AS37-H39B Series

39-Bit Battery Backup Multi-Turn Absolute Encoder

Application Note

BROADCOM®

Introduction

The AS37-H39B series encoder is a high-resolution optical absolute encoder produced by Broadcom®, which offers 23-bit single-turn and 16-bit multi-turn counts, hence a combined 39-bit high resolution. The AS37-H39B series encoder is a house encoder consisting of a patterned disk, a light source, and photosensitive elements to translate the mechanical motion into electrical signal.

The AS37-H39B series encoder has a built-in communication protocol that is supported by a full-duplex or half-duplex line transmissions drive, offering good noise immunity for more robust transmission of data up to 10 Mb/s in harsh industrial application. Because the product is intended for industrial application, ESD protection circuitry has been designed in to achieve Class 3 ESD immunity per IEC -61000-4-2 standard. The AS37-H39B series is also compliant with IP40 per IEC 60529 standard.

The key advantage of the AS37-H39B series is multi-turn tracking employs battery backup technology. It is gearless multi-turn counting that eliminates the gear wear-out or acoustics noise issue that is encountered in conventional geared multi-turn encoder.

Operating Theory

Structures-wise, the encoder contains two main functional blocks: the single-turn optical engine block and the battery backup multi-turn counter block. The single-turn engine comprises the Broadcom developed high-performance optical detector ASIC, which is accompanied by high-precision amplifiers circuitry, coupled with a special multi-track code disk that rotates between the LED emitter and detector IC.

On the multi-turn side, the multi-turn counting is enabled utilizing battery backup counter technology. During battery mode (encoder operates in main power OFF state), the battery backup circuitry periodically powers up the LED emitter and enables the photo sensor to scan the code disk multi-turn tracks for detection of shaft rotation. In order to prolong the battery life, extra effort has been put in the design of the ASIC to ensure minimum current consumption during battery mode operation. Therefore, no miscounts occur even in the absence of external power supply.
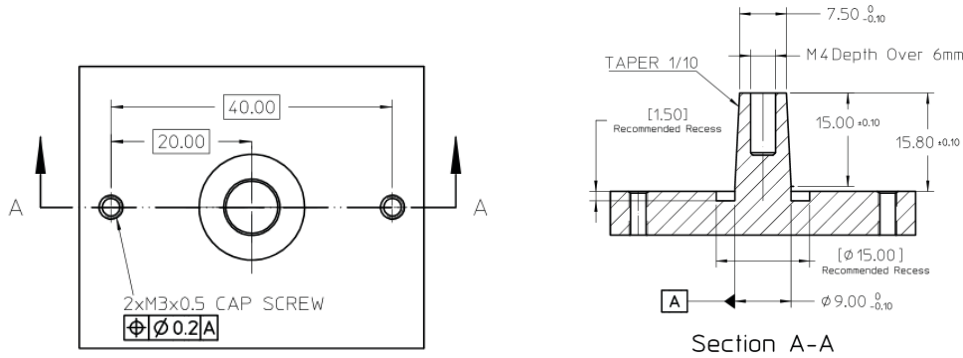
Applications

- Robotics
- Factory automation
- CNC machine tool

Mounting Requirement and Guideline

Standard Hollow Taper Shaft (Φ9 mm to Φ7.5 mm; 1:10)

Figure 1 Recommended Shaft and Mounting Holes for Standard Taper Shaft
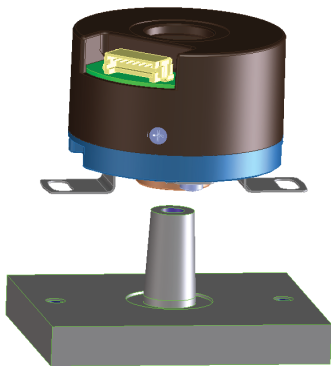

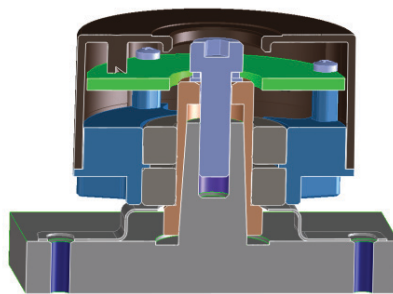Notes:

Dimensions are in millimeters.

3rd angle projection.

Unless otherwise specified, all tolerances are within ±0.5 mm.

Recommended to have a recess on motor mounting surface to prevent encoder shaft interference with motor base.

Step 1:

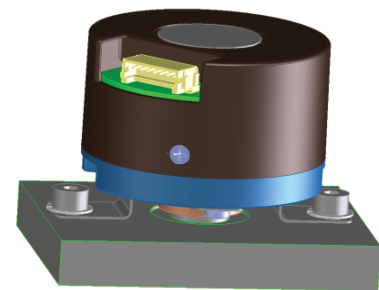Slide encoder taper shaft into motor shaft until the taper shaft of encoder is fully touching on the motor shaft.

Step 2:

Fasten the M4 socket head cap screw on top to the encoder shaft.

Recommended screw driver torque: 1.5 Nm

Seal the housing opening by using the sticker as dust protection. It is recommended to use Polyester film sticker.

NOTE To remove the encoder from motor shaft, an M5 X 40 mm screw is needed to eject encoder shaft from motor shaft.
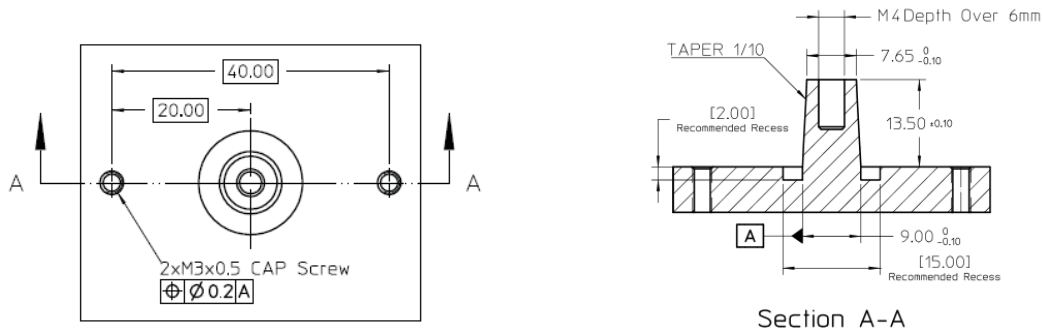
Step 3:

If necessary, perform a minor adjustment on the encoder orientation (M3 slot allows ±5 degree rotation). Follow by fastening both of the M3 coupling mounting screws.

It is recommended to use spring washer and flat washer. Apply screw thread lock fluid to better secure the coupling plate.

Recommended screw driver torque: 1 Nm with M3 socket head cap screw.

Short Hollow Taper Shaft Option (Φ9 to Φ7.65 mm; 1:10)

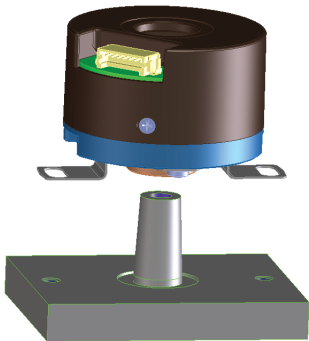**Figure 2 Recommended Shaft and Mounting Holes for Short Taper Shaft**

Note:

Dimensions are in millimeters.

3rd angle projection.
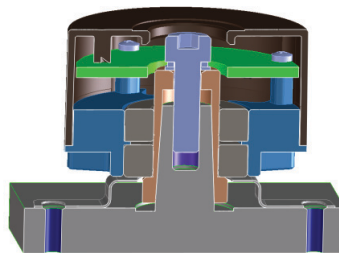
Unless otherwise specified, all tolerances are within ±0.5 mm.

Recommended to have a recess on motor mounting surface to prevent encoder shaft interference with motor base.

Step 1:

Slide encoder taper shaft into motor shaft until the taper shaft of encoder is fully touching on the motor shaft.
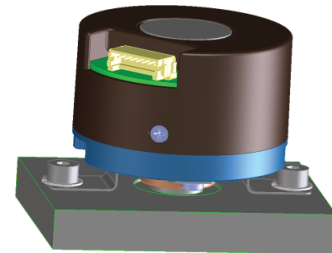
Step 2:

Fasten the M4 socket head cap screw on top to the encoder shaft.

Recommended screw driver torque: 1.5 Nm.

Seal the housing opening by using the sticker as dust protection. It is recommended to use Polyester film sticker.

NOTE To remove the encoder from motor shaft, an M5 X 40 mm screw is needed to eject encoder shaft from motor shaft.

Step 3:

If necessary, perform a minor adjustment on the encoder orientation (M3 slot allows ±5 degree rotation). Follow by fastening both of the M3 coupling mounting screws.

It is recommended to use spring washer and flat washer. Apply screw thread lock fluid to better secure the coupling plate.

Recommended screw driver torque: 1 Nm with M3 socket head cap screw.

Hollow Blind Shaft Option (Φ8 mm)

Figure 3 Recommended Shaft and Mounting Holes for Hollow Blind Shaft

Note:

Dimensions are in millimeters.

3rd angle projection.

Unless otherwise specified, all tolerances are within ±0.5 mm.

Recommended to have a recess on motor mounting surface to prevent encoder shaft interference with motor base.

Right

Step 1:

Slide encoder hollow shaft into motor shaft until the coupling plate is touching the motor base.

Step 2:

Fasten the M3 X 3 set screw on the right, followed by the set screw on the left.

Apply screw thread lock fluid to better secure the set screws.

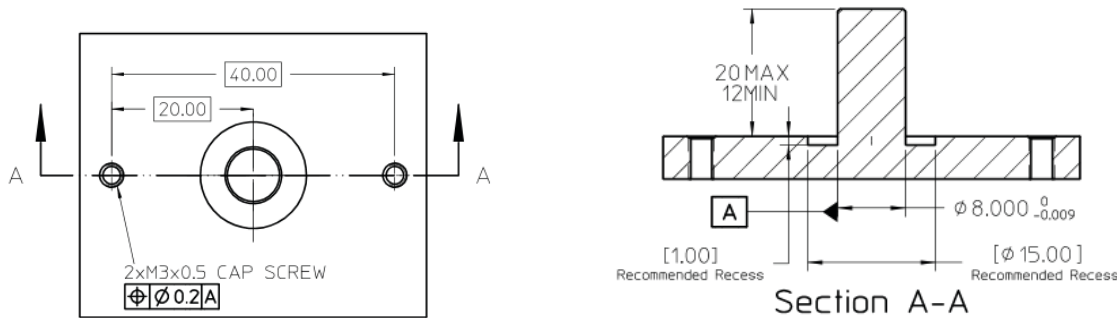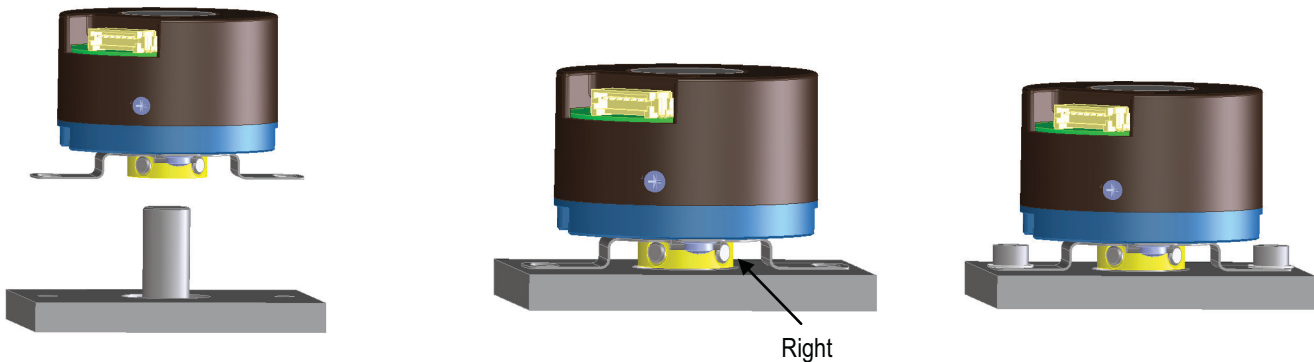Recommended screw driver torque: 0.35 Nm with 45H steel cup point M3 set screw.

Step 3:

If necessary, perform a minor adjustment on the encoder orientation (M3 slot allows ±5 degree rotation). Follow by fastening both of the M3 coupling mounting screws.

It is recommended to use spring washer and flat washer. Apply screw thread lock fluid to better secure the coupling plate.

Recommended screw driver torque: 1 Nm with M3 socket head cap screw.

Battery Backup

Recommended external battery to use:

- Product name = Toshiba ER6V/3.6V ER6VP
- Mfr. part no. = ER6VP
- Brand range = Toshiba Ultra Lithium
- Nominal voltage = 3.6V
- Nominal capacity = 2000 mAh
- Operating temperature range = –55°C ~ +85°C
- Size = AA

Figure 4 Recommended External Battery

NOTE The multi-turn data position is maintained with battery power during battery mode. The battery replacement process causes data loss. Therefore, you must reset the multi-turn counter after the battery is changed.

Battery life calculation depends on user application condition. Consult factory if assistance needed.

Connector Output Assignment

Pin	AS37-H39B-Bxxx (BiSS-C) (Output: 10-Pin Connector)	AS37-H39B-Sxxx (SSI) (Output: 10-Pin Connector)	AS37-H39B-Kxxx (RS-485 Half-Duplex) (Output: 7-Pin Connector)
1	Vcc, Encoder Supply	Vcc, Encoder Supply	Vcc, Encoder Supply
2	GND, Ground	GND, Ground	GND, Ground
3	GND (External Battery)	GND (External Battery)	GND (External Battery)
4	BATPWR (External Battery)	BATPWR (External Battery)	BATPWR (External Battery)
5	MA+	SCL+	DATA+
6	MA–	SCL–	DATA–
7	SLO+	DOUT+	Cable Shield, Connect to Chassis
8	SLO–	DOUT–	N/A
9	Cable Shield, Connect to Chassis	Cable Shield, Connect to Chassis	N/A
10	Cable Shield, Connect to Chassis	Cable Shield, Connect to Chassis	N/A

Figure 5 7- Pin Connector Pin Assignment

1st pin
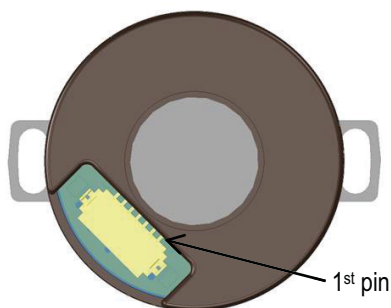
Figure 6 10-Pin Connector Pin Assignment

1st pin
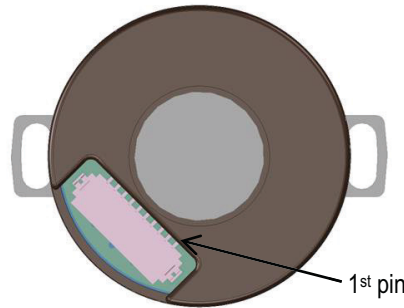
NOTE Recommended mating connector:

Hirose Part No: DF13-7S-1.25C for 7-pin connector and DF13-10S-1.25C for 10-pin connector (CL No.536-0006-8).

Hirose (Terminal Pin for Wire 26~30AWG): DF13-2630SCF (CL No.536-0300-5).

Recommended I/O Connection

- It is strongly recommended to provide encoder power supply, Vcc within 4.5V ~ 5.5V. Typical value is 5V.
- For best noise immunity, use twisted-pairs shielded cable for connection to controller (servo driver).
- Connect the encoder chassis and the cable shield to frame ground (FG) in application for enhanced noise immunity in harsh operating condition.
- To prevent undesirable signal reflections, the termination resistor is needed. Termination resistor, *120Ω and *220Ω ¼W are recommended but depend on the characteristic impedance of the cable used.

Full-Duplex Transceiver (BiSS C Mode/SSI Mode Protocol)

Figure 7 Circuit Diagram of Full-Duplex Transceiver

Half-Duplex Transceiver (RS-485 Half-Duplex Protocol)

Figure 8 Circuit Diagram of Half-Duplex Transceiver

Interface Protocol — BiSS-C

Data Communication

Interface	Circuit
Serial Clock (MA)	Transceiver (P/N: SN65LBC179Q)
Serial Data (SLO)	Transceiver (P/N: SN65LBC179Q)

Timing Characteristics

Parameter	Symbol	Condition	Value			Unit	Note
			Min	Typ	Max		
MA Frequency	f_{MA}	—	0.08	—	10	MHz	1
Busy	T_{busy}	—	$2/f_{MA} + 3.35$ μs	—	$2.5/f_{MA} + 3.75$ μs	μs	2
Timeout	$t_{BiSS\text{-}timeout}$	—	$1.5/f_{MA}$	—	$1.5/f_{MA} + 90$ ns	ns	2
Encoder Initialization Time	—	—	—	500	—	ms	

Figure 9 Timing Characteristics of MA and SLO

16bits MT + 23bits ST + 1 nErr bit + 1 nWar bit + 6bits CRC
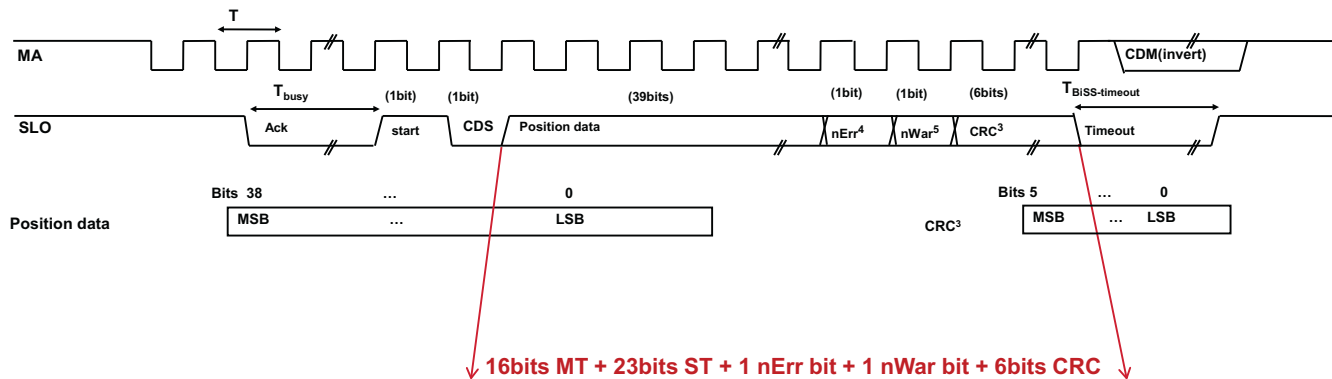
NOTE

1. MA low-time = $0.50/f_{MA}$; high-time = $0.50/f_{MA}$.

2. Refer to Figure 9 for timing description.

3. CRC Polynomial = Invert of $(X^6 + X^1 + X^0)$.

4. nErr bit is active low. (Combine all the Error Status and reflect in nErr bit.)

5. nWar bit is active low. (Combine all the Warning Status and reflect in nWar bit.)

Register Communication and Assignment

Refer to BiSS-C Interface Protocol Description Rev C5 document for detailed information.

http://biss-interface.com/files/Bissinterface_c5es.pdf

Memory Map (Non-Volatile Memory)

There are a total of 10 register banks user areas (register bank 0 to register bank 9) that are accessible by users.

The memory data are kept in non-volatile memory.

Table 1 Memory Map (Non-Volatile Memory)

BiSS C		Remarks
Bank	**Address**	
0	00h ~ 3Fh	User Area
1	00h ~ 3Fh	
2	00h ~ 3Fh	
3	00h ~ 3Fh	
4	00h ~ 3Fh	
5	00h ~ 3Fh	
6	00h ~ 3Fh	
7	00h ~ 3Fh	
8	00h ~ 3Fh	
9	00h ~ 3Fh	
—	40h	Bank Selection
	48h ~ 77h	Slave Register (Refer to the Slave Register Description – user area)

Note: EDS-Bank is not available.

Slave Register Descriptions

Address 72(0x48) — Error Status [7:0]

Bit7	**Bit6**	**Bit5**	**Bit4**	**Bit3**	**Bit2**	**Bit1**	**Bit0**
Battery Supply Alarm	Battery Supply Error	Multi-turn Counting Error	N/A	Multi-turn Counter Overflow Error	Single-turn Counting Error	N/A	Over Speed Error

Address 73(0x49) — Warning Status [7:0]

Bit7	**Bit6**	**Bit5**	**Bit4**	**Bit3**	**Bit2**	**Bit1**	**Bit0**
N/A						LisErr Warning	LedErr Warning

Address 74(0x4A) — Encoder Clear Command

Bit7	**Bit6**	**Bit5**	**Bit4**	**Bit3**	**Bit2**	**Bit1**	**Bit0**
N/A				Warning Clear Command[a]	Error Clear Command[a]	Single-turn Clear Command[a]	Multi-turn Clear Command[a]

a. Encoder Clear Command operation.
    — Write 1 to execute one time clear command.
   — Only one command should be accessed for each time.

Interface Protocol — SSI

Data Communication

Interface	Circuit
SSI Serial Clock (SCL)	Transceiver (P/N: SN65LBC179Q)
SSI Serial Data (DOUT)	Transceiver (P/N: SN65LBC179Q)

Timing Characteristics

Parameter	Min.	Typ.	Max.	Unit
SCL Frequency	0.133	—	1	MHz
Position Latency	3.4	3.6	3.8	µs
Position Jitter (Data Latch Uncertainty)	0.38	0.4	0.42	µs
tREQ	—	—	0.5	µs
SSI Time Out (DOUT Held Low when SCL High)	—	—	4.5	µs

Figure 10 Timing Characteristics of SCL and DOUT
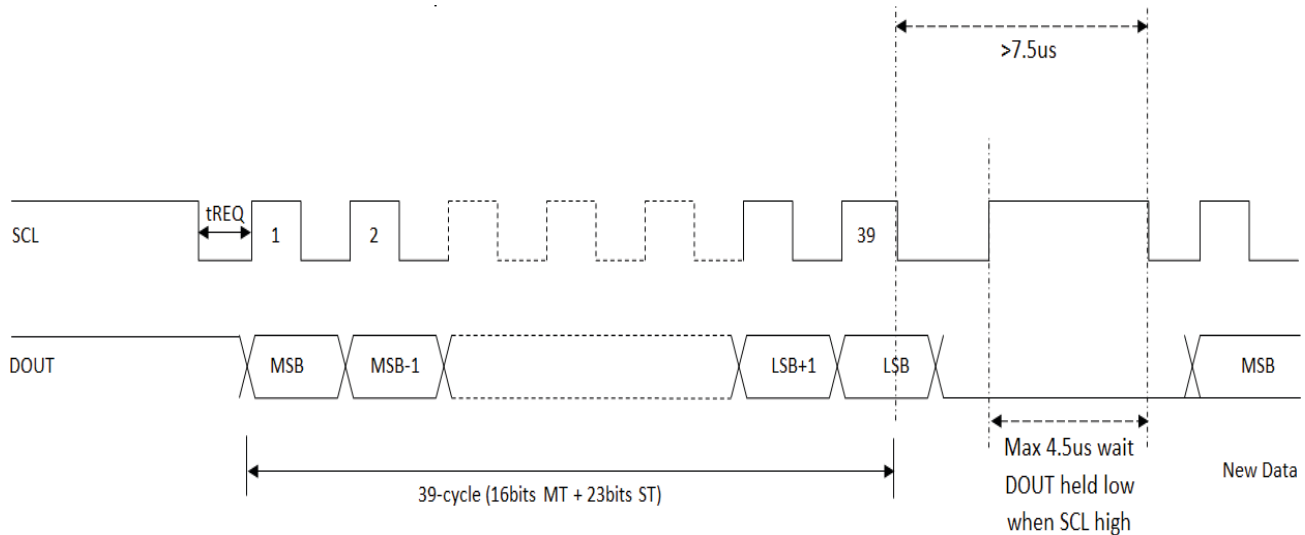
Note: The MSB is at first rising edge of SCL.

Interface Protocol — RS-485 Half-Duplex
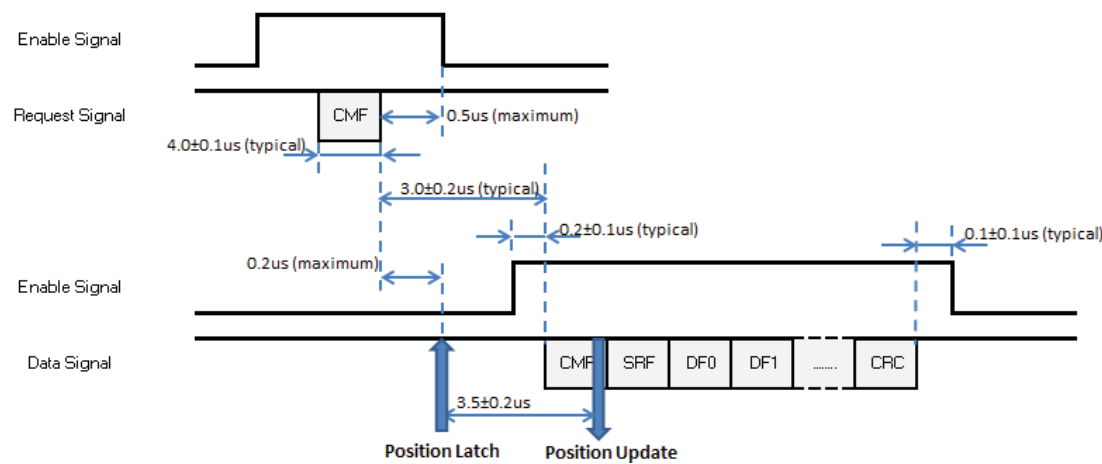
Data Communication

Interface	Circuit
RS-485 Serial Data (DATA+)	Transceiver (P/N: ISL8485E)
RS-485 Serial Data (DATA−)	Transceiver (P/N: ISL8485E)

Timing Characteristics

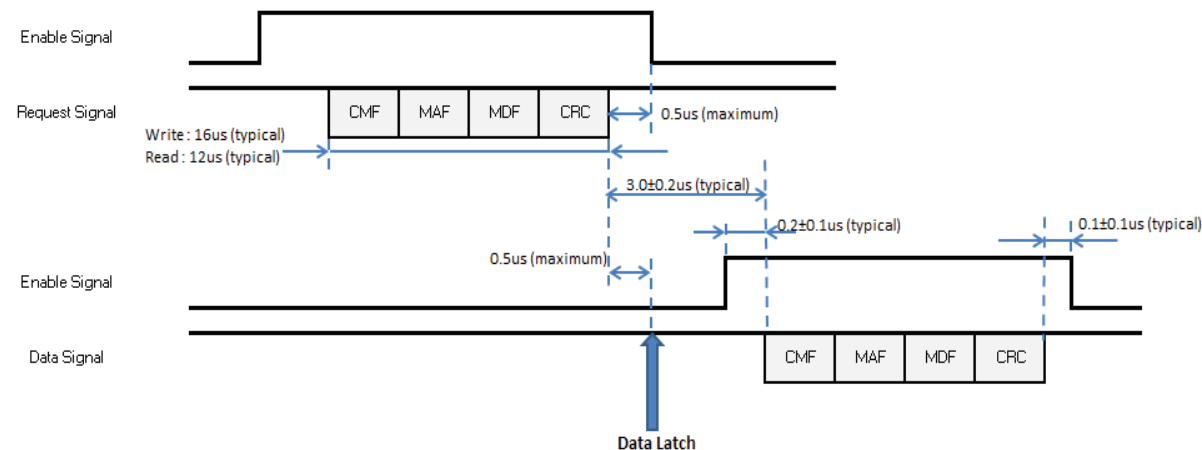| Parameter	Min.	Typ.	Max.	Unit
Communication Baud Rate	—	—	2.5	MHz
Frame Length	—	10	—	Bit/Frame

Position Red Frame

Figure 11 Timing Characteristics of Enable, Request, and Data Signals

EEPROM Read/Write Frame

Figure 12 Timing Characteristics of Enable, Request, and Data Signals

Register Communication and Assignment

Refer to AS37-H39B-Kxxx software specification document for detailed information.

Memory Map (Non-Volatile Memory)

There are a total of 5 register banks user areas (register bank 0 to register bank 4) that are accessible by users.

The memory data are kept in non-volatile memory.

Table 2 Memory Map (Non-Volatile Memory)

Bank	Address	Remarks
0	00h ~ 7Eh	User Area
Bank Selection	7Fh	
1	00h ~ 7Eh	
Bank Selection	7Fh	
2	00h ~ 7Eh	
Bank Selection	7Fh	
3	00h ~ 7Eh	
Bank Selection	7Fh	
4	00h ~ 7Eh	
Bank Selection	7Fh	

Note: EDS-Bank is not available.

Alarm Description

Error Flags	Detection Mode	Description	Reset Method
Over Speed Error	Battery mode	To detect over speed and wrong multi-turn counting during Battery mode. The error flag is latched and will be transmitted out once encoder entering normal mode. 1: Shaft rotation speed > 6000 rpm and wrong multi-turn count detected. 0: Condition 1) Shaft rotation speed < 6000 rpm or, Condition 2) Shaft rotation speed > 6000 rpm but no wrong multi-turn count detected. This error flag are Not defined if speed > 14000 rpm.	Perform all error clear
Single-turn Counting Error	Normal mode	To check integrity of single-turn position data calculation. 1: Error detected in single-turn position counting. 0: No Error detected.	Cycle power encoder
Counter Overflow Error	Battery mode	To indicate multi-turn counter overflow condition. (See Figure 13). The error flag is latched and will be transmitted out once encoder entering normal mode. 1: Multi-turn counter overflowed. 0: Multi-turn counter not overflowed.	Perform MT counter reset and all error clear
Multi-turn Counting Error	Normal mode	To check integrity of multi-turn position data counting. The error flag is latched. 1: Error detected in multi-turn position counting. 0: No Error detected.	Perform MT counter reset and all error clear
Battery Supply Error	Battery mode	To check backup battery supply low voltage condition. The error flag is latched and will be transmitted out once encoder entering normal mode. 1: Battery voltage is lower than 2.9 ± 0.25V. 0: Battery voltage is higher than 2.9 ± 0.25V.	Perform all error clear
Battery Supply Alarm	Normal mode	To check backup battery supply low voltage condition. The error flag will be automatically cleared once the battery voltage return to normal value. 1: Battery voltage is lower than 3.1 ± 0.1V. 0: Battery voltage is higher than 3.1 ± 0.1V.	Error flag automatically clear once battery voltage return to normal
LedErr Error	Normal mode	To indicate if LED current is out of operating range. 1: LED out of operating range. 0: LED within operating range.	Cycle power encoder
LisErr Error	Normal mode	To check integrity of ADC Sin and Cos signals by means of Lissajous specifications. 1: Lissajous out of specification. 0: Lissajous within specification.	Cycle power encoder

Multi-Turn Counter Overflow Flag Explanation

Figure 13 Relation between Multi-Turn Counting and Overflow Flag
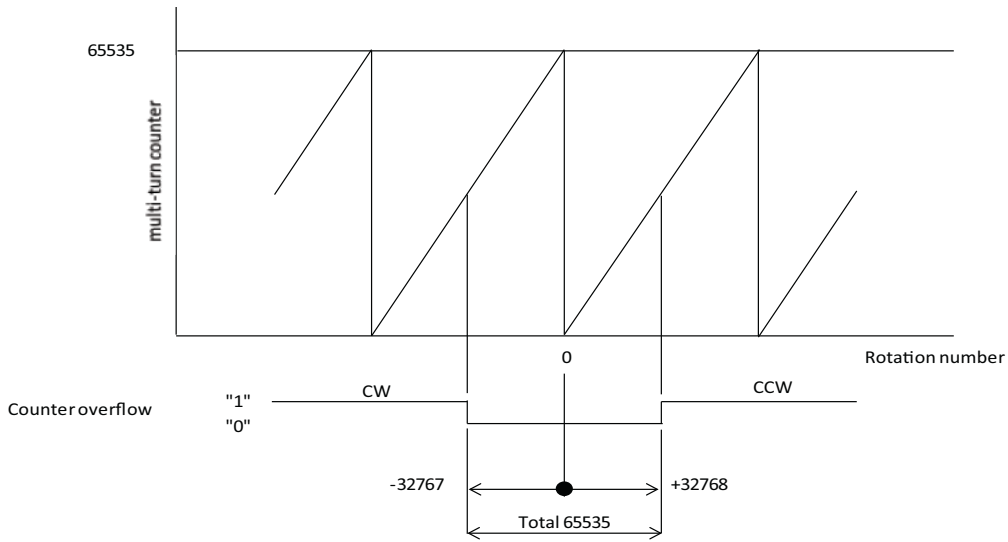
Trouble Shooting Guide

No.	Description	Causes	Counter Measure
1	No output	Encoder power supply too low	Check if Vcc versus ground potential is within 4.5V ~ 5.5V.
		Poor connectivity between encoder connector to customer connector	Check encoder connector and customer connector connectivity.
		Wrong wire connection assignment	Check connector wire connection assignment.
		Detector IC faulty/shorted	Perform power cycle. If the problem still exists, consult factory.
		Transceiver faulty/shorted	
2	Encoder high current consumption (>200 mA at 25°C)	LED faulty/ shorted	
		Detector IC faulty/shorted	
		Transceiver faulty/shorted	
3	Single-turn Counting Error triggered	Single-turn block faulty	
4	Multi-turn Counting Error triggered	Multi-turn block faulty	
5	LedErr triggered	LED faulty	
6	LisErr triggered	LED faulty	
		Codewheel issue	
		Single-turn block faulty	
7	Over Speed triggered	Speed > 6000 rpm	Check motor speed and make sure it is <6000 rpm.
8	Multi-turn Counter Overflow triggered	Out of the range of −32767 and +32768	Perform multi-turn data reset request.
9	Battery Supply Error triggered	Battery voltage is less than 2.9 ± 0.25V	Check battery voltage.
		Battery installation issue	Check battery installation condition (e.g., polarity is correct).
		Battery low/damage	Replace battery.
10	Battery Supply Alarm triggered	Battery voltage is less than 3.1 ± 0.1V	Check battery voltage.
		Battery low/damage	Replace battery.

Do

- Do ensure clean environment during installation.
- Do ensure encoder power supply is within 5V ± 10%.
- Do replace batteries with the recommended size and type.
- Do provide adequate protection from dust and moisture when using in harsh environment.
- Do ensure pin configuration is per data sheet.
- Do observe all ESD precautions when performing installation or handling the encoder.

Don't

- Do not overload transceiver by using wrong termination resistor.
- Do not hammer encoder shaft into motor shaft during installation.
- Do not deform coupling plate during installation.
- Do not reverse the power source polarity for both encoder main power and battery power.
- Do not operate encoder under extreme temperature over time.

For the detail specification of this encoder, refer to the *AS37-H39B Series Data Sheet*:

https://docs.broadcom.com/docs/AS37-H39B-DS100

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