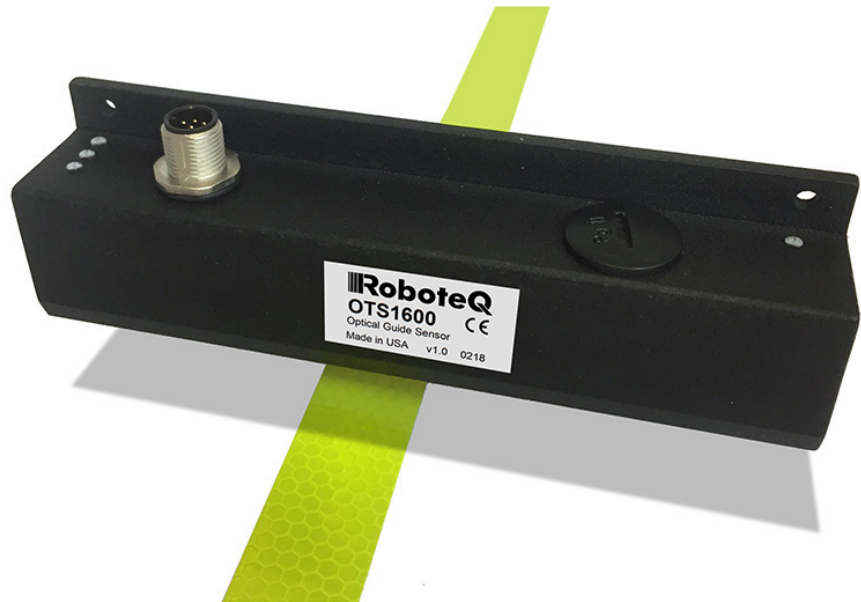


Precision Optical Track Following Sensor



The OTS1600 is a sensor capable of detecting and reporting the position of an optical tape along its horizontal axis. The sensor is intended for line following robotic applications, using a reflective optical tape to form a track guide on the floor. The OTS1600 is built into a rugged, all-metal enclosure. It uses an 8-pin M12-type connector for its power supply and IO signals.

The sensor accurately measures its lateral distance from the center of the track, with millimeter resolution, resulting in 160 points end to end. Tape position information can be output in numerical format on the sensor's RS232, CANbus or USB ports. The position is also reported as a 0 to 3V voltage output and as a variable PWM output. Additionally, the sensor supports a dedicated MultiPWM mode allowing seamless communication with all Roboteq motor controllers using only one wire.

The sensor will detect and manage 2-way forks and can be instructed to follow the left or right track using commands issued via the serial/USB or its CAN bus interface.

The sensor incorporates a Basic-like scripting language that allows users to add customized functionality to the sensor. A PC utility is provided for configuring the sensor, capturing and plotting the sensor data on a strip chart recorder, and visualizing in real time the magnetic field as it is seen by the sensor.

The sensor firmware can be updated in the field to take advantage of new features as they become available.

Applications

- Automatic Guided Vehicles
- Automated warehouses
- Automated shelves restocking system
- Material conveying robots
- Flexible assembly lines

Key Features

- Detects and measures position of optical track along horizontal axis
- Optimized for use with 25mm wide adhesive reflective tape
- 20 to 100mm operating height
- 160mm sensing width with 1mm resolution
- 2-way fork/merge detection and management
- Simple interface to most PLC brands and to micro-computers
- Direct and seamless interface to Roboteq motor controllers
- 100Hz update rate
- Status LED indicator lights for tape detection and position
- Numerical Tape position data output on RS232, CAN or USB ports
- Tape position on PWM output at 250Hz or 500Hz
- Tape position on 0-3V analog output
- CAN interface up to 1Mbit/s
- CANOpen, and 3 other CAN protocol support
- Built-in programming language for optional local processing of tape data
- Easy configuration, testing and monitoring using provided PC utility. Real time visualization of the magnetic field
- Field upgradeable software for installing latest features via the Internet
- Waterproof 8-pin, M12-type connector for power supply, CANbus, RS232, Analog and PWM signals.
- Shock resistant, all-aluminum enclosure
- Wide range 4.5V to 30V DC operation
- 166 mm, wide x 30 mm deep x 38.5 mm tall
- -40o to +85o C operating environment
- IP65 rated enclosure.

Orderable Product References

Reference	Description
OTS1600	160mm wide, optical guide sensor with Gyroscope, serial, USB, analog, PWM and CAN output
OTAPE25YEL	25 mm wide yellow reflective optical tape. 50m (150ft) roll

Tape Selection & Installation

The sensor is factory calibrated for use with 25mm wide tape from Roboteq, but may be used with tape from other suppliers as well. Use only reflective tape in order to ensure very high contrast and to eliminate disturbance from ambient lighting.

Operating height is up to 100mm when used with 25mm wide tape. For best results, operate at 30 to 60mm.

Sensor Installation

The sensor must be mounted so that it is parallel with the floor and the optical track. Two mounting holes are provided at both ends of the enclosure. When installing, allow room for accessing the USB connector under the plug.

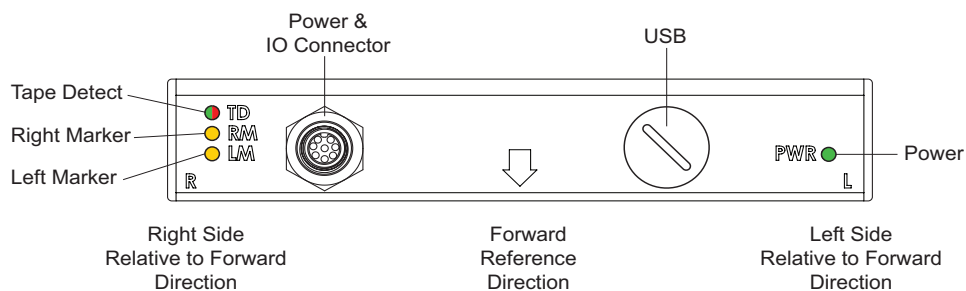


FIGURE 1. Sensor Outline

I/O and Power Connector

The OTS1600 is fitted with a waterproof 8-pin M12-type male. Connector for powering the sensor and accessing all the I/O signals. The connector pins are identified in the table below.

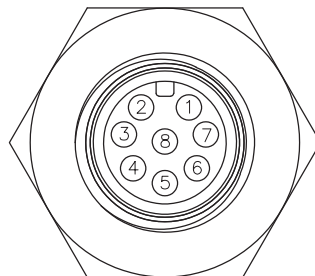


FIGURE 2. Connector Pin Locations

TABLE 1.

Connector Pin	Signal	Description
1	Power	4.5V to 30V DC Power supply input
2	RxDData	RS232 Receive Data
3	TxDData	RS232 Transmit Data
4	CANL	CANbus Low
5	CANH	CANbus High
6	Analog(1) Out	0-3V (1.5V center) Analog track position
7	PWM(2) Out	Track position PWM output
8	GND	Ground
Note 1: Analog Output can be configured as Tape Detect when operatin in PWM mode Note 2: PWM Output can be configured as Tape Detect when operating in Analog mode		

Powering the sensor

Apply a 4.5V to 30V Max voltage between the ground, and the power input pins. The sensor will also be powered if it is connected to a PC via the USB connector.

RS232 Connection

Serial communication with the sensor is done using the RxData and TxData signals. The ground pin must be connected in order to provide a reference to the RxData and TxData signal.

PWM Output

The PWM Output is always active. In default configuration, multiple pulses of variable width are used to carry all sensor information, including tape detect, to the motor controllers. Also, the output can be configured to carry the tape position by varying the duty cycle of a single, continuous pulse from 50%, when the tape is centered, to 25% and 75% duty cycle when the tape is at one end or the other of the sensor. The PWM output is centered at 50% when no tape is detected. Additionally the output can be configured as the tape detect output so that the sensor is always on when tape detected and always off when no tape is detected.

Analog Output

The Analog Output is always active and will give the tape position by varying the voltage from 1.50V, when the tape is centered, to 0 and 3V when the tape is at one end of the sensor or the other. The Analog output is centered at 1.50V when no tape is detected. The output can also be configured as tape detect output (3Volts when tape detected, 0 Volts when no tape detected).

RxDData as digital input

The RxData line can also be configured as a digital input in order to select which of the Left or Right tape captures must be output on the PWM and Analog wires. The configuration is done using the DIM configuration parameter. If the input is high the right track is selected, if it is low the left track is selected.

CAN Low and CAN High

The CAN Low and CAN High pins are used to connect the sensor to a CAN network. The sensor does not include a 120 ohm termination resistor.

Serial Port Settings

The baud rate and communication settings on the sensor are set as follows:

- 115200 bits/s
- 8-bit data
- No parity
- No flow control

The baud rate can be changed to different values, but only while the controller is connected to the configuration PC utility via USB. It is important to note that once the baud rate is changed, it will no longer be possible to have the PC utility communicate with the sensor via the serial port until the speed is changed back to 115200 bit/s.

Track information

The presence and position of a magnetic track is output on the I/O connector, and/or is transmitted via the serial communication port or USB. The track position information is also output as a 0-3V analog signal, and a PWM pulse of user definable period and duty cycle range. The track detect and position are reported on the RS232, CANbus or USB ports. The position is reported as a signed value, in millimeters, using the center of the sensor as the 0 reference.

Fork and Merge Management

The sensor has an algorithm for detecting and managing 2-way forks and merges along the track. Internally, the controller always assumes that two tracks are present: a left track and a right track. When following a single track, the sensor considers that the two tracks are superimposed. When entering forks, the track widens, so does the distance between the left and right track, as shown in Figure 3, below:

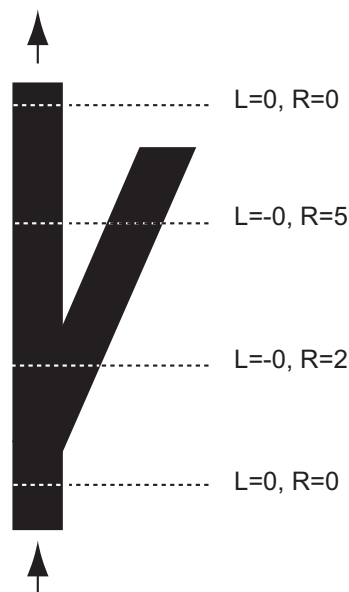


FIGURE 3. Fork Management

When approaching merges, the sensor will report a sudden spread of the left and right tracks, but will otherwise operate the same way as at forks, as shown in Figure 4, below:

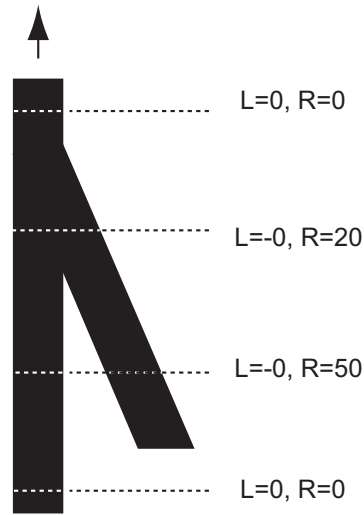


FIGURE 4. Merge Management

Both track positions can be read via the serial port.

The selected track will be based on the command received via the sensor’s serial/USB port, or set using the sensor’s scripting language.

Tape Detection Threshold

The sensor evaluates the shape of the curve independently of its position relative to the 0 level. It then sets the detection level to around the middle of the curve, as shown in Figure 5:

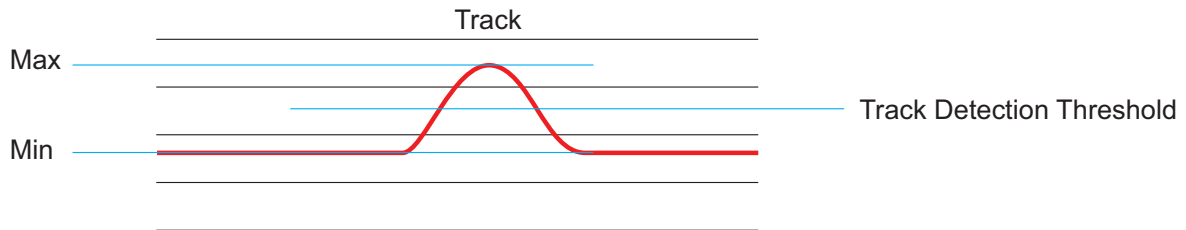


FIGURE 5. Relative Capture is Independent of the Ambient 0 Level

This technique is therefore almost immune to variations to the ambient level.

Gyroscope

The sensor is equipped with a built-in 3-axis MEMS Gyroscope. The Gyroscope provides an accurate measurement of the rate of rotation along each of the sensors planes with three levels of resolution: +/-250 degrees/s, +/-500 degrees/s and +/-2000 degrees/s. The Gyroscope can be used to provide added stability to the AGV. It can also be used to make the AGV continue to move in a straight line, without guiding tape, between two magnetic tapes or magnetic pins.

The Gyroscope values can be read via USB, Serial or CANbus. The Z sensor value is also automatically transmitted to a Roboteq motor controller, along with the magnetic sensor data, using a single wire and the Multi-PWM mode. Finally angle integration is implemented out of the gyroscope data, using ANG query and command. The angle is given in degrees*10.

The Gyroscope values are integers with the following range:

TABLE 2.

Resolution	Value Range	Divider
+/-250	+/-25000	100
+/-500	+/-5000	10
+/-2000	+/-20000	10

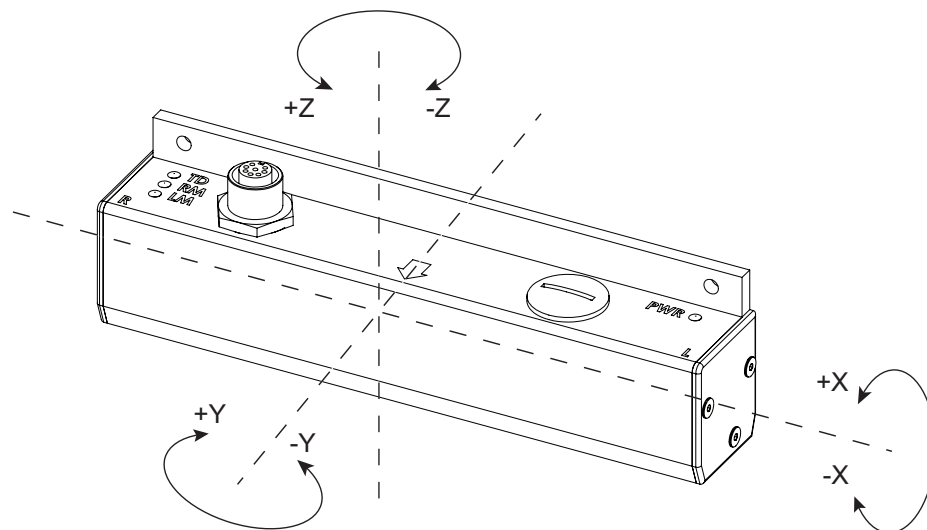


FIGURE 6. Orientation of the Gyroscope Axis

Diagnostic LEDs

Since magnetic fields are invisible, the sensor is equipped with four LEDs to help with setup and troubleshooting. The LED positions are shown in Figure 2, on Page 4. The Power LED will light up when the sensor is on. The Track Detect/Track Position LED is a dual usage LED that will light up when a track is present. The LED is bi-color and will gradually shift to red when the track is at the left of the sensor, and to green as the track moves to the right. The LEDs marked LM and RM are not currently used.

Interfacing the Sensor to PLCs

The sensor can be fully interfaced to a PLC via its CANbus or RS232 interface. It is also possible to use the PWM and analog inputs. The CAN and RS232 mode are the preferred interfaces as these enable the full functionality of the sensor.

Interfacing the Sensor to Roboteq Motor Controllers

The OTS1600 will interface directly and seamlessly to all Roboteq models of controllers for brushed and brushless DC motors. The sensor can be powered from the controller's 5V output, as shown in Figure 7, below. The left and right tape information is sent from the sensor using the PWM Output configured as "Roboteq MultiPWM". The signal must be connected to one of the controller's Pulse Inputs configured with the PC utility as "Magsensor". The data is sent continuously with a 10ms update rate. Roboteq provides script examples that run in the motor controller for implementing basic line following AGV functionality.

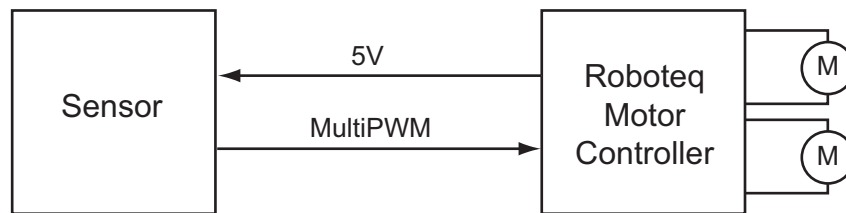


FIGURE 7. Roboteq Motor controllers Interfacing

Interfacing the Sensor to PCs or Microcomputers

Interfacing the sensor to a PC requires a simple USB connection. The sensor will be powered via the 5V present on the USB, as shown in Figure 8:

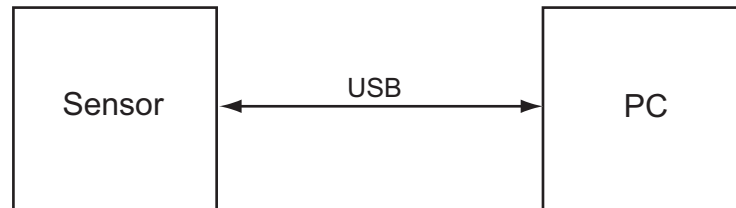


FIGURE 8. PC Interfacing

If no USB is available, interfacing can be done using the PC or Microcomputer RS232 port and a separate 4.5V to 30V power supply.

MicroBasic Scripting

The OTS1600 features the ability for the user to write programs that are permanently saved into, and run from the sensor's Flash Memory. This capability is the equivalent of combining the functionality of a PLC or Single Board Computer, directly into the sensor. The language is a very simple, yet powerful one that resembles Basic. Scripts can be simple or elaborate, and can be used for various purposes. For example, sensor data manipulation, or even the full motion and steering control for a simple line following robot. See the Microbasic manual for details on the language.

Sensor Zero Calibration

The sensor is factory calibrated to compensate for the natural ambient light. For best results, the ambient “zero” must be reset in every new installation. This is done by clicking on the “Calibrate Zero” button on the Setup tab of the PC utility. Make sure that the sensor is away a track when doing the zero calibration. Zero Calibration can also be initiated by sending the %ZERO maintenance command followed by %EESAV for storing the new calibration permanently in Flash.

When the calibration takes place, an integrity test is executed in order to detect if any of the internal sensors has failed. If the test detects an error, a respective message is printed, the LEDs flash and bit 8 in the Sensor’s Status byte (accessible using the MGS query) is set. If this happens make sure the sensor is not close to any reflective and retry sensor calibration. If the problem remains, then most probably the sensor is damaged.

Gyroscope Zero Calibration

It is normal for gyroscope that is built in the sensor to have some drift. To minimize this drift the sensor must be immobilized, then click on the “Calibrate Gyro Zero” button on the PC utility. It is recommended to calibrate the Gyroscope Zero at least once. The calibration can be done at any time as long as the sensor is not moving at all when calibrating. Calibration only needs to be done if you intend to use the Gyroscope.

Command Reference Summary

The sensor accepts a number of commands via its RS232 and USB ports for reading operational data, sending commands, setting configuration, and performing maintenance.

Real Time Queries

These are commands for reading sensor data. They begin with the question mark character. Table 6 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 every nn ms. Example: # 100 to execute one query from the history queue every 100ms
- # C clear queue

TABLE 3.

Command	Arguments	Description	Examples
B	Index Value	Read User Boolean Variable	?B 1
MGD	None	Read Track Detect	?MGD
MZ	[SensorNumber]	Read all internal sensor values, or one of the 16	?MZ, ?MZ 16
T	None	Read selected track	?T
MGT	[TrackNumber]	Read both the left and right tracks, or one of the 2	?MGT, ?MGT 2
VAR	Index Value	Read User Integer Variable	?VAR 5
MGS	None	Read MagSensor Status	?MGS
MGX	None	Read Tape CrossDetection	?MGX
ANG	[Axis]	Read Integrated Angle (degrees*10)	?ANG 1

Real Time Commands

These are commands used to instruct the sensor to do something. They begin with the exclamation mark character. Table 4 shows the list of supported commands.

TABLE 4.

Command	Arguments	Description	Example
B	Index Value	Set User Boolean Variable	!B 1 1
R	option	Run/Stop/Resume MicroBasic scripts	!R = Run/Resume, !R 0 = Stop, !R 2 = Restart
TV	none	Follow Right track	!TV
VAR	Index Value	Set User Integer Variable	!VAR 5 12345
TX	none	Follow Left track	!TX
ANG	[Axis]	Set the angle reference (degrees*10)	!ANG 2 900

Configuration Commands

These commands are used to read or modify sensor configuration parameters. They begin with the tilde (~) character for reading and the caret (^) character for writing. Table 5 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 manually changing a command, remember to save the new configuration to the flash memory with the %EESAV. Otherwise, the sensor will revert to the previously active configuration next time it is powered on.

TABLE 5.

Command	Arguments	Range	Default	Description
ANAM	Value	0 = Selected Track (0-3V), 1= Tape Detection	0	Analog Output mode
BADJ	Value	0 = disable, 1 = enable	0	Auto start MicroBasic script at power up
BRUN	Value	+/- 100	0	Correction to Left/Right tape reading
DIM	Value	0 = disable, 1 = enable	0	RxData as digital Input
GRNG	Value	0= 250 dps, 1= 500 dps, 2= 2000 dps	0	Select Gyroscope Range
PWMM	Value	0 = Roboteq MultiPWM, 1= Selected Track at 250Hz, 2= Selected Track at 500Hz, 3=Tape Detection	0	PWM Output mode
RSBR(1)	Mode	0 = 115.2K 1= 57.6K 2 = 38.4K 3 = 19.2K 4 = 9600	0	Set serial port bit rate
SCRO	ScriptOutput	0 = last port used, 1 = RS232, 2 = USB	0	Output port for MicroBasic print commands

Command	Arguments	Range	Default	Description
TINV	Value	0 = Left - to Right +, 1= Left + to Right -	0	Change sign of position values
TXOF	Value	-100 to +100	0	Offset added/subtract to track position values
ZADJ	Ch Value	+/- 1000	0	Zero Level User Offset for each of the 16 internal sensors. Send ^ZADJ 0 nn to change all sensors at once.

Note 1: Serial port bit rate can only be changed while the sensor is connected to the PC via USB

Maintenance Commands

These commands are used to perform maintenance functions on the sensor. They begin with the percent (%) character. Table 6 shows the list of supported maintenance commands.

TABLE 6.

Command	Arguments	Description
CLSAV	None	Save calibration to EEPROM
CLRST	Key (1)	Load factory default calibration
EELD	None	Load configuration from EEPROM
EERST	Key (1)	Load factory default configuration
EESAV	None	Save configuration to EEPROM
ZERO	None	Set zero calibration level for magnetic sensors

Note 1: To prevent accidental entry, the command must be followed by the key 321654987

USB communication

Use USB only for configuration, monitoring and troubleshooting. USB is not a reliable communication method when used in electrically noisy environments. Further more, communication will not always recover after it is lost without unplugging and replugging the connector, or restarting the controller. RS232 is the preferred communication method when interfacing with a computer. USB and CAN are able to operate at the same time on the OTS1600. Connecting to a computer via USB will not disable the CAN interface.

CANbus Communication

The sensor supports 4 different CAN protocols:

RoboCAN: a simple meshed networking system to exchange commands and queries with any other Roboteq motor controller or sensor.

RawCAN: a low level system that allows to build and parse CAN frames using the MicroBasic scripting language
 MiniCAN: a system that borrows CANOpen's TPDO and RPDO mechanisms for sending and capturing frames with fixed content.

CANOpen: an industry standard for ensuring interoperability with other vendor's PLCs and devices.

Details on these protocols can be found in the separate CAN Communication manual.

The structure and content of the TPDO and RPDO frames is the same in both MiniCAN and CANOpen and is shown in the table below.

Header: TPD01: 0x180 + NodeID

TPD02: 0x280 + NodeID

	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7	Byte8
TPDO1	Left Track		Right Track		Flags			
TPDO2	VAR 1				VAR 2			

CANOpen Flag Bits:

Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1
Sensor Failure	-	-	-	-	-	Tape Detect	Tape Cross

MiniCAN Flag Bits:

Bit8	Bit7	Bit6	Bit5	Bit4	Bit3	Bit2	Bit1
Sensor Failure	-	-	-	Tape Cross	-	-	Tape Detect

Header: RPD01: 0x200 + NodeID

RPD02: 0x300 + NodeID

	Byte1	Byte2	Byte3	Byte4	Byte5	Byte6	Byte7	Byte8
RPD01	VAR 2				VAR 3			
RPD02	VAR 4				VAR 5			

In CAN Open the sensors Real-time Commands and Queries are mapped as shown Table 7. (Object Dictionary), below. Configuration commands are not directly accessible via CANOpen.

TABLE 7.

Index	Sub (Hex)	Entry Name	Data Type & Access	Command Name
Runtime Commands				
0x2005	01 to 10	Set User Integer Variable n	S32 WO	VAR
0x2015	01 to 32	Set User Bool Variable n	S32 WO	B
0x2017	00	Save Config to Flash	U8 WO	EESAV
0x2018	00	MicroBasic Run	U8 WO	BRUN
0x201A	00	Follow Left track	U8 WO	TX
0x201B	00	Follow Right track	U8 WO	TV

TABLE 8.

Index	Sub (Hex)	Entry Name	Data Type & Access	Command Name
Runtime Queries				
0x2106	1 to 10	Read User Integer Variable n	S32 RO	VAR
0x210F	00	Read Dominant Track	S8 RO	T
0x2115	01-10	Read User Bool Variable n	U8 RO	B
0x211D	01	Read Track Detect	U8 RO	MGD
0x211E	01	Read Left Track	S16 RO	MGT
	02	Read Right Track		
	03	Read Selected Track		
0x2120	01	Read Status	U16 RO	MGS
0x212D	01 -10	Read Raw Sensor N	U32 RO	MRS
0x212E	01 -10	Read Zero Adjusted Raw Sensor n	S32 RO	MZ
0x2131	01	Read Gyro X	S16 RO	GY
	02	Read Gyro Y		
	03	Read Gyro Z		
0x2138 (1)	01	Read Cross Tape Detection	U8 RO	MGX

Sensor Characteristics

TABLE 9.

Parameter	Min	Typical	Max	Units
Capture width		160		mm
Resolution	1	1	2	mm
Operating height	30	50	100 (1)	mm
Update rate		100		Hz
Note 1: Ambient light may impair sensor data at highest height. A greater height can be reached with doubled tape, or by using stronger magnetic material.				

Electrical Characteristics

Absolute Maximum Values

The values in the table below should never be exceeded. Permanent damage to the controller may result.

TABLE 10.

Parameter	Measure point	Min	Typ	Max	Units
Power Supply Input Voltage	Ground to Power Input	-1		35	Volts
Analog Output Current	Analog Output			10	mA
CAN Input Voltage	Ground to CAN-H and CAN-L pins			40	Volts
RS232 I/O pins Voltage	External voltage applied to Rx/Tx pins			25	Volts

Power Supply Electrical Specifications

TABLE 11.

Parameter	Measure point	Min	Typ	Max	Units
Power Supply Input Voltage	Ground to Red wire	4.5		30	Volts
Power consumption	Power supply input	120 (1)		20 (1)	mA

Note 1: Consumption is lower as the power supply voltage is higher.

Command, I/O and Sensor Signals Specifications

TABLE 12.

Parameter	Measure point	Min	Typ	Max	Units
Analog Output Range	Ground to Output pin	0		3	Volts

TABLE 13.

Parameter	Measure point	Min	Typ	Max	Units
Analog Output Current	Ground to Output pin			10	mA
PWM Frequency	PWM Output	250 (1)		500 (1)	Hz
PWM Duty Cycle	PWM Output	25		75	%

Note 1: 250 or 500Hz user selectable

Scripting

TABLE 14.

Parameter	Measure Point	Min	Typ	Max	Units
Scripting Flash Memory	Internal		32k		Bytes
Max Basic Language programs	Internal		8K	12K	Lines
Integer Variables	Internal			1024	Words (1)
Boolean Variables	Internal			1024	Symbols
Execution Speed	Internal		50 000		Lines/s

Note 1: 32-bit words

Environmental & Mechanical Specifications

TABLE 15.

Parameter	Measure Point	Min	Typ	Max	Units
Operating Temperature	Sensor	-20		85	oC
Weight	Sensor		250 (.55) (1)		g (lbs)
Protection	Case		IP65		

Note 1: Excluding cable

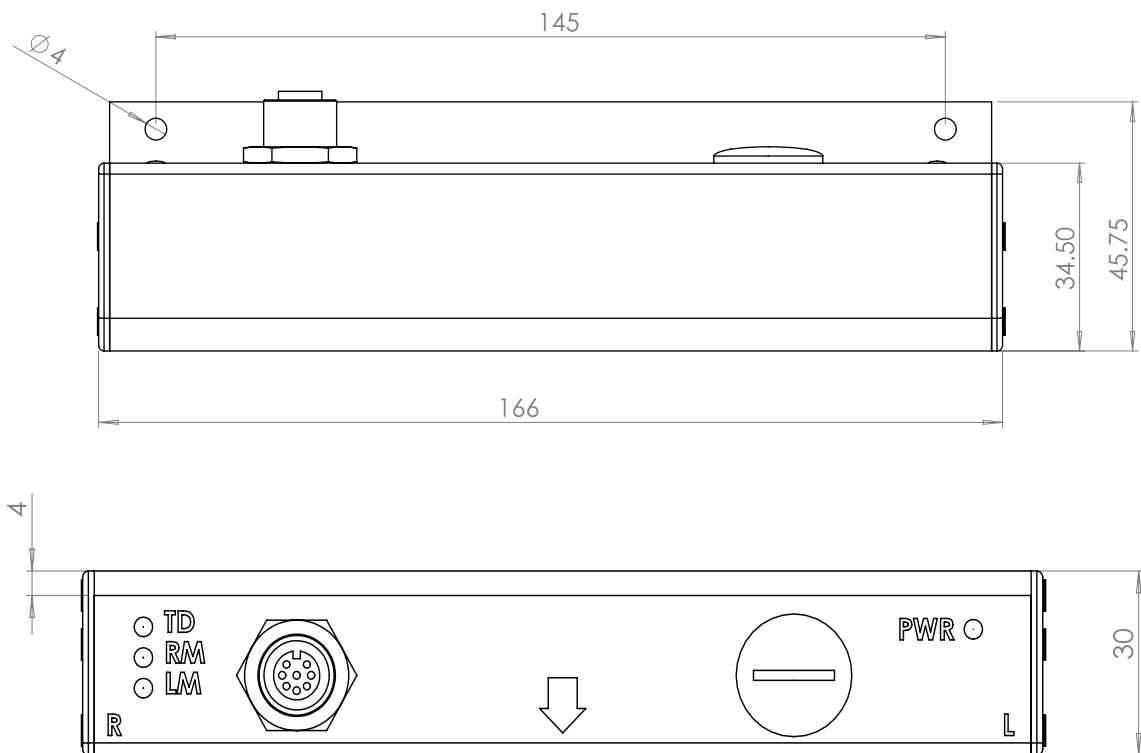


FIGURE 9. OTS1600 Front View and Dimensions