Application Note

AS38-H39E Series

39-Bit Energy-Harvesting Multi-Turn Absolute Encoder

Introduction

The Broadcom® AS38-H39E series encoder is a high-resolution optical absolute encoder that offers 23-bit single-turn and 16-bit multi-turn counts, hence a combined 39-bit high resolution. The AS38-H39E 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 AS38-H39E 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 AS38-H39E series is also compliant with IP50 per IEC 60529 standard.

The key advantage of the AS38-H39E series is its multi-turn tracking that employs energy-harvesting technology by harvesting the magnetic energy as the encoder shaft rotates. It is the gearless multi-turn counting that eliminates the gear wear-out or acoustics noise issue that is encountered in conventional geared multi-turn encoder. On the other hand, when comparing to battery backed up multi-turn counting, this technology does not require periodic maintenance of the battery backup components and the down time associated with it.

Operating Theory

Structures-wise, the encoder contains two main functional blocks: the single-turn optical engine block and the energy-harvesting multi-turn counter block. The single-turn engine comprises a 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 energy-harvesting technology. When the shaft is rotating, the magnet mounted on the shaft moves in tandem. The energy-harvesting coil module cuts the moving magnet field, and generates energy as a result.

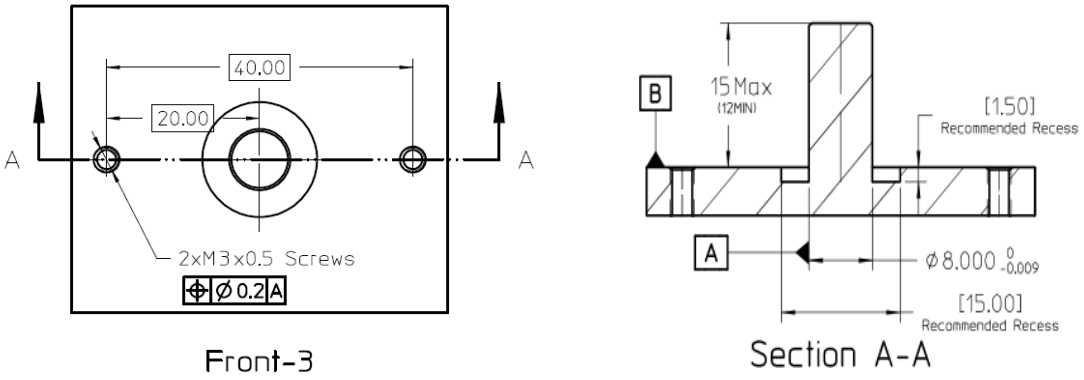
The beauty of the energy-harvesting effect is that the same amount of energy is generated independent of the rotation speed. The generated energy is sufficient to power up the revolution tracking circuitry. Therefore, no miscounts occur even in the absence of external power supply.

Applications

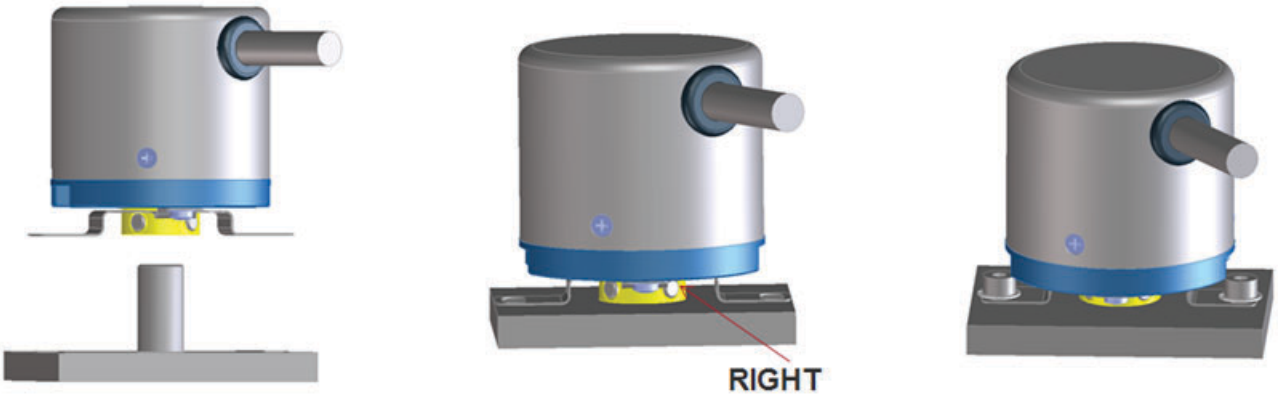
- Robotics
- Factory automation
- Linear positioning system
- CNC machine tool
- Medical and lab equipment

Mounting Requirement and Guideline

Figure 1: Recommended Shaft and Mounting Holes



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

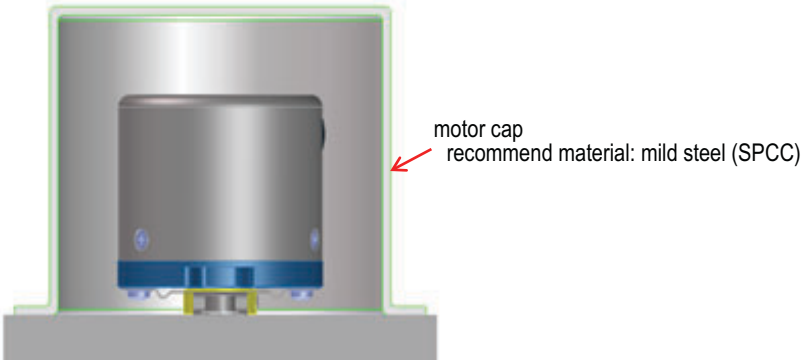
Step 2:
Fasten the M3 X 3 set screw on the right, followed by the set screw on the left.
Apply thread lock fluid to better secure the set screws.
Recommended screw driver torque: 0.35 Nm with 45H steel cup point M3 set screw

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.
Recommended to use spring washer and flat washer. Apply thread lock fluid to better secure the coupling plate.
Recommended screw driver torque: 1 Nm with M3 socket head cap screw.

Recommended Magnetic Shield Design

To eliminate external magnetic field interference, add the motor cap as Figure 2 shows for shielding.

Figure 2: Add Motor Cap as Shield



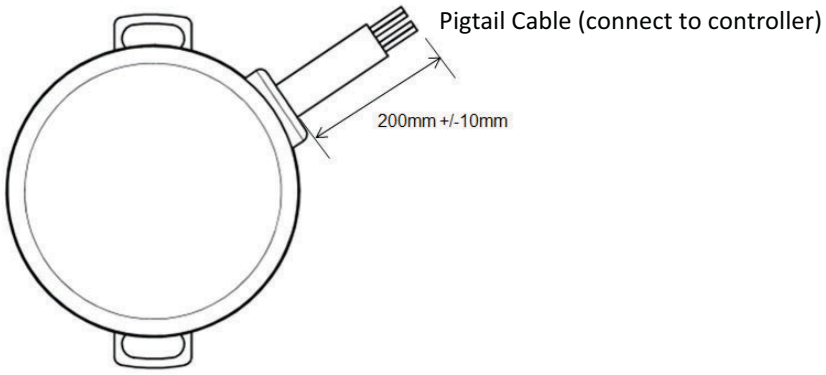
Notes:
External magnetic field interference varies by the application and operating environment.
Proper study of external magnetic field and appropriate shield design is needed.
Consult factory for technical assistance.

Cable Connection Information

No	Cable Color	AS38-H39E-Bxxx (BiSS-C) (Output: 7-Core Cable)	AS38-H39E-Sxxx (SSI) (Output: 7-Core Cable)	AS38-H39E-Kxxx (RS-485 Half-Duplex) (Output: 5-Core Cable)
1	RED	Vcc, Positive Supply	Vcc, Positive Supply	Vcc, Positive Supply
2	BLACK	GND, Ground	GND, Ground	GND, Ground
3	BROWN	MA+	SCL+	DATA+
4	WHITE	MA–	SCL–	DATA–
5	ORANGE	SLO+	DOUT+	N/A
6	BLUE	SLO–	DOUT–	N/A
7	Cable Shield Strand	Cable Shield, Connect to Chassis	Cable Shield, Connect to Chassis	Cable Shield, Connect to Chassis

NOTE: Cable provided is 200 mm ± 10 mm (included pigtail length) with AWG28.

Figure 3: Cable Dimensions

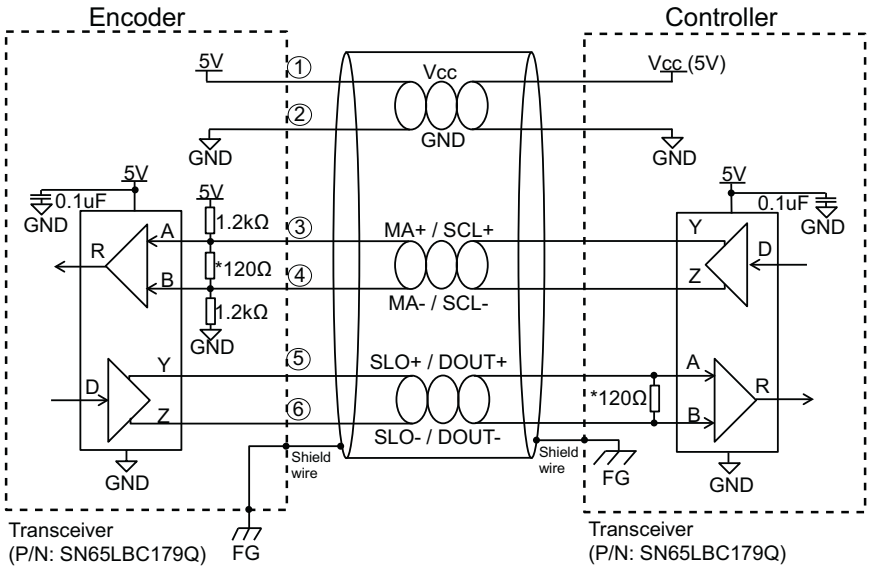


Recommended I/O Connection

- 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.

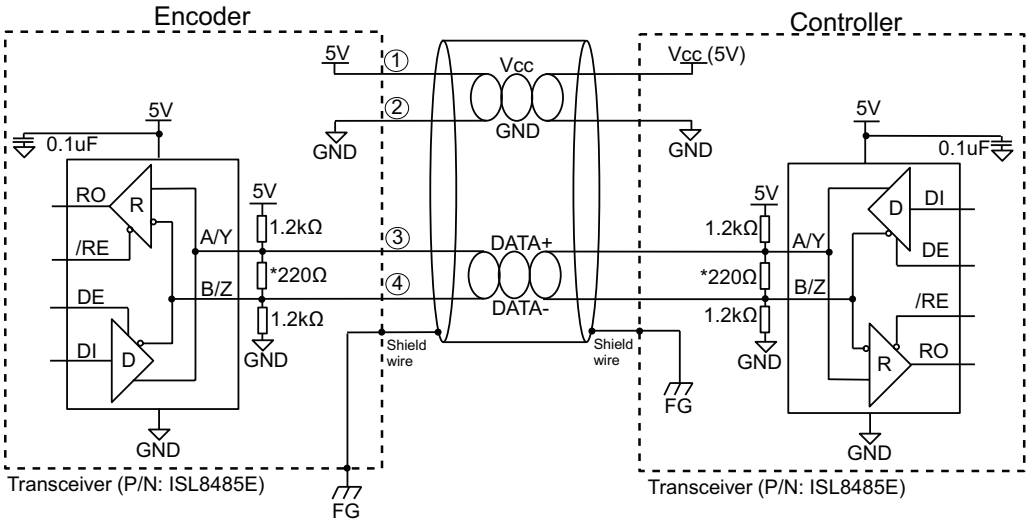
Full-Duplex Transceiver (BiSS C Mode/SSI Mode Protocol)

Figure 4: Circuit Diagram of Full-Duplex Transceiver



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

Figure 5: Circuit Diagram of Half-Duplex Transceiver



Interface Protocol — BiSS-C

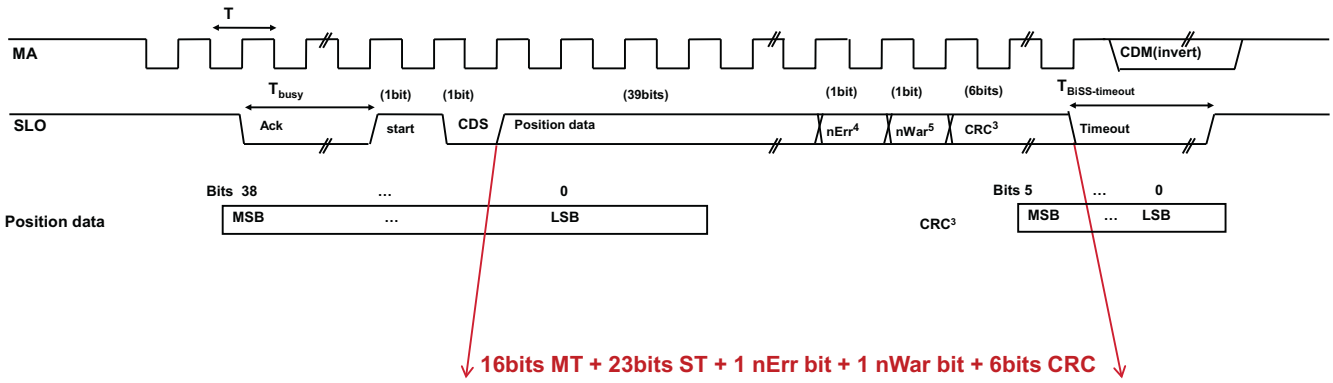
Data Communication

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	6

Figure 6: Timing Characteristics of MA and SLO



NOTE:

1. MA low-time = $0.50/f_{MA}$; high-time = $0.50/f_{MA}$.
2. Refer to Figure 6 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.)
6. After encoder initialization duration of 500 ms upon power-up, perform an alarm clear command before starting to interface with the encoder.

Register Communication and Assignment

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

http://biss-interface.com/download/biss-c-protocol-description-english/

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
N/A			MLSErr Error	Multi-turn Counting Error	Single-turn Counting Error	MemoryErr Error	XCErr 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

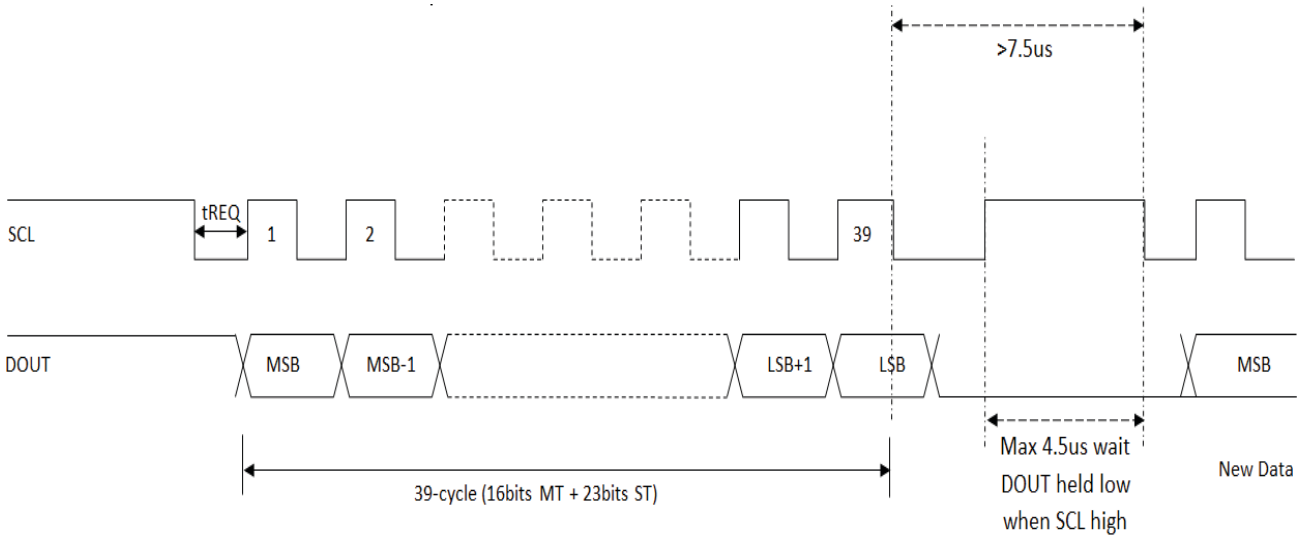
Data Communication

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 7: Timing Characteristics of SCL and DOUT



Note: The MSB is at first rising edge of SCL.

Interface Protocol — RS-485 Half-Duplex

Data Communication

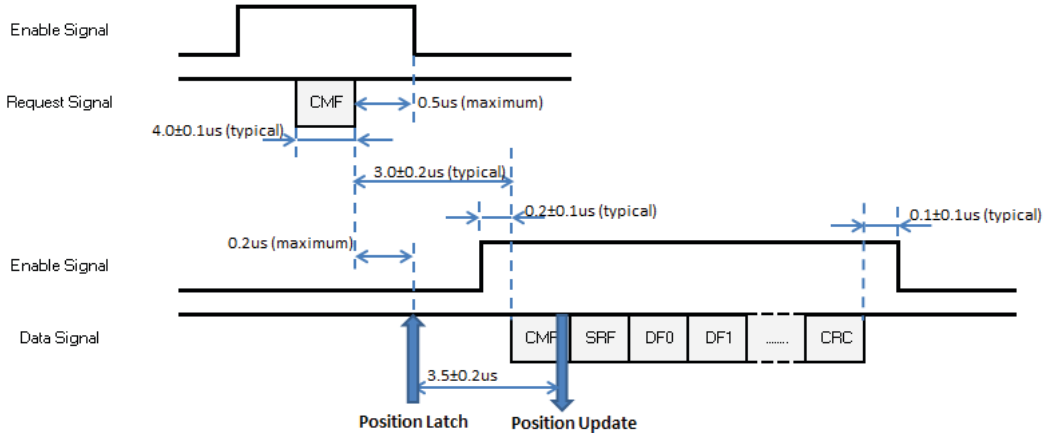
Interface	Circuit
RS-485 Serial Data (DATA+)	Transceiver (P/N: ISL8485E)
RS-485 Serial Data (DATA–)	Transceiver (P/N: ISL8485E)

Timing Characteristics

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

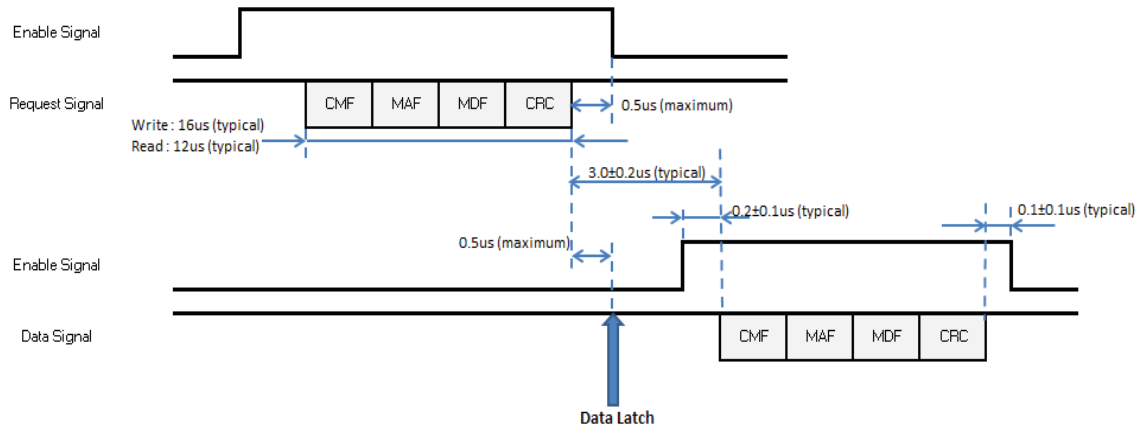
Position Read Frame

Figure 8: Timing Characteristics of Enable, Request, and Data Signals



EEPROM Read/Write Frame

Figure 9: Timing Characteristics of Enable, Request, and Data Signals



Register Communication and Assignment

Refer to AS38-H39E-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	

Alarm Definition

No.	Alarms	Alarms Definition
1	XCErr Error	To indicate multi-turn block hardware miscount. 1: Hardware miscount occur. 0: No hardware miscount.
2	MemoryErr Error	To indicate eeprom content loading status upon encoder power up. 1: Fail to load EEPROM memory data. 0: Success to load EEPROM memory data.
3	Single-turn Counting Error	To check integrity of single-turn position. 1: Error in single-turn position. 0: No error in single-turn position.
4	Multi-turn Counting Error	To check integrity of multi-turn position. 1: Error in multi-turn position. 0: No error in multi-turn position.
5	MLSErr Error	To detect error in MLS (Mcode) generation. 1: MLS code error. 0: MLS code good.
6	LedErr Warning	To indicate if LED current is out of operating range. 1: LED out of operating range. 0: LED within operating range.
7	LisErr Warning	To check integrity of ADC Sin & Cos signals by means of Lissajous specifications. 1: Lissajous out of specification. 0: Lissajous within specification.

NOTE: After encoder initialization duration of 500 ms upon power-up, perform an alarm clear command before starting to interface with the encoder.

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 cable to customer connector	Check cable 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	XCErr triggered	Multi-turn block faulty	
4	MemoryErr triggered	Memory block faulty	
5	Single-turn Counting triggered	Single-turn block faulty	
6	Multi-turn Counting triggered	Multi-turn block faulty	
7	MLSErr triggered	LED faulty	
		Codewheel issue	
		Single-turn block faulty	
8	LedErr triggered	LED faulty	
9	LisErr triggered	LED faulty	
		Codewheel issue	
		Single-turn block faulty	

Do

- Do ensure clean environment during installation.
- Do ensure encoder power supply is within 5V ± 10%.
- 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.
- Do not operate encoder under extreme temperature over time.

For the detailed specification of this encoder, refer to the *AS38-H39E Series Data Sheet*:

https://docs.broadcom.com/docs/AS38-H39E-DS101