CROWCON	**Nimbus** **ModBus Interface Specification**		
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MODBUS Communications Interface Specification

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Change History

Issue	Change	Author	Date
Draft A	Created 5-Nov-98. Released for Information.	Duncan Grant	18-Nov-98
Draft B	Simplify register map. Release for information.	Duncan Grant	01-Dec-98
Draft C	Update register map as per implementation. Preliminary release.	Duncan Grant	04-May-99
Issue 1	Rearrange and update register map as per software version 1 issue 1.0 Beta 05. Complete application notes. Register definitions incomplete.	Duncan Grant	10-Sep-99
Issue 2	Revise section on Learning of Temperature Compensation Points. Add Commissioning section. Add section on Applying a Local Inhibit. Revise Installation Configuration registers in Group 6. Corrections to register storage sizes, types, valid limits and availability. Rename alarms, regs: 600-603. Rename regs: 5, 6, 8 & 9.	Duncan Grant	15-Oct-99
Issue 3	Add Modbus Registers for Temperature Correction	Paul Fine	03-Mar-06

Contents

1. Introduction

1.1 Abstract

This document specifies of ModBus serial communications interface for Nimbus and includes details of the register set and application notes.

1.2 Overview

Nimbus is a single gas detector, intended for low cost industrial applications and deployment in remote fixed locations. Typically units are placed in inaccessible locations and monitored either from a control room or local control panel.

Thus typically user interaction with Nimbus is via a serial communications. The standard user interface is implemented using the ModBus message protocol (see Ref. [1]) as via an RS485 half-duplex multi-drop asynchronous serial communications link.

The standard Nimbus ModBus user interface supports the following features:

- Monitoring of gas levels, unit status, integrity and condition
- Calibration and adjustment of zero and span settings
- Setting linearisation constants, including gas and temperature coefficients
- Configuration of customisable options and installation parameters
- Tuning of factory settable constants
- Diagnostics for production testing, service centre and onsite servicing

1.3 Scope

This is a technical document is **intended for internal publication only**, aimed primarily at systems developers and diagnostic level personnel. Additionally it may be provided under third party agreement for restricted use by external systems developers, and qualified service and field application engineers.

The information contained in this document is likely to be used as the source material to prepare user documentation for various user interface and control programs (executing under Windows or equivalent on a desktop, laptop or palmtop) for customers, distributors and sales staff, as well as service, field application engineers and production staff.

1.4 Related documents

This document refers to the following related Crowcon originated documents:

Doc. #:	Title:	Doc. Issue:	Remarks:
NIM-003	Target Design Specification for Nimbus	B (02-Jul-98)	Formal Non-Functional and Performance Requirements
NIM-011	Nimbus System Requirements and Interface	1 (10-Nov-98)	System interface details & use case study

1.5 References

This document refers to the following external documents:

Ref. #:	Title:	Doc. Ident. & Issue:	Organisation:
[1]	ModBus Protocol Reference Guide	PI-MBUS-200 Rev. D. (1992)	Modicon Industrial Automation Systems Inc., Massachusetts.

1.6 Abbreviations and Definitions

Abbreviation	**Definition**
ASCII	Refers to the standard binary representation of text characters used by most computers.
CRC	Cyclic Redundancy Check – this value is calculated from a string of data values and is used by the recipient of the data string to check the string integrity.
FRAM	Ferro-magnetic Random Access Memory – a type of non-volatile memory.
FSD	Full Scale Deflection – refers to the configured scaling for the unit. At the current loop output 100% FSD is represented as 20mA and 0% FSD as 4mA.
LEL	Lower Explosive Limit – a measure of gas with respect to the necessary concentration in air to cause an explosion under normal conditions.
LSB	Least significant byte/bit.
MSB	Most significant byte/bit.
PPM	Parts Per Million.
RS485	Serial communications standard.
RTU	Remote Terminal Unit – In the ModBus protocol this refers to 8 bit bytes composed of 2 x 4 bit hexadecimal characters. Sometimes called ModBus-B or Binary format. Message packets are delimited by a gap (or quiet period) in transmission of at least 3.5 characters.
V/V	Volumetric measure of gas normally expressed as a percentage.
Word	A measure of data size associated with a particular ModBus register number. A word is equivalent to 2 bytes or 16 bits.

2. Physical and Data Specification

2.1 RS485 Interface

Serial communications with Nimbus is available via an RS485 link with the following physical characteristics and uses channel 0 of the Serial Communications Interface (SCI) device on the Hitachi H8 chip :

• Serial Communications Interface Type:	**RS485**
• Electrical Characteristics:	**2 wire, half duplex, multi-drop**
• Baud Rate:	**9600**
• Data Format:	**8 data bits, 2 stop bits, no parity**

Data is transferred as 8 bit characters, with no parity checking, each framed with 1 start and 2 stop bits, via a 2 wire differential line, conforming to the RS458 standard (-7 to +12 volts, differential of between 2 and 6 volts).

Two or more slave units may be connected to one master unit (ie: multi-drop).

Only one unit may transmit at any one time (ie: half duplex).

A unit receives all bytes transmitted by other units on the RS485 serial communications interface, including messages destined to other units and their responses.

2.2 ModBus Communications Protocol

The ModBus protocol governs all communications over the RS485 link and employs packet based messaging. All user interactions with Nimbus are converted into ModBus messages, with the following characteristics :

• Communications Protocol:	**ModBus**
• Message Format:	**Binary RTU (or ModBus-B)**
• Inter-packet Gap:	**10.0 mS min** (>8.7 character times at 9600 baud)
• Minimum Response Time:	**50 mS**
• Maximum Response Time:	**500 mS**
• Retry Transmission Attempts:	**20**

Nimbus only acts as a slave on ModBus and therefore never initiates unsolicited transmissions. A slave only transmits in response to a valid message from the master containing it's configured unit address (see 2.4).

Nimbus uses the binary RTU message format (sometimes called ModBus-B), where each byte of data is transmitted in binary, rather than two ASCII characters. Each packet is terminated by a gap in transmission of at least 8**.**7 characters.

When responding to a ModBus request, Nimbus will respond between the minimum and maximum response time (above) after receipt of the last byte of a packet from the master.

The minimum response time gives the master time to switch its transceiver from transmit back to receive ready for the response, as well as ensuring that the slowest unit on the link recognises the gap in transmission as a packet terminator.

If the master does not receive a response after the maximum response time then it should assume that the request message was invalid and attempt a retry. A communications failure is only reported after the number of consecutive retries.

2.3 General ModBus RTU Packet Format

All ModBus packets, when using the RTU message framing scheme, have the following basic format, for both requests (sometimes called queries) from master to slave and responses from slave to master.

General ModBus binary RTU packet format :

Byte 1	**Slave Address**	1 to 247
Byte 2	**Function Code**	1 to 127
Byte 3 : :	**Variable length data section …** **… B bytes in length (B = 0 to 255)**	
Byte 3+B	**CRC - low byte**	
Byte 4+B	**CRC - high byte**	

A variable length data section is framed by a header and a footer section. The header section contains the slave address (see 2.4) and a function code (see 2.5). The footer contains a 16 bit cyclic redundancy check in a pair of bytes (see 2.6).

The slave address (byte 1) is the first byte in the message to be transmitted and received, followed by the function code and the variable length data section. The last pair of bytes is always the CRC, the low byte is always transmitted and received before the high byte [1].

For each byte of the message, the least significant bit is transmitted and received first and the most significant bit last.

2.4 Slave Address

The slave address allows the master to address a specific slave on a RS485 link and is obligatory when using a multi-drop configuration.

- Valid slave address range: **001** to **247**

2.4.1 Configured Unit Address

- Default configured unit address is: **001**

The configured unit address is held in non-volatile memory. It defaults to the above value when leaving the factory or when the factory set default configuration is restored.

When connected to a one-to-one RS485 link, the default configured unit address may be used for communications with Nimbus.

However when connected to a multi-drop RS485 link, each Nimbus unit must be configured to a unique unit address in the valid range above.

The unit's address is configured via the ModBus interface, typically using a global address over a one-to-one RS485 link.

2.4.2 Global Address

- Global address: **000**

The above global address is reserved for issuing global requests from the master to all slaves on an RS485 link.

On receiving a global request each slave must validate and action the request as if it is specifically addressed to that slave. However none of the slaves may transmit a response to a global request since conflict would result.

[1] NB: With the exception of the CRC, all 16-bit quantities (such as starting register, number of registers and register data) are always transmitted and received most significant byte first and least significant byte last. This is irrespective of whether the processor uses the big-endian or little-endian data storage model.

2.5 Function Codes

Nimbus only implements the following ModBus function codes :

⇒	**3**	**Read Holding Registers (single or multiple)**	Read from one or more consecutive register
⇒	**16**	**Pre-set Holding Registers (single or multiple)**	Write to one or more consecutive register

Any other function code will result in an illegal function exception (see 2.10).

2.6 ModBus Cyclic Redundancy Check (CRC)

For all ModBus messages the footer section contains a 16 bit cyclic redundancy check in a pair of bytes (low byte first).

2.6.1 Message Transmission

During message transmission the CRC is computed for all the bytes in the message, starting with the slave address (byte 1) up to but excluding the CRC bytes themselves. The result is placed in the last two bytes in the message (least significant byte first followed by most significant byte, which is the last byte of the packet).

2.6.2 Message Reception

During message reception the CRC is again computed for all the bytes in the message, starting with the slave address (byte 1) up to but excluding the CRC bytes themselves. The result is compared with the CRC bytes received in the last two bytes of the message.

If the CRC matches then the message is valid and is decoded and actioned. However if the CRC is invalid then the message is discarded and no further action takes place.

2.6.3 Computing the CRC

- The CRC polynomial value is: **A001** hex

The CRC algorithm is as follows (as described in Chapter 6 of Ref 1) **:**

Step 1: The 16-bit CRC register is first pre-loaded with all bits set (FFFF hex).

Step 2: Exclusive-OR the 8-bit byte from the message with the low order byte of the 16-bit CRC register, putting the result back in the CRC register.

Step 3: Shift the CRC register one bit to the right (toward the LSB), zero filling the MSB. Extract and examine the previous LSB.

Step 4: If the LSB was 0, repeat Steps 5 once (another shift). Else if the LSB was 1, exclusive-OR the CRC register with the polynomial value (above).

Step 5: Repeat steps 3 and 4 until eight shifts have been performed, one for each of the 8 bits in the byte…

Step 6: Repeat steps 2 to 5, for each successive byte in the message, excluding the CRC bytes themselves…

Step 7: When the CRC is placed into or compared with the message, its upper and lower bytes must be swapped. The low order byte is transmitted and received first followed by the high order byte, which is always last.

2.7 ModBus Registers

The concept of ModBus registers allows items of data to be individually or collectively addressable by their assigned register number and is independent of the storage type, size and access method etc.

A *register* is the identity of a *data entity* (a monolithic data item) that cannot be sub-divided or partially accessed. Typically an entity is stored in a physical *location* in the slave unit and has a physical storage *size*. A data entity may typically be a simple data type (such as a bit, byte or integer), but it may also be a complex data type (such as an array or data structure).

The collection of all registers in a slave unit is called a *register map* and can be visualised as a ragged array, where each element may be a different size, but any element may indexed using it's unique register number.

The register number is effectively an index to the physical storage of a data entity and its properties (such as: size, interpretation, meaning, type of storage, physical location and access method,…).

2.7.1 ModBus Register Sizes

Strictly speaking the size of a ModBus register is equal to a 16 bit word (2 bytes). However the specification [Ref 1] implies that a register may be any multiple of 16-bits, from 1 to 125 words. In practice no register may be larger since the maximum number of data bytes allowed in a single ModBus message is 250 bytes.

2.7.2 Transporting Different Sized Data Entities through ModBus Registers

The storage size of a location is unrestricted and may be a smaller or indeed a larger than 16 bits. For transportation over ModBus, a data entity is transformed from its storage size, into an appropriately sized register, by extending it to the next multiple of 16-bits and visa versa.

When a location is less than 16-bits in length, then it is extended to occupy a single 16-bit register upon transmission and truncated on reception to the appropriate storage size of the location. If the data is signed, then it is sign extended to 16-bits, otherwise it is zero padded to 16-bits.

However if a location is larger than 16-bits in length, then it is extended to the next multiple of 16-bits upon transmission and truncated on reception to the appropriate storage size of the location. If the data is signed, then it is sign extended as appropriate, otherwise it is zero padded as appropriate.

2.7.3 The 'Number of Registers' Field

There are two schools of thought as to the interpretation of this field in the header of a ModBus message :-

1. The number of 16-bit words to be transferred.
   This is the interpretation applied in Nimbus.
2. The number of data entities to be transferred.

The two interpretations are synonymous when dealing with uniformly sized registers of 16-bits. However if registers may on occasion contain entities that are larger than a single 16-bit word then confusion can occur.

2.7.4 The 'Number of Data Bytes' Field

At first sight this field appears to be a duplication of information contained in the 'number of registers' field.

However when the 'number of registers' field is interpreted as the number of data entities to transfer then it becomes apparent that the addition of this field clarifies the confusion (mentioned above).

This field in both the request and response message always equals the total number of data bytes contained in the message, excluding the ModBus header and CRC bytes.

2.7.5 Numbering ModBus Registers in a Register Map

Registers need not be sequentially numbered, unless it is intended that they should be addressable collectively or transferred in a single message. In the latter case they must all support the required collective operation.

Correspondingly, sequential registers need not be stored in contiguous memory nor accessed by the same method.

Normally sequential register numbers are assigned, even if the preceding register contains a data entity larger than 16-bits.

2.7.6 The ‘Starting Register’ Field

The ‘starting register’ field in both the request and response message identified the first register location to be accessed. Please not that this field contains the register number decremented by one. Thus the ‘Starting Register’ field contains zero (0) for register one (1), etc.

2.8 Read Multiple Registers (3)

The following request and response messages are used to read one or more sequential registers from Nimbus.

Function 3 request (query) message format from master :

1	Slave Address	1 to 247
2	Function Code	**3**
3	**Starting register (S) - high byte**	
4	**Starting register (S) - low byte**	
5	**Number of registers (r) - high byte**	
6	**Number of registers (r) - low byte**	
7	CRC - low byte	
8	CRC - high byte	

Function 3 response message format from Nimbus :

1	Slave Address	1 to 247
2	Function Code	**3**
3	**Number of data bytes (N) following …**	0 to 250
4	**Register (S) data - high byte**	
5	**Register (S) data - low byte**	
: : **: :**	**Repeat register data (high & low bytes) …** **… for number of registers (r)**	
4+N	CRC - low byte	
5+N	CRC - high byte	

2.9 Pre-Set Multiple Registers (16)

The following request and response messages are used to write one or more sequential registers to Nimbus.

Function 16 request (query) message format from master :

1	Slave Address	1 to 247
2	Function Code	**16**
3	**Starting register (S) - high byte**	
4	**Starting register (S) - low byte**	
5	**Number of registers (r) - high byte**	
6	**Number of registers (r) - low byte**	
7	**Number of data bytes (N) following …**	0 to 250
8	**Register (S) data - low byte**	
9	**Register (S) data - high byte**	
: : **: :**	**Repeat register data (low & high bytes) …** **… for number of registers (r)**	
8+N	CRC - low byte	
9+N	CRC - high byte	

Function 16 response message format from Nimbus :

1	Slave Address	1 to 247
2	Function Code	**16**
3	**Starting register (S) - high byte**	
4	**Starting register (S) - low byte**	
5	**Number of registers (r) - high byte**	
6	**Number of registers (r) - low byte**	
7	CRC - low byte	
8	CRC - high byte	

2.10 ModBus Exception Response

Nimbus responds with an exception response message, in place of the normal response, if any of the following conditions is detected for one or more locations accessed.

ModBus exception response message format :

Byte 1	Slave Address	1 to 247
Byte 2	**Function Code (F + 128)**	**128 to 255**
Byte 3	**Exception Code (X)**	**1 to 5**
Byte 4	CRC - low byte	
Byte 5	CRC - high byte	

An exception response is only sent provided :

- The slave address in the request directly matches the unit’s configured address (ie: not addressed to another unit or a global request);
- and the request message is valid (ie: the CRC check did not fail).

2.11 Exception Codes

Nimbus supports the following ModBus exception codes (X) :

		No response	ρ	Request contained global address
			ρ	Unrecognised slave address
			ρ	Failed CRC
⇒	**1**	**Illegal Function**	ρ	Requested function code is not supported
⇒	**2**	**Illegal Data Address**	ρ	An invalid or unknown register address
			ρ	Invalid number of registers
			ρ	Invalid number of data words for specified registers in request
			ρ	Currently unable to perform request on a register (eg: invalid user access rights, invalid mode of operation)
			ρ	Request is invalid for a register (eg: write to read-only location)
			ρ	Location access failure, invalid type or physical address
⇒	**3**	**Illegal Data Value**	ρ	Invalid value or data type
⇒	**4**	**Slave Device Failure**	ρ	Gross failure of the slave unit
⇒	**5**	**Acknowledge**	ρ	An operation is deferred or in progress

3. Application Notes

3.1 Register Groups

For convenience and extensibility Nimbus registers are arranged into groups (see Appendix A and B).

This simplifies register number decode and enables fast and effective access, using one Register Access Table (RAT) per group (see NIM-007 for details).

3.2 Register Properties

The properties of a register are defined by its :-

- address
- type and size of physical storage
- type and interpretation of data
- valid data values
- read and/or write access permissions (not to be confused with user access rights – see next)

All register accesses are validated to ensure they conform with the properties of the register. If the access violates any of the properties of the register then the operation cannot be performed and an exception response is returned.

The Register Access Table (RAT) contains the knowledge about the properties of every addressable register.

3.3 User Classes and Roles

Four classes of user have been identified as follows (see NIM-011 for details):

- Operator: Basic end-user (plant operator). May monitor gas levels, operational status and inspect the configuration. May not alter the operational state of the unit, change its behaviour, accuracy or configuration. Default user type.
- Supervisor: Advanced end-user or third party distributor. Extends operator privileges to allow standard calibration procedures as well as altering linearisation and end-user configurations etc.
- Factory: Factory technician. Extends Supervisor privileges to allow production testing, diagnostics and factory only configurations etc.
- Service: Service or diagnostic engineer. Extends Supervisor privileges to allow on-site diagnostics and installation configurations etc.

Thus each class of user is granted particular set of access rights.

3.4 User Access Rights

In order to read from or write to a register a user must have the appropriate access rights for the operation.

By default only operator access privileges are enabled, until a valid user access command changes the access level. This is achieved via the User Access Control register (see Appendix A, Register Group 3), a special security register which only sets the user access level if the appropriate user validation code is entered.

Very few registers may be written to without a higher level of access privileges. Only operational registers may be read, allowing by default, the gas level, obscuration level, operational state and identity of the unit to be monitored. Any operation that might alter the operational state, behaviour or accuracy of the unit is not permitted.

Most registers may be safely read whilst Nimbus is operational, without effecting the unit’s behaviour, accuracy, operational state or ability to respond.

Provided the user has the appropriate access rights then they may perform operations that may effect the unit's behaviour, accuracy, operational state or ability to respond. Some examples of this are: calibrating, altering linearisation coefficients, scaling factors or other configuration parameters, or performing intrusive test or diagnostic functions.

3.5 Diagnostic Rights

For test and diagnostic purposes it is occasionally useful to set a register, which is normally read only, to a particular value, in order to test a software process or directly control an output.

This is inherently intrusive and therefore may only be performed in Diagnostic Mode, by users with diagnostic access rights.

If the register is normally updated by some process then it is also necessary to inhibit the normal process to ensure that the diagnostic setting persists for the duration of the test. For this reason inhibit control registers are provided but are only effective in Diagnostic Mode.

Only service, factory and supervisor class users may additionally be granted diagnostic rights. Diagnostic access rights are obtained via the Diagnostic Access Control register (see Appendix A, Register Group 3), a special security register which only enables diagnostic mode if the appropriate diagnostic validation code is entered.

3.6 Control Registers

Most of the Nimbus functionality exposed via the ModBus interface is achieved through simple registers that act as parameters to regular processes being performed continuously.

However in some cases it is necessary to trigger a special one-shot process to perform some action on command.

For example (see Appendix A, Register Group 3 for details):

- Set zero gas calibration
- Set full scale gas calibration gain
- Set gas transfer scaling
- Update user configuration bank
- Restore factory configuration

This is achieved with control registers. An associated status register is normally provided where the action may take longer than the response time allowed by ModBus or may have more than one completion state (eg: 'Success' or 'Fail').

The status register is normally polled until the requested operation completes. Whilst the control operation is being performed the status register indicates the 'busy' state. On completion the status register indicates either 'success' or a failure state until either a new control operation is initiated or the 'NOP' command is issued. Writing the 'NOP' command will set the status register to 'ready', thus confirming that the transaction is complete and subsequent transactions may detect a change of status to confirm command actioning.

3.7 Writing to Configuration Registers

Beware that changing any configuration register is likely to result in changes in the behaviour or accuracy of the unit in some way. Ensure that the unit is off-line or isolated before changing its configuration.

Whilst most configuration changes have immediate effect, others may only take effect after the unit has reinitialised or reset. Writing to some configuration registers may cause an automatic re-initialisation in order to make the change effective immediately.

Writing to a configuration register does not guarantee that the change is permanent or written into non-volatile memory. This allows multiple configuration changes to be made and tested before updating a configuration bank in non-volatile memory.

However a few configuration changes (such as invoking a calibration command) result in an automatic update to the user configuration bank.

3.8 Updating and Restoring Configuration Banks

To make a configuration change permanent, thus ensuring that the change persists after a reset or power cycle, it is normally necessary to request the configuration to be updated in non-volatile memory through the Configuration Bank Control register (see Appendix A, Register Group 3).

Notionally there are four configuration banks, three in non-volatile memory, one in read-only memory. The access rights required to restore or update each bank and their intended use is described as follows (see NIM-007 for details) :-

Bank:	Restore Rights:	Update Rights:	Description of Use:
0: User:	Supervisor, Factory, Service	Supervisor, Factory, Service	Holds current operational configuration and is restored automatically to RAM during start-up. Calibration operations automatically update calibration data only in this bank.
1: Install:	Supervisor, Factory, Service	Factory, Service	Copy of the configuration when the service engineer last updated the configuration on-site or when the unit was installed on-site or when the unit was customised before shipping to the site. (Useful for reference to check for end-user alterations and calibration shifts).
2: Factory:	Supervisor, Factory, Service	Factory, Service (with diagnostic rights)	Copy of the configuration following temperature cycling, final test and calibration at the factory. (Useful for comparison to check for any significant calibration shifts). WARNING: **If factory settings are corrupted or over-written with default settings in non-volatile storage then the unit will require return to factory for re-learning.**
3: Defaults:	Factory, Service (with diagnostic rights)	None	Default read-only configuration, used to initialise a virgin unit. WARNING: When restored, over-writes all factory settings in RAM, including temperature compensation characteristics and unit's serial number and identification. Also the default calibration data ensures unit will report an under-range fault, indicating a calibration error. **Beware**: avoid using default data to update the factory bank (see above)!

Not every item of configuration data is duplicated in each bank (see NIM-007 and software design documents for details). For example, detector temperature compensation settings are only contained in the factory bank.

However when a selected bank is restored then all configuration data items are restored to RAM, using the appropriate copy of the each configuration item, either from the requested bank if it contains the configuration item, or if not then from the first bank following the selected bank, which does contain the configuration item.

Thus for example, the detector temperature compensation settings may be restored through the user bank, even though they are actually only contained in the factory bank.

Configuration data may only be altered in RAM. This allows multiple configuration changes to be made and tested before updating a configuration bank in non-volatile memory.

In most cases configuration changes are not permanently stored until updated in an appropriate non-volatile configuration bank. Only the configuration data items contained in the selected bank to be updated are stored permanently.

Thus for example, the detector temperature compensation settings are not updated through the user bank, because they are only contained in the factory bank.

The factory bank can only be updated by factory class users or service class users with diagnostic rights, as it contains sensitive configuration that can only be set-up at the factory (such as detector temperature compensation settings).

The default configuration bank cannot be updated and may only be restored by factory class users or service class users with diagnostic rights, as restoring this bank causes all configuration data (including factory only settings) to be set to their default state in RAM.

Beware that the behaviour and accuracy of the unit will be effected when a different configuration is restored. Ensure that the unit is off-line before changing its configuration.

3.9 Monitoring Gas Level and Operational State

All parameters that are routinely monitored are conveniently grouped together (see Appendix A, Register Group 2). This enables polling using a single ModBus message using the Read Multiple Registers function.

The current gas level and its rate of change is indicated through the ‘Gas Level’, ‘Inst Gas Level’ and ‘Gas Rate of Change’ registers. The instantaneous gas level should not be routinely be displayed as it is mainly intended for servicing and diagnostics.

However it is particularly useful to display the instantaneous gas level and the gas rate of change during calibration as the relative stability of the reading or the rate at which it is changing is an indication of saturation of the gas chamber with a calibration gas.

The ‘Mode’ register indicates when the unit is operational or in some non-operational mode, such as during Calibration.

The current operational state of the unit is indicated through the ‘Status’ register as an enumerated type. All the conditions that may effect or contribute to the current operational state of the unit are indicated through the ‘Conditions’ register as bit flags. Together these registers provide valuable information for diagnosing any fault or alarm condition.

3.10 Performing Calibration

Calibration is performed using the Calibration Control and Status registers (see Appendix A, Group 3).

3.10.1 Applying a Local Inhibit of the Current Loop Output

To enable one-man calibration on site, where the sensors are remotely monitored by a control panel, it is necessary to apply a local inhibit, to prevent the triggering of gas alarms at the control panel during calibration.

This is achieved by fixing the current loop output typically to either 4.0 mA or 2.0 mA or 0.0 mA, using the ‘Current Loop Installation Registers’ (see Appendix A, Group 6) as described below :-

1. Obtain appropriate user access rights and preset the desired inhibit level for the current loop output using the ‘Loop Inhibit Level’ register.
2. When the inhibit level is required it is activated by writing ‘Diag_Inhibit’ to the ‘Diag Access Control’ register (see Appendix A, Group 2).
3. The inhibit can be deactivated again by writing ‘Normal’ to the ‘Diag Access Control’ register.

Note that diagnostic mode has a timeout of 15 minutes. So (unless refreshed) the inhibit will be automatically deactivated after 15 minutes.

3.10.2 Zero Gas Calibration

Zero gas calibration is performed by the following sequence and typically takes between 10 and 30 seconds :-

1. Obtain appropriate user access rights. Write ‘NOP’ to the ‘Cal Control’ register to reset the ‘Cal Status’ register to ‘Ready’ and check appropriate access rights have been obtained.
2. Apply an inhibit to the current loop output as required (see above).
3. Ensure zero gas level by flushing the gas chamber with compressed air or Nitrogen, for about 10 to 15 seconds. Allow the readings to become reasonably settled.
4. Invoke the zero calibration operation by writing ‘Set_Zero’ to the ‘Cal Control’ register.
5. During the calibration operation the ‘Cal Status’ register returns the ‘Busy’ state and the ‘Mode’ register (see Appendix A, Group 2) returns the ‘Cal’ state.
6. Poll the ‘Cal Status’ register (no more than once per second) until it returns either ‘Success’ or ‘Fail’.
7. Disengage any local inhibit.
8. Write ‘NOP’ to the ‘Cal Control’ register to reset the ‘Cal Status’ register to ‘Ready’.

Only the ‘Success’ status indicates a successful calibration operation. The calibration procedures should be repeated if the operation is unsuccessful.

A failure may be due to one or more of the following :-

- The ModBus command was not recognised or was rejected.
  (Check that unit is communicating and that user access rights are valid).

- The gas level did not stabilise sufficiently after 120 seconds.
  (Ensure gas flow is shut off during calibration).

3.10.3 Full Scale Gas Calibration

Zero gas calibration must be valid before proceeding. Full scale gas calibration is performed by the following sequence and typically takes between 20 and 120 seconds (depending upon gas flow rate) :-

1. Obtain appropriate user access rights. Write ‘NOP’ to the ‘Cal Control’ register to reset the ‘Cal Status’ register to ‘Ready’ and check appropriate access rights have been obtained.
2. Apply an inhibit to the current loop output as required (see above).
3. Apply calibration gas. Allow about 10 to 15 seconds for the readings to become reasonably settled.
4. Invoke the full scale calibration operation by writing ‘Set_Gain’ to the ‘Cal Control’ register.
5. During the calibration operation the ‘Cal Status’ register returns the ‘Busy’ state and the ‘Mode’ register (see Appendix A, Group 2) returns the ‘Cal’ state.
6. Poll the ‘Cal Status’ register (no more than once per second) until it returns either ‘Success’ or ‘Fail’.
7. Disengage any local inhibit.
8. Write ‘NOP’ to the ‘Cal Control’ register to reset the ‘Cal Status’ register to ‘Ready’.

Only the ‘Success’ status indicates a successful calibration operation. The calibration procedures should be repeated if the operation is unsuccessful.

A failure may be due to one or more of the following :-

- The ModBus command was not recognised or was rejected.
  (Check that unit is communicating and that user access rights are valid).

- The gas level did not stabilise sufficiently after 300 seconds.
  (Try shutting off or reducing calibration gas flow when readings are no longer increasing during calibration).

- Invalid separation between zero and full scale gas levels.
  (Check that the gas chamber is fully purged during zero gas calibration and that an appropriate concentration of calibration gas is applied during full scale calibration).

3.10.4 Setting Gas Transferability Scaling

Zero and full scale gas calibration must be valid before proceeding. Gas transferability scaling is normally only performed once at factory or by a qualified service agent following installation. The sequence is as follows and typically takes between 20 and 120 seconds (depending upon gas flow rate) :-

1. Obtain appropriate user access rights. Write ‘NOP’ to the ‘Cal Control’ register to reset the ‘Cal Status’ register to ‘Ready’ and check appropriate access rights have been obtained.
2. Apply an inhibit to the current loop output as required (see above).
3. Apply secondary calibration gas. Allow about 10 to 15 seconds for the readings to become reasonably settled.
4. Invoke the gas transferability scaling operation by writing ‘Set_Xfer’ to the ‘Cal Control’ register.
5. During the calibration operation the ‘Cal Status’ register returns the ‘Busy’ state and the ‘Mode’ register (see Appendix A, Group 2) returns the ‘Cal’ state.
6. Poll the ‘Cal Status’ register (no more than once per second) until it returns either ‘Success’ or ‘Fail’.
7. Disengage any local inhibit.
8. Write ‘NOP’ to the ‘Cal Control’ register to reset the ‘Cal Status’ register to ‘Ready’.

Only the ‘Success’ status indicates a successful calibration operation. The calibration procedures should be repeated if the operation is unsuccessful.

A failure may be due to one or more of the following :-

- The ModBus command was not recognised or was rejected.
  (Check that unit is communicating and that user access rights are valid).
- The gas level did not stabilise sufficiently after 300 seconds.
  (Try shutting off or reducing calibration gas flow when readings are no longer increasing during calibration).
- Invalid gas transfer scaling result.
  (Check that an appropriate concentration of secondary calibration gas is applied).

3.11 Commissioning

3.11.1 Setting the Current Loop Output Level for System Commissioning

To facilitate system configuration, it is desirable to drive the current loop output to any fixed level (eg: 0.0 mA, 2.0 mA, 4.0 mA, 12.0 mA, and 20.0 mA).

This is achieved using the ‘Current Loop Installation Registers’ (see Appendix A, Group 6) as described below :-

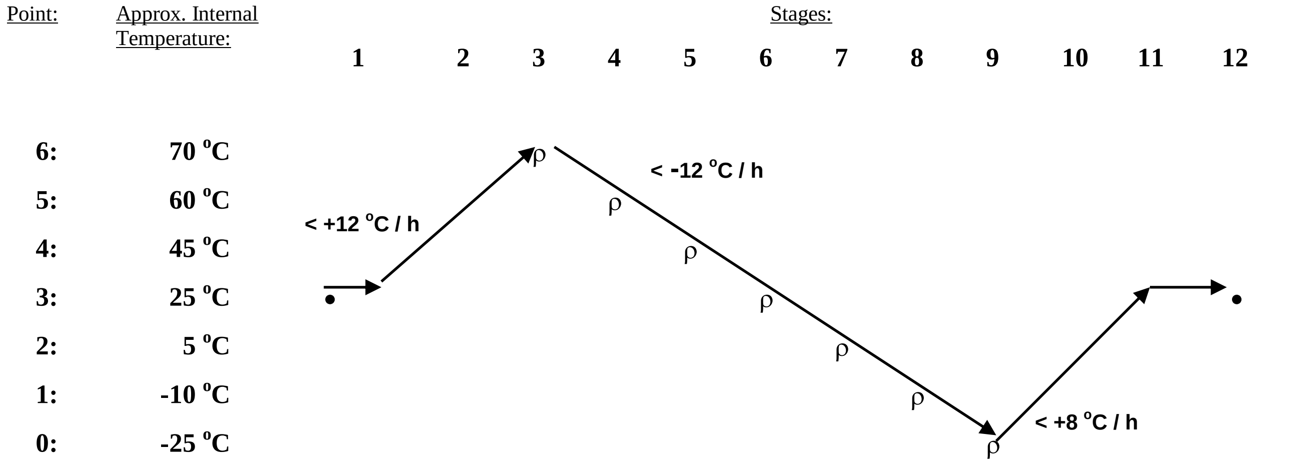
1. Obtain appropriate user access rights and set the ‘Loop Source’ register to ‘Commissioning’ to select the ‘Loop Commissioning Level’ register as the source for diagnostic mode.
2. Preset the desired commissioning level for the current loop output using the ‘Loop Commissioning Level’ register.
3. When the commissioning level is required, it is activated by writing ‘Diag_Only’ to the ‘Diag Access Control’ register (see Appendix A, Group 2).
4. The current loop can now be directly controlled by writing to the ‘Loop Commissioning Level’ register.
5. The commissioning level can be deactivated again by writing ‘Normal’ to the ‘Diag Access Control’ register.

Note that diagnostic mode has a timeout of 15 minutes. So (unless refreshed) the commissioning level will be automatically deactivated after 15 minutes.

3.12 Learning Detector Temperature Compensation Points

The detector temperature compensation learning is performed at the factory during temperature cycling.

Raw readings, from each of the two detectors, are sampled after a dwell at each of seven temperature points, for decreasing temperatures, as illustrated below :-



Note: Temperatures are referenced to internal temperature (which is approximately 8 °C above ambient when stable), with the supply set to 24 volts.

The sequence starts and ends at ambient temperature, nominally around 25 °C. Learning starts at around 70 °C with learn point 6 and ends at around –25 °C with learn point 0. Each temperature point must be separated by at least 5.0 °C from the points above and below it in the table. The oven should dwell at each learn point, long enough for the internal temperatures of the units to stabilise for a few 10's of minutes, before the sample is learnt.

The temperatures for each point need not be accurately reproduced, as the software records the temperature as well as averages over 10 seconds the detector compensation adjustments to fit the temperature characteristics of each detector.

The whole sequence should take no more than 20 hours and ideally only 16 hours. Each point is learnt using the appropriate point learn command using the Factory Control and Status registers (see Appendix A, Group 3). Calibration operations are performed as described previously using the Calibration Control and Status registers (see Appendix A, Group 3). Raw detector signal levels at zero gas are available from the Calibration Constants registers (see Appendix A, Group 4).

1. At stage 1: the unit is zero gas calibrated at ambient before learning begins. Record the raw detector signal levels at zero gas.
2. The oven temperature should first be increased at no more than 12 °C/hour up to around 65 °C.
3. Then the oven temperature should be decreased at no more than 12 °C/hour down to around -30 °C, learning points from 6 to 0, dwelling long enough to stabilise the temperature each time before issuing the learn command.
4. Finally the oven temperature should be increased at no more than 12 °C/hour up to –10 °C and no more than 8 °C/hour between -10 °C and +25 °C (to avoid obscuration due to condensation).
5. Allow the units to settle back to ambient (oven door open) for a minimum of two hours.
6. At stage 12: the zero gas calibration is repeated. The new raw detector signal levels at zero gas are recorded and compared with those recorded at the start of the sequence. If there has been a significant shift (say more than 5%) then the sequence must be repeated for the unit.
7. The unit is now calibrated for full scale using 100% LEL gas. The gas in the gas chamber is purged then the zero gas calibration is repeated. The final raw detector signal levels at zero gas are recorded and compared with those recorded at the end of the sequence. If there has been a significant shift (say more than 2%) then the unit must be checked for gas ingress.
8. Finally a report is automatically produced, giving details of the raw detector signals at each calibration as well as detector adjustments and temperatures for each learn point.

Appendix A: Nimbus ModBus Register Map

The following indicates the current and intended levels of implementation:

Key:	ModBus Register, Implementation:
Normal	Implemented
Bold	**Mandatory -- required for implementation of minimal interface**
Half-Tone	Not implemented yet -- reserved for future implementation -- preliminary information only !

The user access rights to a register is indicated as follows for any of the seven user roles identified in the register maps:

Key:	User Access Rights:
r	**R**ead only access
D	Read only access, except whilst **D**iagnostics enabled
B	**B**oth read and write access
W	**W**rite only access (zero when read)
7	No access
	Blank -- to be determined

The storage size of a register location is indicated as follows in the register maps:

Key:	Location Storage Size:
INT8	Signed 8-bit integer
UINT8	Unsigned 8-bit integer
INT16	Signed 16-bit integer
UINT16	Unsigned 16-bit integer
INT32	Signed 32-bit integer (occupies register pairs)
UINT32	Unsigned integer (occupies register pairs)
BOOL	Signed 8-bit integer containing a boolean (ie: 0 = FALSE , -1 = TRUE)
PFloat_1dp	Signed 16-bit integer, scaled to 1 decimal place (ie: 1000 = 100**.** 0)
PFloat_2dp	Signed 16-bit integer, scaled to 2 decimal places (ie: 1000 = 10**.** 00)
PFloat_3dp	Signed 16-bit integer, scaled to 3 decimal places (ie: 1000 = 1**.** 000)
String xx	Text string of fixed length, null padded to xx packed bytes (does not include null terminator; occupies xx / 2 registers)
Bit Array xx	Array of flag bits of length xx packed bytes (occupies xx / 2 registers)
	Blank -- to be determined

The units of a value or parameter accessed through a register is indicated as follows in the register maps:

Key:	**Units:**
%	Expressed as a percentage – normally in the range 0 to 100
% FSD	Expressed as a percentage of Full Scale Deflection – normally in the range -6 to +106
% LEL	Expressed as a percentage of Lower Explosive Limit – normally in the range -6 to +106 %
% Unit	Expressed as a percentage of an appropriate measurement unit (eg: LEL, LFL, Vol, ppm,…) – normally in the range -6 to +106 %
V	Expressed as volts
mA	Expressed as milli-amps
^{o}C	Expressed as degrees centigrade
Samples	Expressed as a number of detector samples (nominally 320 Hz)
Cycles	Expressed as a number of lamp cycles (nominally 4 Hz)
Readings	Expressed as a number of readings (two per cycle)
Sec	Expressed as seconds
Min	Expressed as minutes
Hour	Expressed as hours
hex	Expressed as a hexadecimal
raw	Raw quantity (eg: as read from or written to hardware register)
enum	Enumerated type – value has meaning in context (to be assigned)
flags	Packed bit flags – bit state has meaning in context (to be assigned)
xx-bits	Value constrained to xx bits
10^{ths}	Value fixed to 1 decimal place of units
100^{ths}	Value fixed to 2 decimal places of units
1000^{ths}	Value fixed to 3 decimal places of units
	Blank – no applicable units

A1: Register Group 1: Identification Registers

The following registers provides information about the identity, location and purpose of a Nimbus unit. All registers in this group may be read by any user in virtually any mode. In addition, some registers as indicated may be configured by a user with an appropriate access level or with diagnostic access privileges.

ModBus Register:	Typical Setting:	Valid Range:	Units:	Number of Registers:	Location Storage Size:	Service	Factory	Supervisor	Operator
Unit Type and Version Information: (see Note 1)									
1. Unit Type	"Nimbus"			8	String 16	**r**	**r**	**r**	**r**
2. Software Version	"Nim1_1i0_B 07 $"			8	String 16	r	r	r	r
3. ModBus Comms Version	"1.10 $"			8	String 16	r	r	r	r
4. PROM Checksum	89AB 89AB		hex	2	2 x INT16	r	r	r	r
5. Manufacture Ident	"BN991017-01 P"			8	String 16	**D**	**D**	**r**	**r**
Unit Identification:									
6. Calibration Ident	"CN991018-01"			8	String 16	**D**	**D**	**r**	**r**
7. ModBus Address (see Note 2)	1	1..247		1	UINT8	**B**	**B**	**B**	**r**
8. Tag	"(no tag)"			8	String 16	**B**		**B**	**r**
9. User	"(empty)"			8	String 16	**B**		**B**	**r**

Note 1: The unit type and version information registers are for product identification and are fixed for a particular software release.

Note 2: With the exception the ModBus Address, none of the above registers affect the operation or functionality of the unit.

A2: Register Group 2: Operational Status Registers

The following registers are normally updated frequently and are used for operational monitoring of gas levels and operational status. It is expected that the ModBus master will regularly poll these registers. All registers in this group may be read by any user in virtually any mode. A user with service and diagnostic access privileges may force register contents for diagnostic testing purposes only.

ModBus Register:	Typical Setting:	Valid Range:	Units:	Number of Registers:	Location Storage Size:	Service	Factory	Supervisor	Operator
Operational Monitoring:									
100. Gas level	0.0	-10.0 .. 1000.0	10^{ths} % FSD	1	Float_1dp	**D**	**r**	**r**	**r**
101. Mode	Op	StartUp | WarmUp | Cal | Op | Test | Restart	enum	1	INT8	**D**	**r**	**r**	**r**
102. Status (see Note 2)	Obscured	Normal | Diag | Fault_Soft | Comms_Err | Alarm_L1_Fall | Alarm_L1_Rise | Alarm_L2_Fall | Alarm_L2_Rise | Under_Range | Over_Range | Zero_Drift | Obscured | Warm_Up | Cal | Start_Up | Fault_Hard | Blocked | Integrity | Det_Fail | Lamp_Fail | Soft_Fail	enum	1	INT8	**r**	**r**	**r**	**r**
103. Detector Signal Rate of Change		-320.00 .. 320.00	100^{ths} count per 10 sec	1	Float_2dp	**D**	**r**	**r**	**r**
104. Inst Gas Reading	0.0	-10.0 .. 1000.0	10^{ths} % FSD	1	Float_1dp	**D**	**r**	**r**	**r**
105. Obscuration Factor	0.0	0.0 .. 100.0	10^{ths} %	1	Float_1dp	**D**	**r**	**r**	**r**
106. Supply Voltage	24.0	5.00 .. 40.00	100^{ths} V	1	Float_2dp	**D**	**r**	**r**	**r**
107. Temperature	20.0	-50.0 .. 100.0	10^{ths} °C	1	Float_1dp	**D**	**r**	**r**	**r**
108. Conditions (see Note 2)	Normal & Fault_Soft & Under_Range & Obscured	Normal & Diag & Fault_Soft & Comms_Err & Alarm_L1_Fall & Alarm_L1_Rise & Alarm_L2_Fall & Alarm_L2_Rise & Under_Range & Over_Range & Zero_Drift & Obscured & Warm_Up & Cal & Start_Up & Fault_Hard & Blocked & Integrity & Det_Fail & Lamp_Fail & Soft_Fail	flags	2	Bit Array 3	**D**	**r**	**r**	**r**

Note 1: Operational monitoring registers are intended for routine monitoring; register contents are updated frequently (twice per second).

Note 2: The status register indicates the highest priority condition that determines the units current operational state; the conditions register simultaneously indicates the current states of all conditions that may effect or contribute towards the current operational state of the unit.

A3: Register Group 3: Control and Status Registers

The following registers are used for access and configuration control purposes, as well as invoking calibration operation sequences. Access privileges are restricted as indicated.

Warning: Calibration and configuration operations will effect unit behaviour and accuracy. Ensure the unit is off-line before invoking these operations.

ModBus Register:	**Typical Setting:**	**Valid Range:**	**Units:**	**Number of Registers:**	**Location Storage Size:**	**Service**	**Factory**	**Supervisor**	**Operator**
Access Control & Status:									
200. User Access Control (see Note 1)	Operator	Operator | Supervisor | Factory | Service	enum	1	INT8	**B**	**B**	**B**	**B**
+ Verification Code	12345678		hex	2	UINT32	**W**	**W**	**W**	**W**
201. Diag Access Control (see Note 1)	Disabled	Normal | Diag_Only | Diag_Inhibit	enum	1	INT8	**B**	**B**	**B**	**r**
+ Verification Code	12345678		hex	2	UINT32	**W**	**W**	**W**	
Configuration Bank Control & Status:									
202. Config Bank Control	Update_ User	NOP | Update_User | Update_Install | Update_Factory | Restore_User | Restore_Install | Restore_Factory | Restore_Defaults	enum	1	INT8	**B**	**B**	**B**	**r**
203. Config Bank Status (see Note 2)	OK	Ready | Busy | Success | Fail	enum	1	INT8	**r**	**r**	**r**	**r**
204. Config Bank Checksum	BA98 BA98		hex	2	2 x INT16	r	r	r	r
Calibration Control & Status:									
205. Cal Control	Set_Zero	NOP | Set_Zero | Set_Gain | Set_Zdrift	enum	1	INT8	**B**	**B**	**B**	**r**
206. Cal Status (see Note 2)	OK	Ready | Busy | Success | Fail	enum	1	INT8	**r**	**r**	**r**	**r**
… cont …									

ModBus Register:	**Typical Setting:**	**Valid Range:**	**Units:**	**Number of Registers:**	**Location Storage Size:**	**Service**	**Factory**	**Supervisor**	**Operator**
Factory Control & Status:									
207. Factory Control	Learn_TCP3	NOP | Learn_TCP0 | Learn_TCP1 | Learn_TCP2 | Learn_TCP3 | Learn_TCP4 | Learn_TCP5 | Learn_TCP6 | Set_Transfer_Scaling	enum	1	INT8	**B**	**B**	7	7
208. Factory Status (see Note 2)	OK	Ready | Busy | Success | Fail	enum	1	INT8	**r**	**r**	7	7
Unit Control:									
209. Unit Control	Reset	NOP | Reset	enum	1	INT8	**B**	**B**	**B**	**B**

Note 1: Access control registers (eg: User Access Control) require a valid Verification Code before the access level is accepted. The verification code is zeroed on reading an access control register, and may be used to determine the current setting.

Note 2: Status registers (eg: Cal Status) hold their ‘Success’ or ‘Fail’ status until the next control operation. Writing the ‘NOP’ control code causes the status register to be reset to ‘Ready’, and should be used to terminate all control transactions.

A4: Register Group 4: Calibration Configuration

The following registers allow calibration constants and information to be inspected and configured. Calibration constants are normally set by invoking the calibration operations. Only a service level user with diagnostic privileges may alter calibration constants. The calibration information is maintained and used by the ModBus master and should be updated whenever a calibration operation is performed. Access privileges are restricted as indicated.

Warning: Alterations to calibration constants will effect unit behaviour and accuracy. Ensure the unit is off-line before making alterations.

ModBus Register:	**Typical Setting:**	**Valid Range:**	**Units:**	**Number of Registers:**	**Location Storage Size:**	**Service**	**Factory**	**Supervisor**	**Operator**
Calibration Information: (see Note 1)									
300. Zeroed on Date	“22/11/99”			8	String 16	**B**	**B**	**B**	**r**
301. Zeroed by Who	“XYZ”			8	String 16	**B**	**B**	**B**	**r**
302. Calibrated on Date	“01/02/99”			8	String 16	**B**	**B**	**B**	**r**
303. Calibrated by Who	“ABC”			8	String 16	**B**	**B**	**B**	**r**
Calibration Constants: (see Notes 2, 3 & 4)									
304. Gas Det Level at Zero		0 .. 4096	12-bit raw	1	INT16	**D**	**r**	**r**	**r**
305. Ref Det Level at Zero		0 .. 4096	12-bit raw	1	INT16	**D**	**r**	**r**	**r**
306. Temp at Zero	27.0	-50.0 .. 100.0	10^{ths} °C	1	Float_1dp	**D**	**r**	**r**	**r**
307. Gas Det Zero Drift		-1024 .. 1024	raw	1	INT16	**D**	**r**	**r**	**r**
308. Ref Det Zero Drift		-1024 .. 1024	raw	1	INT16	**D**	**r**	**r**	**r**
309. Temp at Auto Zero	27.0	-50.0 .. 100.0	10^{ths} °C	1	Float_1dp	**D**	**r**	**r**	**r**
310. Gas Det Signal Gain at FSD		0 .. 2048	raw	1	INT16	**D**	**r**	**r**	**r**
311. Ref Det Signal Gain at FSD		0 .. 204	raw	1	INT16	**D**	**r**	**r**	**r**
312. Temp at FSD	27.0	-50.0 .. 100.0	10^{ths} °C	1	Float_1dp	**D**	**r**	**r**	**r**
… cont …									

ModBus Register:	Typical Setting:	Valid Range:	Units:	Number of Registers:	Location Storage Size:	Service	Factory	Supervisor	Operator
Detector Temperature Compensation Constants: (see Note 5)									
313. TCP0 Temp		-50.0 .. 100.0	10ths ºC	1	Float_1dp	**D**	**r**	7	7
314. TCP0 Gas Adjust		-812 .. 812		1	INT16	**D**	**r**	7	7
315. TCP0 Ref Adjust		-812 .. 812		1	INT16	**D**	**r**	7	7
316. TCP1 Temp		-50.0 .. 100.0	10ths ºC	1	Float_1dp	**D**	**r**	7	7
317. TCP1 Gas Adjust		-812 .. 812		1	INT16	**D**	**r**	7	7
318. TCP1 Ref Adjust		-812 .. 812		1	INT16	**D**	**r**	7	7
319. TCP2 Temp		-50.0 .. 100.0	10ths ºC	1	Float_1dp	**D**	**r**	7	7
320. TCP2 Gas Adjust		-812 .. 812		1	INT16	**D**	**r**	7	7
321. TCP2 Ref Adjust		-812 .. 812		1	INT16	**D**	**r**	7	7
322. TCP3 Temp		-50.0 .. 100.0	10ths ºC	1	Float_1dp	**D**	**r**	7	7
323. TCP3 Gas Adjust		-812 .. 812		1	INT16	**D**	**r**	7	7
324. TCP3 Ref Adjust		-812 .. 812		1	INT16	**D**	**r**	7	7
325. TCP4 Temp		-50.0 .. 100.0	10ths ºC	1	Float_1dp	**D**	**r**	7	7
326. TCP4 Gas Adjust		-812 .. 812		1	INT16	**D**	**r**	7	7
327. TCP4 Ref Adjust		-812 .. 812		1	INT16	**D**	**r**	7	7
328. TCP5 Temp		-50.0 .. 100.0	10ths ºC	1	Float_1dp	**D**	**r**	7	7
329. TCP5 Gas Adjust		-812 .. 812		1	INT16	**D**	**r**	7	7
330. TCP5 Ref Adjust		-812 .. 812		1	INT16	**D**	**r**	7	7
331. TCP6 Temp		-50.0 .. 100.0	10ths ºC	1	Float_1dp	**D**	**r**	7	7
332. TCP6 Gas Adjust		-812 .. 812		1	INT16	**D**	**r**	7	7
333. TCP6 Ref Adjust		-812 .. 812		1	INT16	**D**	**r**	7	7

Note 1: The calibration information (date zero or gain calibration was last invoked and the identity of the user) are only updated and used by the ModBus master. Their contents do not effect the function, behaviour or accuracy of the unit.

Note 2: Zero gas calibration constants are normally set by invoking the calibration operation ‘Set_.Zero’ through the ‘Cal_Control’ register.

Note 3: Zero gas drift calibration constants are normally set automatically by the Auto Zeroing process, or manually by invoking the calibration operation ‘Set_.Zdrift’ through the ‘Cal_Control’ register.

Note 4: Full scale gas gain calibration constants are normally set by invoking the calibration operation ‘Set_.Gain’ through the ‘Cal_Control’ register.

Note 5: Detector Temperature Compensation constants are normally set by invoking one of the learn temperature compensation point operations ‘Learn_TCP#’ through the ‘Factory_Control’ register.

A5: Register Group 5: Linearisation Configuration

The following registers allow linearisation constants and information to be inspected and configured. Linearisation constants may be configured by a user with an appropriate access level. The linearisation information is maintained and used by the ModBus master and should be updated whenever linearisation is changed significantly (eg: new gas type or concentration). Access privileges are restricted as indicated.

Warning: Alterations to linearisation constants will effect unit behaviour and accuracy. Ensure the unit is off-line before making alterations.

ModBus Register:	**Typical Setting:**	**Valid Range:**	**Units:**	**Number of Registers:**	**Location Storage Size:**	**Service**	**Factory**	**Supervisor**	**Operator**
Linearisation Information:									
400. Measurement Units	"0-100% LEL"			8	String 16	**B**		**B**	**r**
401. Measured Gas Type	"Methane"			16	String 32	**B**		**B**	**r**
402. Calibration Gas Type	"Methane 2.5% v/v"			16	String 32	**B**		**B**	**r**
Linearisation Constants:									
403. Polynomial Coefficient	0.727	0.100 .. 10.000	1000ths	1	Float_3dp	**B**		**B**	**r**
404. Gas Type Scaling	1.000	-10.000 .. 10.000	1000ths	1	Float_3dp	**B**		**B**	**r**
405. Gas Transfer Scaling	1.000	-10.000 .. 10.000	1000ths	1	Float_3dp	**B**		**B**	**r**
406. Polynomial A	11.0	-100.0 .. 100.0	10ths	1	Float_1dp	**B**		**B**	**r**
407. Polynomial B	50.0	-100.0 .. 100.0	10ths	1	Float_1dp	**B**		**B**	**r**
408. Polynomial C	39.0	-100.0 .. 100.0	10ths	1	Float_1dp	**B**		**B**	**r**
409. Polynomial D	0.0	-100.0 .. 100.0	10ths	1	Float_1dp	**B**		**B**	**r**
410. Normalised at 200%	350	0 .. 4096	12-bit raw	1	INT16	**B**		**B**	**r**
411. Normalised at 400%	540	0 .. 4096	12-bit raw	1	INT16	**B**		**B**	**r**
412. Normalised at 600%	700	0 .. 4096	12-bit raw	1	INT16	**B**		**B**	**r**
413. Normalised at 800%	830	0 .. 4096	12-bit raw	1	INT16	**B**		**B**	**r**
414. Normalised at 1000%	940	0 .. 4096	12-bit raw	1	INT16	**B**		**B**	**r**
Temperature Correction:									
415. Number of Temperatures	5	0 .. 7		1	UINT16	**B**		**B**	**r**
416. Number of Concentrations	2	0 .. 4		1	UINT16	**B**		**B**	**r**
417. 1st Temperature	-200	-600 .. 1000	10ths °C	1	Float_1dp	**B**		**B**	**r**
418. 2nd Temperature	0	-600 .. 1000	10ths °C	1	Float_1dp	**B**		**B**	**r**
419. 3rd Temperature	200	-600 .. 1000	10ths °C	1	Float_1dp	**B**		**B**	**r**
420. 4th Temperature	400	-600 .. 1000	10ths °C	1	Float_1dp	**B**		**B**	**r**
421. 5th Temperature	600	-600 .. 1000	10ths °C	1	Float_1dp	**B**		**B**	**r**
422. 6th Temperature		-600 .. 1000	10ths °C	1	Float_1dp	**B**		**B**	**r**
423. 7th Temperature		-600 .. 1000	10ths °C	1	Float_1dp	**B**		**B**	**r**

ModBus Register:	Typical Setting:	Valid Range:	Units:	Number of Registers:	Location Storage Size:	Service	Factory	Supervisor	Operator
424. Value at 1st temp, 1st conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
425. Value at 2nd temp, 1st conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
426. Value at 3rd temp, 1st conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
427. Value at 4th temp, 1st conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
428. Value at 5th temp, 1st conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
429. Value at 6th temp, 1st conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
430. Value at 7th temp, 1st conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
431. Value at 1st temp, 2nd conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
432. Value at 2nd temp, 2nd conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
433. Value at 3rd temp, 2nd conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
434. Value at 4th temp, 2nd conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
435. Value at 5th temp, 2nd conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
436. Value at 6th temp, 2nd conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
437. Value at 7th temp, 2nd conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
438. Value at 1st temp, 3rd conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
439. Value at 2nd temp, 3rd conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
440. Value at 3rd temp, 3rd conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
441. Value at 4th temp, 3rd conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
442. Value at 5th temp, 3rd conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
443. Value at 6th temp, 3rd conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
444. Value at 7th temp, 3rd conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
445. Value at 1st temp, 4th conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
446. Value at 2nd temp, 4th conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
447. Value at 3rd temp, 4th conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
448. Value at 4th temp, 4th conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
449. Value at 5th temp, 4th conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
450. Value at 6th temp, 4th conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r
451. Value at 7th temp, 4th conc'n		1 .. 4000	10ths %	1	Float_1dp	B		B	r

Note 1: The linearisation information (gas types and units) are only updated and used by the ModBus master. Their contents do not effect the function, behaviour or accuracy of the unit.

Note 2: The Gas Transfer Scaling constant is normally set by invoking the calibration operation 'Set_.Xfer' through the 'Cal_Control' register.

Note 3: The Gas Curve Lookup table may be transferred through more than one ModBus message or register.

Note 4: If there is no temperature correction, the number of temperatures (and the number of concentrations) should be set to 0. 1 is not permitted for the number of temperatures.

A6: Register Group 6: Installation Configuration

The following registers determine the configuration of a Nimbus unit for a particular installation. Installation configuration constants may be configured as indicated by a user with an appropriate access level.

Warning: Alterations to some of the following configuration constants will effect unit behaviour and may also effect accuracy. Ensure the unit is off-line before making alterations.

ModBus Register:	**Typical Setting:**	**Valid Range:**	**Units:**	**Number of Registers:**	**Location Storage Size:**	**Service**	**Factory**	**Supervisor**	**Operator**
Alarm Levels & Outputs:									
500. Level 2 Alarm Threshold	40.0	10.0 .. 200.0	10^{ths} % FSD	1	Float_1dp	**B**		**B**	**r**
501. Level 1 Alarm Threshold	20.0	10.0 .. 200.0	10^{ths} % FSD	1	Float_1dp	**B**		**B**	**r**
502. Level 1 Falling Alarm Threshold	-2.0	-10.0 .. 100.0	10^{ths} % FSD	1	Float_1dp	**B**		**B**	**r**
503. Level 2 Falling Alarm Threshold	-4.0	-10.0 .. 100.0	10^{ths} % FSD	1	Float_1dp	**B**		**B**	**r**
504. Alarm Threshold Hysteresis	2.0	1.0 .. 20.0	10^{ths} % FSD	1	Float_1dp	**B**		**B**	**r**
Status Indicator:									
510. Normal	G _ _ _			2	Bit Array 4	**B**		**B**	**r**
511. Test & Diagnostics	R Y G _			2	Bit Array 4	**B**		**B**	**r**
512. Soft Fault	Y _ _ _			2	Bit Array 4	**B**		**B**	**r**
513. Serial Comms Error	Y Y Y Y			2	Bit Array 4	**B**		**B**	**r**
514. Level 1 Falling Alarm	G G _ _			2	Bit Array 4	**B**		**B**	**r**
515. Level 1 Rising Alarm	R R _ _			2	Bit Array 4	**B**		**B**	**r**
516. Level 2 Falling Alarm	G _ G _			2	Bit Array 4	**B**		**B**	**r**
517. Level 2 Rising Alarm	R _ R _			2	Bit Array 4	**B**		**B**	**r**
518. Under Range / Flow	G G G _			2	Bit Array 4	**B**		**B**	**r**
519. Over Range / Flow	R R R _			2	Bit Array 4	**B**		**B**	**r**
520. Excessive Zero Drift	Y _ _ _			2	Bit Array 4	**B**		**B**	**r**
521. Optics Obsured	Y _ _ _			2	Bit Array 4	**B**		**B**	**r**
522. Warm-Up	Y G Y G			2	Bit Array 4	**B**		**B**	**r**
523. Inhibited	Y _ G _			2	Bit Array 4	**B**		**B**	**r**
524. Start Up & Restart	Y G Y G			2	Bit Array 4	**B**		**B**	**r**
525. Hard Fault	Y _ Y _			2	Bit Array 4	**B**		**B**	**r**
526. Optics Blocked	Y _ Y _			2	Bit Array 4	**B**		**B**	**r**
527. Integrity Fault	Y _ Y _			2	Bit Array 4	**B**		**B**	**r**
528. Detector or Amp Fail	Y Y Y _			2	Bit Array 4	**B**		**B**	**r**
529. Lamp Fail	Y Y Y _			2	Bit Array 4	**B**		**B**	**r**
530. Software Fail	Y Y Y Y			2	Bit Array 4	**B**		**B**	**r**
… cont …									

ModBus Register:	**Typical Setting:**	**Valid Range:**	**Units:**	**Number of Registers:**	**Location Storage Size:**	**Service**	**Factory**	**Supervisor**	**Operator**
Current Loop:									
540. Loop Source		GasDet | RefDet | LampIn | Supply | RegSupply | Temp | LampOut | GasTrough | GasPeak | GasStrength | GasScore | RefTrough | RefPeak | RefStrength | RefScore | Commissioning | Ratio | Slope | Obscuration | GasNorm | GasInst GasDamp | GasLevel | GasInst_4_20 | GasDamp_4_20 | GasLevel_4_20	enum		INT8	**B**		**B**	**r**
541. Loop Commissioning Level	4.0	0.0 .. 25.5	10^{ths} mA	1	Float_1dp	**B**		**B**	**r**
542. Loop Inhibit Level	4.0	0.0 .. 25.5	10^{ths} mA	1	Float_1dp	**B**		**B**	**r**
543. Loop Scale Zero	0.0	-100.0 .. 100.0	10^{ths} % Unit	1	Float_1dp	**B**		**B**	**r**
544. Loop Scale Full	100.0	0.0..1000.0	10^{ths} % Unit	1	Float_1dp	**B**		**B**	**r**
545. (reserved)									
546. (reserved)									
547. Test & Diagnostics	2.0	0.0, 2.0, 4.0 or 24.0	10^{ths} mA	1	Float_1dp	**B**		**B**	**r**
548. Warm Up	2.0	0.0, 2.0 or 4.0	10^{ths} mA	1	Float_1dp	**B**		**B**	**r**
549. Calibration Inhibit	4.0	0.0, 2.0 or 4.0 or 25.5	10^{ths} mA	1	Float_1dp	**B**		**B**	**r**
550. Start Up & Restart	0.0	0.0, 2.0, 4.0 or 24.0	10^{ths} mA	1	Float_1dp	**B**		**B**	**r**
551. Soft Fault	0.0	0.0, 2.0 or 24.0	10^{ths} mA	1	Float_1dp	**B**		**B**	**r**
552. Under Range / Flow	2.0	0.0, 2.0, 3.0 or 4.0	10^{ths} mA	1	Float_1dp	**B**		**B**	**r**
553. Over Range / Flow	24.0	0.0, 20.0, 21.0 or 24.0	10^{ths} mA	1	Float_1dp	**B**		**B**	**r**
554. Excessive Zero Drift	0.0	0.0 or 2.0	10^{ths} mA	1	Float_1dp	**B**		**B**	**r**
555. Optics Obscured	2.0	0.0, 2.0 or 24.0	10^{ths} mA	1	Float_1dp	**B**		**B**	**r**
556. Hard Fault	0.0	0.0 or 24.0	10^{ths} mA	1	Float_1dp	**B**		**B**	**r**
557. Optics Blocked	0.0	0.0 or 24.0	10^{ths} mA	1	Float_1dp	**B**		**B**	**r**
558. Integrity Fault	0.0	0.0 or 24.0	10^{ths} mA	1	Float_1dp	**B**		**B**	**r**
559. Detector or Amp Fail	0.0	0.0 or 24.0	10^{ths} mA	1	Float_1dp	**B**		**B**	**r**
560. Lamp Fail	0.0	0.0 or 24.0	10^{ths} mA	1	Float_1dp	**B**		**B**	**r**
561. Software Fail	0.0	0.0 or 24.0	10^{ths} mA	1	Float_1dp	**B**		**B**	**r**
Zero Suppression:									
570. Zero Suppress Min	1.0	-10.0 .. 25.0	10^{ths} % FSD	1	Float_1dp	**B**	**r**	7	7
571. Zero Suppress Max	5.0	-10.0 .. 50.0	10^{ths} % FSD	1	Float_1dp	**B**	**r**	7	7

Appendix B: Nimbus ModBus Extended Register Map

The following register groups are for use by diagnostic, service and factory level users only.

NB: **Publication of this appendix is restricted to internal developers and production engineers**.

B1: Register Group 7: Service and Diagnostics

The following registers are used for diagnostic and service monitoring and testing. Read and write permissions depend upon the current user access level as indicated. Alterations to these registers are only permitted in diagnostic mode.

ModBus Register:	Typical Setting:	Valid Range:	Units:	Number of Registers:	Location Storage Size:	Service	Factory	Supervisor	Operator
Process Monitoring & Inhibits:									
526. Det0 Inhibit	0		flags	1	UINT16	r	r	7	7
527. Det1 Inhibit	0		flags	1	UINT16	r	r	7	7
528. LampIn Inhibit	0		flags	1	UINT16	r	r	7	7
529. Supply Inhibit	0		flags	1	UINT16	r	r	7	7
530. Reg Supply Inhibit	0		flags	1	UINT16	r	r	7	7
531. Temp Inhibit	0		flags	1	UINT16	r	r	7	7
532. Signal Process Inhibits	0		flags	1	UINT16	r	r	7	7
533. Measurement Inhibits	0		flags	1	UINT16	r	r	7	7
534. Damping Inhibit	0		flags	1	UINT16	r	r	7	7
535. Loop Inhibit	0		flags	1	UINT16	r	r	7	7
536. TSig Inhibit	0		flags	1	UINT16	r	r	7	7
537. Lamp Inhibit	0		flags	1	UINT16	r	r	7	7
538. LED Inhibit	0		flags	1	UINT16	r	r	7	7
539.									
540.									
541.									
542.									
543.									
544.									
545.									
… cont …									

ModBus Register:	**Typical Setting:**	**Valid Range:**	**Units:**	**Number of Registers:**	**Location Storage Size:**	**Service**	**Factory**	**Supervisor**	**Operator**
Gas Level Monitoring & Test:									
546. Gas Level		-10.0 .. 1000.0	10ths % FSD	1	Float_1dp	r	r	7	7
547. Damped Gas Level		-10.0 .. 1000.0	10ths % FSD	1	Float_1dp	r	r	7	7
548. Instantaneous Gas Reading		-10.0 .. 1000.0	10ths % FSD	1	Float_1dp	r	r	7	7
549. Normalised Gas Reading		-320.00 .. 320.00	100ths %	1	Float_2dp	r	r	7	7
550. Obscuration Factor		0.0 .. 100.0	10ths %	1	Float_1dp	r	r	7	7
551. Raw Gas Ratio		0 .. 4095	12-bit raw	1	INT16	r	r	7	7
552. Gas Signal Strength		0 .. 4095	12-bit raw	1	INT16	r	r	7	7
553. Reference Signal Strength		0 .. 4095	12-bit raw	1	INT16	r	r	7	7
554. Gas Signal Score		0 .. 4095	12-bit raw	1	INT16	r	r	7	7
555. Reference Signal Score		0 .. 4095	12-bit raw	1	INT16	r	r	7	7
Gas Trend Monitoring:									
556. Gas Rate of Change		-1000.0 .. 1000.0	10ths % FSD per Min	1	Float_1dp	r	r	7	7
557. Gas Score Ave		+- 2e9	raw	2	INT32	r	r	7	7
558. Ref Score Ave		+- 2e9	raw	2	INT32	r	r	7	7
559. Gas Score Delta		+- 2e9	raw	2	INT32	r	r	7	7
560. Ref Score Delta		+- 2e9	raw	2	INT32	r	r	7	7
561. Gas Score Sum		+- 2e9	raw	2	INT32	r	r	7	7
562. Ref Score Sum		+- 2e9	raw	2	INT32	r	r	7	7
563. Gas Score Max		0 .. 4095	12-bit raw	1	INT16	r	r	7	7
564. Gas Score Min		0 .. 4095	12-bit raw	1	INT16	r	r	7	7
565. Ref Score Max		0 .. 4095	12-bit raw	1	INT16	r	r	7	7
566. Ref Score Min		0 .. 4095	12-bit raw	1	INT16	r	r	7	7
567. Gas Ratio Sum		+- 2e9	12-bit raw	2	INT32	r	r	7	7
568. Readings Count		0 .. 40	raw	1	INT8	r	r	7	7
569.									
570.									
571.									
572.									
573.									
574.									

ModBus Register:	Typical Setting:	Valid Range:	Units:	Number of Registers:	Location Storage Size:	Service	Factory	Supervisor	Operator
575.									
… cont …									
Input Monitoring & Test:									
576. Lamp Sense	20.0	0.0 .. 200.0	10^{ths} mA	1	Float_1dp	r	r	7	7
577. Supply Voltage	24.0	5.00 .. 40.00	100^{ths} V	1	Float_2dp	r	r	7	7
578. Reg Supply Sense	5.0	4.000 .. 6.000	1000^{ths} V	1	Float_3dp	r	r	7	7
579. Temperature	20.0	-50.0 .. 100.0	10^{ths} ºC	1	Float_1dp	r	r	7	7
580. Raw Lamp Sense Input	51	0 .. 1024	10-bit raw	1	INT16	r	r	7	7
581. Raw Supply Voltage Input	489	0 .. 1024	10-bit raw	1	INT16	r	r	7	7
582. Raw Reg Supply Input	561	0 .. 1024	10-bit raw	1	INT16	r	r	7	7
583. Raw Temperature Input	157	0 .. 1024	10-bit raw	1	INT16	r	r	7	7
584.									
585.									
Current Loop & Test Signal Diagnostics:									
586. Current Loop Source			enum		INT8	D	r	7	7
587. Current Loop Output	4.0	0.0 .. 25.0	10^{ths} mA	1	Float_1dp	D	r	7	7
588. Raw Current Loop Output	40	0 .. 255	8-bit raw	1	UINT8	D	r	7	7
589.									
590. Test Signal Source			enum		INT8	D	r	7	7
591. Test Signal Output		0.0 .. 100.0	10^{ths} %	1	Float_1dp	D	r	7	7
592. Raw Test Signal Output		0 .. 255	8-bit raw	1	UINT8	D	r	7	7
593.									
594.									
595.									
Lamp Drive Diagnostics:									
596. Lamp Cycle Rate	4	0 .. 8	per Sec	1	INT8	D	r	7	7
597. Lamp Gain	100.0	0.0 .. 100.0	10^{ths} %	1	Float_1dp	D	r	7	7
598. Lamp Drive Duty Cycle	10.0	0.0 .. 100.0	10^{ths} %	1	Float_1dp	D	r	7	7
599. Raw Lamp Drive Duty Cycle	6554	0 .. 65535	16-bit raw	1	UINT16	D	r	7	7

B2: Register Group 8: Factory Configuration

The following registers are used for factory configuration purposes only. Read and write permissions depend upon the current user access level as indicated. Alterations to these configuration are only permitted in diagnostic mode.

ModBus Register:	**Typical Setting:**	**Valid Range:**	**Units:**	**Number of Registers:**	**Location Storage Size:**	**Service**	**Factory**	**Supervisor**	**Operator**
Damping:									
2000.Readings Follow	16		Readings	1	INT8	B	r	7	7
2001.Readings Slow	4		Readings	1	INT8	B	r	7	7
2002.Readings Med	2		Readings	1	INT8	B	r	7	7
2003.Readings Fast	1		Readings	1	INT8	B	r	7	7
2004.Threshold Follow	3.7		10ths % FSD	1	Float_1dp	B	r	7	7
2005.Threshold Slow	7.5		10ths % FSD	1	Float_1dp	B	r	7	7
2006.Threshold Med	15.0		10ths % FSD	1	Float_1dp	B	r	7	7
2007.Threshold Fast	100.0		10ths % FSD	1	Float_1dp	B	r	7	7
2008.Factor Follow	10.0		10ths % FSD	1	Float_1dp	B	r	7	7
2009.Factor Slow	20.0		10ths % FSD	1	Float_1dp	B	r	7	7
2010.Factor Med	50.0		10ths % FSD	1	Float_1dp	B	r	7	7
2011.Factor Fast	100.0		10ths % FSD	1	Float_1dp	B	r	7	7
2012.									
2013.									
2014.									
2015.									
2016.									
2017.									
2018.									
2019.									
Calibration:									
2020.Cal Span Min	82	0 .. 4095	12-bit raw	1	INT16	B	r	7	7
2021.									
2022.									
2023.									
2024.									
… cont …									

ModBus Register:	Typical Setting:	Valid Range:	Units:	Number of Registers:	Location Storage Size:	Service	Factory	Supervisor	Operator
Auto Zeroing:									
2025.						B	r	7	7
2026.									
2027.									
2028.									
2029.									
2030.									
2031.									
2032.									
2033.									
2034.									
2035.									
2036.									
2037.									
2038.									
2039.									
Diagnostic Functions:									
2040.Diagnostics Timeout	15	0 .. 255	Sec	1	UINT8	B	r	7	7
2041.									
2042.									
2043.									
2044.									