KVH E·Core 2000 Fiber Optic Gyro

Technical Manual

E·Core™ 2000

Congratulations!

The E•Core™ 2000 Fiber Optic Gyro (FOG) is the perfect replacement for troublesome mechanical gyroscopes in applications such as antenna and optical stabilization, navigation, positioning, robotics, and instrumentation. Wide bandwidth, excellent resolution, and bias stability combined with resistance to shock and vibration make the KVH E•Core 2000 the ideal upgrade and state-of-the-art solution for tracking, stabilization and GPS/FOG navigation.

Should you have any questions, comments, or suggestions, please direct them to:

KVH Industries, Inc.
50 Enterprise Center
Middletown, RI 02842 USA
tel: (401) 847-3327
fax: (401) 849-0045
e-mail: info@kvh.com
Internet: http//www.kvh.com

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1 Introduction

1.1 Applicability

This technical manual is for KVH Industries' E•Core 2000 fiber optic rate gyros with analog and digital outputs. Technical and performance specifications, interfaces, installation guidance and procedures are included, as well as a brief troubleshooting guide. This manual covers model RA2000 (analog) and RD2000 (digital) rate gyros with the following part numbers:

Table 1: Part Numbers

Model No.	Max. Deg/sec.	Power (VDC)	Output	Rate (Hz)	Part No.
RA2030	30	12	Analog	---	225386-1
RA2030	30	24	Analog	---	225386-2
RA2100	100	12	Analog	---	225386-3
RA2100	100	24	Analog	---	225386-4
RD2030	30	12	RS232	10	225382-1
RD2030	30	12	RS422	10	225382-2
RD2030	30	24	RS232	10	225382-3
RD2030	30	24	RS422	10	225382-4
RD2100	100	12	RS232	10	225382-5
RD2100	100	12	RS422	10	225382-6
RD2100	100	24	RS232	10	225382-7
RD2100	100	24	RS422	10	225382-8
RD2030	30	12	RS232	100	225382-9
RD2030	30	12	RS422	100	225382-10
RD2030	30	24	RS232	100	225382-11
RD2030	30	24	RS422	100	225382-12
RD2100	100	12	RS232	100	225382-13
RD2100	100	12	RS422	100	225382-14
RD2100	100	24	RS232	100	225382-15
RD2100	100	24	RS422	100	225382-16

1.2 Product Description

The RA2000 and RD2000 rate gyros are single-axis interferometric fiber optic rate sensors for use in a wide range of stabilization and navigation applications. Based on proprietary polarization-maintaining fiber and precision fiber optic gyroscope technology, the 2000 series rate sensors employ an analog electronic signal processor and an all-fiber optical system. The gyros measure angular rate of rotation, which can be integrated to allow turning angle to be measured accurately. Operating either from nominal 12 VDC or 24 VDC unconditioned power, it outputs either an analog voltage or a digital message proportional to rotation rates of up to ±30 degrees or ±100 degrees per second, depending on the version selected. The E•Core 2000 series of rate gyros are self-initializing and ready for use approximately one second after power is applied.

Product specifications are given in Table 2. Please read the entire manual prior to making connections between the unit and your system.

Table 2: Product Specifications

Attribute	Low Rate	Standard
Performance		
Input rotation rate (deg/sec)	±30	±100
Resolution rate (deg/sec)	0.014	
Scale factor		
Analog version (mV/deg/sec)	66.7	20
Digital version (deg/sec/bit)	0.000915	0.00305
Non-linearity (% rms)	0.2	0.5
Bias stability over full temperature (deg/sec p-p)	0.12	0.4
Angle Random Walk (deg/hr/rt-Hz)	5	
Angle Random Walk (deg/rt-hr)	0.08	
Bandwidth, 3 dB, 45° phase shift	100 Hz	
Initializing (start up) time	1 second	

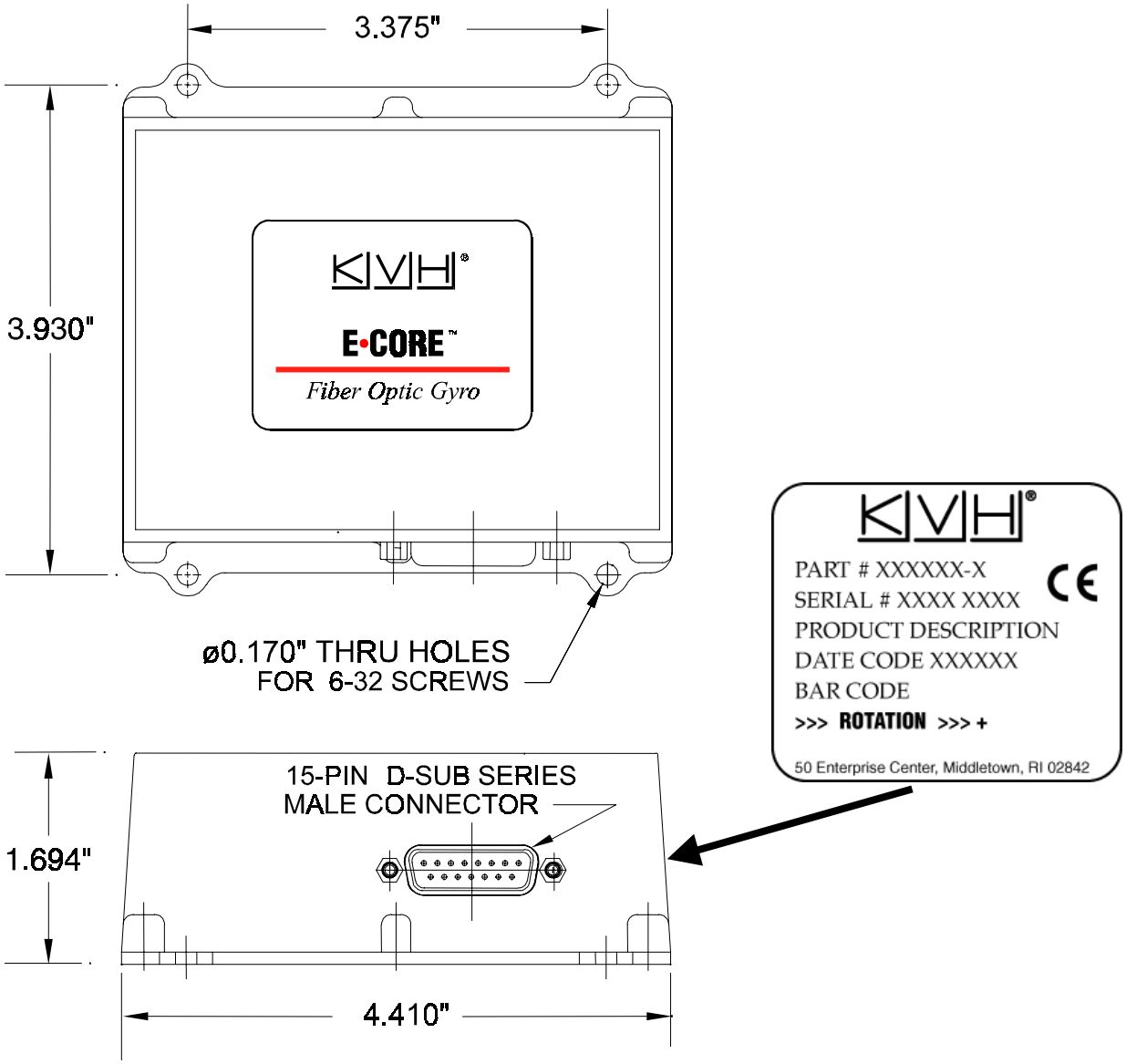
(Continued on next page)

Table 2: Product Specifications (continued)

Attribute	Low Rate Standard
Electrical	
Operating power (transient and reverse polar protected)	+9 to +18 VDC or +18 to +36 VDC or analog 2W; digital 3W
Analog output	
Turning rate	+2.5 VDC ±2.0 VDC into 10 kΩ load
Rate reference	+2.5 VDC into 10 kΩ load
Internal temperature	20 mVDC/°C into 10 kΩ load
Digital output	RS232 or RS422 @ 9600 baud
Rate	15 bits plus sign precision
Internal temperature	0.05°C/bit
Environmental	
Operating temperature	-40° to +75°C (-40° to +167°F)
Storage temperature	-50° to +85°C (-58° to +185°F)
Dimensions	112mm x 108mm x 43mm 4.41" x 4.27" x 1.69"
Weight	340 gm (12 oz)

An interface control drawing (ICD) illustrating the dimensions, connector placement and mounting arrangements is provided in Figure 1. Note that an arrow on the label of the product shows the sense of rotation corresponding to a positive output.

Figure 1: Interface Control Drawing



2 Installation and System Test

Installation requirements are similar for both versions of the RA2000 and RD2000 series fiber optic gyro rate sensors; testing procedures differ between the analog and digital versions and are discussed separately below. A simple familiarization test is suggested if this is your first introduction to the rate sensor product. This will also verify proper unit operation and assist in troubleshooting.

2.1 Preliminary Testing

2.1.1 RA2000 Series (Analog)

Equipment needed to test the analog version is a +12 VDC or +24 VDC power supply (depending on your version's power option), a digital voltmeter, and an interface cable with a female 15-pin D-sub connector wired as shown in Table 3.

Table 3: Electrical Interface (Analog Output)

Pin	Function	Characteristics
1	+12 VDC (-1, -3 versions)	+9 to +18 VDC @ 170 mA
2	Power common	- - -
3	Spare	- - -
4	+24 VDC (-2, -4 versions)	+18 to +36 VDC @ 85 mA
5	Spare	- - -
6	VSS (odometer) output	TTL low pulses, 0-2550 Hz
7	REVERSE output	TTL (low = reverse)
8	Fault	TTL (low = fault)
9	Temperature	0°C = 2.5 VDC; scale factor 20 mV/°C
10	Chassis ground	- - -
11	Rotational rate output	+2.5 VDC ±2 VDC into 10 kΩ
12	Rate/temperature reference	+2.5 VDC into 10 kΩ
13	VSS (odometer) input	+2 to +40 VDC, 0-2550 pps
14	REVERSE input	+2 to +40 VDC
15	Signal common	- - -

Notes:

VSS and REVERSE signal outputs can drive two TTL loads each.

Case ground may be either through an external connection to chassis ground (pin 10) or through the module mounting flange. A case ground to both points may result in a ground loop.

2.1.1.1 Test Procedure (Analog)

1. Place the module on a flat surface with the mounting surface down.
2. Connect the proper source voltage to the interface cable pins listed in Table 3.
3. Connect the voltmeter positive probe to pin 11; connect the negative probe to pin 15.
4. Measure the voltage; it should be a steady +2.5 V ±0.2 VDC.
5. Connect the voltmeter to pins 11 and 12, with pin 12 as the reference in a differential mode. (If a differential mode is not available, use pin 15 as the signal ground. There may be a slight error in the zero rotation measurement.)
6. Grasp the module and slowly rotate in the direction of the arrow on the serial number label. The measured voltage should increase. Rotate the module in the opposite direction, the resulting voltage should go negative. Note that this is a differential measurement with respect to the reference voltage.
7. Connect the voltmeter to pin 8 (positive) and pin 15 (negative). Observe a TTL level voltage (+5 VDC nominal).
8. If the REVERSE interface is used, connect the voltmeter to pin 7 (positive) and pin 15. A +5 VDC level should be present. Apply a +12 ±3 VDC signal to pin 14 (positive) and the negative connected to pin 2. The voltage seen at pin 7 should decrease to less than 0.7 VDC (REVERSE condition).
9. If the VSS interface is used, connect the voltmeter to pin 6 (positive) and pin 15 (negative). A +5 VDC level should be present. Apply a +12 ±3 VDC signal to pin 13 (positive) and the negative connected to pin 2. The voltage seen at pin 6 should decrease to less than 0.7 VDC.

If an A/D converter is used to digitize the data, be sure to provide sufficient dynamic range. A minimum of 14 to 16 bits is recommended.

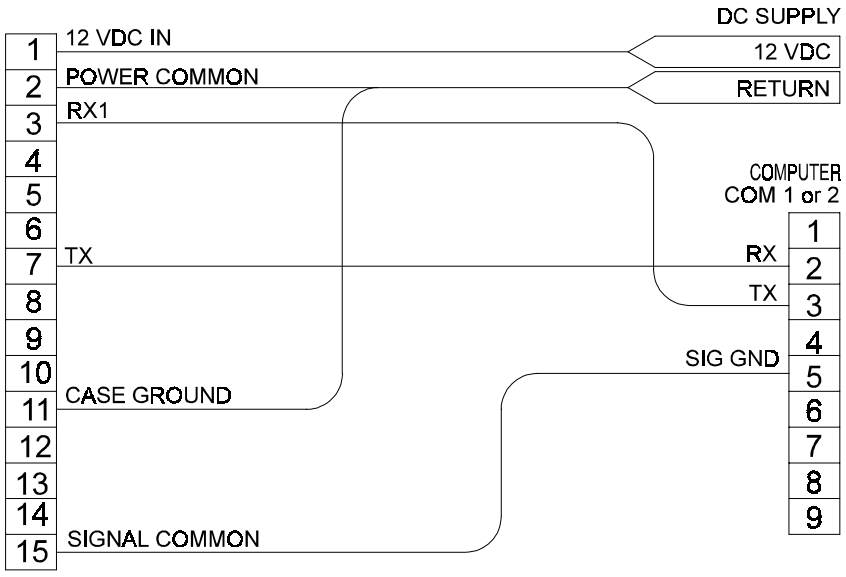
2.1.2 RD2000 Series (Digital)

Required equipment includes a +12 VDC or +24 VDC power supply (depending on your version's power option), an MS-DOS compatible computer (80386 microprocessor or higher), and an interface cable with a female 15-pin D-sub connector wired as shown in Table 4. A test cable to connect the gyro module, power supply and computer is illustrated in Figure 2 on the following page. Optional connections may be made to a voltage source and pulse generator to simulate a vehicle backup light and odometer pulse trains if your application requires it.

Table 4: Electrical Interface (Digital Output)

Pin	Function	Characteristics
1	+12 VDC (-1, -3 versions)	+9 to +18 VDC @ 170 mA
2	Power common	- - -
3	Spare	- - -
4	Spare	- - -
5	Spare	- - -
6	Spare	- - -
7	Tx1+ (host)	RS232 or RS422, 9600 baud
8	Tx1-	RS422 only
9	Spare	- - -
10	Spare	- - -
11	Chassis ground	- - -
12	+24 VDC (-2, -4 versions)	+18 to +36 VDC @ 85 mA
13	VSS (odometer) input	+2 to +40 VDC, 0-2500 pps
14	REVERSE input	+2 to +40 VDC
15	Signal common	- - -

Figure 2: Test Cable Wiring Diagram
(Configured for +12 VDC power)



A test software program is shipped with each RD2000 module on a 3½" diskette. Install the software as directed by the README.TXT file on the diskette. Please refer to the diskette for a discussion of serial data interfacing techniques and sample code to capture data from the digital interface.

2.1.2.1 Test Procedure (Digital)

Place the RD2000 module on a flat surface with the mounting surface down.

If your module is designed for 12 volt operation, connect the DC power supply positive to pin 1; connect the negative to pins 2 and 11. If your module is designed for 24 volt operation, connect the DC power supply positive to pin 12; connect the negative to pins 2 and 11.

1. Connect the DB9 plug from the test cable harness. Open the test data acquisition program. Select a serial port (COM1 or COM2).
2. With the module held stationary, the indicated rotation rate should be less than 0.2 degrees per second. If no data is received or is garbled, check the wiring for proper data line connection. Check the communications program parameters in the computer for proper settings: 9600 baud, 8 bits, and no parity.
3. Enter the AUTOZERO command to establish the at-rest count output.

4. Grasp the module and slowly rotate it in the direction of the arrow on the serial number label. The output data should indicate a positive change. Rotation in the opposite direction should result in a negative change. The FAULT indicator should show TTL HI (+5 VDC) at all times.
5. Apply the power supply positive output to pin 14, with pin 2 as the signal ground. The REVERSE indicator should show True. When the voltage is removed from pin 14, the indicator should revert to False.
6. Apply a pulse train between +2 and +40 VDC and less than 2500 Hz to pin 13, with pin 2 as signal ground. The odometer indicator count should be one-tenth the applied pulse rate (odometer pulses are summed for 0.1 second).

2.2 Installation Tips

2.2.1 Attitude and Orientation

The sensed axis of rotation is perpendicular to the plane of the baseplate. The arrow on the label on the side of the module casing indicates the direction of rotation resulting in a positive-going output. To minimize output errors and cross-coupling to the sensitive axis of the gyro, the mounting surface should be within five degrees of parallel to the plane normal to the rotational axis. If this is not observed, the output data varies as a function of the cosine of the misalignment angle.

2.2.2 Vehicle Installations

The installation site in the vehicle is principally determined by ambient environmental considerations. Most installations are in the trunk, or the module may be mounted under a seat. The module should not be exposed to direct sunlight or immersion in fluids. The gyro should not be mounted within 12 inches of any source of strong magnetic fields.

The module's internal circuitry generates a nominal amount of heat, which must be conducted away from the module to maintain an operating temperature within specified levels. The baseplate should be in full contact with a metal surface of at least 0.043 m^2 (65 in^2) surface area. If this is not possible, then a metal plate of the same area should be attached to the baseplate as a heat sink.

2.2.3 Power Connections

The rate gyro is designed to be connected to unconditioned vehicle power within specified limits. It is protected against reverse voltage polarity and transients normally experienced in automotive electrical systems. To limit voltage drops, a minimum wire gauge of 24 AWG is suggested for runs under 5 feet and at least 20 AWG for longer runs. Chassis and power grounds should be connected together at the module connector if the mounting location does not provide a good ground. Poor grounds generally result in increased rate noise.

2.2.4 Data Connections

For analog outputs, the rotation rate and reference outputs should be fed to high impedance (10 kΩ or higher) analog-to-digital (A/D) converters. If a differential input A/D converter is used, the zero rotation rate will correspond to a 0 VDC signal. If the converter is single-ended, the rotation rate and signal ground connections should be utilized; in this case the zero rotation rate will correspond to +2.5 VDC, and will not be as accurate as the differential measurement. Connections should be made with twisted shielded pairs, with the shield connected to pin 2 and left open (unconnected) at the A/D converter end.

2.2.5 Sensor Zero Offset

As with most sensors, the gyro has a zero offset bias (i.e., the output at zero rotational rate usually differs from nominal zero). In some applications it is useful to measure the offset for 5 to 30 seconds when the gyro is known to be stationary and use the average of this measurement as the zero offset. This offset would then be subtracted from all later readings before proceeding with other calculations. The offset can be re-estimated as necessary and appropriate for the system accuracy required. Since the offset is primarily a function of temperature, the user may measure the offset for a given gyro at various temperatures and create a table of offset vs. temperature.

3 Troubleshooting

This section is intended to provide a simple means of determining if a problem exists in the KVH E•Core 2000 series gyro and assumes that the unit has passed the bench testing described in Section 2.

The E•Core 2000 is supplied as a sealed unit. Breaking the QA seals voids the warranty and may violate the contract under which the unit was supplied.

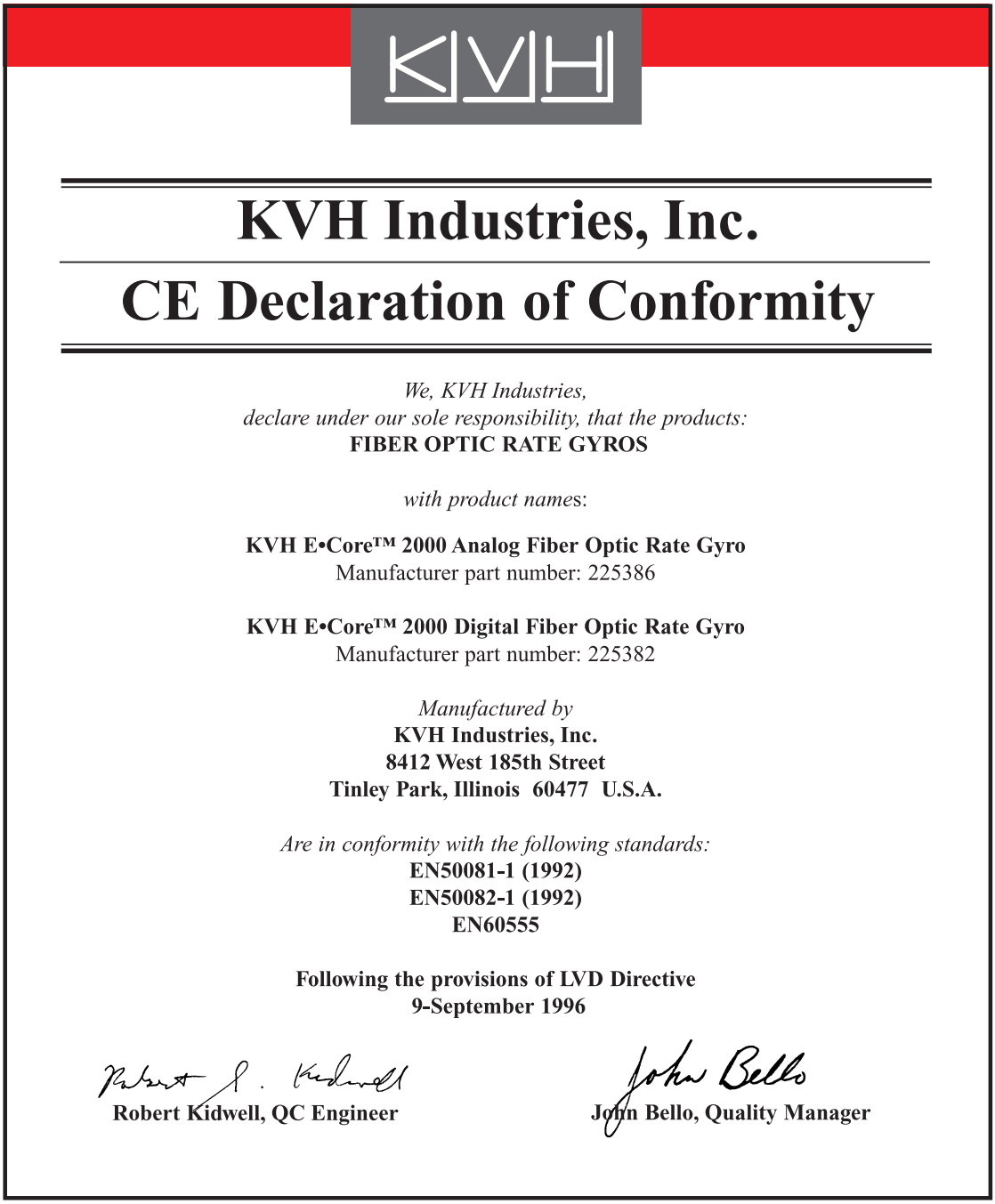
The warranty does not apply if the unit has been damaged by misuse or as the result of service or modification other than by KVH Industries.

Table 5: Troubleshooting

Symptom	Possible Cause	Action
No output	No DC power	Use supplied test software to verify output
	Internal fault	Fault line level (pin 8) should be TTL high (+5VDC)
Erratic or low output	Faulty ground	Ground shield at gyro end only
	Magnetic field near sensor	Check for new wiring or equipment
	Improper output impedance	Check load impedance for minimum 10 kΩ
High noise	Ground loop	Check grounds and grounding

4 CE Mark

The E•Core 2000 series fiber optic gyros conform to the European community CE Mark as indicated by the following declaration:



KVH Industries, Inc.

CE Declaration of Conformity

We, KVH Industries,
declare under our sole responsibility, that the products:
FIBER OPTIC RATE GYROS

with product names:

KVH E•Core™ 2000 Analog Fiber Optic Rate Gyro
Manufacturer part number: 225386

KVH E•Core™ 2000 Digital Fiber Optic Rate Gyro
Manufacturer part number: 225382

Manufactured by
KVH Industries, Inc.
8412 West 185th Street
Tinley Park, Illinois 60477 U.S.A.

Are in conformity with the following standards:
EN50081-1 (1992)
EN50082-1 (1992)
EN60555

Following the provisions of LVD Directive
9-September 1996

Robert Kidwell, QC Engineer

John Bello, Quality Manager

Appendix A Digital Interface Specification

A.1 Digital Data Output Functions

- Angle change-per-unit time with 16-bit resolution. Full scale gyro output represents ±100 (or ±30) degrees/second velocity when one second of data is integrated. For the 10 Hz output rate versions, one sample (0.1 second) represents 10 (or 3) degrees rotation at a maximum ±100 degrees/second rotation rate. For the 100 Hz output rate versions, one sample (0.01 second) represents ±1 (or ±0.3) degree of rotation at a maximum ±100 (±30) degrees/second rotation rate.

- Temperature output with a range of –55°C to +100°C and a resolution of 0.05°C; 0 output=0°C.

- Odometer count representing the pulse count of the VSS (Vehicle Speed Sensor) during a 0.1 (or 0.01) second sample time for pulse rates from 0 to 2550 pps. The output count is the difference from the previous count to insure no over/under counts.

- Built-in test (BIT), “vehicle in reverse”, gyro serial number.

- CHECKSUM

A.2 Specifications

Table 6: Digital Data Information

Data Type	Definition/Setting
Interface format	Serial asynchronous, RS232e or RS422
Characters per data group	8
Character format	See Table 4
Baud rate	9600 (default) or 4800
Parity	No parity
Start bits	1 (LO Level)
Stop bits	1 (HI Level)
Data bits	8 (Logic 1 = HI, Logic 0 = LO)
Inter-character spacing	None
Character group spacing	0.1 second or 0.01 second
Character group spacing accuracy	0.001 second
Group synchronization	Embedded
Connector type	15 pin (D-Subminiature) Male

A.3 Data Group Structure

Characters within an eight-character data group are referred to as Character 1 through 8, with Character 1 being the first character sent. In Table 7, D0 to D7 refers to the bit positions, where D0 is the first bit sent and D7 is the last bit sent per character. It also shows the position of each data bit in the eight-bit data group, as well as the contents of each data bit. Scaling factors are discussed after Table 7.

Table 7: Data Format

Character 1	D0	DATA49	Character 5	D0	DATA21
	D1	DATA50		D1	DATA22
	D2	DATA51		D2	DATA23
	D3	DATA52		D3	DATA24
	D4	DATA53		D4	DATA25
	D5	DATA54		D5	DATA26
	D6	DATA55		D6	DATA27
	D7	SYNCBIT (HI)		D7	SYNCBIT (LO)
Character 2	D0	DATA42	Character 6	D0	DATA14
	D1	DATA43		D1	DATA15
	D2	DATA44		D2	DATA16
	D3	DATA45		D3	DATA17
	D4	DATA46		D4	DATA18
	D5	DATA47		D5	DATA19
	D6	DATA48		D6	DATA20
	D7	SYNCBIT (LO)		D7	SYNCBIT (LO)
Character 3	D0	DATA35	Character 7	D0	DATA7
	D1	DATA36		D1	DATA8
	D2	DATA37		D2	DATA9
	D3	DATA38		D3	DATA10
	D4	DATA39		D4	DATA11
	D5	DATA40		D5	DATA12
	D6	DATA41		D6	DATA13
	D7	SYNCBIT (LO)		D7	SYNCBIT (LO)
Character 4	D0	DATA28	Character 8	D0	DATA0
	D1	DATA29		D1	DATA1
	D2	DATA30		D2	DATA2
	D3	DATA31		D3	DATA3
	D4	DATA32		D4	DATA4
	D5	DATA33		D5	DATA5
	D6	DATA34		D6	DATA6
	D7	SYNCBIT (LO)		D7	SYNCBIT (LO)

Gyro rate and temperature data are always in two's complement binary form. The least significant (LSB) is always placed in DATA0. Character synchronization can be verified by viewing the SYNCBITs in an eight-character group for the 1, 0, 0, 0, 0, 0, 0, 0 sequence prior to using the data.

A.4 Message Contents and Scaling

Table 8: Message Contents

Bit Name	Bit	Bit Name	Bit	Bit Name	Bit
DATA0	R0 (LSB)	DATA19	T3	DATA38	B6
DATA1	R1	DATA20	T4	DATA39	B7
DATA2	R2	DATA21	T5	DATA40	B8
DATA3	R3	DATA22	T6	DATA41	B9
DATA4	R4	DATA23	T7 (MSB)	DATA42	B10
DATA5	R5	DATA24	C0 (LSB)	DATA43	B11
DATA6	R6	DATA25	C1	DATA44	B12
DATA7	R7	DATA26	C2	DATA45	B13
DATA8	R8	DATA27	C3	DATA46	B14
DATA9	R9	DATA28	C4	DATA47	B15
DATA10	R10	DATA29	C5	DATA48	X0
DATA11	R11	DATA30	C6	DATA49	X1
DATA12	R12	DATA31	C7 (MSB)	DATA50	X2
DATA13	R13	DATA32	B0	DATA51	X3
DATA14	R14	DATA33	B1	DATA52	X4
DATA15	R15 (MSB)	DATA34	B2	DATA53	X5
DATA16	T0 (LSB)	DATA35	B3	DATA54	X6
DATA17	T1	DATA36	B4	DATA55	X7
DATA18	T2	DATA37	B5		

R0 to R15 represent angle rate bits counts with full scale from -100.0 degrees to +99.999695 degrees per second standard option. The LSB is 0.00305 degrees/second for 100 deg/sec rate units, 0.000915 degrees/second for 30 deg/sec rate units. Increment of angle is the rate scale times the measuring interval (0.1 or 0.01 second), e.g., for a 100 deg/sec unit with 10 Hz output rate, the LSB would show 0.000305 degrees angle increment in the 0.1 second measuring interval.

T0 to T7 (Message 1) and T0 to T7 (Message 2) provide a temperature word of 12-bits resolution plus sync bits, and are scaled for a range of -55 to +100°C. T0 (LSB) through T6 provide temperature data and T7 is the sync bit (logic HI in Message 1 and logic LO in Message 2). T5 and T6 in Message 2 are held low. Message 1 provides seven low bits and Message 2 provides five high bits, totaling 12 bits. Temperature is transmitted every two messages. The least significant bit is 0.05°C, and a zero out equals 0°C.

C0 to C7 represent odometer counts with the LSB representing a count of 1 and a full scale value of 255. The maximum input rate that can be processed is 2550 Hz.

B0 is the Built-in-Test (BIT) indicator and is logic HI during normal operation. B1 represents “vehicle in reverse” status and is logic LO when the reverse signal is received from the vehicle. B2 and B3 are the gyro serial number in 20-bit binary format. The serial number is output in consecutive data messages one bit at a time, starting with the least significant bit (LSB) and ending with the most significant bit (MSB). After the MSB, the process repeats in the next data message with the LSB. The serial number bits are encoded into the SNBIT bit in the message block (B3). The SNSYNC bit (B2) is high when SN0 is output, otherwise it is low. Bits B4 to B15 are not used.

X0 to X7 are the CHECKSUM for the data message. The CHECKSUM is calculated by the gyro processor as the sum of the six other data bytes, modulo 256 and then negated.

Appendix B Product Information

B.1 Patent Protection

One or more of the following patents protect the technology in KVH fiber optic rate sensors:

Australia	514,840
	562,456
	574,343
	582,425
	584,745
	594,847
	661,187
Canada	1,143,197
	1,234,005
	1,236,322
	1,248,383
	1,240,015
	1,267,790
	1,270,055
	1,293,397
	1,304,566
	2,138,814
France	0 021 712
	0 127 257
	0 196 168
	0 215 674
	0 254 462
Germany	P30 64 691.4
	P34 84 284.5
	P36 71 972.2
	P36 88 959.8
	P37 76 017.3
Italy	0 021 712
	67,166-BE/92
	67,730-BE/91
	69,253-BE/93
Japan	1,561,748
	1,870,145
	2,076,012
	2,509,580
Netherlands	0 196 168
	0 021 712
	0 215 674
United States	4,307,938
	4,557,551
	4,589,725
	4,589,728
	4,668,264
	4,669,814
	4,697,876
	4,712,866
	4,755,021
	4,784,454
	4,818,071
	4,950,318
	5,074,665
	5,323,255
	5,340,371
	5,437,000
	5,444,534
	5,481,358
	5,512,904
	5,552,887
United Kingdom	0 196 168
	0 021 712
	0 127 257
	0 215 674
	0 254 462
	1,599,345

KVH Industries, Inc.
50 Enterprise Center Middletown, RI 02842 U.S.A.
Phone: +1 401 847-3327 Fax: +1 401 849-0045
E-Mail: info@kvh.com
Internet: http://www.kvh.com

KVH Fiber Optic Group
8412 West 185th Street Tinley Park, IL 60477
Phone: +1 708 444-2800 Fax: +1 708 444-2801
E-Mail: info@kvh.com
Internet: http://www.kvh.com