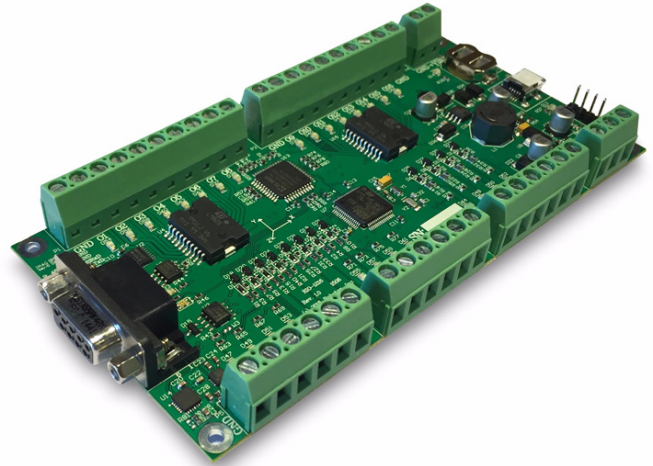


## Smart IO Expansion Card with Optional AHRS for Robotics



Roboteq's I/O eXtender (RIOX) module is an intelligent I/O expansion card, with an optional Attitude and Heading Reference System (AHRS), that seamlessly integrates with Roboteq Motor Controllers. It is intended for use in robotics navigation, unmanned vehicles, machine control, industrial automation and any other applications that need interfacing to the real world. The RIOX module can also be used stand-alone, or as an IO extender to PC, PLC or microcomputer based systems.

The module features 12 inputs, each of which can be individually configured as digital, 0-5V analog, or as pulse inputs. In the pulse mode, the inputs can capture pulse width, frequency, duty cycle, or quadrature encoder counts. Each input pin can also be configured as a driver for RC servos.

The RIOX module has Digital Outputs capable of driving resistive loads such as lights, or inductive loads such as relay, solenoids or motors up to 1A each at 40V. Each output can be used as Input as well.

The card also includes a 32-bit ARM microcontroller for processing and buffering the IO, and managing the communication with motor controllers and/or other components of the system. The processor can be configured to perform, on its own, a long list of conversion, capture, filtering, or conditioning on the IO. A simple and powerful Basic-like programming language is built into the card and allows users to write programs that process the I/O in real time.

RIOX provides a standard RS232 and RS485 interface for communication to PCs and various peripherals. A CAN bus interface allows RIOX to be a master or slave in a CAN bus network that can be up to 1000m long and contain up to 127 nodes. CAN bus also allows the simple interfacing to Roboteq motor controllers.

The RIOX module uses screw terminals to ensure easy insertion and removal while providing a most reliable connection.

RIOX is available in a version with an AHRS (Attitude and Heading Reference System (RIOX1216AH), including 3 axis accelerometer, 3 axis gyroscope, 3 axis magnetometer and a Fusion algorithm.

The RIOX module's firmware can easily be updated in the field to take advantage of new features as they become available.

### Applications

- Robot navigation
- Unmanned air, land, sea and submarine vehicles
- Motion stabilization systems
- Industrial automation
- Machine Control
- Movie/Stage props
- Automated Test Equipment

### Features List

- Built-in 8V to 40V DCDC Converter. 5V output for local power and external accessories
- Up to 28 Digital Inputs
- Up to 12 Analog Inputs
- Up to 12 pulse Inputs
- 2 Analog Outputs
- 0-5V Analog inputs range, 12-bit resolution
- Pulse width, Duty Cycle or Frequency pulse capture
- Pulse IO pins configurable as PWM for driving RC servos
- Pulse IO pins configurable as interfaces to Ping ultrasound distance sensors
- Inputs for up to 3 quadrature encoders
- 16 Digital outputs up to 1A each, 40V max
- Direct interfacing to Roboteq Magnetic Guide Sensor

- Standard RS232 port for interfacing to computers and other peripherals
- CAN bus interface
- Heartbeat LEDs to indicate proper operation and CAN communication
- Optional AHRS with 3-axis Gyroscope, Accelerometer, Magnetometer and Fusion algorithm
- RS485 interface
- Real Time Clock calendar with on-board battery
- 100 words of fast non-volatile RAM
- Easy connection to IO using screw terminals
- High performance on-board 32-bit ARM Cortex M3 processor with FPU
- Built-in Programming Language for local processing of I/O data in realtime. 50000 lines/s execution time
- Field upgradable firmware

## Orderable Product References

TABLE 1.

<b>Reference</b>	<b>IO</b>	<b>Communication</b>	<b>AHRS</b>
<b>RIOX1216</b>	12 Ana/Dig/Pulse Ins, 2 Ana Outs, 16 Dig IO	CAN, RS232, RS485	No
<b>RIOX1216AH</b>	12 Ana/Dig/Pulse Ins, 2 Ana Outs, 16 Dig IO	CAN, RS232, RS485	Yes

**Block diagram**

The diagram below shows the RIOX processor.

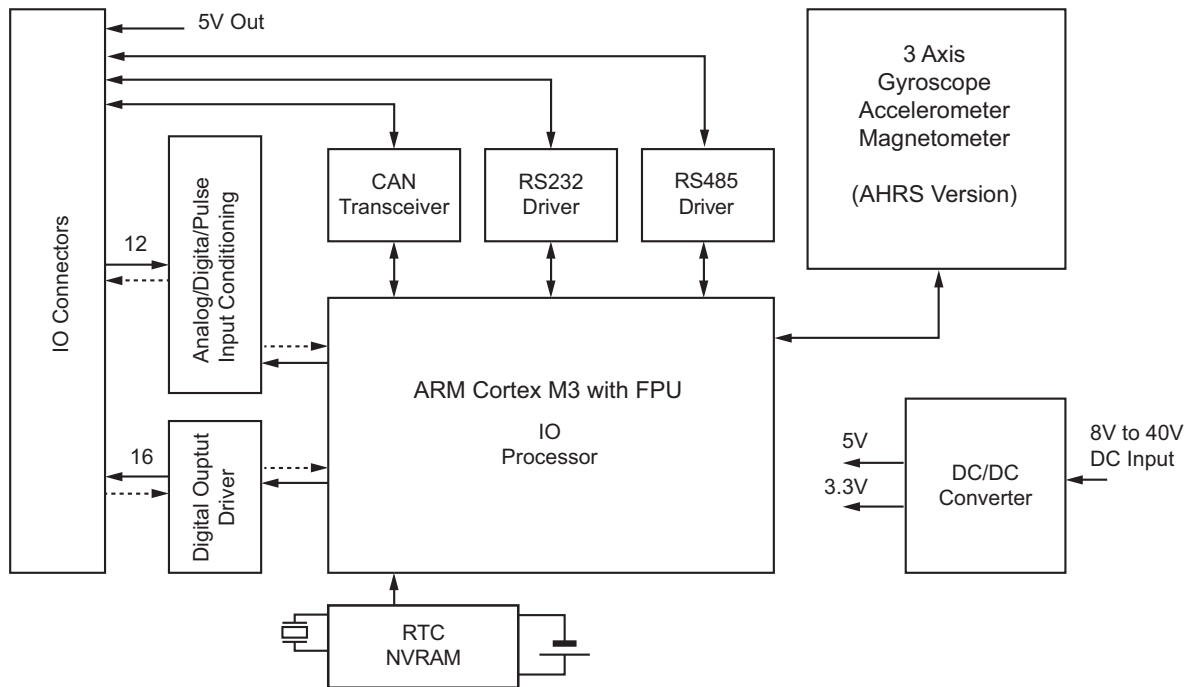


FIGURE 1. RIOX I/O Processor

**Module Connectors and LEDs**

The RIOX1216 is fitted with LEDs for easy monitoring and diagnostics. LEDs position are shown in the figure below.

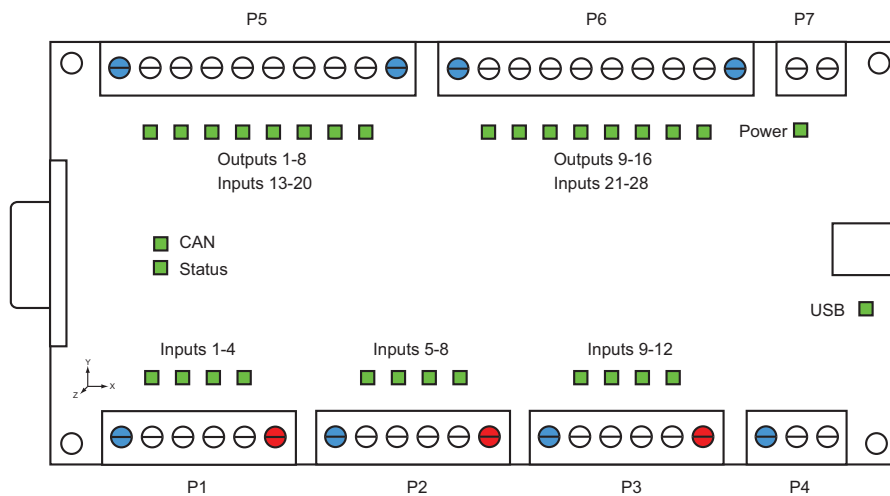


FIGURE 2. RIOX board connectors and status LEDs

## Power and Status LEDs

The power LED will lit whenever the module is powered.

The status LED will flash to indicate that the MCU is running. The LED flashing rate and color can change to indicate fault or warning conditions.

## CAN Communication LED

The CAN LED will flash whenever data frames are detected on the CAN bus, regardless of the originating and receiving nodes. The LED will keep flashing up to 1 second after the last packet was detected. LED will flash only upon receiving data.

## Input LEDs

The Input LEDs will lit whenever the voltage at one of the 12 Analog/Digital/Pulse input is above around 2.5V.

## Output LEDs

In normal operation, the LEDs located near the Digital Output connector will lit whenever an output is activated. Digital outputs are Open Drain drivers that can also be used as inputs when they are in the off state. As input, these lines appear as inputs 13 to 28. When an Output is configured as Input Only, the LED will be lit if a voltage above 2.5V is present on the terminal. Figure 3 identifies the input, outputs and power terminals.

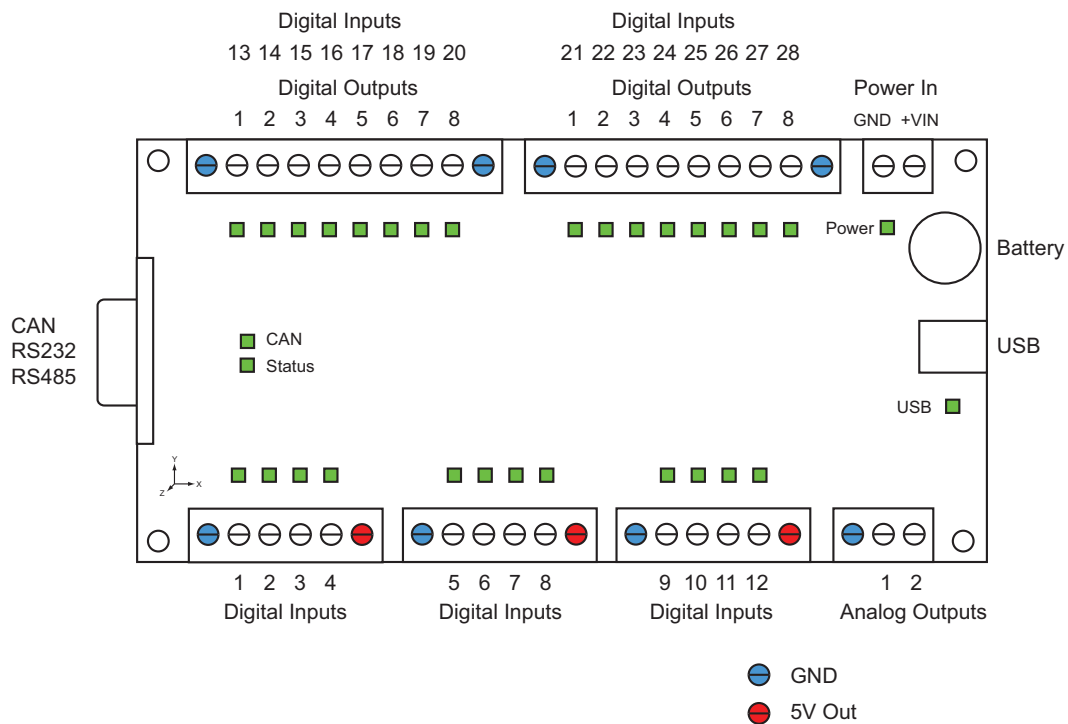


FIGURE 3. Input, outputs and power terminals

## I/O Terminals

The module uses screw terminals for the IO. The 12 Digital/Pulse/Analog inputs are shared between three 6-position terminals. The two Analog outputs are placed on a 3-position terminal. The 16 Digital outputs are shared between two 10-position terminals. Ground signal are provided on each terminal blocks. A 5V output is provided on the Digital/Analog/Pulse terminals for powering outside sensors.

## Communication I/O Connector Pinout

Pin assignment is found in the table below.

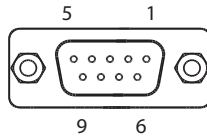


FIGURE 4. DSub 9 pin locations

TABLE 2.

Connector Pin	Signal	Type	Description
1	GND	Power	Power Ground
2	RS232-TxD	Output	RS232 Transmit Data
3	RS232-RxD	Input	RS232 Receive Data
4	GND	Power	Power Ground
5	GND	Power	Power Ground
6	CANL	I/O	CAN Low
7	CANH	I/O	CAN High
8	RS485A	I/O	RS485 A (Non Inverted)
9	RS485B	I/O	RS485 B (Inverted)

## Power Supply Connector

Power to the module is provided via the 2-pin connector. The RIOX1216 will power up and be immediately functional upon applying a voltage of 8V to 40V.

## Powering via USB

Plugging the USB to the module will power it up whether voltage is present on the power connector or not. This feature allows the card to easily be configured and tested with a PC. When powered via USB, only the module's internal circuits are powered. No power will be present on the module's 5VOut terminals.

## Connections to Inputs 1 to 12

The RIOX module has up to 12 inputs which can be used to capture digital, analog or pulse signals. Each input has a 53kOhm pull down resistance. In certain conditions, these inputs are also capable of outputting a low power signal for driving RC Servos or Ultrasound distance sensor.

## Digital Input Connection

The diagrams below show how to connect switches to the input. A DC voltage can also be applied and a logic 1 will be detected above 2.5V.

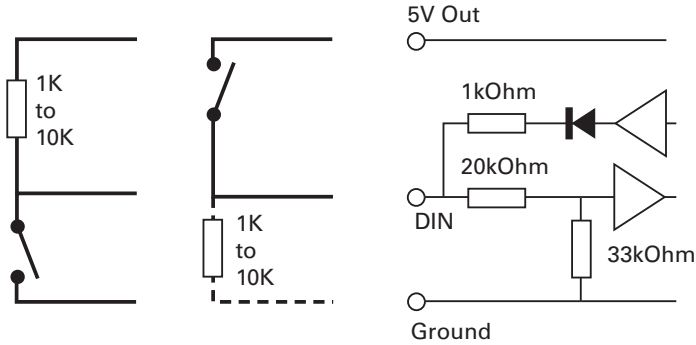


FIGURE 5. Pull down and Pull up switch wiring

### Analog/Pulse Input Connection

DC, Pulse or AC voltage sources can be applied directly to the input. Analog captures must be configured in Absolute mode.

Potentiometers and other ratiometric sensors can use the 5V output available on the I/O connector. For best precision, capture must then be configured in Relative mode, to compensate fluctuations in the 5V output.

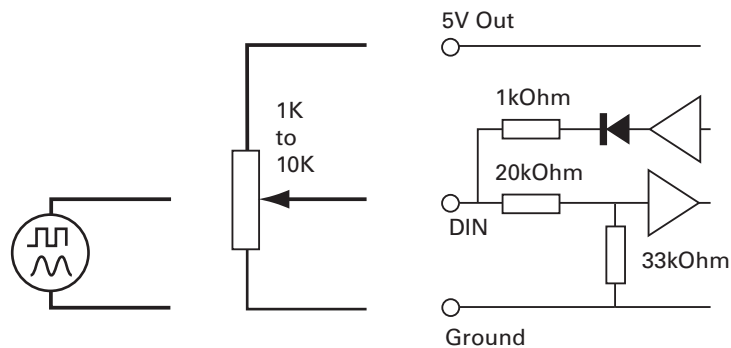


FIGURE 6. Analog/Pulse and Potentiometer wiring

### Connection to RC Servos

All input pins can also be used to drive RC servos. The servos should be powered from an external voltage source and only be connected to the module's 5V output if they consume little power. When powered from the module, insert a 500uF/10V capacitor or higher. RIOXs output drive capability is limited and not all servos may be compatible with the output signal. A pull down resistor at the pin may be required in some condition to make it work.

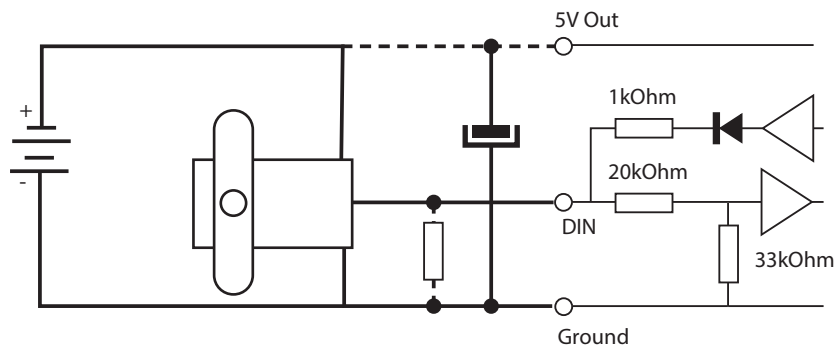


FIGURE 7. RC Servo wiring

### Connection to Ultrasound Sensor

All inputs can be used to interface directly to inexpensive Parallax Ping ultrasound distance sensors.

### Digital Output Connections

The 16 Digital Outputs are Open Drain MOSFET outputs capable of driving over 1A at up to 40V. Since the outputs are Open Drain, the output will be pulled to ground when activated. The load must therefore be connected to the output at one end and to a positive voltage source (e.g. a battery) at the other. Inductive loads must have a diode across the coil to prevent high voltage damage to the output driver.

Resistive and inductive loads can be connected simply as shown in the diagrams below.

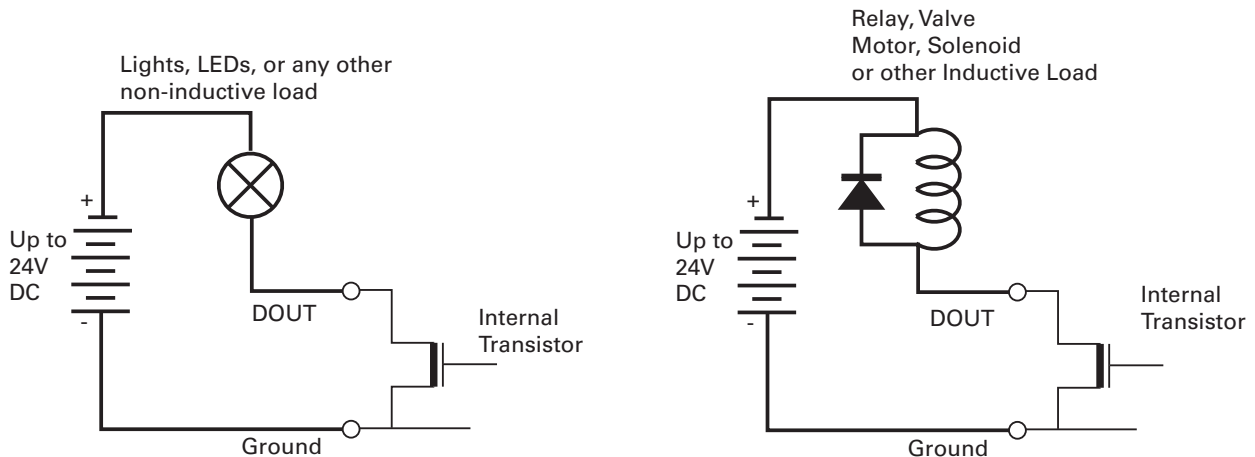


FIGURE 8. Connecting loads to DOUT pins

### Digital Outputs as Inputs

The Driver of Digital Outputs 1-16 has a read-back function allowing to read the presence or absence of voltage at the terminal. Using this function, the Output pins can be used as extra inputs. The diagram below shows the various ways to wire a switch or voltage source to the input.

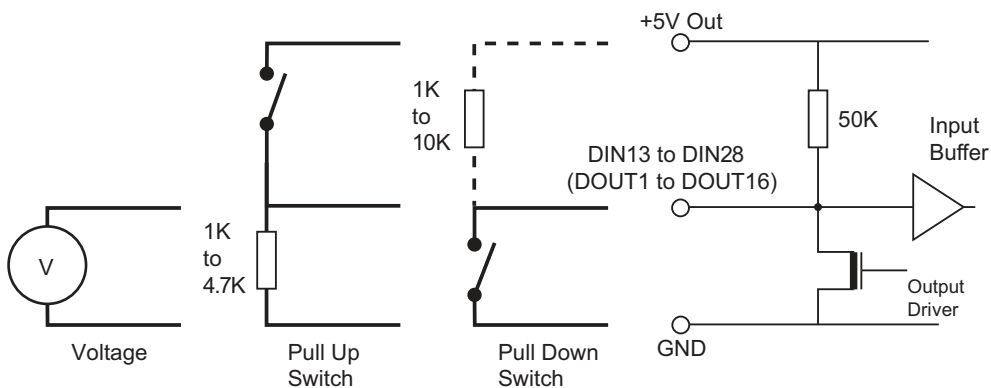


FIGURE 9. Digital Output used as Input

Note that for this function to work, the output must be in the off state, or configured as Input Only.

## Analog Output Connection

The two analog outputs will generate a voltage ranging from 0 to 3300 mV. The output is connected directly to an operational amplifier with limited current drive capability. It should therefore only be connected to relatively high impedance loads (1kOhm or higher).

## Electrical Specifications

### Absolute Maximum Values

The values in the table below should never be exceeded, permanent damage to the card may result.

TABLE 3.

Parameter	Measure point	Min	Typ	Max	Units
Power Supply Voltage	Ground to Vin			40	Volts
Reverse Voltage on Battery Leads	Ground to Vin			40	Volts
Digital Output Voltage	Ground to Output pins			40	Volts
Analog and Digital Inputs Voltage	Ground to any signal pin on user connectors			15	Volts
RS232 I/O pins Voltage	External voltage applied to Rx/Tx pins			15	Volts
Board Temperature	Board	-40		85	oC
Humidity	Board			100 (1)	%
Note 1: Non-condensing					

### Power Stage Electrical Specifications

TABLE 4.

Parameter	Measure point	Min	Typ	Max	Units
Operating Voltage	Ground to Vin	8		40	Volts
Operating Current	Ground to Vin		50(1)		mA
5V Output Voltage	Ground to 5V pins on user connectors	4.6	4.75	4.9	Volts
5V Output Current	5V pins on 40-pin connector			500 (2)	mA
Digital Output Voltage	Ground to Output pins			40	Volts
Digital Output Current	Output pins, sink current			1 (4)	Amps
Output On resistance	Output pin to ground		0.75	1.5	Ohm
Output Short circuit threshold	Output pin	1.05	1.4	1.75	Amps
Input Impedances	ADIN Input to Ground		53		kOhm
Digital Input 0 Level	Ground to Input pins	-1		1	Volts
Digital Input 1 Level	Ground to Input pins	3		15	Volts
Analog Input Range	Ground to Input pins	0		5.1	Volts
Analog Input Precision	Ground to Input pins		0.5		%
Analog Input Resolution	Ground to Input pins		1		mV
Analog Output Range	Ground to Input pins	0		3.3	Volts
Analog Output Resolution	Ground to Input pins			12	bits
Pulse durations	Pulse inputs	20000		10	us
Pulse repeat rate	Pulse inputs	50		250	Hz



TABLE 4.

<b>Parameter</b>	<b>Measure point</b>	<b>Min</b>	<b>Typ</b>	<b>Max</b>	<b>Units</b>
Pulse Capture Resolution	Pulse inputs		1		us
Frequency Capture	Pulse inputs	100		10000	Hz
Encoder count	Internal	-2.147		2.147	10 <sup>9</sup> Counts
Encoder frequency	Encoder input pins			1000	kHz
Note 1: Current decreases as input voltage increases Note 2: Sum of all 5VOut outputs Note 3: Total average current on all outputs of a driver not to exceed 4.5A					

## Operating & Timing Specifications

TABLE 5.

<b>Parameter</b>	<b>Measure Point</b>	<b>Min</b>	<b>Typ</b>	<b>Max</b>	<b>Units</b>
Command Latency	Command to output change	1	0.5	1	ms
IO Update rate	Internal		1000		Hz
RS232 baud rate	Rx & Tx pins		115200 (1)		Bits/s
Note 1: Default 115200, 8-bit, no parity, 1 stop bit, no flow control					

## Scripting

TABLE 6.

<b>Parameter</b>	<b>Measure Point</b>	<b>Min</b>	<b>Typ</b>	<b>Max</b>	<b>Units</b>
Scripting Flash Memory	Internal		32768		Bytes
Max Basic Language programs	Internal	2000		3000	Lines
Integer Variables	Internal		1024		Words (1)
Boolean Variables	Internal		1024		Symbols
Execution Speed	Internal	50 000	100 000		Lines/s
Note 1: 32-bit words					

## Reading/Setting Configuration and Accessing I/O via Serial

USB, RS232 and RS485 serial communication can be used to read and change the many configuration and operating parameters of the RIOX. It can also be used to read and write I/O. A set of commands are available for this purpose and described in the serial commands section of this document.

## AHRS

The RIOX1216AH is equipped with a 3-axis Accelerometer, Gyroscope and Magnetometer. A special algorithm “fuses” the data of each of these sensors to give the board’s Attitude and Heading. The board’s Pitch, Roll and Yaw angles is given using Euler angles or Quaternions. Figure below shows the angles relative to the board hardware.

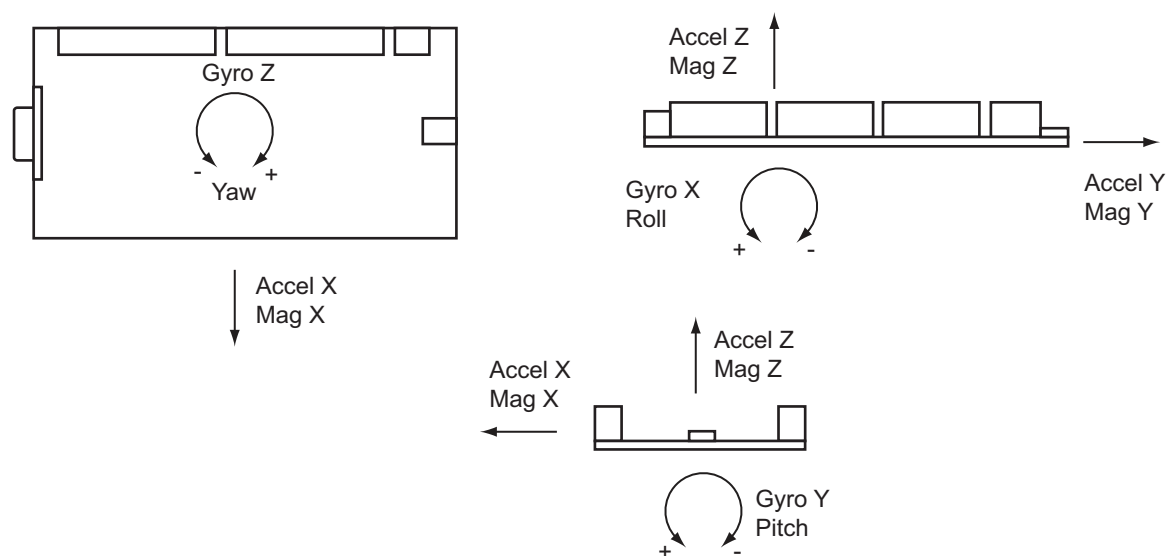


FIGURE 10. Sensors and AHRS references

## Sensor Monitoring with PC Utility

The value of each sensor can be plotted in real time using the supplied PC utility. The utility’s chart recorder has six tracks, each of which can be assigned to a sensor output. Sensor data can be saved in a log for later analysis.

The AHRS Pitch, Roll and Yaw data is used to animate a 3D figure that, with proper calibration, will move on the screen the same way as the board is moved. The AHRS output angles can also be plotted and logged in the 2D chart.

## Sensor Calibration

The sensor must be calibrated before using it for the first time. For the magnetometer in particular, the calibration must be done in the actual place where the board will be used, in order to take into account the possible distortion to the magnetic field induced that the surrounding hardware. Calibration is done using the PC utility in the **Setup** tab, in two steps.

The Gyroscope zero offset must first be calibrated. This is done by leaving the RIOX on a surface (in any position) and make sure it does not move. Click then the **Gyroscope Calibration** button. The offset will be measured and stored into the RIOX’s EEPROM. You can verify that the calibration was successful by monitoring the Gyroscope data in the chart recorder. A small amount of noise (approx. +/- 20) will show in the chart instead of 100 or more for an uncalibrated gyroscope.

The AHRS calibration process requires that the sensor be rotated in every direction, in every angle, for approximately one minute. The rotation must be made while keeping the board in the same location in space, i.e. not moved laterally, up or down). The collected data is then analyzed to automatically determine a couple of dozen parameters needed by the AHRS fusion algorithm to work correctly. A button is provided on the setup screen of the PC utility. It must be pressed only after gyroscope calibration. Once pressed, the utility will prompt you on what to do next. At the end of the process, the new calibration values are stored in RIOX's RAM and are effective immediately. You must click on **Save to Device** for the calibration to be stored in the RIOX's EEPROM and then automatically reloaded every time the board is powered up.

## Using the PC Utility

A powerful utility is available for download from Roboteq's web site for setting up, monitoring and performing maintenance functions. While RIOX is delivered ready to use right off the box, it contains many parameters that can easily be changed using user-friendly menus. The utility can be used for testing and troubleshooting, for performing field updates of the RIOX firmware and for editing and running scripts.

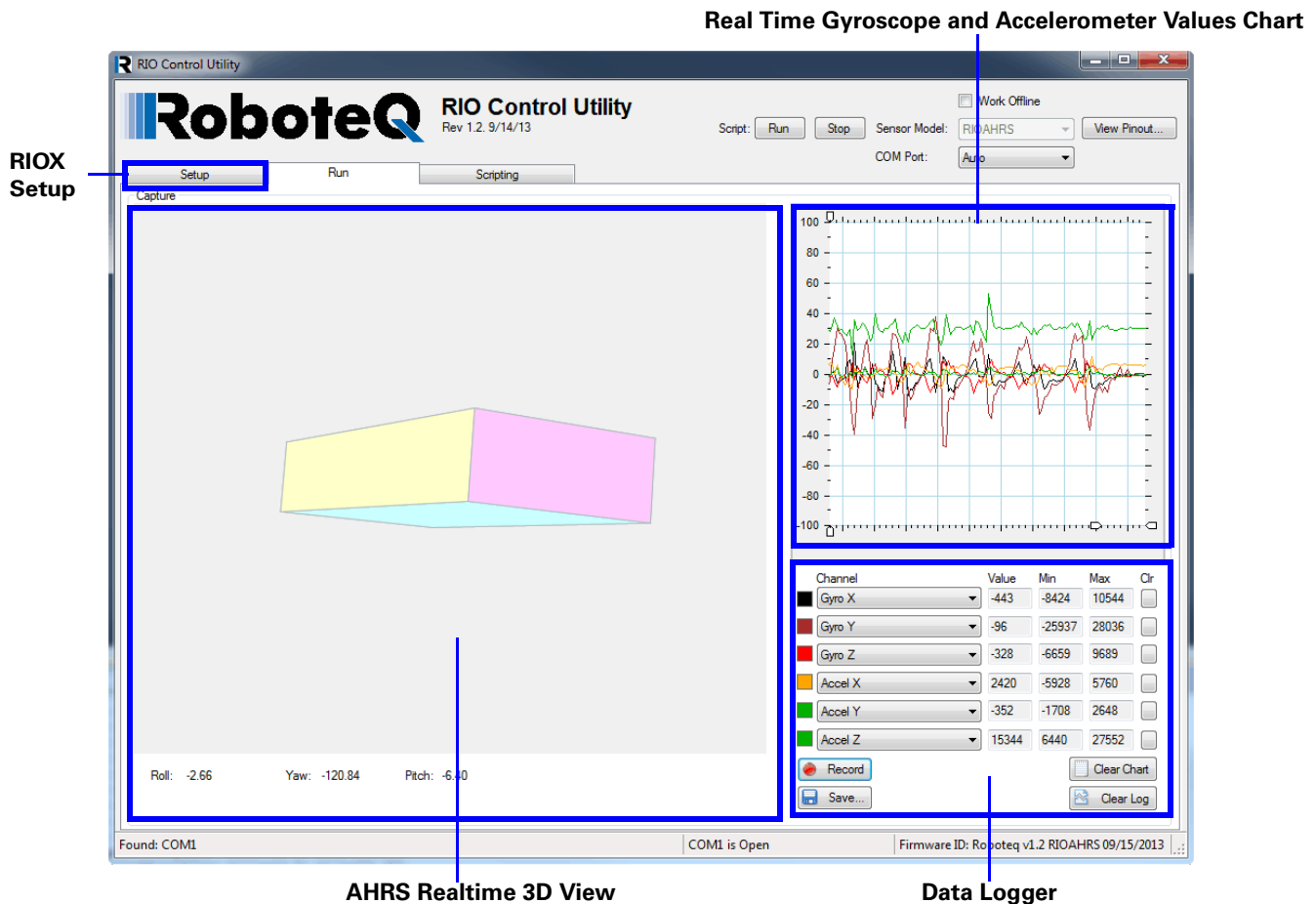


FIGURE 11. RIOX PC Configuration Utility

## MicroBasic Scripting

The RIOX features the ability for the user to write programs that are permanently saved into, and run from the card's Flash Memory. This capability is the equivalent of combining the functionality of a PLC or Single Board Computer directly into the expansion card. The language is a very simple, yet powerful language that resembles

Basic. Scripts can be simple or elaborate, and can be used for various purposes. Language description and reference can be found on the Roboteq web site.

## Command Reference Summary

RIOX accepts a number of commands via its serial port for reading operational data, sending commands, setting configuration, and performing maintenance. Commands can be sent from any port: RS232, RS485, TTL Serial and are processed as they arrive.

## Real Time Queries

These are commands for reading RIOX data. They begin with the question mark character. Table 7 shows the list of supported queries.

Each time a query is executed, it is stored in a history buffer and may therefore be automatically repeated at a periodic rate using the **#** character with the following syntax:

- #** repeat last query in queue
- # nn** repeat last queries ever nn ms. Example: **# 100** to execute one query from the history queue every 100ms
- # C** clear queue

TABLE 7.

Query	Arguments	Description
AI	[InputNbr]	Read Analog Inputs
AIC	[InputNbr]	Read Analog Inputs Converted
B	[VarNbr]	Read User Boolean Variable
C	[Channel]	Read Absolute Encoder Count
CAN	[Channel]	Read Raw CAN Message
CF	[Channel]	Read Raw CAN Received Frames Count
D	[InputNbr]	Read All Digital Inputs
DI	[InputNbr]	Read Individual Digital Inputs
DO	none	Read Current Digital Outputs
EO	[Channel]	Read AHRS Degrees Output
FID	none	Read Firmware ID String
MA	[Channel]	Read AHRS Q Out
MBB	[VarNumber]	Read Microbasic Integer Variable
MBV	[VarNumber]	Read Microbasic Boolean Variable
MG	[Channel]	Read MEMS Gyroscope
MGD	none	Read Magsensor Track Detect
MGM	[Channel]	Read Magsensor Markers
MGS	none	Read Magsensor Status
MGT	[Channel]	Read Magsensor Track Position
ML	[Channel]	Read all MEMS
MM	none	Read Magnetometer
PI	[InputNbr]	Read Pulse Inputs
PIC	[InputNbr]	Read Pulse Inputs Converted
QO	[Channel]	Read AHRS Quaternion Output
T	none	Read IC Temperatures

TABLE 7.

<b>Query</b>	<b>Arguments</b>	<b>Description</b>
TM	[Channel]	Read Time
TRN	none	Read Power Unit Tree filename
V	none	Read 5V output
VAR	[VarNumber]	Read User Integer Variable

## Real Time Commands

These are commands used to instruct RIOX to do something. They begin with the exclamation mark character. Table 8 shows the list of supported commands

TABLE 8.

<b>Command</b>	<b>Arguments</b>	<b>Description</b>
AO	Value	
B	Value	Set User Boolean Variable
C	Channel Counter	Set Encoder Counters
CS	Var number Value	Send Raw CAN frame
D0	BitNumber	Reset Individual Digital Out bits
D1	BitNumber	Set Individual Digital Out bits
DS	Value	Set all Digital Out bits
EES	None	Save Config to Flash
R	Option	Run MicroBasic Script
RC	Channel RCPulse	Set RC Pulse Out
VAR	Value	Set User Variable

## Configuration Commands

These commands are used to read or modify the configuration parameters. They begin with the ~ character for reading and the ^ character for writing. Table 9 shows the list of supported configuration commands. However, it is easier and preferable to use the PC utility menus for inspecting and changing configurations. If changing manually, remember to save the new configuration to flash with the %EESAV. Otherwise, RIOX will revert to the previously active configuration next time it is powered on.

TABLE 9.

<b>Command</b>	<b>Argument</b>	<b>Default</b>	<b>Description</b>
ACTR	InputNbr	2500	Analog Center
ADB	InputNbr	5%	Deadband
ALIN	InputNbr	Linear	Analog Linearity
AMAX	InputNbr	5000	Analog Max
AMIN	InputNbr	0	Analog Min
AMOD	InputNbr	Absolute	Analog Input Mode
AOS	none	ADInput	Source of Analog Output value
APOL	InputNbr	Direct	Analog Input Polarity
BRUN	none	Disabled	MicroBasic Auto Start
CBR	none	250Kbit/s	CAN Bit Rate
CEN	none	Disabled	CAN Mode Select

TABLE 9.

<b>Command</b>	<b>Argument</b>	<b>Default</b>	<b>Description</b>
CHB	none	100ms	CAN HeartBeat
CLSN	none	0	CAN Listening COB
CNOD	none	1	CAN Node Address
CSRT	none	0	CAN SendRate
DINL	InputNbr	Direct	Digital Input Active Level
DOL	InputNbr	Direct	Digital Output Level
DOS	none	RPI	Digital Output Source
ECHOF	none	Echo On	Disable/Enabe RS232 & USB Echo
EE	Address	0	User EE Storage
EQS	none	Euler	Euler or Quaternion
INS	Channel	ADinput	Digital Input Source
PCTR	InputNbr	1500 (us)	Pulse Center
PDB	InputNbr	5%	5% Pulse Deadband
PLIN	InputNbr	Linear	Pulse Linearity
PMAX	InputNbr	2000 (us)	Pulse Max
PMIN	InputNbr	1000 (us)	Pulse Min
PMOD	InputNbr	RC Pulse	Pulse Input Mode
POS	none	RPI	Pulse Output Source
PPOL	InputNbr	Direct	Pulse Input Polarity
RSBR	none	115200	Set RS232 bit rate
SCRO	none	Last Used	Select Print output port for scripting

## Maintenance Commands

These commands are used to perform maintenance functions. They begin with the % character. Table 10 shows the list of supported configuration commands.

TABLE 10.

<b>Command</b>	<b>Arguments</b>	<b>Description</b>
CLRST	Key 321654987	Load Factory default configs
CLSAV	Key 321654987	Calibration values to EEPROM
EELD		Load Parameters from EEPROM
EERST	Key 321654987	Restore Factory Defaults
EESAV		Save Parameters to EEPROM
FUPD	Key 321654987	Enter Firmware Update Mode
GRES		Sets Gyro 0 Ref
RESET		Reset Controller
SLD		Load Minibasic scripts
STIME		Set Time
YREF		Sets Yaw 0 Ref