINT64	DisabledSteps	64	Map of disabled load steps
41111	UINT64	FaultySteps	64	Map of faulty load steps

2.1.3. 41201 Load Capacity

The Load Capacity registers are read only. Reading the registers will return the load bank total capacity and minimum load step sizes at the operating voltage. The load capacity will be re-calculated each time the operating voltage changes.

The load capacity registers start at 41201.

Address	Type	Tag	Bit Size	Scaling	Description
41201	UINT16	kWStep	16	*10	Smallest Resistive (kW) Load Step
41202	UINT16	kVArLStep	16	*10	Smallest Inductive (kVArL) Load Step
41203	UINT16	kVArCStep	16	*10	Smallest Capacitive (kVArC) Load Step
41204	UINT16	kWMax	16		Total Resistive Load (kW)
41205	UINT16	kVArLMax	16		Total Inductive Load (kVArL)
41206	UINT16	kVArCMax	16		Total Capacitive Load (kVArC)

2.1.4. 41301 Operating Voltage and Frequency

When the Load bank Operating Voltage and Frequency is set, the load bank recalculates the load for each of the load step groups, and determines the new de-rated load at that voltage. This will achieve more accurate loading when load has been accepted and avoid overload. When the load control software (Sigma PC System or the IHT) sets the Operating Voltage and Frequency, it compares the current instrumentation voltage to the nearest standard Voltage and Frequency. For example, if the voltage was reading 481V, then the Operating Voltage would be set to 480V.

If controlling by Modbus, the Modbus Registers 41705 and 41706 can be used to set the operating Voltage and Frequency.

With no controller, these are set at the default Voltage and Frequency set in the load bank configuration.

The read-only Operating Voltage and Frequency registers start at 41301.

Address	Type	Tag	Bit Size	Description
41301	UINT16	Voltage	16	Operating Voltage
41302	UINT16	Frequency	16	Operating Frequency
41303	UINT16	Spare	6	Not Used
		Fan60Hz	1	Fan Running at 60 Hz
		SinglePhase	1	Single Phase Mode
		Spare	8	Not Used

2.1.5. 41401 Load Bank ID

The identification (ID) data provides details of the load bank operating limits and load bank type, such as resistive load is available. ID data is returned from register 41401 onwards.

Address	Type	Tag	Bit Size	Description
41401	UINT8	Station	8	Station Number
	UINT8	Version	8	Load bank configuration version
41402	UINT16	InstVolts	1	Voltage instrumentation scaled in volts else in tenths of volts
		SupplyReverse	1	Supply reversal checking enabled
		DeltaLoad	1	Load bank has 3 wire connection so no load neutral
		MaxSingle	1	Load bank configured for maximum single phase load
		Spare	1	Not used
		ContactorDelay	1	Contactor delay enabled
		AirFlow	1	Air flow monitoring enabled
		DuctSensor	1	Duct/Louvres fitted
		FanReverse	1	Fan supply reverse check enabled
		FanStarDelta	1	Star/Delta fan motor
		FanAutoStart	1	Fan auto start on load enabled
		InstAmps	1	Current instrumentation scaled in amps else in tenths of amps
		Spare	1	Not used
		Capacitive	1	Capacitive load available
		Inductive	1	Inductive load available
		Resistive	1	Resistive load available
41403	UINT16	NomVoltage	16	Nominal Voltage
41404	UINT16	NomFrequency	16	Nominal Frequency
41405	UINT16	Max Voltage	16	Maximum Voltage
41406	UINT16	MinFrequency	16	Minimum Frequency
41407	UINT16	MaxFrequency	16	Maximum Frequency
41408	UINT16	LcpVersion	16	Loaded LCP Version
41409	UINT16	SerialNo	16*6	Load bank serial number by char

*Convert LcpVerison into 00.0.00 format, formula is:-

(LcpVersion / 1000) . ((LcpVersion / 100) % 10) . (LcpVersion % 100)

Instrumentation scaling is determined from the InstAmps register as follows:

InstAmps	InstVolts	Amps Scale	Volts Scale	Power Scale	Notes
0	0	A*10	V*10	kW*10	Default for load banks less than 2MW in size
1	0	A*1	V*10	kW	Load banks over 2MW
0	1	A*10	V*1	kW	Instrumentation Unit set for use at MV or HV
1	1	A*1	V*1	kW/10	

2.1.6. 41501 Inputs and Outputs

The 64 bits of load bank Outputs data is returned from read/write registers 41501-41504 Inputs data starts at register 41505. The input and output structures can be used to monitor load bank operation, and to set any unused Outputs. Register 41507 is used to set the control level of allowing outputs to be written via Modbus.

Address	Type	Tag	Bit Size	Description
Outputs				
41501	UINT8	SevenSegDisplay	8	Seven Segment value. This is used to display a pattern on the module LCD, used as an indicator of the firmware status.
	BOOL	Estop	1	Emergency Stop Control Relay Enabled
	BOOL	FanSupplyError	1	Control or Fan supply fault indicator
	BOOL	LoadSupplyError	1	Load Supply out of range Indicator
	BOOL	CommsError	1	Communications Fault Indicator
	BOOL	CoolError	1	Cooling Fault Indicator
	BOOL	LampTest	1	Lamp Test Indicator – on during startup
	BOOL	StopIndicator	1	Load Bank Stopped Indicator (flashes on Error)
	BOOL	RunIndicator	1	Load Bank Running Indicator
41502	BOOL	LoadOn	1	Load On Indicator
	BOOL	Fan0Run	1	Fan 0 Run Relay
	BOOL	Fan1Run	1	Fan 1 Run Relay
	BOOL	Fan2Run	1	Fan 2 Run Relay
	BOOL	Fan3Run	1	Fan 3 Run Relay
	BOOL	FanReverse	1	Fan Reverse Relay
	UINT	Load	10	Main Load Relays (32..41)
41503	UINT16	Load	16	Main Load Relays (16..31)
41504	UINT16	Load	16	Main Load Relays (0..15)
Inputs				
41505	BOOL	AirFlow3	1	Fan 3 Airflow Detector
	BOOL	OverTemp3	1	Fan 3 Over Temperature
	BOOL	FanRun3	1	Fan 3 Contactor In
	BOOL	FanTrip3	1	Fan 3 Trip
	BOOL	AirFlow2	1	Fan 2 Airflow Detector
	BOOL	OverTemp2	1	Fan 2 Over Temperature
	BOOL	FanRun2	1	Fan 2 Contactor In
	BOOL	FanTrip2	1	Fan 2 Trip
	BOOL	AirFlow1	1	Fan 1 Airflow Detector
	BOOL	OverTemp1	1	Fan 1 Over Temperature
	BOOL	FanRun1	1	Fan 1 Contactor In
	BOOL	FanTrip1	1	Fan 1 Trip
	BOOL	AirFlow0	1	Fan 0 Airflow Detector
	BOOL	OverTemp0	1	Fan 0 Over Temperature
	BOOL	FanRun0	1	Fan 0 Contactor In
	BOOL	FanTrip0	1	Fan 0 Trip
41506	UINT	Station	4	Station Number
	BOOL	DuctOK1	1	Duct 1 Open
	BOOL	DuctOK0	1	Duct 0 Open
	BOOL	CBTrip1	1	Circuit Breaker 1 Tripped

Address	Type	Tag	Bit Size	Description
	BOOL	CBTrip0	1	Circuit Breaker 1 Tripped
	BOOL	LowCT	1	Low Current Transformer
	BOOL	HiTempWarn	1	High Temperature Warning
	BOOL	RemVolt	1	Remote Voltage
	BOOL	LoadOn	1	Load Contactors Energised
	BOOL	FanToGen	1	Fan to Generator
	BOOL	StartShare	1	SLC Start Input
	BOOL	EStopOK	1	Estop Relay
	BOOL	Reset	1	Reset Button
Write Control				
41507	BOOL	EnableWriteOutput	1	Enable write to all unused outputs
	UINT	Spare	15	Not Used

Inputs may be inverted, and a mask is provided in the main configuration to define the inversion.

2.1.7. 41601 Load Select and Apply

The read-only Load Select and Apply registers return the current load selected and applied values of the load bank and is returned from register 41701.

Address	Type	Tag	Bit Size	Description
41601	UINT32	W Now	32	Watts Applied
41603	UINT32	W Next	32	Watts Selected
41605	UINT32	VArL Now	32	Inductive Load Applied (VArL)
41607	UINT32	VArL Next	32	Inductive Load Selected (VArL)
41609	UINT32	VArC Now	32	Capacitive Load Applied (VArC)
41611	UINT32	VArC Next	32	Capacitive Load Selected (VArC)

2.1.8. 41701 Load Control

The Load Control registers are Read/Write holding registers used to enable Modbus Control, and to select and apply load.

The Control On (MSB) and Control Off registers are used to enable and disable Modbus load control. Disable Load Accept, Reject and Set Load override the IHT or Sigma PC software's load control. For example, setting the Disable Load Accept register will inhibit the operator from applying load from the IHT but will still allow load to be rejected.

Load Accept and Load Reject are used to apply and remove the pre-selected load (set by kW Selected for example).

The LSB's of the control word scale the units as 10 units. To work in kilowatts, this would be 3 (or 00000011b), and all selected values will be multiplied by 103, or 1000

Address	Type	Tag	Bit Size	Description
41701	BOOL	ControlOn	1	Enable control of the load via Modbus
	BOOL	ControlOff	1	Disable control of the load via Modbus
	BOOL	LoadAccept	1	Accept the Load
	BOOL	LoadReject	1	Reject All Load
	BOOL	ControlVoltage	1	Control operating Voltage and Frequency via Modbus
	BOOL	DisableAccept	1	Ignore Accept from IHT or Sigma PC System
	BOOL	DisableReject	1	Ignore Reject from the IHT or the Sigma PC System
	BOOL	DisableSetLoad	1	Ignore Set Load Messages from the IHT or the Sigma PC System
	UINT8	Units	8	Selected Load is specified in 10^{Units} in Watts or VAr
41702	UINT16	WSelected	16	Resistive Load Requested to scale of selected * 10^{Units} (LSB of 41701)
41703	UINT16	VALSelected	16	Inductive Load Requested to scale of selected * 10^{Units} (LSB of 41701)
41704	UINT16	VACSelected	16	Capacitive Load Requested to scale of selected * 10^{Units} (LSB of 41701)
41705	UINT16	OperatingVoltage	16	Operating Voltage (Volts)
41706	UINT16	OperatingHz	16	Operating Frequency (Hz)
41707	BOOL	Single phase	1	Operating in Single Phase
	UINT	Spare	15	Not Used
41708	UINT16	SmoothV	16	Smoothed Voltage
41709	UINT16	SmoothHz	16	Smoothed Frequency
41710	BOOL	SmoothSinglePhase	1	Set if Smoothed Voltage in Single Phase Pattern
	BOOL	SmoothOK	1	Smoothed Voltage and Frequency is Stable
	UINT	Spare	14	Not Used
41711	UINT16	LoadOnMsgTimeout	16	Time in seconds after which the load bank will drop load if no Modbus Message has been received. The load bank will not timeout if the value is zero.

2.1.9. 42001 System

The 42101 System registers provides details of the load bank internal values used for debug purposes and is returned from register 42001 onwards.

Address	Type	Tag	Bit Size	Description
42001	UINT32	MainLoopTimings	64*10	Main Loop Timing
42041	UINT32	InstMainTimings	64*10	Main Instrumentation timing
42081	UINT32	InstAuxTimings	64*10	Auxiliary Instrumentation timing

2.1.10. 42201 Global Counters

The 42201 Global Counters registers provides details of the load bank internal values used for runtime service schedules.

Address	Type	Tag	Bit Size	Description
42201	UINT32	PowerOnTime	32	Total Power on time of module in seconds.
42203	UINT32	PowerOnTimeTrip	32	Power on time of module since power on in seconds.
42205	UINT32	LoadOnTime	32	Total number of seconds load has been applied
42207	UINT32	LoadOnTImeTrip	32	Number of seconds load has been applied Since power up
42209	UINT32	EnergyDissipated	32	Centiwatt hours of energy used by the load bank in total
42211	UINT32	EnergyDissipatedTrip	32	Centiwatt hours of energy used by the load bank since Powerup

2.1.11. 42301 Contactor Counters

The 42301 Contactor count registers provides the number of switching operations each contactor has completed.

Address	Type	Tag	Bit Size	Description
42301	UINT32	ContactorCount0	32	Contactor 0 switching ON/OFF count.
42303	UINT32	ContactorCount1	32	Contactor 1 switching ON/OFF count.
42305	UINT32	ContactorCount2	32	Contactor 2 switching ON/OFF count.
42307	UINT32	ContactorCount3	32	Contactor 3 switching ON/OFF count.
42309	UINT32	ContactorCount4	32	Contactor 4 switching ON/OFF count.
42311	UINT32	ContactorCount5	32	Contactor 5 switching ON/OFF count.
42313	UINT32	ContactorCount6	32	Contactor 6 switching ON/OFF count.
42315	UINT32	ContactorCount7	32	Contactor 7 switching ON/OFF count.
42317	UINT32	ContactorCount8	32	Contactor 8 switching ON/OFF count.
42319	UINT32	ContactorCount9	32	Contactor 9 switching ON/OFF count.
42321	UINT32	ContactorCount10	32	Contactor 10 switching ON/OFF count.
42323	UINT32	ContactorCount11	32	Contactor 11 switching ON/OFF count.
42325	UINT32	ContactorCount12	32	Contactor 12 switching ON/OFF count.
42327	UINT32	ContactorCount13	32	Contactor 13 switching ON/OFF count.
42329	UINT32	ContactorCount14	32	Contactor 14 switching ON/OFF count.
42331	UINT32	ContactorCount15	32	Contactor 15 switching ON/OFF count.
42333	UINT32	ContactorCount16	32	Contactor 16 switching ON/OFF count.
42335	UINT32	ContactorCount17	32	Contactor 17 switching ON/OFF count.
42337	UINT32	ContactorCount18	32	Contactor 18 switching ON/OFF count.
42339	UINT32	ContactorCount19	32	Contactor 19 switching ON/OFF count.
42341	UINT32	ContactorCount20	32	Contactor 20 switching ON/OFF count.
42343	UINT32	ContactorCount21	32	Contactor 21 switching ON/OFF count.
42345	UINT32	ContactorCount22	32	Contactor 22 switching ON/OFF count.
42347	UINT32	ContactorCount23	32	Contactor 23 switching ON/OFF count.
42349	UINT32	ContactorCount24	32	Contactor 24 switching ON/OFF count.
42351	UINT32	ContactorCount25	32	Contactor 25 switching ON/OFF count.
42353	UINT32	ContactorCount26	32	Contactor 26 switching ON/OFF count.
42355	UINT32	ContactorCount27	32	Contactor 27 switching ON/OFF count.
42357	UINT32	ContactorCount28	32	Contactor 28 switching ON/OFF count.
42359	UINT32	ContactorCount29	32	Contactor 29 switching ON/OFF count.
42361	UINT32	ContactorCount30	32	Contactor 30 switching ON/OFF count.
42363	UINT32	ContactorCount31	32	Contactor 31 switching ON/OFF count.
42365	UINT32	ContactorCount32	32	Contactor 32 switching ON/OFF count.
42367	UINT32	ContactorCount33	32	Contactor 33 switching ON/OFF count.
42369	UINT32	ContactorCount34	32	Contactor 34 switching ON/OFF count.
42371	UINT32	ContactorCount35	32	Contactor 35 switching ON/OFF count.
42373	UINT32	ContactorCount36	32	Contactor 36 switching ON/OFF count.
42375	UINT32	ContactorCount37	32	Contactor 37 switching ON/OFF count.
42377	UINT32	ContactorCount38	32	Contactor 38 switching ON/OFF count.
42379	UINT32	ContactorCount39	32	Contactor 29 switching ON/OFF count.
42381	UINT32	ContactorCount40	32	Contactor 40 switching ON/OFF count.
42383	UINT32	ContactorCount41	32	Contactor 41 switching ON/OFF count.

2.1.12. 42401 Contactor On-Time

The 42401 Contactor on time registers provides details of the amount of time contactor has been powered on. Contactor on time is returned in seconds

Address	Type	Tag	Bit Size	Description
42401	UINT32	ContactorOnTime0	32	Contactor 0 total on time (secs)
42403	UINT32	ContactorOnTime1	32	Contactor 1 total on time (secs)
42405	UINT32	ContactorOnTime2	32	Contactor 2 total on time (secs)
42407	UINT32	ContactorOnTime3	32	Contactor 3 total on time (secs)
42409	UINT32	ContactorOnTime4	32	Contactor 4 total on time (secs)
42411	UINT32	ContactorOnTime5	32	Contactor 5 total on time (secs)
42413	UINT32	ContactorOnTime6	32	Contactor 6 total on time (secs)
42415	UINT32	ContactorOnTime7	32	Contactor 7 total on time (secs)
42417	UINT32	ContactorOnTime8	32	Contactor 8 total on time (secs)
42419	UINT32	ContactorOnTime9	32	Contactor 9 total on time (secs)
42421	UINT32	ContactorOnTime10	32	Contactor 10 total on time (secs)
42423	UINT32	ContactorOnTime11	32	Contactor 11 total on time (secs)
42425	UINT32	ContactorOnTime12	32	Contactor 12 total on time (secs)
42427	UINT32	ContactorOnTime13	32	Contactor 13 total on time (secs)
42429	UINT32	ContactorOnTime14	32	Contactor 14 total on time (secs)
42431	UINT32	ContactorOnTime15	32	Contactor 15 total on time (secs)
42433	UINT32	ContactorOnTime16	32	Contactor 16 total on time (secs)
42435	UINT32	ContactorOnTime17	32	Contactor 17 total on time (secs)
42437	UINT32	ContactorOnTime18	32	Contactor 18 total on time (secs)
42439	UINT32	ContactorOnTime19	32	Contactor 19 total on time (secs)
42441	UINT32	ContactorOnTime20	32	Contactor 20 total on time (secs)
42443	UINT32	ContactorOnTime21	32	Contactor 21 total on time (secs)
42445	UINT32	ContactorOnTime22	32	Contactor 22 total on time (secs)
42447	UINT32	ContactorOnTime23	32	Contactor 23 total on time (secs)
42449	UINT32	ContactorOnTime24	32	Contactor 24 total on time (secs)
42451	UINT32	ContactorOnTime25	32	Contactor 25 total on time (secs)
42453	UINT32	ContactorOnTime26	32	Contactor 26 total on time (secs)
42455	UINT32	ContactorOnTime27	32	Contactor 27 total on time (secs)
42457	UINT32	ContactorOnTime28	32	Contactor 28 total on time (secs)
42459	UINT32	ContactorOnTime29	32	Contactor 29 total on time (secs)
42461	UINT32	ContactorOnTime30	32	Contactor 30 total on time (secs)
42463	UINT32	ContactorOnTime31	32	Contactor 31 total on time (secs)
42465	UINT32	ContactorOnTime32	32	Contactor 32 total on time (secs)
42467	UINT32	ContactorOnTime33	32	Contactor 33 total on time (secs)
42469	UINT32	ContactorOnTime34	32	Contactor 34 total on time (secs)
42471	UINT32	ContactorOnTime35	32	Contactor 35 total on time (secs)
42473	UINT32	ContactorOnTime36	32	Contactor 36 total on time (secs)
42475	UINT32	ContactorOnTime37	32	Contactor 37 total on time (secs)
42477	UINT32	ContactorOnTime38	32	Contactor 38 total on time (secs)
42479	UINT32	ContactorOnTime39	32	Contactor 39 total on time (secs)
42481	UINT32	ContactorOnTime40	32	Contactor 40 total on time (secs)
42483	UINT32	ContactorOnTime41	32	Contactor 41 total on time (secs)

2.1.13. 42501 Contactor Type & State

The 42501 Contactor Type & State registers provide details of the configuration type for each Contactor 1-42 and if it has been disabled due to fault or not assigned.

Contactor Type: 0 = not assigned, 1 = Resistive, 2 = Inductive, 3 = Capacitive

Contactor Disabled: 0 = enabled, 1 = disabled

Address	Type	Tag	Bit Size	Description
42501	UINT8	ContactorType0	8	Contactor 0 configuration
	UINT8	ContactorDisabled0	8	Contactor 0 disabled
42502	UINT8	ContactorType1	8	Contactor 1 configuration
	UINT8	ContactorDisabled1	8	Contactor 1 disabled
42503	UINT8	ContactorType2	8	Contactor 2 configuration
	UINT8	ContactorDisabled2	8	Contactor 2 disabled
42504	UINT8	ContactorType3	8	Contactor 3 configuration
	UINT8	ContactorDisabled3	8	Contactor 3 disabled
42505	UINT8	ContactorType4	8	Contactor 4 configuration
	UINT8	ContactorDisabled4	8	Contactor 4 disabled
42506	UINT8	ContactorType5	8	Contactor 5 configuration
	UINT8	ContactorDisabled5	8	Contactor 5 disabled
42507	UINT8	ContactorType6	8	Contactor 6 configuration
	UINT8	ContactorDisabled6	8	Contactor 6 disabled
42508	UINT8	ContactorType7	8	Contactor 7 configuration
	UINT8	ContactorDisabled7	8	Contactor 7 disabled
42509	UINT8	ContactorType8	8	Contactor 8 configuration
	UINT8	ContactorDisabled8	8	Contactor 8 disabled
42510	UINT8	ContactorType9	8	Contactor 9 configuration
	UINT8	ContactorDisabled9	8	Contactor 9 disabled
42511	UINT8	ContactorType10	8	Contactor 10 configuration
	UINT8	ContactorDisabled10	8	Contactor 10 disabled
42512	UINT8	ContactorType11	8	Contactor 11 configuration
	UINT8	ContactorDisabled11	8	Contactor 11 disabled
42513	UINT8	ContactorType12	8	Contactor 12 configuration
	UINT8	ContactorDisabled12	8	Contactor 12 disabled
42514	UINT8	ContactorType13	8	Contactor 13 configuration
	UINT8	ContactorDisabled13	8	Contactor 13 disabled
42515	UINT8	ContactorType14	8	Contactor 14 configuration
	UINT8	ContactorDisabled14	8	Contactor 14 disabled
42516	UINT8	ContactorType15	8	Contactor 15 configuration
	UINT8	ContactorDisabled15	8	Contactor 15 disabled
42517	UINT8	ContactorType16	8	Contactor 16 configuration
	UINT8	ContactorDisabled16	8	Contactor 16 disabled
42518	UINT8	ContactorType17	8	Contactor 17 configuration
	UINT8	ContactorDisabled17	8	Contactor 17 disabled
42519	UINT8	ContactorType18	8	Contactor 18 configuration
	UINT8	ContactorDisabled18	8	Contactor 18 disabled
42520	UINT8	ContactorType19	8	Contactor 19 configuration
	UINT8	ContactorDisabled19	8	Contactor 19 disabled
42521	UINT8	ContactorType20	8	Contactor 20 configuration
	UINT8	ContactorDisabled20	8	Contactor 20 disabled

Address	Type	Tag	Bit Size	Description
42522	UINT8	ContactorType21	8	Contactor 21 configuration
	UINT8	ContactorDisabled21	8	Contactor 21 disabled
42523	UINT8	ContactorType22	8	Contactor 22 configuration
	UINT8	ContactorDisabled22	8	Contactor 22 disabled
42524	UINT8	ContactorType23	8	Contactor 23 configuration
	UINT8	ContactorDisabled23	8	Contactor 23 disabled
42525	UINT8	ContactorType24	8	Contactor 24 configuration
	UINT8	ContactorDisabled24	8	Contactor 24 disabled
42526	UINT8	ContactorType25	8	Contactor 25 configuration
	UINT8	ContactorDisabled25	8	Contactor 25 disabled
42527	UINT8	ContactorType26	8	Contactor 26 configuration
	UINT8	ContactorDisabled26	8	Contactor 26 disabled
42528	UINT8	ContactorType27	8	Contactor 27 configuration
	UINT8	ContactorDisabled27	8	Contactor 27 disabled
42529	UINT8	ContactorType28	8	Contactor 28 configuration
	UINT8	ContactorDisabled28	8	Contactor 28 disabled
42530	UINT8	ContactorType29	8	Contactor 29 configuration
	UINT8	ContactorDisabled29	8	Contactor 29 disabled
42531	UINT8	ContactorType30	8	Contactor 30 configuration
	UINT8	ContactorDisabled30	8	Contactor 30 disabled
42532	UINT8	ContactorType31	8	Contactor 31 configuration
	UINT8	ContactorDisabled31	8	Contactor 31 disabled
42533	UINT8	ContactorType32	8	Contactor 32 configuration
	UINT8	ContactorDisabled32	8	Contactor 32 disabled
42534	UINT8	ContactorType33	8	Contactor 33 configuration
	UINT8	ContactorDisabled33	8	Contactor 33 disabled
42535	UINT8	ContactorType34	8	Contactor 34 configuration
	UINT8	ContactorDisabled34	8	Contactor 34 disabled
42536	UINT8	ContactorType35	8	Contactor 35 configuration
	UINT8	ContactorDisabled35	8	Contactor 35 disabled
42537	UINT8	ContactorType36	8	Contactor 36 configuration
	UINT8	ContactorDisabled36	8	Contactor 36 disabled
42538	UINT8	ContactorType37	8	Contactor 37 configuration
	UINT8	ContactorDisabled37	8	Contactor 37 disabled
42539	UINT8	ContactorType38	8	Contactor 38 configuration
	UINT8	ContactorDisabled38	8	Contactor 38 disabled
42540	UINT8	ContactorType39	8	Contactor 39 configuration
	UINT8	ContactorDisabled39	8	Contactor 39 disabled
42541	UINT8	ContactorType40	8	Contactor 40 configuration
	UINT8	ContactorDisabled40	8	Contactor 40 disabled
42542	UINT8	ContactorType41	8	Contactor 41 configuration
	UINT8	ContactorDisabled41	8	Contactor 41 disabled

2.2. Controlling Load

To use the Modbus interface on the load bank to control load requires the following steps:

- Obtain Modbus Control.
- Check load bank status
- Select and Apply the Load
- Reject the Load

The following sections detail the above steps.

2.2.1. Obtaining Modbus Control on the Load Bank

To set the load bank operating (supply on test) voltage and change load using Modbus, the following steps must be taken in order to obtain control of the load bank:

1. Press the green START button on the load bank to enable the load bank control system
2. Read the Output Registers from address 41502 data using a Function 03. Check that the **LoadOn** status is not set. This is the default after the load bank has been powered on.
3. Set the **ControlOn** bit (bit 15) and clear the **ControlOff** bit (bit 14) in the Control Register 41701 using a Function 16
4. Read the Load Control registers from 41701, and check **ControlOn** is set to verify you have control.

The Sigma PC or IHT will still operate whilst Modbus control is enabled. To disable load control on the IHT or PC System set the ***DisableAccept*** and ***DisableSetLoad*** bits in the control register – the operator will only be able to reject load. If required, the ***DisableReject*** bit can be set to inhibit rejects from the IHT or PC System.

2.2.2. Releasing Modbus Control on the Load Bank

To release Modbus Control,

Set the **ControlOff** bit on the Control Register 41701 using a Function 16 – this will latch the Control On bit.

Read the Load Control registers from 41701, and check **ControlOn** is not set, and **ControlOff** is set.

Note: It is necessary to reject the load before exiting Modbus control.

2.2.3. Check Load Bank Status

Read the Status using register 41102, and check the load bank is in the running state (not **Stopped**), and none of the Error bits are set.

Read the Load Control Register 41705 and verify the operating voltage, frequency and number of phases are correct. If necessary, the Supply Voltage and Frequency can be set via Modbus using the same register with a Function 16 Message. On setting the Operating Voltage the load bank will derate all of the load steps available for use at the operating voltage, hence giving accurate load when the load is applied.

2.2.4. Selecting & Applying Load

Preset the required load in register 41702 and then sending an accept command.

- Make sure the START button is pressed on the load bank.
  Verify the operating voltage and frequency by reading registers 41301 and 41302. The operating voltages can be overridden by writing to Load Control registers 41705 and 41706 after setting the ***ControlVoltage*** bit. All loads applied will be calculated based on the operating voltage and frequency.
- Obtain Modbus control as above.
- Set the Units to use for load selection in register 41701
  Units is used to scale the load selection values, if Units is zero, then the selected load will be in watts.

  The selected value in 41702 will be multiplied by 10^{Units},
  To achieve selecting load in kW, then set Units to 3. (00000011b) in the lower byte of 41701.

Units	Selected load
0	0.001kW
1	0.010kW
2	0.100kW
3	1.000kW

- The load word is at holding register 41702, expressed 10^{Units}
  If Units has been set at 3 then starting with the LSB. 150 KW would therefore appear as: 0000000010010110.
- Select the Resistive (W) and optionally Reactive (VAL) load using Function 16 on register 41702 and 41703.
- Verify the selected load by reading the Load Select Registers 41702 and 41703
- Apply the selected load by setting the ***Accept*** bit on the Control Register 41701 using a Function 16 message. To apply a load, the third MSB goes high as in1010000000000011.
- Confirm Load applied by reading the Load Applied Registers (41601 for Watts applied and

41603 for VAr applied) or by reading the instrumentation.

- Clear the ***Accept*** bit (toggle off) on the Control Register 41701 ready to apply the next load 1000000000000011.

Repeat these steps for each load required.

Note

The life of the load bank and switchgear will be reduced if the load ***Accept*** bit is toggled continuously at a rate greater than once every minute.

2.2.5. Rejecting Load

Reject all load by setting the ***Reject*** bit on the Control Register 41701 using a Function 16 message.

After a ***Reject*** command the ***Load On*** bit is cleared in the Outputs register 41502.

Load can be reapplied after a reject command by sending an ***Accept*** command as the selected load registers are not cleared.

Note:

Set the ***Reject*** bit at the end of a load sequence to start the load bank fan run-on time. The fan will stop automatically after the fan run-on time.

It is necessary to reject the load before exiting Modbus control.

3. Sigma 2 Site Load Correction (SLC)

To use this feature, the load bank would have to be setup in Site Load Correction mode, where the load bank is configured to maintain a minimum load on a genset, normally a permanent installation. A Sigma 2 load bank in Site Load Correction (SLC) status can be monitored using Modbus read registers and the write SLC Control registers are used to set the SLC Setpoint or to reject load. The Modbus SLC control takes priority over the physical set point switch operation on the load bank.

The Site Load Correction settings, the Start Delay Time and Ramp Down are set at time of manufacture.

3.1. SLC Registers

Register Address	Description	Function	Length
41801	SLC Status	Read Only	5
41901	SLC Control	Read/Write	2

3.2. 41801 SLC Status

Use the following read-only registers for SLC Status are used to monitor the SLC errors from the setpoint. The Next section will describe the SLC Control Registers to set the SLC setpoint.

The read-only Status registers return the calculated kW Error from the setpoint and Voltage. SLC Status registers start at 41801.

Address	Type	Tag	Bit Size	Scaling	Description
41801	UINT16	Measured kW	16		Measured Instrumentation kW
41802	UINT16	Load bank kW	16		Load bank load kW
41803	INT16	kW Error	16		Error from SLC Setpoint in kW
41804	UINT16	Voltage	16		Smoothed Voltage V

Address	Type	Tag	Bit Size	Scaling	Description
41805	UINT16	State	16		Internal SLC status 0 – No SLC 1 - Waiting SLC Remote Control 2 – Wait Start Delay Time 3 – Wait for Min kW OK 4 – Running SLC 5 – Increase load 6 – Decrease load 7 – Ramping down

3.3. 41901 SLC Control

When site load falls below the setpoint load, the load bank will apply load to maintain the setpoint on the generator or supply. Load is applied slowly as the site load reduces but removed immediately when the site load increases. Use register 40751 to set the load set point value.

Address	Type	Tag	Bit Size	Scaling	Description
41901	UINT16	Setpoint kW	16		SLC Remote Setpoint Value kW
41902	BOOL	Control On	1		Remote Control of the SLC is on
	BOOL	Control Off	1		Remote control of the SLC is off
	BOOL	Accept	1		Accept the SLC setpoint
	BOOL	Reject	1		Reject all load
	UINT	Spare	12		Spare Bits

3.4. Control of the SLC Setpoint

If a Sigma load bank has been setup for SLC, the SLC Setpoint can be defined remotely using Modbus. To obtain control of the SLC Setpoint:

- Enable Estop
- Set the ***Control On*** bit on the Register 41902 using a Function 16 – Preset one or more output or holding registers.
- Verify Modbus control by reading on the Register 41902 using a Function 03 and confirming the ***Control On*** bit is set, and ***Control Off*** bit is not set

After the Start Delay Time the SLC will be operational if the minimum site load is met.

- Change the ***SetpointkW*** value to the required kW using register 41901 and Function 16, and verify with a Function 03

- Set the ***Accept*** bit and clear the ***Reject*** bit on register 41902
- Verify the ***Accept*** Bit is set.
- Clear and reset the ***Accept*** Bit to enable a change of ***SetpointkW***

The load bank will now monitor load and adjust loading to maintain the setpoint value.

To reject load, set the ***Reject*** bit, and to turn Modbus control off set the ***Control Off*** bit in the register.

www.avtronpower.com

Avtron Power Solutions

6255 Halle Drive
Cleveland, OH 44125, USA
Tel: 216 573 7600
LBsales@ascopower.com

Cliffe Road, Easton-on-the-Hill
Stamford PE9 3NP, United Kingdom
Tel: +44 1780 480033
LBsalesint@ascopower.com