NEODYM

PicoKnowz™

Gas Sensing Module with I²C™ Interface

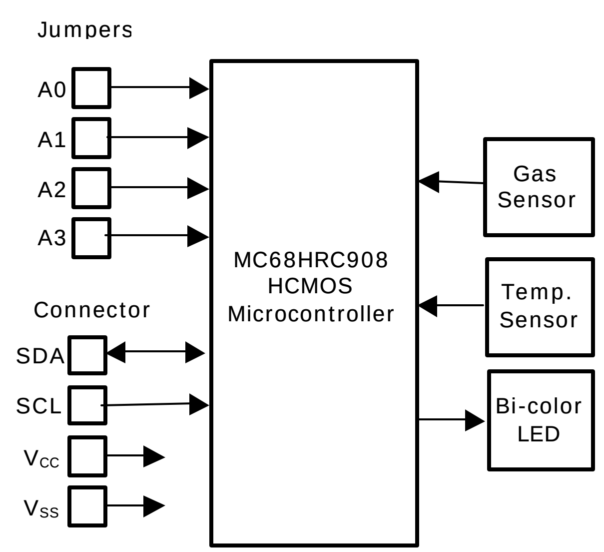
FEATURES

- MOS Sensor & HCMOS microcontroller
- Hydrogen, methane and propane versions
- 0 to 50% LEL measurement
- 50-100 ppm logical resolution
- 30 seconds start-up time
- 4 seconds response time to T90
- 10 seconds recovery time to T10
- I^2C digital interface (4 Kbits/s)
- 4-bit (1-of-16) jumper addressing
- *PK-Port*™ compatible via I^2C master adapter
- 4-pin 0.1" male header for power & I/O
- Digital FLASH-based calibration
- Each device factory pre-calibrated
- Field re-programmable firmware
- Bi-color LED status indicator
- -20 to +70 Celsius active compensation
- Sensor & temperature error detection
- Fail-safe reliability features
- 5VDC @ 80mA (400 mW) operation
- 37mm x 20mm x 11mm circuit size

DESCRIPTION

The Neodym PicoKnowz™ is compact, intelligent gas sensing module intended for safety applications in microprocessor-based systems. Linear measurement of hydrogen, methane and propane concentrations is possible up to 50% of LEL with 50 to 100 ppm resolution. Each device is factory calibrated for accuracy and linearity. Calibration values are FLASH memory-based and are field-adjustable via Neodym's *PK-Port*™ PC interface. Gas readings and status may be continuously read out via the digital I^2C bus interface. The device operates at 5VDC, consumes about 400mW, and features active temperature compensation from –20 to +70 Celsius. Custom form factors, connector types and mounting provisions are available by special order.

BLOCK DIAGRAM



I^2C is a trademark of Philips Corporation

1 - FUNCTIONAL DESCRIPTION

1.1 - OVERVIEW

Neodym PicoKnowz™ gas sensors are comprised of an HCMOS microcontroller, a MOS gas sensing element, a semiconductor temperature sensor, a bi-color LED and various support components.

The system is independent and performs its gas sensing functions and indications without any outside intervention. The system starts up automatically each time that power is applied and continues to function until power is removed. The communications port provides a passive interface for device interrogation and other remote access functions.

Each time that power is applied the device enters a brief warm-up state after which active gas sensing functions commence. Gas concentrations and sensing state indications become available after the warm-up period has elapsed.

Gas sensor signals are continuously sampled by an 8-bit A-D subsystem and are digitally filtered to reject burst noise and other spurious events. The gas sensor signal is actively compensated over the operating range using data from a co-located temperature transducer. The filtered and compensated signal is then stripped of its baseline component and is spanned according to its memory-resident calibration values. The normalized signal has a logarithmic response to gas and a table look-up algorithm is applied to the signal to produce linear readings of gas concentration that may be accessed in real-time via the interface bus.

1.2 - DEVICE STATES

WARM-UP

The warm-up state is entered whenever the device is powered-on and lasts approximately 30 seconds. This period permits the gas sensor to reach its proper operating temperature and allows the sensor signal to stabilize after periods of inactivity. During the warm-up state gas sensing is not active and zero value gas readings are returned. A master command can cause the warm-up state to be terminated at any time, if appropriate. The LED blinks green/off during the warm-up period.

NORMAL

The normal state is entered upon the expiry of the warm-up period. During the normal state the LED remains steady green. The normal state is maintained while the power level is valid and while there is an absence of error conditions or actionable gas concentrations. All other states return to the normal state upon their expiry or resolution.

WARNING

The warning state reports a gas concentration that is a specific percentage of the alarm state. This action percentage is stored in memory and is usually configured at order time. *PK-Port*™ may be used to modify the action level. During the warning state the LED blinks red/green.

ALARM

The alarm state is entered when the gas concentration reaches or exceeds a predetermined threshold. The action level is stored in memory as is usually configured at order time although it may be reconfigured using *PK-Port*™. During the alarm state the LED blinks red/off.

ERROR

The error state is asserted whenever the device is prevented from providing reliable readings. The error sources are gas sensor failure/removal, temperature out of bounds and loss of firmware integrity detectable via a checksum failure. During the error state gas concentration readings are invalid and return full-scale values to assure failsafe operation. During the error state the LED remains off and briefly pulses red about every 10 seconds. Normal device operation resumes dynamically when the error condition is resolved.

Please note: The device features a Low Voltage Inhibit function and a Computer Operating Properly watchdog timer. A fault from either source does not produce an error state but rather device reset. If such faults persist they are detectable via continuous return to the warm-up state.

TABLE 1.2.1 – Device States Summary

State	Stimulus	Gas Reading	LED Indication
Warm-up	Power-on, COP time-out, software error	Zero reading	Blink green/off
Normal	Ambient conditions	Valid	Steady green
Warning	Intermediate gas concentration	Valid	Blink red/green
Alarm	Alarm threshold reached/exceeded	Valid	Blink red
Error	Sensor failure, temperature error	Full scale	Off, pulse red

1.3 - READINGS

Readings of gas concentration, local temperature and other numeric data are available via the interface bus. Please see the interface section for access details.

GAS CONCENTRATION

The gas concentration is provided using logical reading units. Reading units allow the representation of large ppm values using 8-bit numbers. Each reading unit is equivalent to the logical, internal resolution of the device and can vary according to gas type.

TABLE 1.3.1 – Sensing Capability Summary

Gas	Resolution	Range
Hydrogen	100 ppm	0 – 20,000 ppm
Methane	100 ppm	0 – 25,000 ppm
Propane	50 ppm	0 – 10,000 ppm

For example, a concentration of 12,500 ppm is represented as 125 reading units if the logical resolution is 100 ppm. To calculate the actual gas concentration, multiply the reported reading units with the device resolution. The full-scale (saturated) gas reading is the top range plus one reading unit. For example, in the case of hydrogen, the device will not read out more than a value of 201 even if the gas concentration is significantly above 20,000 ppm.

Please note that the effective resolution of the gas sensor is different from the logical resolution and varies according to gas concentration. This is due to the exponential response of the gas-sensing element. Sensitivity at low concentrations may be as high as 1 ppm and can drop to 1,000 ppm at a concentration of 10,000 ppm. The device's linearization algorithm insulates the user from the variability in the sensing element's inherent resolution.

The gas sensor signal is sampled every 10 milliseconds and is software-averaged to filter out burst noise and transient gas events. Normalized gas readings are recalculated every 0.5 seconds and may be read out as often as required.

TEMPERATURE

The local temperature reading is provided to help diagnose the possible cause of an error state. The temperature value is returned as an absolute number where a value of zero represents –50 Celsius. To convert the temperature reading value into degrees Celsius, subtract 50. The returned value changes by two units to reflect the inherent resolving capability of two degrees. Please note that while the temperature sensor is capable of reading from –50 to +125 Celsius, the permitted operating range of the sensing module is abbreviated. Please consult the specifications section. The temperature reading is updated approximately every 500mS. Please note: the reported temperature may be a few degrees above the expected ambient temperature due to the transducer's close proximity to the heat-producing gas sensing element.

STATE VALUE

Those users making their own response decisions based solely on the proportional gas concentration reading may ignore the normal, warning and alarm state indications. However, the warm-up and error states should be continuously evaluated to determine whether the gas reading is valid.

TABLE 1.3.1 – State Codes Summary

State	Numeric Code
Normal	0
Warning	1
Alarm	2
Error	3
Warm-up	4
(Undefined)	(Other)

Whereas gas readings are recalculated every 0.5 seconds, the device state is subject to software filtering to suppress jitter under boundary conditions. The applied hysteresis calls for a new state to be held for a total of four continuous 0.5-second periods before the new state is asserted.

1.4 – SENSING PERFORMANCE

Sensing performance is only guaranteed over the range of electrical and environmental conditions cited in the specifications sections. The following remarks are provided for general guidance.

ACCURACY

Sensing accuracy is dependent on proper device calibration and the absence of abusive handling. Please see the Use, Care & Maintenance section for recommended handling and usage procedures.

Accuracy is defined as the ability of the sensor to correctly indicate the real gas concentration – whether from the point of view of short-term repeatability or long-term stability.

The specified accuracy error budget takes into account the following factors.

- Supply voltage variation
- Sensing and calibration resolution
- Inherent non-linearity of gas sensor signal
- Application of reading hysteresis
- Sampling jitter due to electrical noise
- Math rounding-off errors

For advanced sensing performance please consult the gas sensing element's manufacturer datasheet: Figaro Engineering Inc. – www.figarosensor.com – product part number TGS2610.

RESOLUTION

The sensing element's response to increasing gas concentrations is a logarithmic function. The system uses a table look-up and interpolation algorithm to provide linear output readings. Whereas the sensing element's sensitivity is better than 25 ppm at gas concentrations of less than 1,000 ppm, the resolving capability drops off rapidly at higher concentrations. The system provides reading indications using 8-bit logical reading units of fixed granularity. The Performance Specifications section cites the physical resolution of the sensing element over various gas concentrations. Care should be taken to establish alarm points and action levels at concentrations where the resolving capability is adequate.

RESPONSE TIME

Whereas the raw gas signal response and recovery time is virtually immediate, the system employs software averaging and hysteresis to filter out spurious gas events and to prevent metastable indications. Please refer to the Electrical Specifications section for these AC characteristics.

ENVIRONMENTAL REQUIREMENTS

The employed sensing element is a tin dioxide type and senses gas based on superficial adsorption of gas molecules. In order for this reversible chemical reaction to take place reliably, the specified minimum relative humidity and atmospheric oxygen levels must be maintained.

CALIBRATION

All devices are individually factory calibrated and certified prior to delivery. Sensor calibration is performed digitally and values are stored in FLASH memory. Baseline offsets (zero) may be captured via a command from the bus master (please see the Interface section). User/field modification of the Span value is only possible via the *PK-Port*™ interface and requires exposure of the device to calibration reference gas in a chamber of known volume.

Please note: Do **not** use pre-mixed calibration test gas with zero moisture content to perform calibrations or accuracy testing.

1.5 – PERFORMANCE SPECIFICATIONS

Note: The following parameters apply under normal operating conditions stipulated in the Electrical Specifications sections.

TABLE 1.5.1 – Sensing Characteristics

Parameter	Min	Typ	Max	Unit	Note
Sensing range Hydrogen: Methane: Propane:	 - - -	 - - -	 20,000 25,000 10,000	ppm	
Resolution 0-5000 ppm: 5000-10,000 ppm: 10,000-15,000 ppm: 15,000-25,000 ppm:	 - - - -	 100 300 1,000 2,000	 - - - -	ppm	
Accuracy Hydrogen: Methane: Propane:	 +/- 2,000 +/- 2,500 +/- 1,000	 +/- 600 +/- 800 +/- 400	 - - -	ppm	1
Linearity Hydrogen: Methane: Propane:	 +/- 1,000 +/- 1,200 +/- 500	 +/- 300 +/- 400 +/- 200	 - - -	ppm	
Overdose detection	90,000	100,000	120,000	ppm	
Start-up time	27	30	33	Sec.	
Response time (T90)	-	4	10	Sec.	
Recovery time (T10)	-	10	20	Sec.	

TABLE 1.5.2 – Environmental requirements

Parameter	Min	Typ	Max	Unit	Note
Relative humidity	10	-	95	% R.H.	2
Operating temperature	-20	-	+70	Deg. C.	
Altitude/pressure	0.9	-	1.1	Atmos.	
Flow rate	-	-	3	m/sec.	
Atmospheric oxygen	10	21	30	% vol.	

Notes: 1. Accuracy specified at ½ FSD. Please see Sensing Performance section for error budget items.
2. Non-condensing

1.6 – RELIABILITY FEATURES

Various fault detection features have been implemented to provide indication of unacceptable sensing conditions. Devices are configured at order time or via *PK-Port*™ to respond to error conditions by simply asserting the error state, or by triggering the alarm state.

SENSOR ERROR

This error is triggered by the removal of the sensor, or a break in the heater and/or electrode circuits. Heater damage due to gas overdoses can also trigger this error. The error state is released when the sensor is replaced.

TEMPERATURE ERROR

Triggered when the operating temperature is above or below levels for which compensation data is available. The error state is released automatically when the temperature returns to the acceptable range.

OVERDOSE RESPONSE

The sensor may be permanently damaged by even brief exposure to extremely high concentrations of target gas (typically >10% volume). The effect of overexposure is usually decreased sensor sensitivity. In most cases such permanent damage is detectable from the signal signature and will trigger an error state. However, the damage from brief but frequent overexposures can be cumulative and may not manifest itself immediately as a sensor failure. Detection of such degradation in accuracy is only possible by testing with a reference gas sample. For this reason, the system is designed to err on the side of safety by reacting to any overexposure events that last more than two seconds. Two response modes are configurable: 1. Self-adjust the calibration values and alarm level for high sensitivity, or 2. Set a flag in FLASH memory to assert a persistent error state.

Either situation is resolvable using *PK-Port*™ access once a calibration check has determined that the sensor has not been degraded beyond acceptable performance levels.

COP TIME-OUT

Electrostatic discharges or other electrical events that may alter system RAM and cause improper program operation will cause the Computer Operating Properly watchdog timer to reset the system (return to the warm-up state).

LOW VOLTAGE INHIBIT

The device will remain in the reset state if the supply voltage is below 4 VDC (nominal). Unstable system power levels may manifest themselves as a continuous return to the warm-up state.

MEMORY CHECKSUMS

Abnormal electrical conditions that may cause a loss of integrity of the FLASH memory are detected via checksum calculations after each power-on. If the firmware checksum value is incorrect then the system will remain in the error state. A similar check and response applies to calibration and configuration values.

BOUND OFFSET VALUE

The system prevents “zeroing-to-death” conditions by rejecting attempts to capture an offset in high gas concentrations. The result register returns a failure code if an offset capture request is not successful.

1.7 – USE, CARE & MAINTENANCE

PicoKnowz™ sensors can provide reliable readings for many years if properly handled and maintained. To derive the maximum serviceable lifetime from the device, please observe the following recommendations.

CHECK CALIBRATION PRIODICALLY

Although the device features several self-diagnosing functions, the only direct method to check accuracy and proper operation is via exposure of the sensor to a reference gas concentration and observing it to read correctly. Devices are delivered factory calibrated and certified, but the accuracy of the unit can and will degrade over time – especially if used in corrosive or hostile environments. It is recommended that calibration checking should be performed as often as is practical and no less frequently than once every six months.

GENERATING REFERENCE GAS

The recommended method for generating calibration test gas mixtures is to dilute pure target gas with clean, normal air in a leak-free chamber of fixed, known volume. A simple procedure is to inject a ratiometric amount of pure target gas using a syringe into a sealed plastic lunch container. EG 50cc of pure gas injected into a chamber with a net volume of 5 liters produces a concentration of 10,000 ppm. Gentle shaking or an enclosed fan may be used to assure proper diffusion of the gas mixture. In applications where it is impractical to immerse the module in such a gas mixture, a pump or aspirator may be used to flow the gas mixture over the sensor. Locate the sensor away from the injection port to avoid high concentration gas plumes from triggering the overexposure detection mechanism.

NO DESICCATED PRE-MIX CAL GAS

Pre-mixed calibration test gas that has been stripped of moisture content and designed for other sensing chemistries is not appropriate for PicoKnowz™ testing and calibration. The employed MOS sensor requires a minimum 10% R.H. moisture content to operate properly.

NOT A GENERAL LEAK DETECTOR

The device is to be used as a monitor in safety applications where high concentration gas releases are rare. If the device is employed as a general leak detector and is exposed to saturation levels of gas, the overexposure mechanism will be triggered. Very high gas concentrations can permanently damage the sensor.

INTEFERENCE GAS

The employed MOS sensor is not specific to any one combustible gas. Modules calibrated for (EG) hydrogen applications will read accurately in the presence of homogeneous hydrogen gas/air mixtures, but will also produce readings in the presence of other inorganic and organic vapors. Heterogeneous gas mixtures have a synergistic effect on the sensor, and in the absence of a target gas presence, the interference gases will manifest themselves as 'false' readings.

AVOID BUMP TESTING

Do not use bursts of high gas concentrations to test whether the sensor is 'alive'. Especially avoid exposing the sensor to blasts of butane gas – EG from a disposable cigarette lighter. The proper testing procedure is to expose the sensor to a reference gas whose concentration is stable and falls within the rated sensing range. A properly operating device reads out the concentration of the reference gas within the limits of the specified accuracy.

AVOID SENSOR OBSTRUCTION

The sensor samples the atmosphere based on the diffusion of gas through the mesh into the internal cavity. Please locate the sensor such that it is not pressed against a surface that will obstruct gas flow, and prevent materials such as dust and lint from clogging the sensor mesh.

PROPER PLACEMENT

For earliest warning of a possible gas hazard, locate the module nearest to the most likely source of the gas leak. Also take into account the relative density of the gas of interest. In the cases of hydrogen and methane that are lighter than air, the module should be located above the leak source. The opposite applies in the case of propane.

AVOID EXPOSURE TO SILICONE VAPORS

Sealants such as caulking compounds, hoses, etc. may contain silicones. These items may continue to off-gas silicone vapors indefinitely, even after full curing – and especially under high temperature conditions. Extra care should be taken when testing the sensor in environmental chambers – many of which use silicones for thermal insulation. The effect of silicone vapors on the sensor is to make it gradually more sensitive to hydrogen, and **less** sensitive to methane and propane.

OTHER DELETERIOUS AGENTS

Avoid exposure to high concentrations (>5,000 ppm) of carbon monoxide (CO). Such exposures lead to short-term sensor poisoning that manifests itself as elevated gas readings. Recovery from high CO exposures entails several hours of burning-off in clean air.

Avoid exposure to high concentrations (>50,000 ppm) of halogenated hydrocarbons such as solvents and refrigerant gases. As with elemental halogen family gases, they can corrode the sensor, lead to short-term poisoning, and reduce the lifetime.

Avoid exposure to other corrosive environments such as salt-containing sea spray. For coastal and marine applications, modules are available with acrylic conformal coating to preserve circuit lifetime. However, the buildup of a salt crust over the sensor mesh will impede gas diffusion and will affect reliability.

NO STRONG ELECTROMAGNETIC FIELDS

While the circuit is relatively low impedance, avoid locating the sensor in the immediate vicinity (<10 cm) of strong and fluctuating field sources such as fans, pumps, motors, RF transmitters, etc. Close proximity to such fields may result in spurious gas readings. Also, make sure that the module's power supply is adequately decoupled from fluctuations caused by the switching of large external loads.

2 - INTERFACE

2.1 – ELECTRICAL SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Note: Maximum ratings are the extreme limits to which the device can be exposed without permanent damage. The device is not guaranteed to operate properly at maximum ratings. Sensing accuracy deteriorates rapidly at 4.75V < Vcc > 5.25V.

TABLE 2.1.1 - Absolute Maximum Ratings

Parameter	Symbol	Value	Unit
Supply voltage	V_{cc}	6.0	V
Input voltage	V_{IN}	V_{SS}-0.3 to V_{CC}+0.3	V
SDAT current	I_{SDA}	25	mA
Storage temperature	t_{STG}	-40 to +125	Deg. C.

FUNCTIONAL OPERATING RANGE

TABLE 2.1.2 – Operating Range

Parameter	Symbol	Value	Unit
Operating voltage range	V_{cc}	4.75 to 5.25	V
Operating temperature range	t_{OP}	-20 to +70	Deg. C.

DC CHARACTERISTICS

TABLE 2.1.3 – DC Characteristics

Parameter	Symbol	Min	Typ	Max	Unit
Output high voltage (I_{LOAD}=-2.0mA)	V_{OH}	V_{CC}-0.8	-	-	V
Output low voltage (I_{LOAD}=1.6mA)	V_{OL}	-	-	0.4	V
Input high voltage	V_{IH}	0.7 x V_{CC}	-	V_{CC}	V
Input low voltage	V_{IL}	V_{SS}	-	0.3 x V_{SS}	V
Vcc supply current	I_{CC}	-	75	85	mA
Low voltage inhibit reset voltage	V_{LVR}	3.6	4.0	4.4	V
Power-on reset rearm voltage	V_{POR}	0	-	100	mV
I/O pin capacitance	C_{IO}	10	12	15	pF
I/O pin pullup resistors	R_{PU}	-	10	-	K-Ohm

AC CHARACTERISTICS

TABLE 2.1.4 – AC Characteristics

Parameter	Symbol	Min	Typ	Max	Unit
Fundamental operating frequency	f_{OP}	8.8	9.8	10.8	MHz
Power-on reset time	T_{PRES}	0.9	1	1.1	mS
COP watchdog time-out time	T_{CTO}	29	32	35	mS
COP time-out reset time	T_{CRES}	90	100	110	uS
Warm-up time	T_{WARM}	27	30	33	S
Offset value capture time	T_{FWT}	2.7	3	3.3	mS
ADC sampling rate	T_{SAMP}	9	10	11	mS
Signal averaging period	T_{AVG}	450	500	550	mS
Reading register update rate	T_{REF}	450	500	550	mS
State debounce period	T_{DEB}	1.8	2	2.2	S
LED blink rate	T_{LBR}	180	200	220	mS
LED pulse on/off rate	T_{LPR}	0.18/9	0.2/10	0.22/11	S
I_2C bus speed	S_{BUS}	-	-	4	Kbits/S

SIGNAL DEFINITIONS

TABLE 2.1.5 – Input/Output Signals

Name	Function	Description
SCLK	Bus Clock	Schmidt trigger input controlled by the bus master. Input data is sampled on falling edges. Falling edges transition output data.
SDAT	Bus Data	Input during control byte and address field writes by the master. It remains an input during data writes by the master. The line becomes an open drain output during master reads or when issuing ACKs.
A3:A0	Address	Four local hardware slave address inputs sampled dynamically during each master access. These lines may be strapped to V_{CC} or V_{SS} (positive logic) to determine the slave address, or may be wired to external logic for dynamic addressing.

2. 2 – BUS OPERATION

GENERAL

The bus is I^2C specification compliant with respect to signal definitions, polarities and relationships. Only a subset of the specification is employed to facilitate the simple, random read/write operations that are supported by the module. The module's clock signal is always an input and the device always responds as a slave.

BANDWIDTH

The gas sensing system employs software averaging that refreshes dynamic register contents approximately every 500mS. Therefore, it is not practical to read the module's registers at usual I^2C bus rates. Furthermore, the module's processor may, from time to time, be engaged in timing-critical operations that may prevent immediate servicing of the bus. For these reasons, the bus data transfer rate has been throttled to approximately 4 Kbits/second (250uS clocks).

Please note: An access during a interval when the module is performing timing-critical functions may result in an absent ACK when the master expects it. In such cases, the transaction should be reattempted and the very next access will be serviced. Attempts to access the device using timing that is too fast may result in unpredictable behavior or invalid data. If your application can support it, please run clocks and observe data set-up and hold times that do not push the absolute maximum limits; a 1 KHz maximum clock rate is best.

DEVICE ADDRESSING

The four address inputs (A3:A0) are used as hardware device select lines. The 4-bit code is compared to the select bits in the control byte during each data frame to determine whether a particular device has been addressed. Only the device whose control byte address field matches the address line states responds with ACKs, data and command execution. Care must be taken that no two slaves have the same hardware address or bus clashes will result.

DATA FRAME STRUCTURE

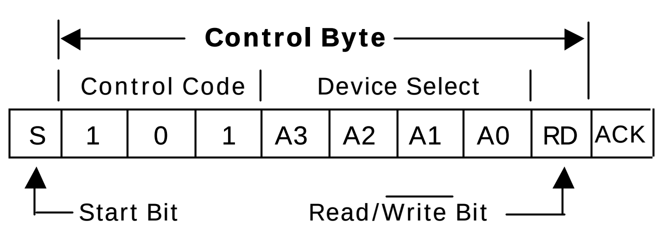
The master determines the structure and timing of data frames. The framing rate may range from DC up to the maximum supported clock rate of 250uS without affecting the scheduling of the module's gas sensing functions.

All transactions must be preceded by a START condition followed by a control field, an address field and a data field. All fields are eight bits in length not including a possible ACK bit. Most significant bits of data values are issued first. All transactions must be terminated with a STOP condition. The required bus idle time should be observed to allow transactions to processed by the slave. Attempts to access the slave too rapidly may result in ignored requests.

CONTROL BYTE STRUCTURE

The following is the control byte structure. Each data transaction must be preceded by a control byte to perform device selection (addressing) and to determine the data direction of the operation. The control code identifies the slave as a PicoKnowz™ module on a diverse I_2C bus. Only the slave whose hardware address lines match the device select field will respond. For clarity, the control byte is shown with the START bit that must precede each transaction and with the ACK bit that will be issued by a properly addressed slave.

FIGURE 2.2.1 – Control Byte Structure



READ OPERATION FRAMING

The master reads a module register by issuing a START condition followed by a control byte with the READ bit **set**. If the device is properly addressed and not busy, it will pull the data line low for the duration of the ACK bit. The master then issues the address of the register of interest and again observes the slave to ACK. After the ACK, the slave will respond with 8 bits of data. The slave does not expect the master to acknowledge the read data and thus the master need not issue an ACK. However, the master should terminate the transaction by asserting the STOP condition after the 8^{th} bit of data. Failure of a properly-addressed slave to respond with an ACK after the control byte or address byte signals that the slave is busy and that the transaction should be reattempted.

Please see FIGURE 2.2.2

WRITE OPERATION FRAMING

The master writes to a module register by issuing a START condition followed by a control byte with the READ bit **clear**. If the device is properly addressed and not busy, it will pull the data line low for the duration of the ACK bit. The master then issues the address of the register of interest and again observes the slave to ACK. Thereafter the master sends the write data and again observes the slave to ACK. After that the master should terminate the transaction by asserting the STOP condition. Failure of a properly addressed slave to respond with expected ACKs signals that the slave is busy and that the transaction should be reattempted. All properly received data and commands should be expected to be ACKed – regardless of whether the desired higher-level operation was successful of not. To determine whether a command was executed properly at a high level, read the Result register.

Please see FIGURE 2.2.3

BUS TIMING

Under normal conditions, data on the SDAT line is only allowed to change while the clock line is low. Exceptions to this rule indicate either a START or a STOP condition.

A bus IDLE condition is present when both the SCLK and SDAT lines are allowed to float high by the master. The master signals a START condition by pulling the SDAT line low while the SCLK line is high. The master asserts a STOP condition by transitioning the SDAT line to a high state while the SCLK line is high.

Please see FIGURE 2.2.4

ACKNOWLEDGE TIMING

Supported bus transactions comprise of three byte frames – whether for read or write operations. The PicoKnowz™ module generates an ACK after every 8^{th} bit received. Please note that the master is not obliged to ACK the data byte received from the module during a read operation.

Please see FIGURE 2.2.5

FIGURE 2.2.2 – Read Operation Frame Format

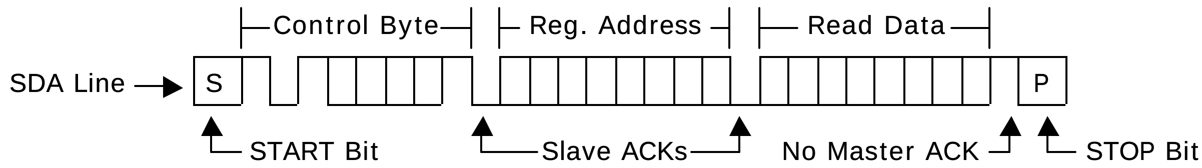


FIGURE 2.2.3 – Write Operation Frame Format

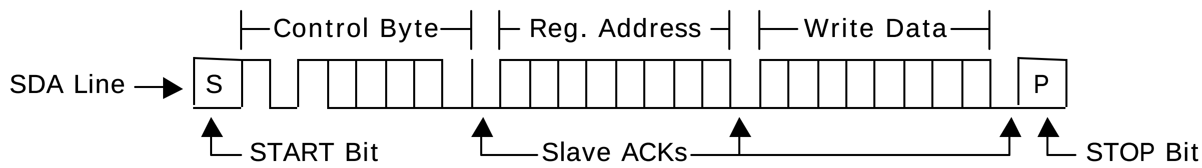


FIGURE 2.2.4 – Bus Timing Diagram

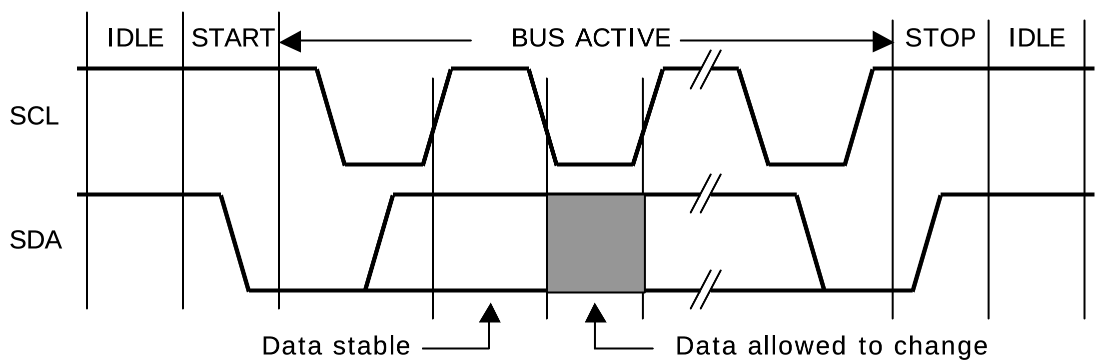
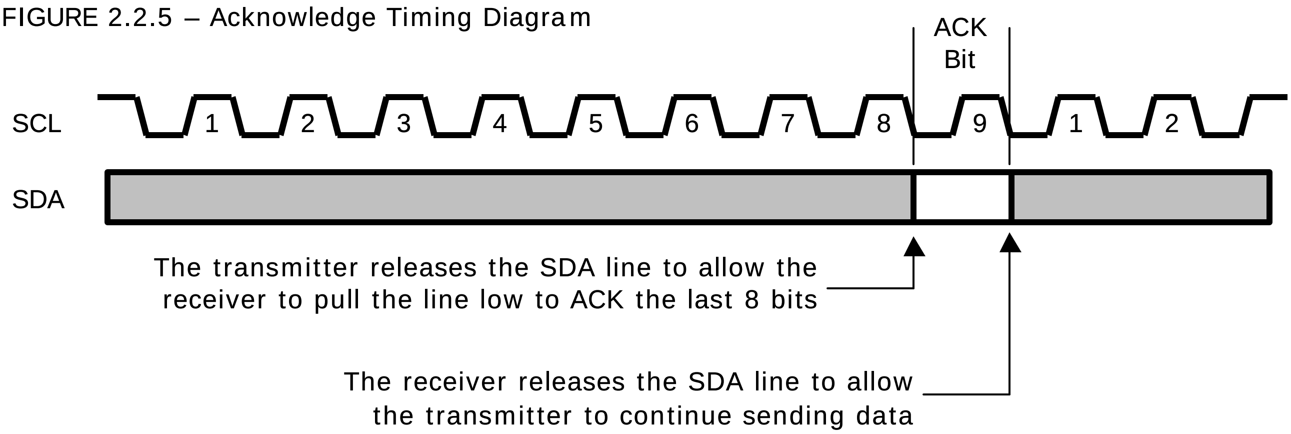


FIGURE 2.2.5 – Acknowledge Timing Diagram



BUS AC PARAMETERS

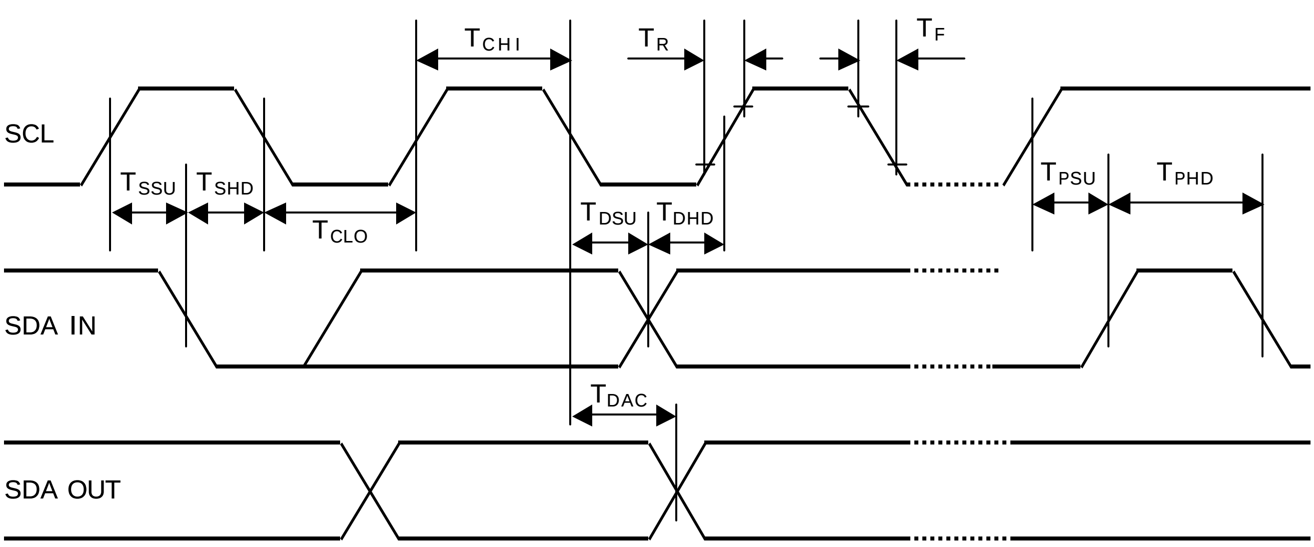
The following are absolute maximum ratings relating to bus timing. Please note that the parameters enumerated below are approximately two orders of magnitude slower than those usually supported by I^2C devices as the local bus control logic is implemented in software. On populous buses containing a variety of faster devices, the clock frequency should be selected to accommodate the slower timing requirements of the PicoKnowz™ module.

TABLE 2.2.1 – AC TIMING PARAMETERS

Parameter	Symbol	Min	Typ	Max	Unit	Remarks
Clock frequency	F_{CLK}	-	-	4	KHz	1 KHz rec. for never busy
Clock high time	T_{CHI}	125	-	-	uS	
Clock low time	T_{CLO}	125	-	-	uS	
SCLK & SDAT rise time	T_R	-	-	500	nS	
SCLK & SDAT fall time	T_F	-	-	500	nS	
START setup time	T_{SSU}	60	-	-	uS	
START hold time	T_{SHD}	60	-	-	uS	
Input data setup time	T_{DSU}	60	-	-	uS	
Input data hold time	T_{DHD}	60	-	-	uS	
Output data valid time	T_{DAC}	-	60	200	uS	Note 1
STOP setup time	T_{PSU}	60	-	-	uS	
STOP hold time	T_{PHD}	120	-	-	uS	Inter-frame idle time

Note 1. Output data is guaranteed to be valid for latching on the next negative clock edge.

FIGURE 2.2.6 – AC BUS TIMING DIAGRAM



2.3 – DATA ACCESS PROTOCOL

ACCESS OVERVIEW

The basic device state can be visually determined by the LED indication. Remote and more detailed information is available by reading various device registers via the interface bus. Various commands may be executed via the same interface and these are detailed below. The following section describes the logical operation of the device. For physical access information, please see the Bus Operation section.

The PicoKnowz™ module responds as a slave device to an I^2C master. All data transactions must be initiated by the master and are followed by slave responses. In order for a particular slave to respond, it must be properly addressed – i.e. the hardware address jumper settings must correspond to the software address issued by the master. The following section details supported user read and write operations. Additional undocumented functions exist to support calibration and configuration via *PK-Port*™; these functions are potentially detrimental to device function, are security locked-out, and are deemed beyond the scope of the normal use described in this document.

All accesses are performed via a data frame that includes the access type (read or write), the register of interest, and a data field. For frame structure and handshaking details, please see the Bus Operation section.

FUNCTIONS OVERVIEW

Device functions are classified by the data direction. The master writes to the module and reads from the device. Data accesses are coded in the control byte to specify a read or a write operation. Either a read or a write operation must specify the address of the register of interest. During write operations, the master's data value is written to the slave register. Read operations transfer the contents of an addressed slave register to the master.

WRITE OPERATIONS

Only the test register write operation changes the contents of the target register. The remaining write operations are commands that cause functions to be executed. In these latter cases, the data value is a command number. Please see TABLE 2.3.1

READ OPERATIONS

Please refer to TABLE 2.3.2 for a summary of supported read functions.

TABLE 2.3.1 – Write Functions Summary

Register	**Function**	**Remarks**
0	User Register	This register may be used to store 8-bit user-defined data or a test pattern (EG when checking the performance of the bus). The value is RAM-resident and is lost when power is removed. The register may be written as frequently as required.
1	Command	This register is used to issue commands. The written data value is the command code. The following commands are supported: 0 – Reboot. Cause the module to re-initialize and enter the warm-up state. 1 – Terminate warm-up period. 2 – Capture gas sensor offset value. See Calibration section.

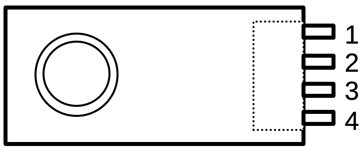
TABLE 2.3.2 – Read Functions Summary

Register	Function	Remarks
0	User Register	This function reads back the value written to the user register. The value is RAM-resident and is lost when power is removed. The initial value of this register is zero.
1	Product Code	This register always returns the value “11” and identifies the device to *PK-Port*™ as a PicoKnowz™ module.
2	Version	The version number is static and is used to identify the features and capabilities of the device.
3	Firmware Rev.	This static value is used to identify the firmware revision level. Since PicoKnowz™ devices are field-upgradeable via *PK-Port*™ the value may change over the lifetime of the device. You may be asked to report this value when seeking technical support.
4	State Code	This register returns the current device state. The codes and their meaning is detailed in the Device States section.
5	Gas Reading	This register is refreshed approximately every 500mS and contains the latest, fully-normalized gas reading expressed in reading units. For more details, please see the Readings section.
6	Reading Resol.	This register returns the static reading resolution value that should be multiplied with the logical gas concentration reading units to calculate a physical gas concentration in ppm. For more details, please see the Readings section.
7	Local Temp.	This register contains the latest temperature in the vicinity of the gas sensor. For more details, please see the Readings section.
8	Result Code	This register is used to report the success or failure of certain write operations such as capturing the calibration-offset value. A zero value indicates the failure of the previous operation.

3 - MECHANICAL

3.1 – PIN CONNECTIONS

FIGURE 3.1.1 – Pin connections

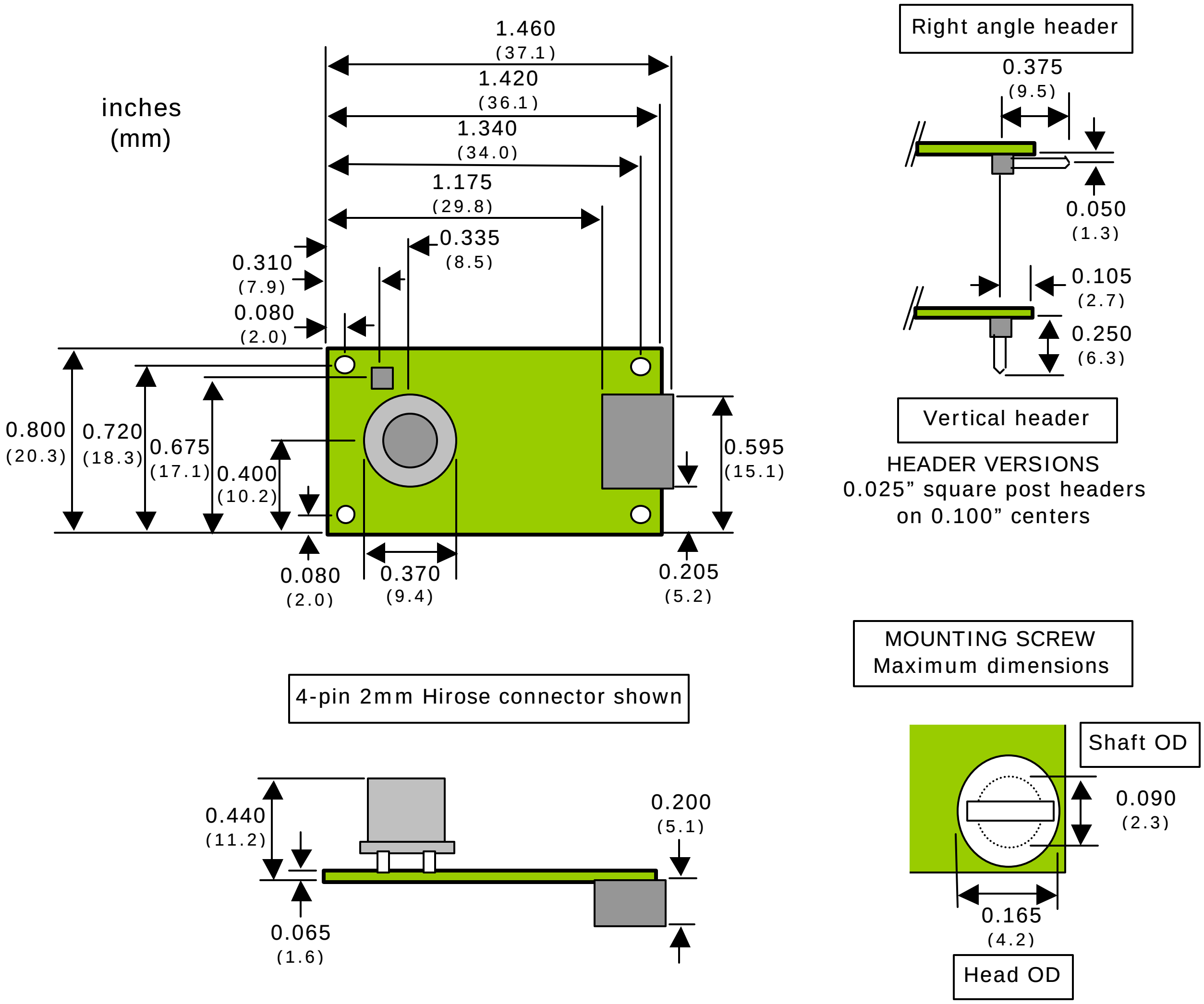


Front view (Sensor Side)

Pin	Symbol	Function
1	V_{CC}	Input power (+5VDC)
2	SDAT	Bus data
3	SCLK	Bus clock
4	V_{SS}	Ground

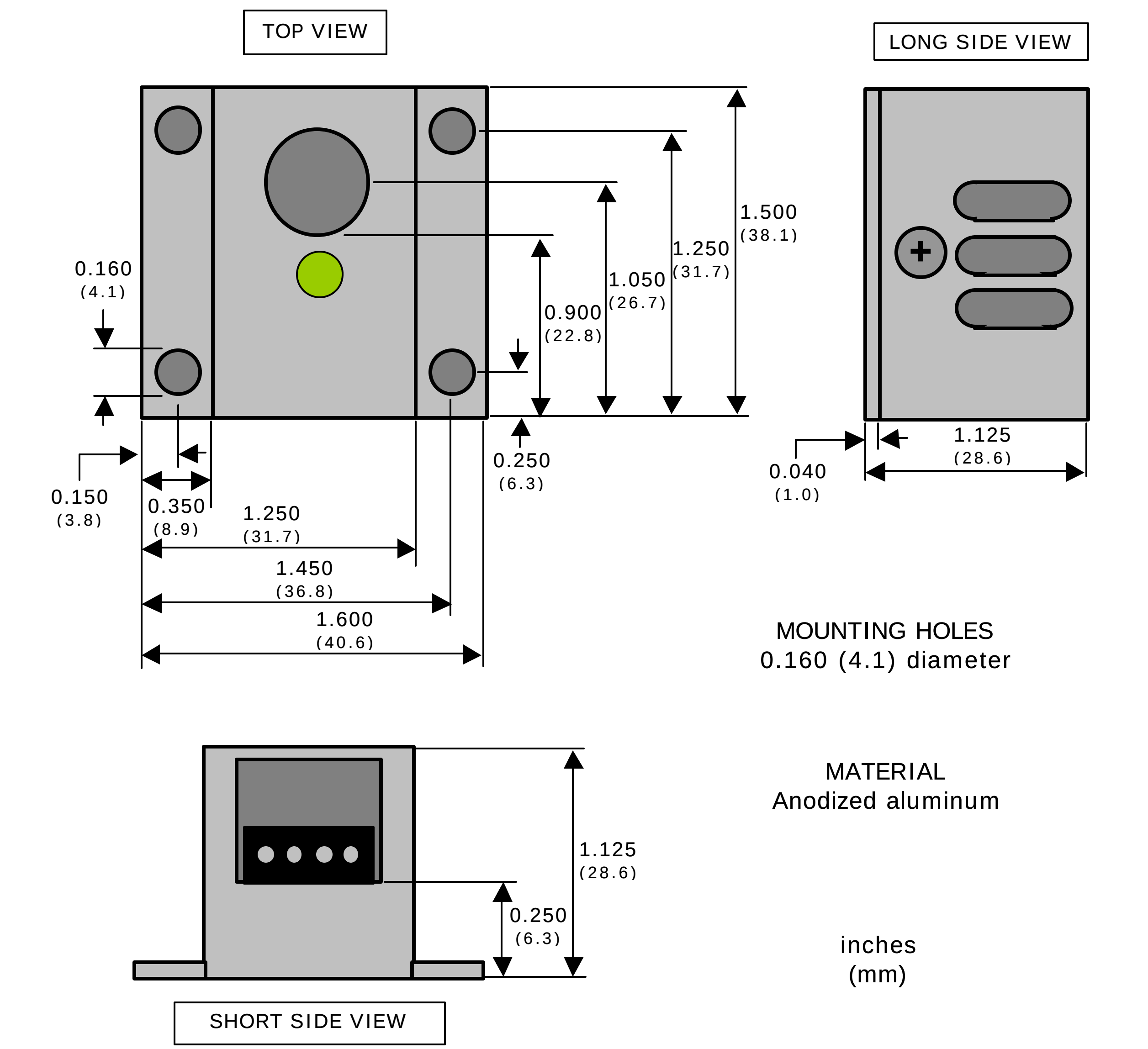
3.2 – PHYSICAL DIMENSIONS

FIGURE. 3.2.1 – Open frame circuit dimensions



3.2 – PHYSICAL DIMENSIONS

FIGURE. 3.2.2 – Enclosure dimensions



4 – SALES & TECHNICAL SUPPORT

4.1 – PART NUMBERING

CK-Gx-Annn-Wnn-Hn-En-Xn

Device ID	PicoKnowz™
Target gas	GH – Hydrogen GM – Methane GP - Propane
Alarm level	Annn, "nnn"=reading units
Warning level	Wnn, "nn"=percent alarm level
Hysteresis	H0 – No reading hysteresis H1 – Apply reading hysteresis
Error handling	E0 – Error state E1 – Errors trigger alarm state
Overdose handling	X0 – Set high sensitivity X1 – Trigger persistent error

4.2 – CONTACT INFORMATION

NEODYM

CORPORATE OFFICE: Neodym Technologies Inc.
#711-675 West Hastings Street
Vancouver, British Columbia
Canada V6B 1N2

TELEPHONE:
Toll-free (North America): 1-877-723-5400
International: +1-604-685-1185
FAX: +1-604-685-3764

INTERNET:
Corporate website: www.neosafe.com

EMAIL:
Sales: sales@neodymsystems.com
Technical Support: engineering@neodymsystems.com