AR49-M49M/M25S Series Reflective Encoder Module

Absolute Encoder with Energy Harvesting Multi-Turn Counter

Description

The Broadcom® AR49 Series is an optical absolute encoder module, which offers up to 25-bit single-turn (ST) position information and 24-bit multi-turn (MT) counts, hence a combined 49 bits high resolution output. The ST block of the encoder consists of a patterned disk, a light source and photosensitive elements to translate the mechanical motion into electrical signal. It is designed with a selection of serial communication protocols, with dedicated electronic circuit designed for a robust signal communication.

Broadcom® AR49 series encoders offer bundles of intelligent features such as Built-In Temperature Sensor, User Programmable Resolution, Zero Reset, System Alarm and more. It comes with a recommended high temperature range of –40°C to 115°C. One of the key advantages is its multi-turn tracking that employs a proprietary energy harvesting (EH) technology by harvesting the magnetic energy as the patterned disk with magnet rotates. The counter ASIC harvests the energy generated by EH Sensor for processing rotational count and generate counting logics to the non-volatile memory, which updates and stores the counting.

The entire operation of energy generation, counting and storage processing is completed within a limited energy and short duration; hence, the kit encoder is suited for both low and high-speed measurement.

Features & Benefits

- 24-bit energy harvesting multi-turn & 25-bit optical single-turn
- Accuracy upon calibration of +/-30 arc-seconds
- Encoder Fault and Status bits with CRC
- Integrated differential transceiver for SSI/BiSS-C/RS485/ESL communication protocols
- Single-ended Serial Protocol Interface (SPI 4-Wire option)
- Overall encoder outer diameter Ø35 mm and maximum height of 17.5 mm
- 8K bits of user accessible memory in EEPROM
- Immediate position detection on power up No battery or capacitor required for position detection during power failure
- RoHS Compliant

Applications

- AC/DC Servo Motor Feedback
- Medical & laboratory equipment
- Robotics
- Factory automation

CAUTION

This product is not specifically designed nor manufactured for use in any specific devices. Customers are solely responsible for determining the suitability of the product for its intended application and solely liable for all loss, damage, expense, or liability in connection with such use. Please contact factory for further enquiry.

1   Product Specifications

1.1   Product Specifications

Table 1 Absolute Maximum Ratings

Parameters	Symbol	Min	Max	Units	Notes
Storage Temperature	T_S	-40	125	°C	
Operating Temperature[1]	T_a	-40	115	°C	
Supply Voltage	V_{dd}	-0.3	6.5	V	
Electrostatic Discharge Immunity, ESD		-8k	+8k	V	Contact discharge
		-12k	+12k	V	Air discharge
Electrical Fast Transient/Burst Immunity, EFT		-2k	+2k	V	5mins, 5kHz
Permissible Speed		–	12,000	RPM	Note (2)
Relative Humidity	RH	–	90	%	T=60°C (non-condensing)
Single-Turn Resolution		15	25	Bit	15 to 25 bits
Multi-Turn Resolution		0	24	Bit	12,14,16, 18, 20, 22 & 24 bits
Transmission Length[3]		–	25	meter	SSI/BiSS-C/RS485 Differential Line

NOTE

1. Maximum junction temperature of PCB shall not exceed 125 °C
2. Encoder works reliably up until this permissible speed.
3. Twisted pair and shielded cable is recommended for robustness against environmental noise. Frame Ground (FG) termination near the motor frame is recommended.
4. Exposure to absolute maximum rating conditions for extended periods may affect reliability. Stress greater than the absolute maximum rating may cause permanent damage to the device.

Table 2 Electrical Characteristics
DC Characteristics over recommended operating V_{DD} 4.5 to 5.5V, Ta = -40 to 115°C

Parameters	Symbol	Min.	Typical	Max.	Unit	Remark
Supply Voltage	V_{DD}	4.5	5.0	5.5	V	
Supply Current	I_{DD}	50	90	100	mA	
Power on Standby		–	–	500	ms	
Protocol IO drive strength	I_{DIO}	5	20	40	mA	Differential driver
Electrically Permissible Speed		-12,000	–	+12,000	RPM	
Differential Transceiver						
Hysteresis	V_{hys}	–	100	–	mV	220Ω termination
Opening	V_{open}	200	–	–	mV	
Peak-Peak Voltage	V_{PP}	–	2	–	V	

Parameters	Symbol	Min.	Typical	Max.	Unit	Remark
IO Line						
Output High Voltage	V_{OH}	4.4	–	–	V	No Load(V_{DD} = 5V)
Output Low Voltage	V_{OL}	–	–	0.5	V	
Input High Voltage	V_{IH}	2.8	–	5.5	V	
Input Low Voltage	V_{IL}	0	–	1.8	V	

Table 3 Mechanical and environmental specifications

Mechanical characteristics over recommended operating conditions of V_{DD} 4.5 to 5.5V, Ta = -40 to 115°C

Parameters	Conditions	Min	Typ	Max	Units
Storage Temperature		-40	–	125	°C
Operating Temperature[1]		-40	–	115	°C
Encoder Accuracy[2]	With reference encoder correction, T_{amb} = 25˚C	–	±30	–	Arc-sec
Mechanical Permissible Speed		-12,000	–	+12,000	RPM
Relative Air Humidity (Non-Condensing)	T_a = 60˚C	–	90	–	RH%
Vibration	EN 60068-2-6	–	–	30	G
Shock	EN 60068-2-27, 6ms	–	–	100	G

NOTE

1. Maximum junction temperature of PCB shall not exceed 125 °C
2. Typical values represent the accuracy and repeatability when calibrated with a reference encoder having 10× higher accuracy than the AR49. Reference Encoder ≈ 3 arc-seconds.
3. Refrained from placing the codewheel magnet or any magnet near to the EH sensor on top of the encoder assembly (maintain <20mT storage condition)

Table 5 General encoder specifications

Parameter	Remarks
Counting Direction	Increase with counter-clockwise (CCW) codewheel rotation, view from encoder top (Figure 1)
User accessible Memory size	8K bits
Encoder Temperature	8-bit data output at 1°C resolution
Initialization Time	500ms

Figure 1 Counting 'Up' direction from top view

2 Mechanical Specifications

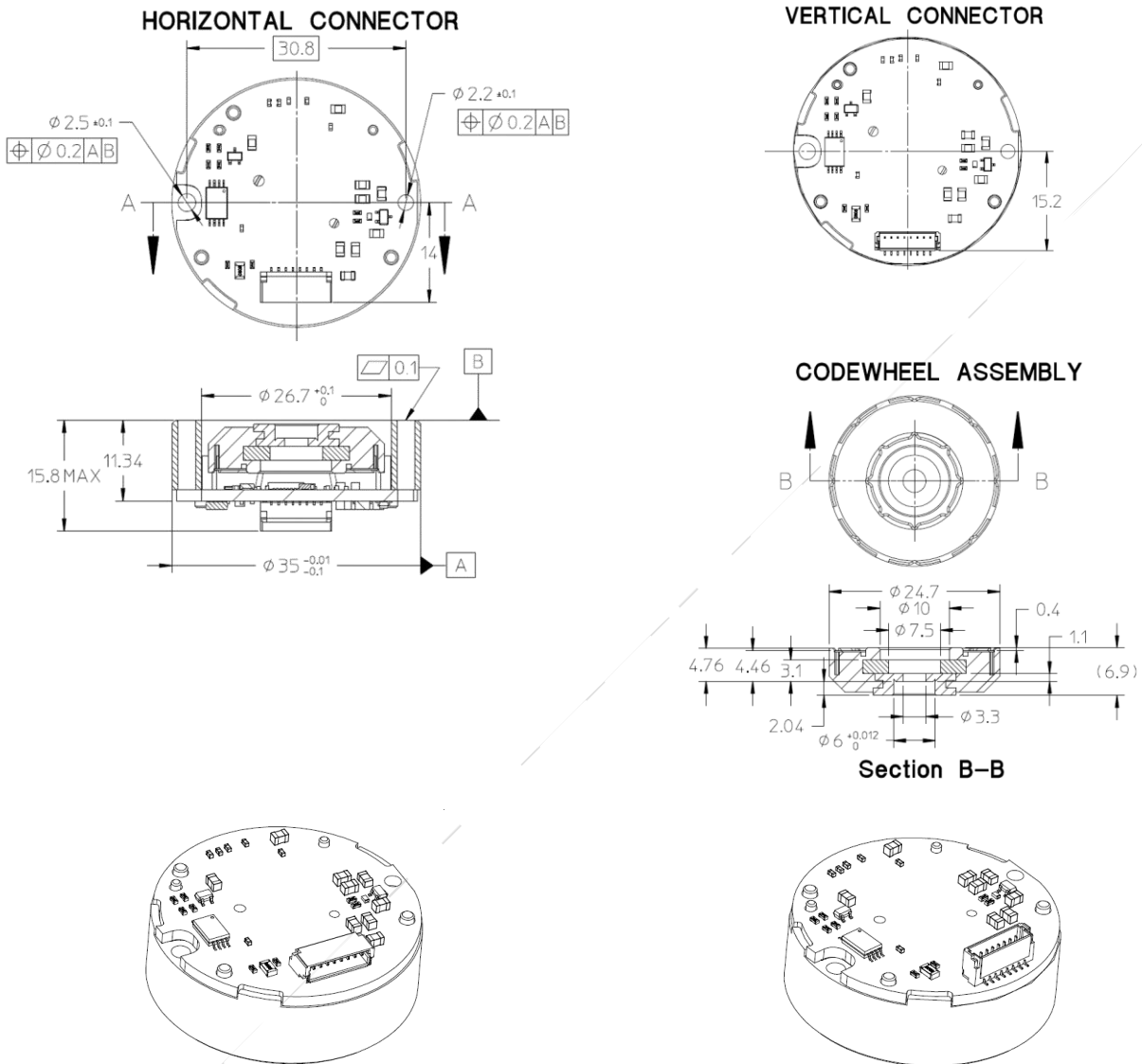## 2.1 Package Dimensions – AR49 Series MT Option

Figure 2 MT Encoder mechanical dimensions
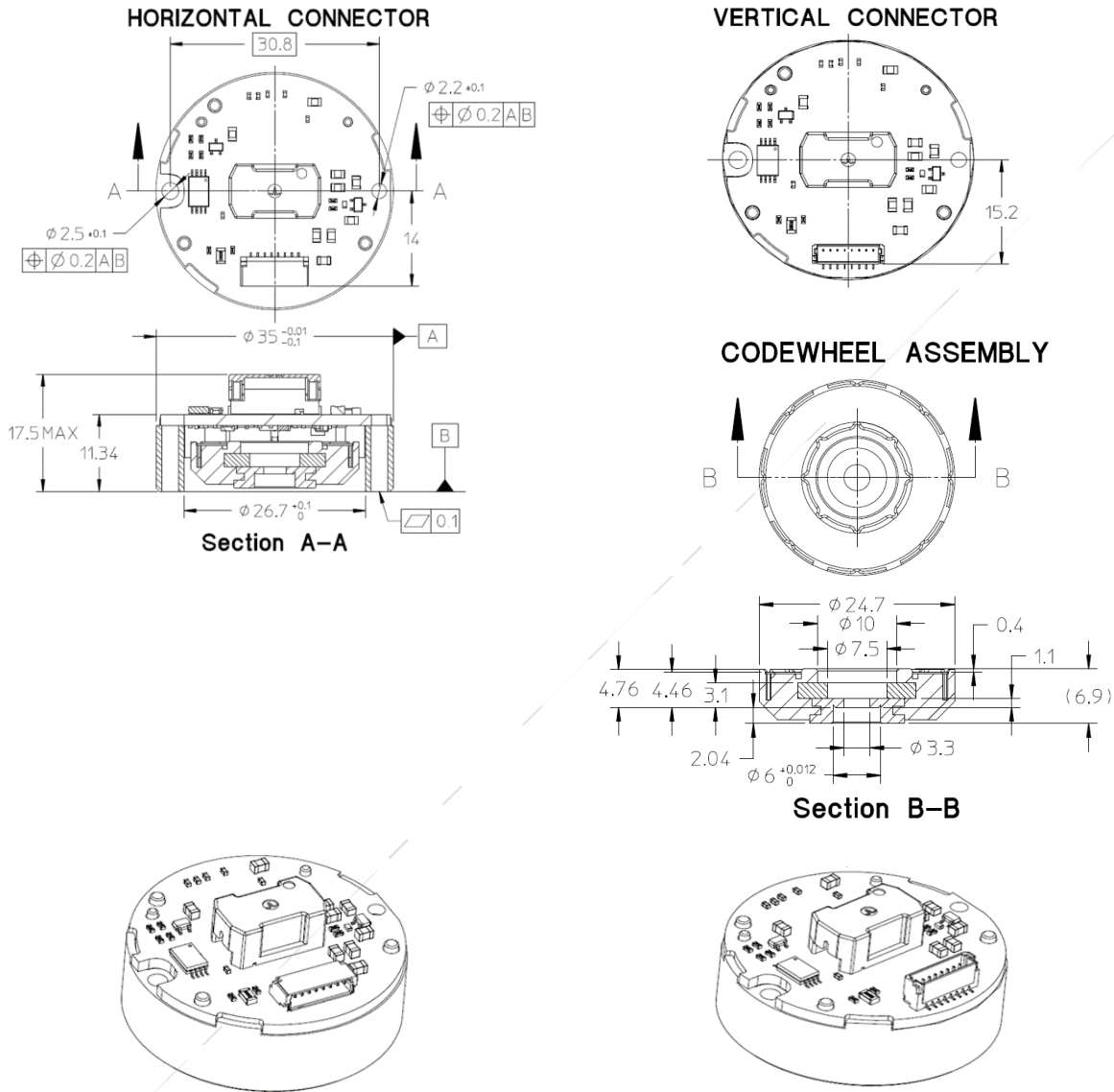
NOTE

4. Dimensions are in millimeters.
5. 3rd angle projection.
6. Motor shaft outer diameter requirement: 6g6 (-0.004, -0.012)mm

2.2 Package Dimensions – AR49 Series ST Option

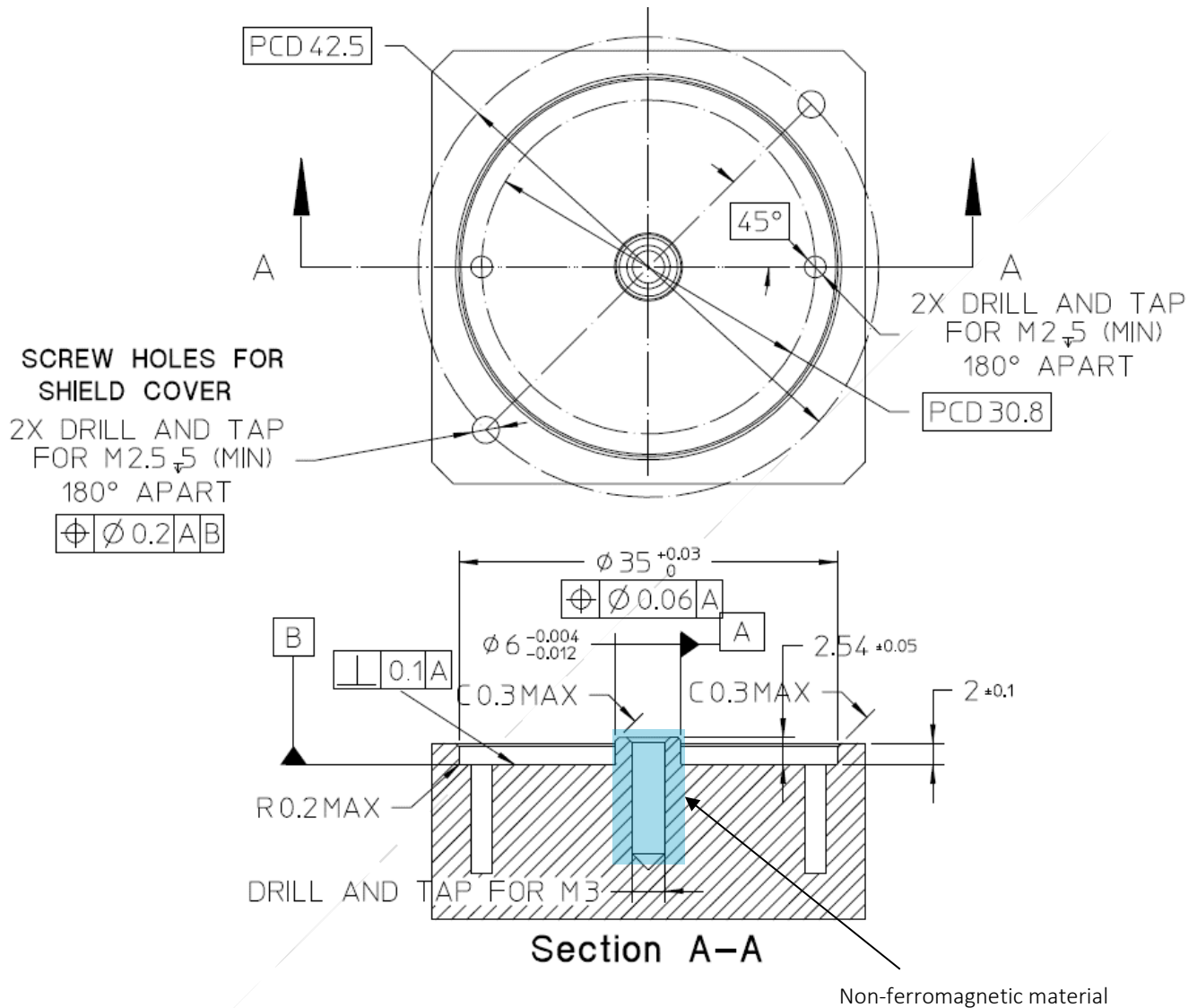**Figure 3 ST Encoder mechanical dimensions**

NOTE

1. Dimensions are in millimeters.
2. 3rd angle projection.
3. Motor shaft outer diameter requirement: 6g6 (-0.004, -0.012)mm
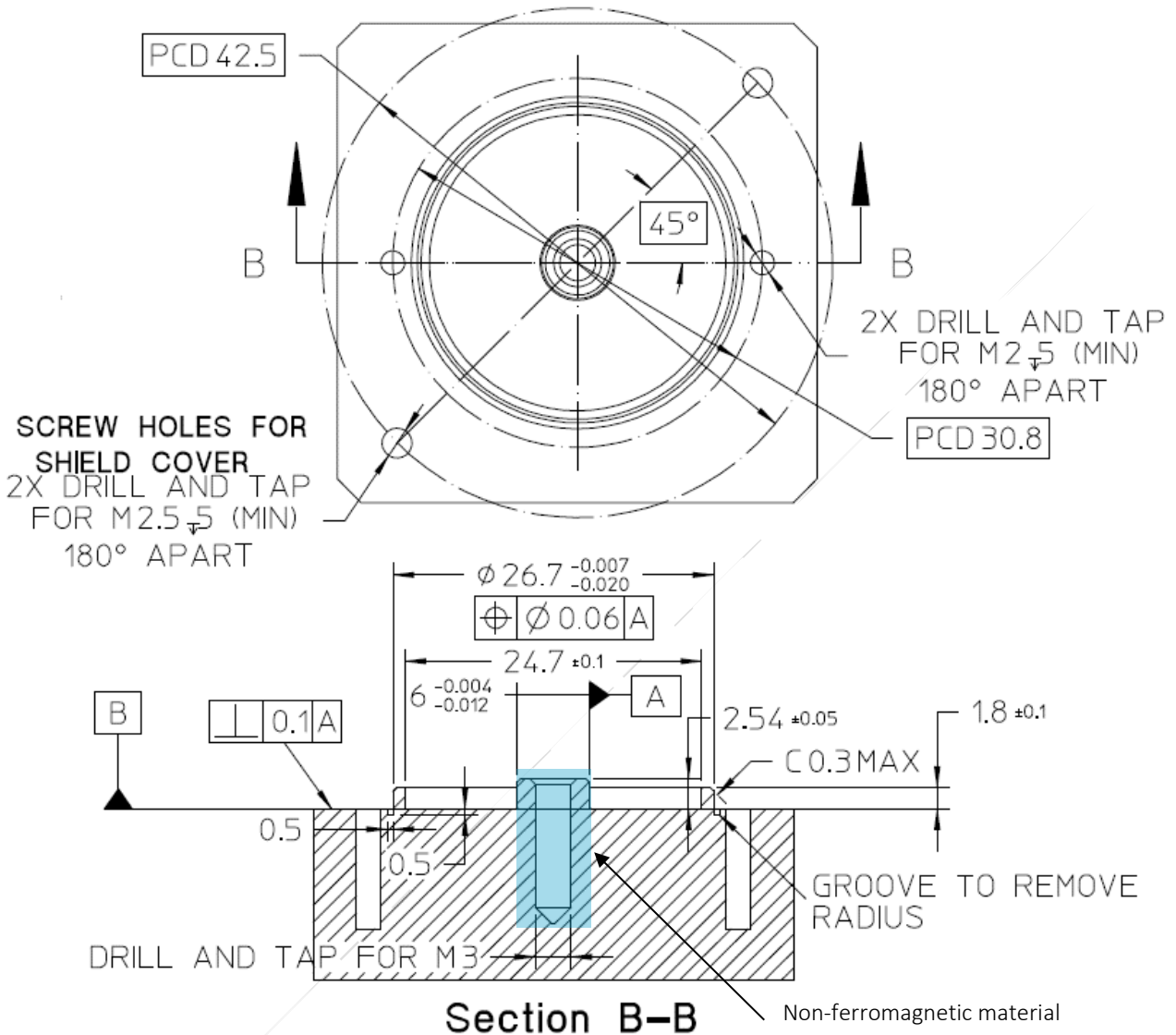
2.3 Recommended Motor Mounting Dimensions

Figure 4 Mounting dimensions when using module outer diameter as the position guide

Non-ferromagnetic material

Section A-A

NOTE

4. Dimensions are in millimeters.
5. 3rd angle projection
6. Use stainless steel M3 screw to secure codewheel-hub assembly to the motor shaft
7. Use screw with pre-applied thread locker
8. Motor shaft-end where code wheel is mounted must be made of non-ferromagnetic material. Recommended motor shaft material: SUS316L

**Figure 5 Mounting dimensions when using module inner diameter as the position guide**

PCD 42.5

45°

B   B

2X DRILL AND TAP
FOR M2.5 (MIN)
180° APART

PCD 30.8

SCREW HOLES FOR
SHIELD COVER
2X DRILL AND TAP
FOR M2.5 (MIN)
180° APART

$\varnothing 26.7 ^{-0.007}_{-0.020}$

⊕ $\varnothing 0.06$ A

24.7 ±0.1

$6 ^{-0.004}_{-0.012}$ A

2.54 ±0.05   1.8 ±0.1

B

⊥ 0.1 A

C 0.3 MAX

0.5

0.5

GROOVE TO REMOVE
RADIUS

DRILL AND TAP FOR M3

Section B−B   Non-ferromagnetic material

NOTE

9. Dimensions are in millimeters.
10. 3rd Angle Projection
11. Use stainless steel M3 screw to secure codewheel-hub assembly to the motor shaft
12. Use screw with pre-applied thread locker
13. Motor shaft-end where code wheel is mounted must be made of non-ferromagnetic material. Recommended motor shaft material: SUS316L

2.4 Recommended Shield Cover Dimensions

To eliminate or minimize the influence of the external magnetic field interference on encoder operation, use of shielding is mandatory.

- Shield cover material requirement: Mild steel SPCC-SD, thickness 0.8 mm (minimum)
- Finishing: Ni plating 8 μm to 12 μm thick, with Cu under coating 2 μm to 4 μm

**Figure 6 Reference shield cover design**
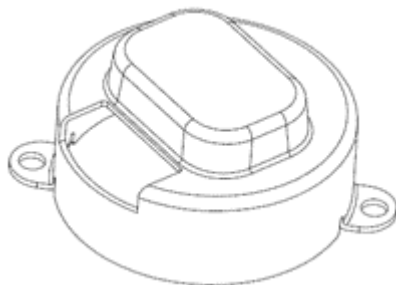
3   Encoder Calibration

Broadcom encoder employs intelligent calibration method by performing auto signal optimization once the encoder is mounted within assembly tolerances. This eliminates the hassle to mechanically adjust the encoder position to a very tight gap and mechanical center. Position accuracy correction is optional and can be carried out with a high accuracy reference encoder, e.g. Broadcom's AR25-AC25 calibration station.

For initial development and early evaluation of the AR49 encoders, the versatile AR49-M49-E01 programming kit can be used to perform the basic encoder configuration and calibration process.

Figure 7 Overview of the AR49 series encoder calibration flow
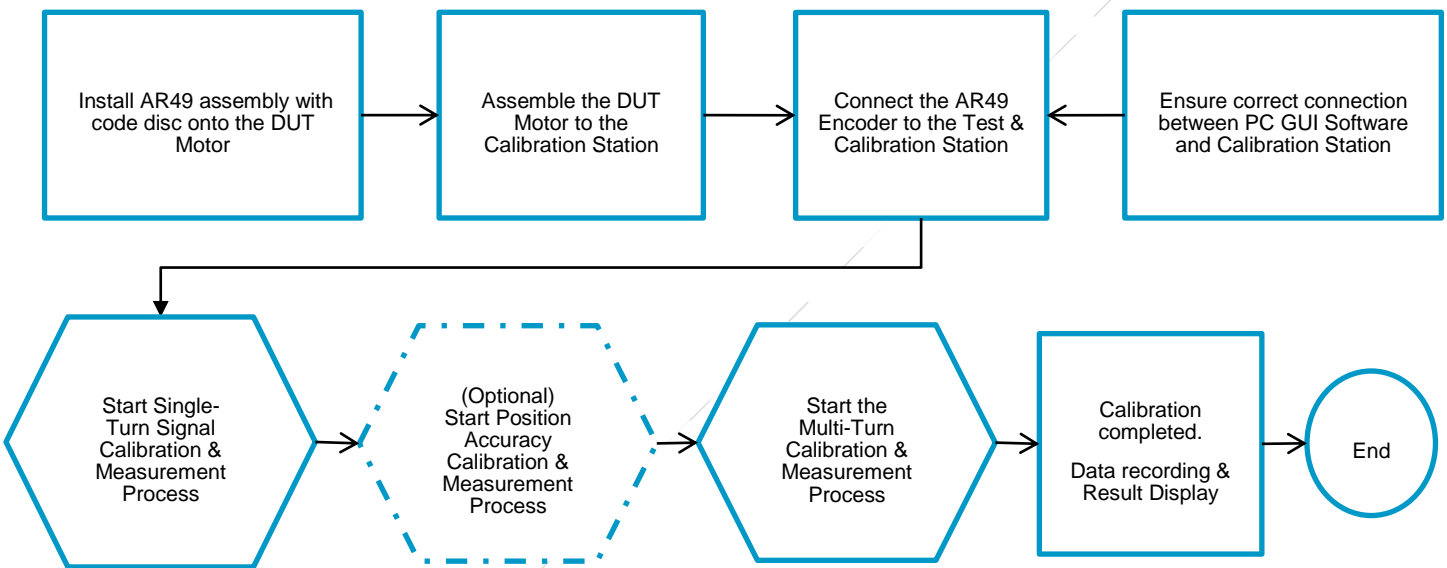
4 Interface Protocol

4.1 AR49-M49M-Kxx with RS485 Half-Duplex Protocol

A one-to-one half-duplex serial communication is established between the Client encoder and the Host (e.g. a servo driver). The communications are in a differential transmission format. The encoder will carry out specific operations based on the command requests made by the Host. An acknowledgment of the command request is necessary before the encoder executes the requested operation, i.e. by checking the Start Bit, Information Data Field and Stop Bit. Failing this checking, the encoder will not acknowledge and execute the received command request.
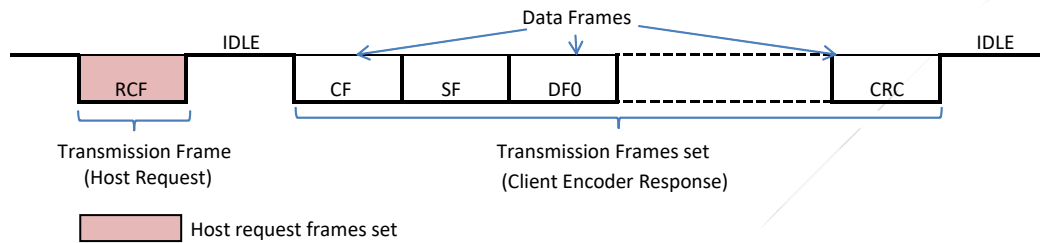

Figure 8 General transmission frames format on half-duplex line

NOTE   **Start of transmission frames set:** Upon detecting of the first logic of Low State "0" on the transmission line after an idling state, and if the following 3 bits conform to the sync code, the encoder will acknowledge it as a valid Request Control Field (RCF) and indicates the start of a transmission frame set. Otherwise, the encoder will continue to search for the next available logic of Low State "0".

                    End of transmission frames set: After the Command Frame is detected, if there is no Start Bit after the End Bit of the last frame read, and no subsequent frame detected, end of transmission frame set is concluded.

                    Idle state: Idle state means a space between each transmission frames set and subsequent transmission frames. At idling state, logic of output in transmission line is kept to high state "1".

Table 3 RS485 Protocol Specifications
Over recommended operating conditions, Vdd 4.5 to 5.5V, Ta = -40 to 115°C

Parameters	Conditions	Min.	Typ.	Max.	Unit	Remarks
Communication Baud Rate		–	2.5	10	Mbps	2.5, 5, 10 Mbps
Frame Length		–	10	–	Bit/Frame	
Cycle Time Between Frames Sets Request	Command ID3	62.5	–	–	µs	2.5 Mbps
		35	–	–		5 Mbps
		20	–	–		10 Mbps
Jitter	Every Frame	-100	–	+100	ns	2.5 Mbps
		-50	–	50	ns	5 Mbps
		-25	–	25	ns	10 Mbps

4.1.1 RS485 Differential Connection

The recommended I/O connection between the encoder and the Host driver has the following basic requirements.

1. Ensure the encoder power supply, V_{CC} should be within the range of 4.5V ~ 5.5V.

2. For best noise immunity, use a twisted-pair shielded cable for connection to the servo driver.

3. To prevent undesirable signal reflection, terminate with 220Ω resistors.
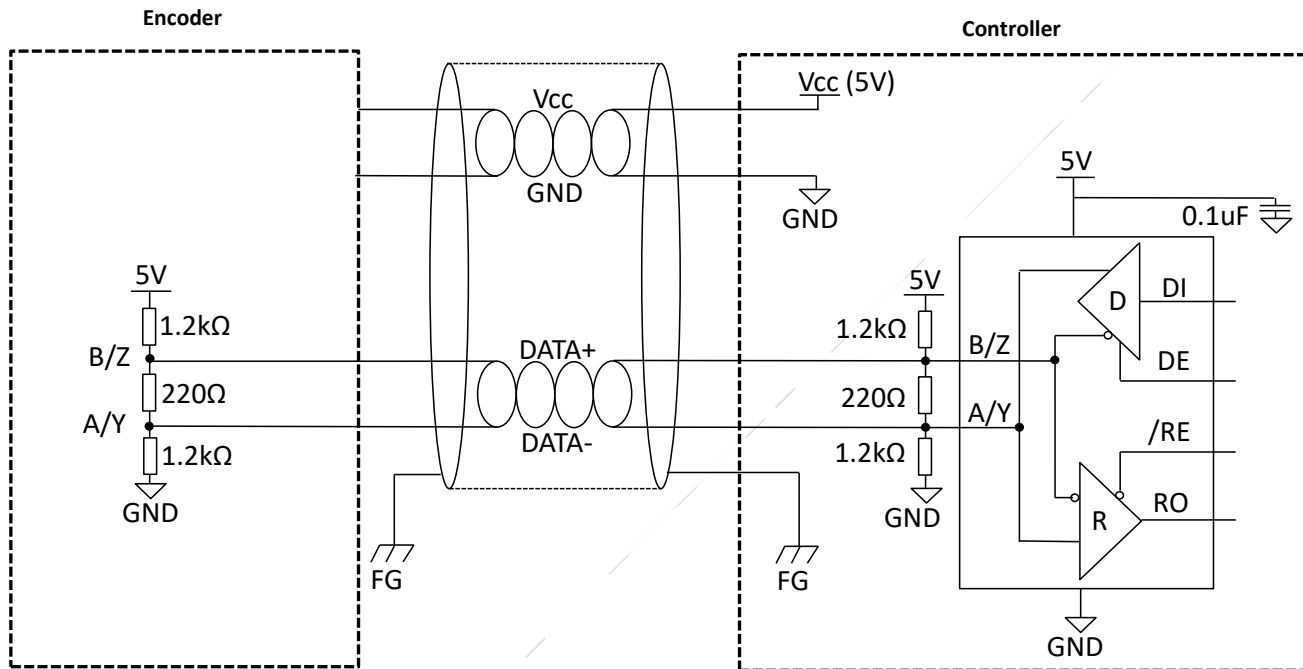
4. Terminate the shield-wire to Frame Ground (FG) at both ends of the communication line.

Figure 9 RS485 Half-Duplex I/O Connection

4.2 AR49-M49M-Bxx with BiSS-C Serial Interface

Table 4 BiSS-C Timing Characteristics

Over recommended operating Vdd 4.5 to 5.5V, Ta = -40 to 115°C

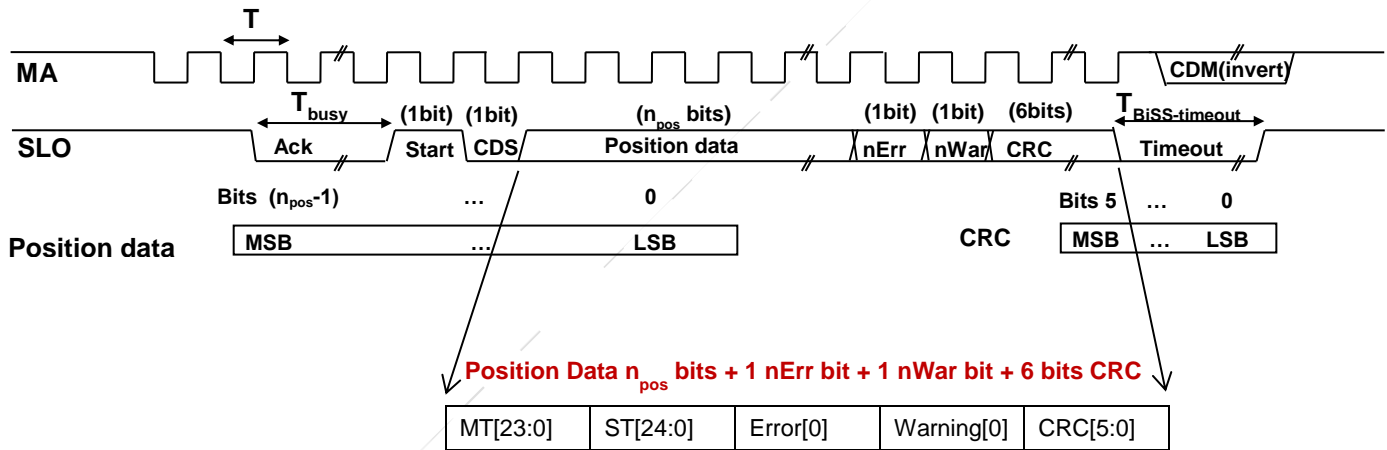| Parameter	Symbol	Condition	Min	Typ.	Max	Units	Notes
MA Frequency	f_{MA}		0.08		10	MHz	
MA duty	DUT_{CLK}	-	-	50	-	%	
Busy	T_{busy}	f_{MA} = 5 to 10MHz		$2/ f_{MA}$			
		$100kHz ≤ f_{MA} < 5MHz$		$1/ f_{MA}$		µs	
Busy	T_{busy}	-	-	-	5	µs	
Timeout	$t_{BiSS-timeout}$		$1.5/ f_{MA}$		5	µs	
Frame to Frame		-	-	-	1	µs	

Figure 10 BiSS-C Data Field and Interface Timing Diagram

NOTE

1. CRC Polynomial = Invert of $(X^6 + X^1 + X^0)$.
2. nErr bit is active low. (Combine all the Error Status and reflect in nErr bit)
3. nWar bit is active low. (Combine all the Warning Status and reflect in nWar bit)
4. Position data varies depending on Single-turn and Multi-turn resolution.

The recommended I/O connection between the encoder and the Master driver has the following basic requirements.

4.2.1   BiSS-C Full-Duplex Connection

1. Provide the following encoder power supply:
    –   For the 5.0V supply, V_{CC} should be within the range of 4.5V ~ 5.5V.

2. For best noise immunity, use a twisted-pair shielded cable for connection to the servo driver.

3. To prevent undesirable signal reflection, terminate with 120Ω resistors.

4. Terminate the shield-wire to Frame Ground (FG) at both ends of the communication line.
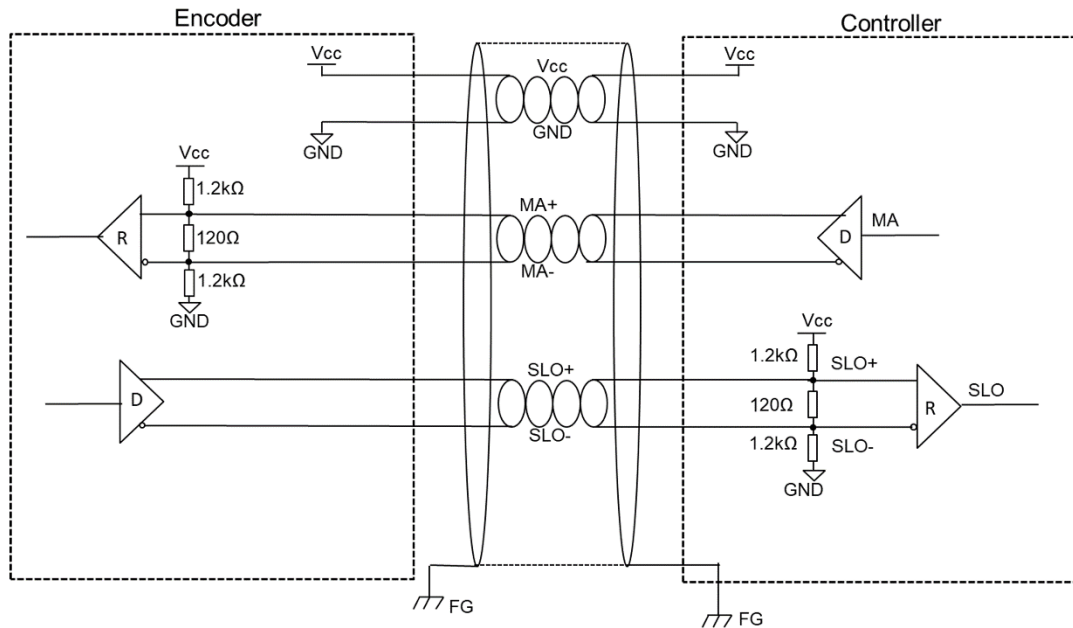

Figure 11 BiSS-C Full-Duplex I/O Connection

4.3 AR49-M49M-Sxx with SSI 2-Wire Serial Interface

Table 5 SSI Protocol Specifications
Over recommended operating Vdd 4.5 to 5.5V, Ta = -40 to 115°C

SSI Communication Parameters	Symbol	Conditions	Min	Typ	Max	Unit	Remark
Clock frequency	f_{CLK}	-	100	-	10,000	kHz	
Clock duty	DUT_{CLK}	-	-	50	-	%	
Monoflop time	t_m	-	-	-	20	µs	
Pause time	t_p	-	21		-	µs	

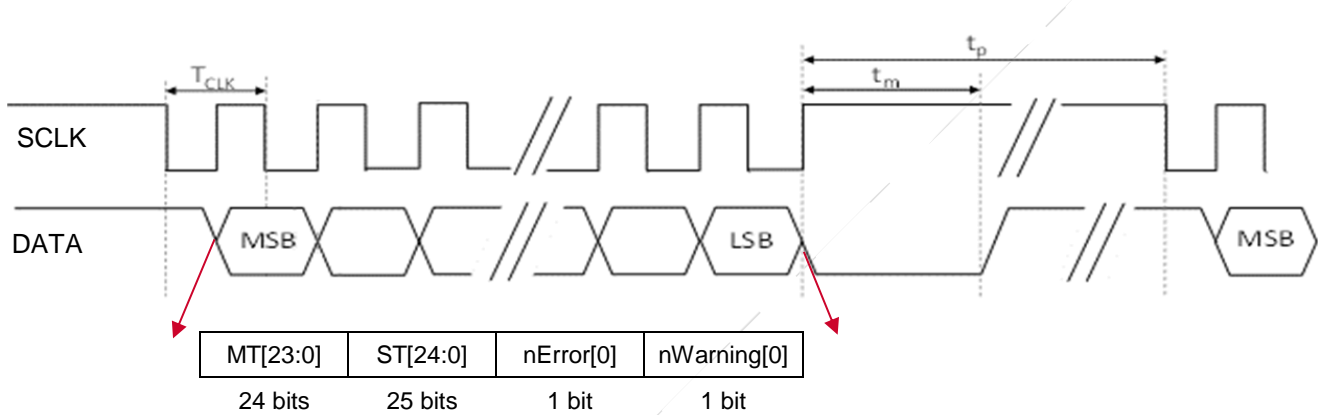| MT[23:0]	ST[24:0]	nError[0]	nWarning[0]
24 bits	25 bits	1 bit	1 bit

Figure 12 SSI Data Field and Timing Diagram
For the SSI option, the encoder calibration and device configuration is achieved by switching to the SPI mode during calibration. By toggling the logic levels of SEL0 and SEL1 pins, the SPI calibration mode can be enabled.

4.3.1 SSI 2-Wire Full-Duplex Connection

1. Provide the following encoder power supply:
   – For the 5.0V supply, V_{cc} should be within the range of 4.5V ~ 5.5V.
2. For best noise immunity, use a twisted-pair shielded cable for connection to the servo driver.
3. To prevent undesirable signal reflection, terminate with 120Ω resistor.
4. Terminate the shield-wire to Frame Ground (FG) at both ends of the communication line.

Figure 13 SSI Full Duplex Connection
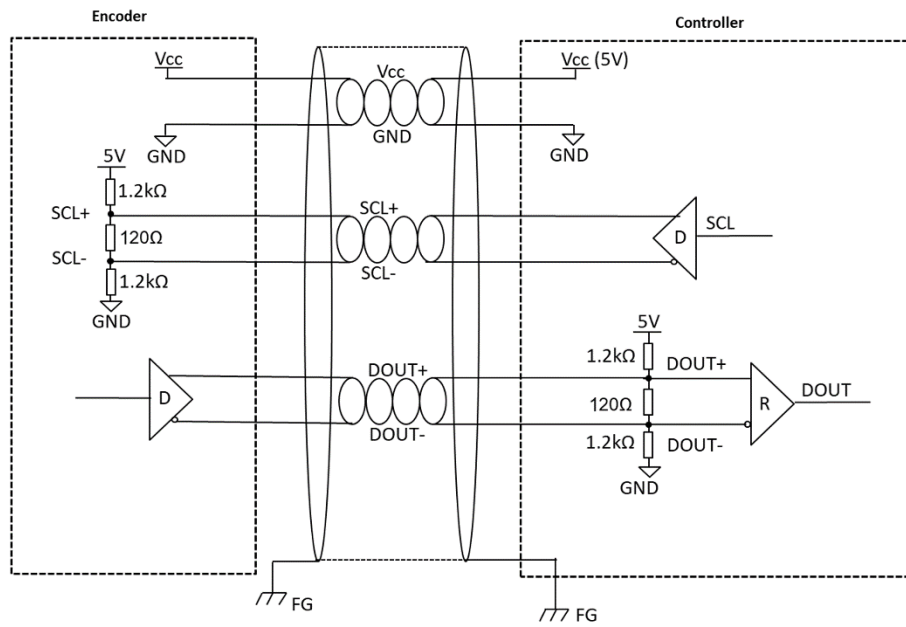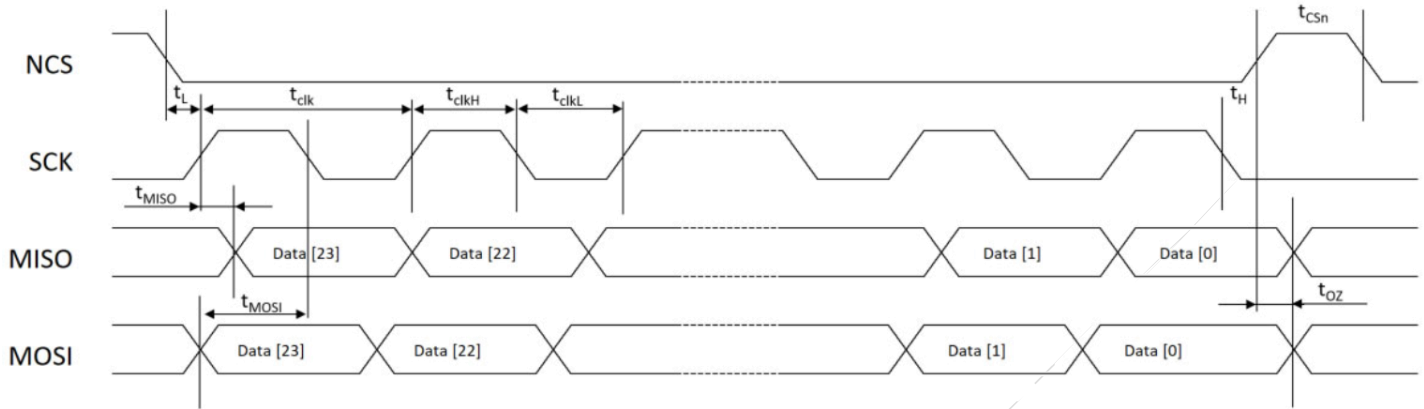
4.4 AR49-M49M-Sxx with SPI 4-Wire Protocol

Figure 14 SPI Timing Diagram

Table 6 SPI Protocol Specifications

Over recommended operating V_{DD} 4.5 to 5.5V, Ta = -40 to 115°C

Symbol	Description	Min.	Typ.	Max.	Units
t_L	Time between NCS falling edge and CLK rising edge	350	—	—	ns
t_{clk}	Serial clock period	100	—	—	ns
t_{clkL}	Low period of serial clock	50	—	—	ns
t_{clkH}	High period of serial clock	50	—	—	ns
t_H	Time between last falling edge of SCK and rising edge of NCS	t_{clk} /2	—	—	ns
t_{NCS}	High time of NCS between two transmission	350	—	—	ns
t_{MOSI}	Data input valid to clock edge	20	—	—	ns
t_{MISO}	SCK edge to data output valid	—	51	—	ns
t_{OZ}	Time between NCS rising edge and MISO Hi-Z	—	10	—	ns

NOTE: The user should read back data to confirm data is written successfully.

5 Connector Information

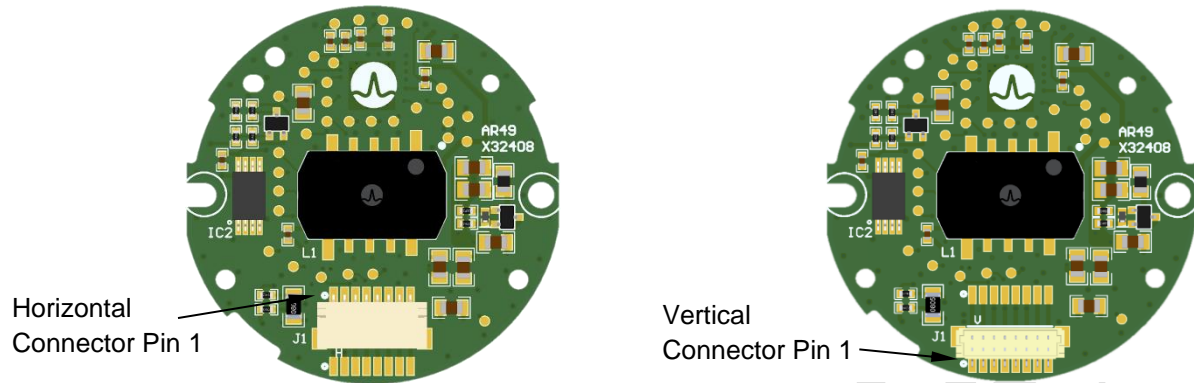**Figure 15 Horizontal and Vertical Connector Information**

Horizontal Connector Pin 1

Vertical Connector Pin 1

Table 7 Recommended Connector Information

Part	Location	Manufacturer	Part Number	Description
Header	On PCB	JST	SM08B-SRSS-TB	Horizontal/Radial connector
		JST	BM08B-SRSS-TB	Vertical/Axial connector
Wire Plug	Mating plug for wires	JST	SHR-08V-S	
Crimp Pins	Crimp pins for wires	JST	SSH-003T-P0.2-H	Terminal Pin for Wire 32~28AWG

Table 8 Encoder Pinout Description

Pin #	BiSS-C	SPI	SSI [1, 2]	RS485
1	+5V	+5V	+5V	+5V
2	0V	0V	0V	0V
3	MA+	SPI-NCS	SCLK+/ SPI-NCS	NC
4	MA-	SPI-CLK	SCLK-/ SPI-CLK	NC
5	SLO+	SPI- DO/MISO	DATA+/ SPI-DO/MISO	DATA+
6	SLO-	SPI- DIN/MOSI	DATA-/ SPI-DIN/MOSI	DATA-
7	NC	NC	SEL0	NC
8	NC	NC	SEL1	NC

NOTE

1. SSI option is configured via the shared SPI pins and setting the correct logic level to the SEL0 and SEL1 pins.
2. The SPI-CLK and MOSI lines of SSI option require a strong driver current. Recommended to be achieved with a level shifter or a line driver circuit.

6 Preliminary Part Numbering

Table 9 Encoder Ordering Information

#	Multi-Turn Part Number	Description
1	AR49-M49M-S12V	49-Bit MT, Differential SSI, 6mm Shaft, M3 Mounting Screw, Vertical Connector
2	AR49-M49M-P12V	49-Bit MT, Single-Ended SPI 4-Wire, 6mm Shaft, M3 Mounting Screw, Vertical Connector
3	AR49-M49M-K12V	49-Bit MT, Differential RS485, 6mm Shaft, M3 Mounting Screw, Vertical Connector
4	AR49-M49M-B12V	49-Bit MT, Differential BiSS-C, 6mm Shaft, M3 Mounting Screw, Vertical Connector
5	AR49-M49M-S12H	49-Bit MT, Differential SSI, 6mm Shaft, M3 Mounting Screw, Horizontal Connector
6	AR49-M49M-S12H	49-Bit MT, Single-Ended SPI 4-Wire, 6mm Shaft, M3 Mounting Screw, Horizontal Connector
7	AR49-M49M-K12H	49-Bit MT, Differential RS485, 6mm Shaft, M3 Mounting Screw, Horizontal Connector
8	AR49-M49M-B12H	49-Bit MT, Differential BiSS-C, 6mm Shaft, M3 Mounting Screw, Horizontal Connector
#	Single-Turn Part Number	Description
9	AR49-M25S-S12V	25-Bit ST, Differential SSI, 6mm Shaft, M3 Mounting Screw, Vertical Connector
10	AR49-M25S-P12V	25-Bit ST, Single-Ended SPI 4-Wire, 6mm Shaft, M3 Mounting Screw, Vertical Connector
11	AR49-M25S-K12V	25-Bit ST, Differential RS485, 6mm Shaft, M3 Mounting Screw, Vertical Connector
12	AR49-M25S-B12V	25-Bit ST, Differential BiSS-C, 6mm Shaft, M3 Mounting Screw, Vertical Connector
13	AR49-M25S-S12H	25-Bit ST, Differential SSI, 6mm Shaft, M3 Mounting Screw, Horizontal Connector
14	AR49-M25S-P12H	25-Bit ST, Single-Ended SPI 4-Wire, 6mm Shaft, M3 Mounting Screw, Horizontal Connector
15	AR49-M25S-K12H	25-Bit ST, Differential RS485, 6mm Shaft, M3 Mounting Screw, Horizontal Connector
16	AR49-M25S-B12H	25-Bit ST, Differential BiSS-C, 6mm Shaft, M3 Mounting Screw, Horizontal Connector

Table 10 Accessories Ordering Information

#	Part Number	Description
1	AS20-C300	8-pin mating connector with 300mm cable length
2	AR49-M49-E01	Programming Kit (applicable for all protocol options) Contents: 1 unit of MCU based programming kit, 1 unit of USB cable for PC interface, DUT cable and the associated programming software.
3	AR25-AC25	Accuracy Calibration Station for AR25/AR49 Series Rotary Reflective Encoder Contents: Mechanical setup including servo motor control, high accuracy reference encoder, programming kits, associated cables assemblies (for PC interface, motor handler communication, DUT encoder connection), and the associated GUI programming software.

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