37HA-MB

39 Bits Battery Backup Multi-Turn Absolute Encoder

Application Note

Introduction

37HA-MB series encoder is a high-resolution optical absolute encoder, which offers 23-bits single turn and 16-bits multi-turn counts, hence a combined 39 bits high resolution. The 37HA-MB 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 37HA-MB series encoder has a built in communication protocol which supported by a full-duplex or half-duplex line transmissions drive, offering good noise immunity for more robust transmission of data up to 10Mbps 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 37HA-MB series is also compliant with IP40 per IEC 60529 standard.

The key advantage of the 37HA-MB series is multi-turn tracking employs battery backup technology. It is gearless multi-turn counting that eliminates the gear worn out or acoustics noise issue that 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 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 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 will periodically power up the LED emitter and enabling 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.

Application

37HA-MB series can be widely used in the following applications:

- Robotics
- Factory automation
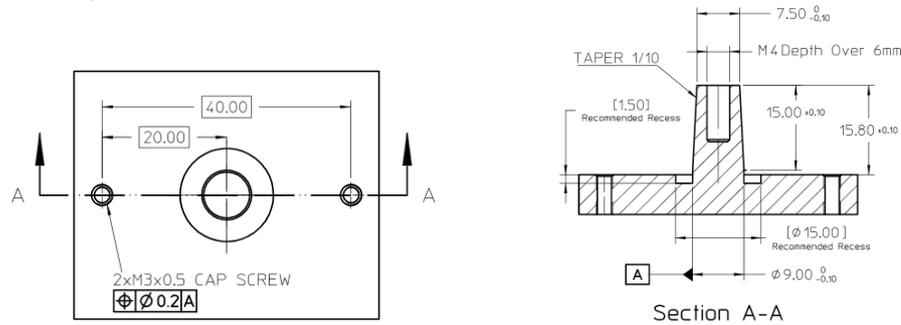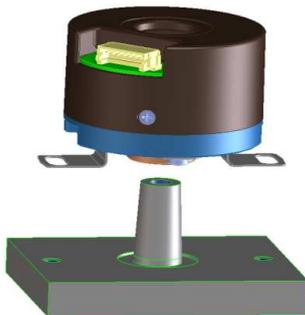- CNC machine tool

37HA-MB Application Note

Mounting Requirement and Guideline

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

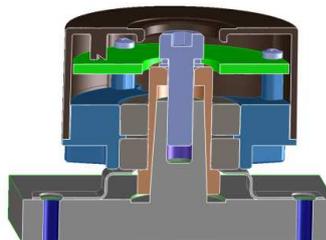Figure 1: Recommended shaft and mounting holes for Standard Taper Shaft.

Note:
1. Dimensions are in millimeters
2. 3rd Angle Projection
3. Unless otherwise specified, all tolerances are within ±0.5 mm
4. 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.
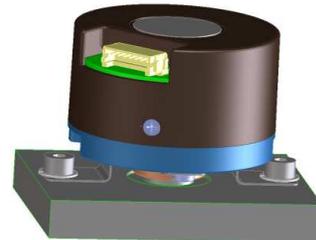
Step 2:
Fasten the M4 socket head cap screw on top to the encoder shaft.

Recommended screw driver torque: 1.5 Nm

Seal the housing opening by using the sticker as dust protection. Recommended to use Polyester film sticker.

(Remark: To remove the encoder from motor shaft, an M5 X 40mm 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 the M3 coupling mounting screws.

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

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

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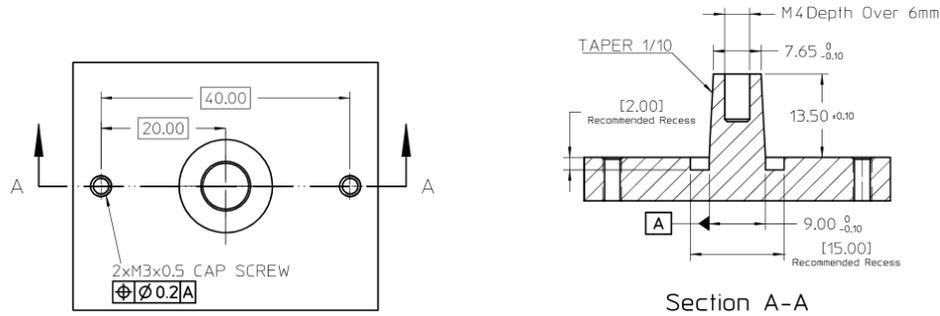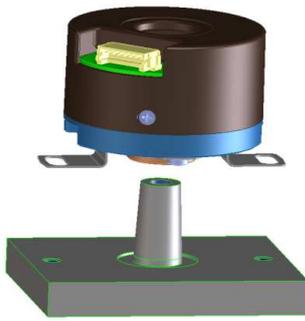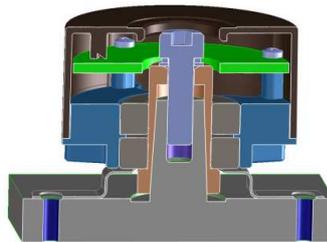**Short Hollow Taper Shaft Option (Φ9-Φ7.65mm; 1:10)**

Figure 2: Recommended shaft and mounting holes for Standard Taper Shaft.

Note:
1. Dimensions are in millimeters
2. 3rd Angle Projection
3. Unless otherwise specified, all tolerances are within ±0.5 mm
4. 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. Recommended to use Polyester film sticker.

(Remark: To remove the encoder from motor shaft, an M5 X 40mm 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 the M3 coupling mounting screws.

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

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

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Hollow Blind Shaft Option (Φ8mm)
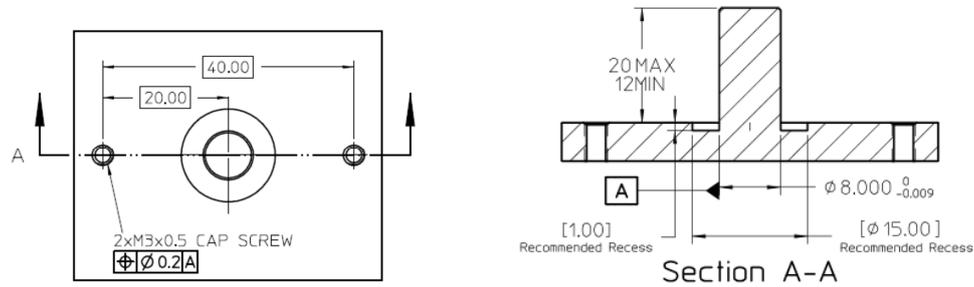
Figure 3: Recommended shaft and mounting holes for Hollow Shaft

Note:
1. Dimensions are in millimeters
2. 3rd Angle Projection
3. Unless otherwise specified, all tolerances are within ±0.5 mm
4. Recommended to have a recess on motor mounting surface to prevent encoder shaft interference with motor base.
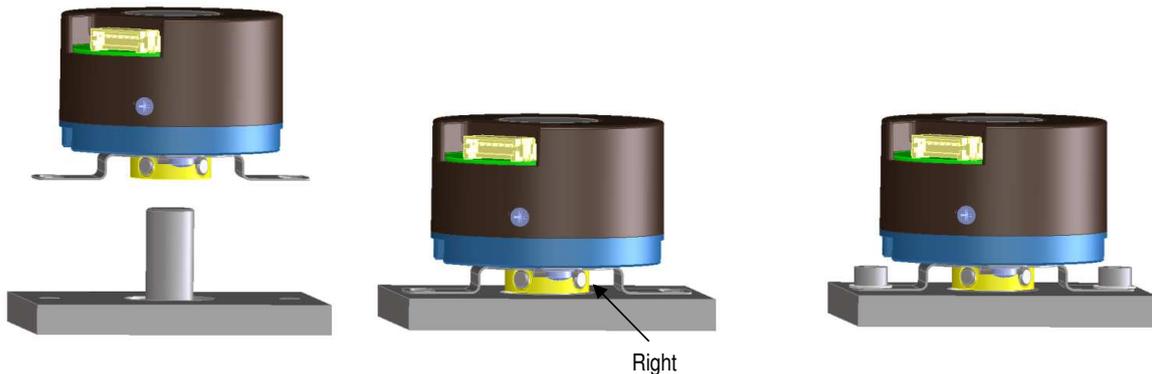
Step 1:
Slide encoder hollow shaft into motor shaft until the coupling plate is touching the motor base.

Step 2:
Fasten the M3X3 set screw on the right, followed by the set screw on the left.

Recommended to apply screw thread lock fluid to better secure the set screws.

Recommended screw driver torque: 0.35Nm 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 the M3 coupling mounting screws.

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

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

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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 = 2000mAh
Operating temperature range = -55 ~ +85˚C
Size = AA

Figure 4: Recommended product of external battery

Important Note:

1) Multi-turn data position is maintains with battery power during battery mode. Battery replacement process will cause data lost, therefore it is required to reset the multi-turn counter after battery changed.

2) Battery life calculation depend on user application condition, please consult factory if assistance needed.

Connector Output Assignment

| Pin	37HA-MB01 (BiSS-C) (Output: 10 pins connector)	37HA-MB02 (SSI) (Output: 10 pins connector)	37HA-MB03 (RS-485 half-duplex) (Output: 7 pins 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
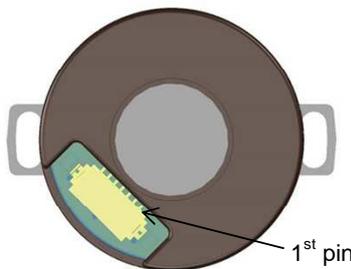
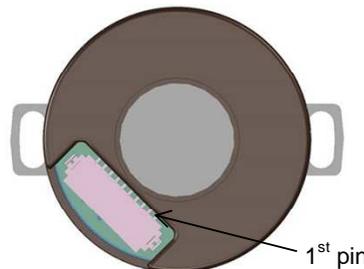Figure 5: 7pins Connector Pin Assignment   Figure 6: 10pins Connector Pin Assignment

*Recommended mating connector:
Hirose Part No: DF13-7S-1.25C for 7pins connector and DF13-10S-1.25C for 10 pins connector (CL No.536-0006-8)
Hirose (Terminal Pin for Wire 26~30AWG): DF13-2630SCF (CL No.536-0300-5)

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Recommended I/O Connection

1) It is strongly recommended to provide encoder power supply, Vcc within 4.5V ~ 5.5V. Typical value is 5V.
2) For best noise immunity, it is recommended to use twisted-pairs shielded cable for connection to controller (servo driver).
3) It is recommended to connect encoder chassis and cable shield to frame ground (FG) in application for enhanced noise immunity in harst operating condition.
4) To prevent undesirable signal reflections, the termination resistor is needed. Termination resistor, *120ohm and *220ohm 1/4W are recommended but may depends on the characteristic impedance of cable used.

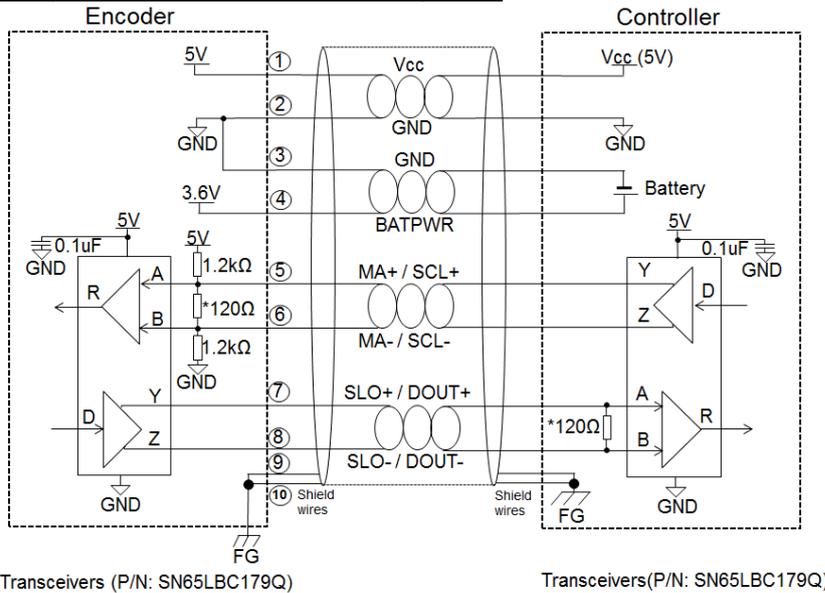Full-duplex transceiver (BiSS C mode / SSI mode protocol):

Figure 7: Circuit diagram of full-duplex transceiver

Half-duplex transceiver (RS-485 half-duplex protocol):
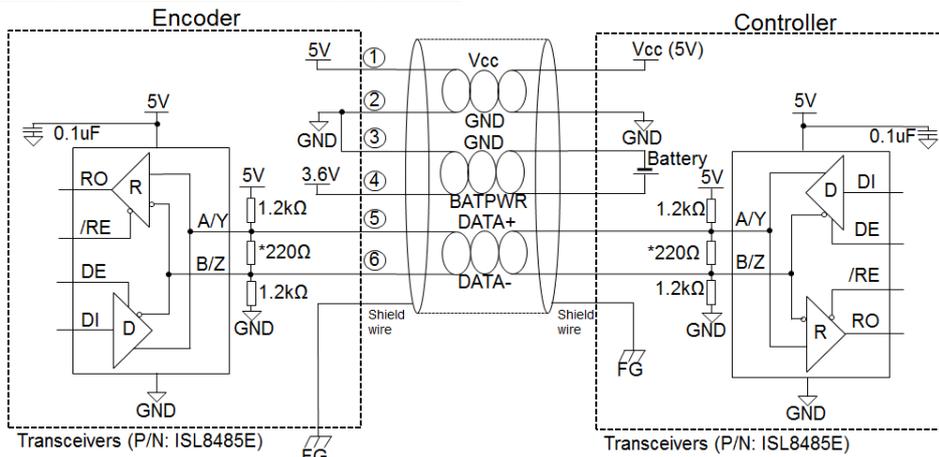
Figure 8: Circuit diagram of half-duplex transceiver

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Interface protocol – BiSS-C

Data Communication

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

Timing Diagram

Parameter	Symbol	Condition	Min	Typ.	Max	Units	Notes
MA Frequency	f_{MA}		0.08		10	MHz	1
Busy	T_{busy}		$2/f_{MA} + 3.35us$		$2.5/f_{MA} + 3.75us$	µs	2
Timeout	$t_{BiSS-timeout}$		$1.5/f_{MA}$		$1.5/f_{MA} + 90ns$	ns	2
Encoder initialization time				500		ms	
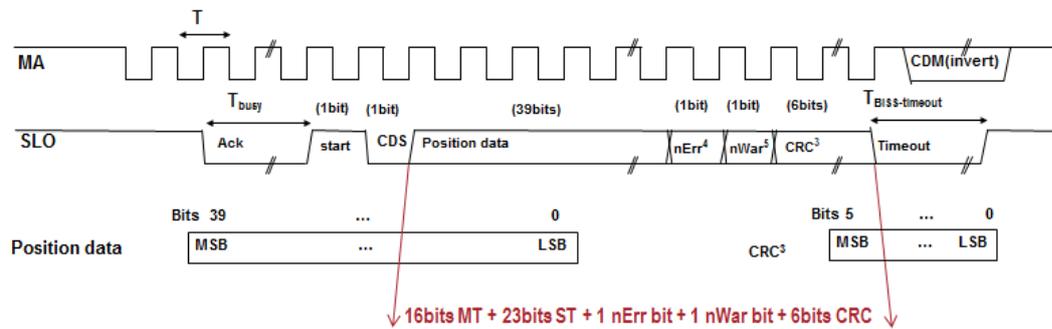
Figure 9: Timing Characteristics of MA and SLO

Note:
1. MA low-time = $0.50/f_{MA}$; high-time = $0.50/f_{MA}$.
2. Refer to Figure 5 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

Please refer to BiSS-C Interface Protocol Description Rev C5 document for detail information.
http://biss-interface.com/files/Bissinterface_c5es.pdf

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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.

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 Slave Register Description - user area)

Note: EDS-Bank is not available.

Slave Register Description

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*	Error clear command*	Single-turn clear command*	Multi-turn clear command*

*Encoder Clear Command operation.
 a. Write 1 to execute one time clear command.
 b. Only one command should be access for each time.

37HA-MB Application Note

Interface Protocol - SSI

Data Communication

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

Timing Characteristics

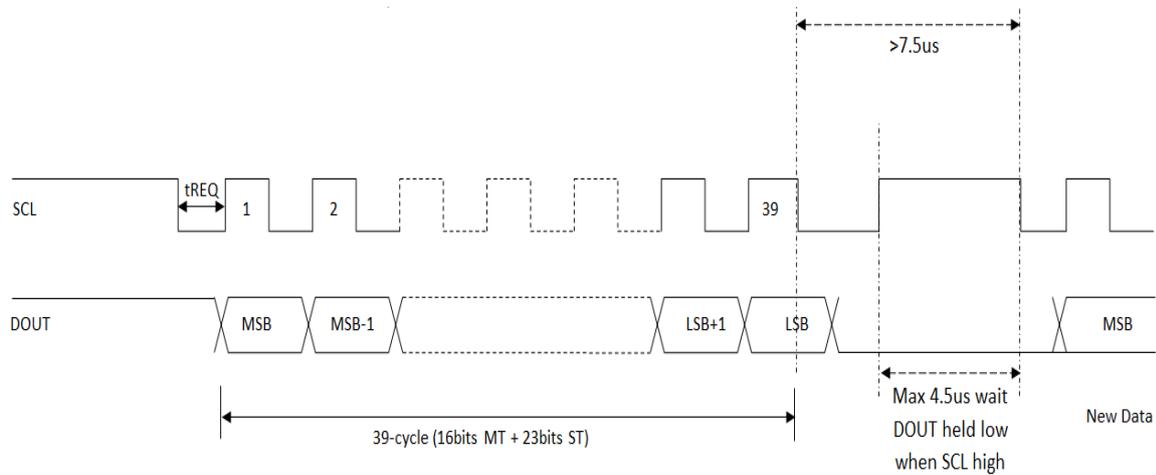| Parameter	Min	Typ.	Max	Units
SCL Frequency	0.133		1	MHz
Position Latency	3.4	3.6	3.8	us
Position Jitter (Data latch uncertainty)	0.38	0.4	0.42	us
tREQ			0.5	us
SSI Time out (DOUT held low when SCL high)			4.5	us

Figure 10: Timing Characteristics of SCL and DOUT

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

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Interface protocol – RS-485 half-duplex

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

Timing Characteristic

Parameter	Min	Typ.	Max	Units
Communication Baud Rate			2.5	MHz
Frame length		10		Bit/Frame

Position Red Frame
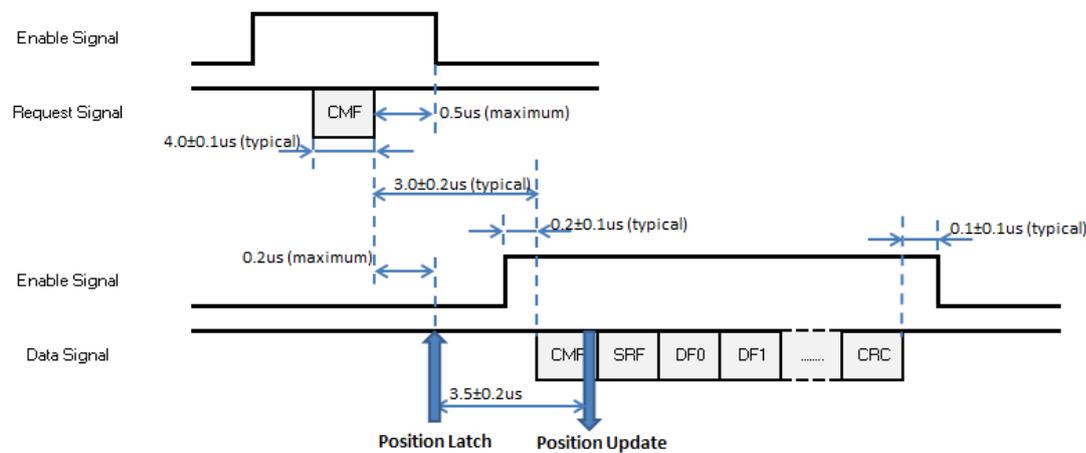
EEPROM Read/Write Frame
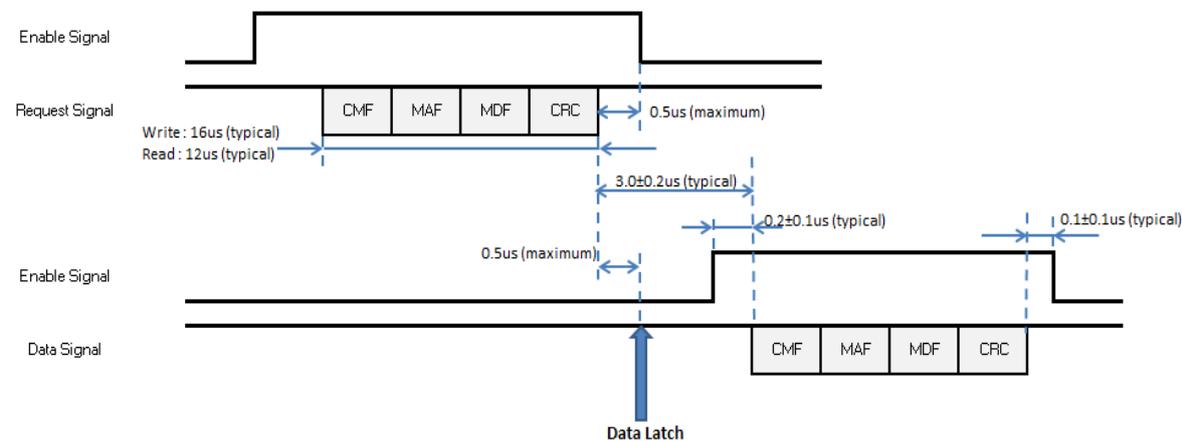
Figure 11: Timing Characteristics of Enable, Request and Data Signals

Register Communication and Assignment

Please refer to 37HA-MB software specification document for details information.

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37HA-MB Application Note

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.

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

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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. (Refer to Figure 8). 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

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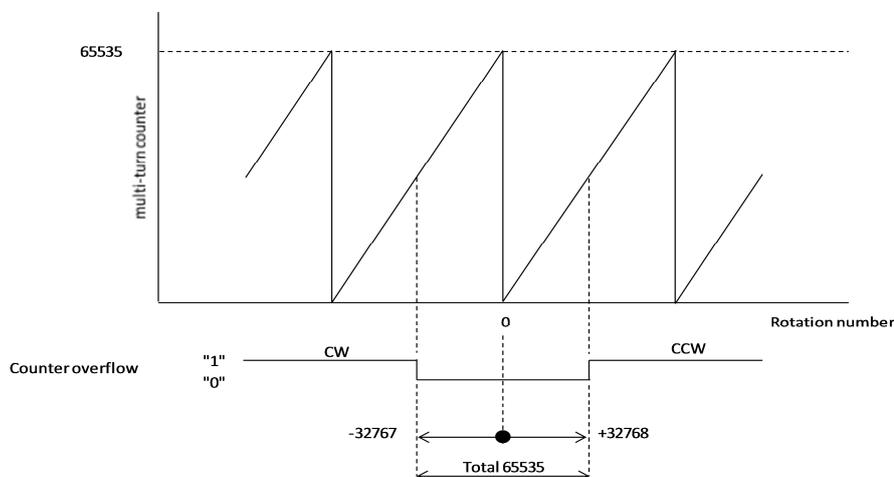
Multi-turn Counter Overflow Flag Explanation:

Figure 12: Relation between multi-turn counting and over flow 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 4.5~5.5V
		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 problem still exist, please consult factory.
		Transceiver faulty/shorted	
2	Encoder high current consumption (>200mA 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 <6000rpm
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

37HA-MB Application Note

Do and Don't

Do
1) Ensure clean environment during installation.
2) Ensure encoder power supply is within 5V +/- 10%.
3) Replace batteries with the recommended size and type.
4) Provide adequate protection from dust and moisture when use in harsh environment.
5) Ensure pin configuration is per datasheet.
6) Observe all ESD precaution when performing installation or handling the encoder.

Don't
1) Do not overload transceiver by using wrong termination resistor.
2) Do not hammer encoder shaft into motor shaft during installation.
3) Do not deform coupling plate during installation.
4) Do not reverse the power source polarity for both encoder main power and battery power.
5) Do not operate encoder under extreme temperature over time.

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