Application Note

AR18 and AR35 Series

Miniature Programmable Single-Turn Absolute Encoder

Introduction

The Broadcom® AR18 and AR35 Series' miniature absolute encoder ASICs are designed to cater to the growing demand for space-constraint applications.

The AR18 encoder has an overall diameter of 18 mm and offers user-programmable resolutions from 17-bit, 19-bit, and 21-bit single-turn absolute outputs. The AR35 encoder has an overall diameter of 35 mm and offers 17-bit and 21-bit single-turn absolute outputs.

The AR18 and AR35 Series provides incremental ABI and UVW in differential mode. Both come with a recommended temperature range of –40°C to 115°C suitable for most industrial applications. Dual-mode operating voltages of 3.3V and 5V are suitable for handheld and portable device applications.

Employing the Broadcom-patented Reflective Optical Encoding Theory, the AR18 and AR35 Series offers high accuracy with correction, which is unattainable by the magnetic encoder.

Applications

- Robotic automation and engineering
- Factory automation and drones
- Medical and dentistry, devices and equipment
- High-accuracy portable and handheld devices
- Miniature motor/servo motor/linear actuator

Part Ordering Information

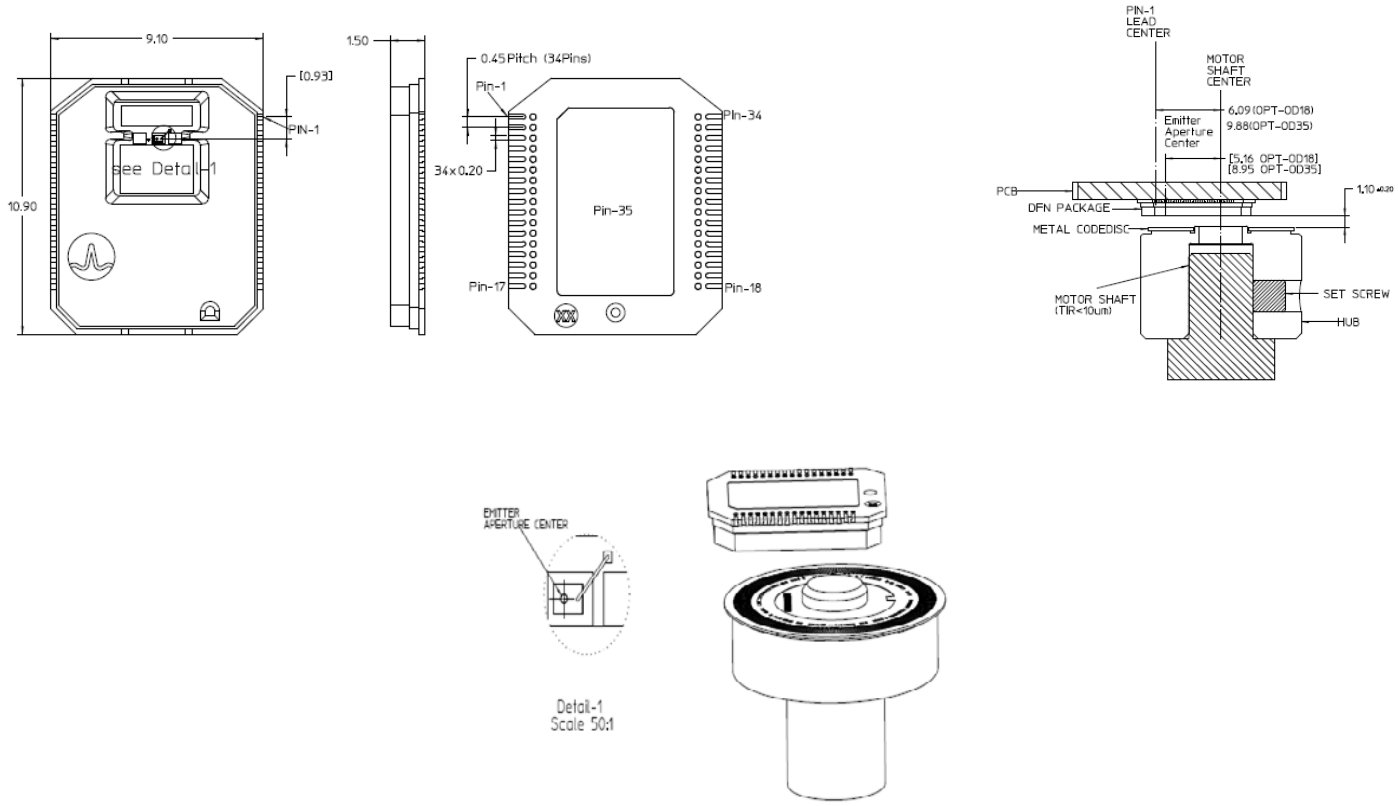
Ordering Information	Type
AR18-A21S/E	AR18 SSI/ESL Single-Turn Absolute Encoder
AR35-A21S/E	AR35 SSI/ESL Single-Turn Absolute Encoder

Mounting Requirements

Figure 1 shows the mounting requirements to set up the encoder to the optimum position for typical encoder performance. Overall mounting requirements are applicable for the following items:

- AR18/AR35 DFN encoder to code-wheel operational gap
- Code-wheel placement

Figure 1: Mounting Requirement



Notes on Assembly

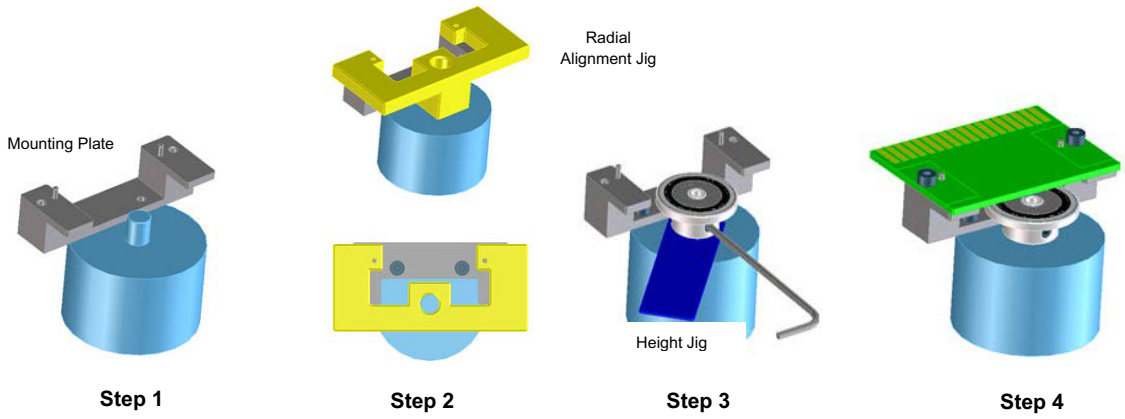
1. The encoder assembly requires a clean room condition of Class 100k or better.
2. The encoder must be enclosed with an IP50-rated enclosure.
3. The encoder has protective tape to prevent contamination. Remove the tape at the location, away from the ASIC slot, as shown in Figure 2 to prevent scratches to the ASIC after the SMT reflow processes.

Figure 2: Removal of Protective Tape

Mounting the Code-Wheel–Hub Assembly with the Alignment Jig

1. Place the mounting plate on the motor base.
2. Align the mounting plate guide pins to the motor shaft with the aid of the radial alignment jig, and secure the position with the mounting screws.
3. Install the code-wheel–hub assembly onto the motor shaft with the aid of a set height jig in between the motor base and the bottom surface of the hub. Secure the hub with a M3x3 set screw. (The recommended tightening torque is 0.15 Nm for the M3x3 set screw.)
4. Position the PCBA on the mounting plate guided by the guide pins. Secure the position with the mounting screws. (The recommended tightening torque is 0.15 Nm for the M2x6 cap screw.)

Figure 3: Mounting Concept with Alignment Jig



Jig Design Concept

Figure 4: Mounting Plate Dimensions

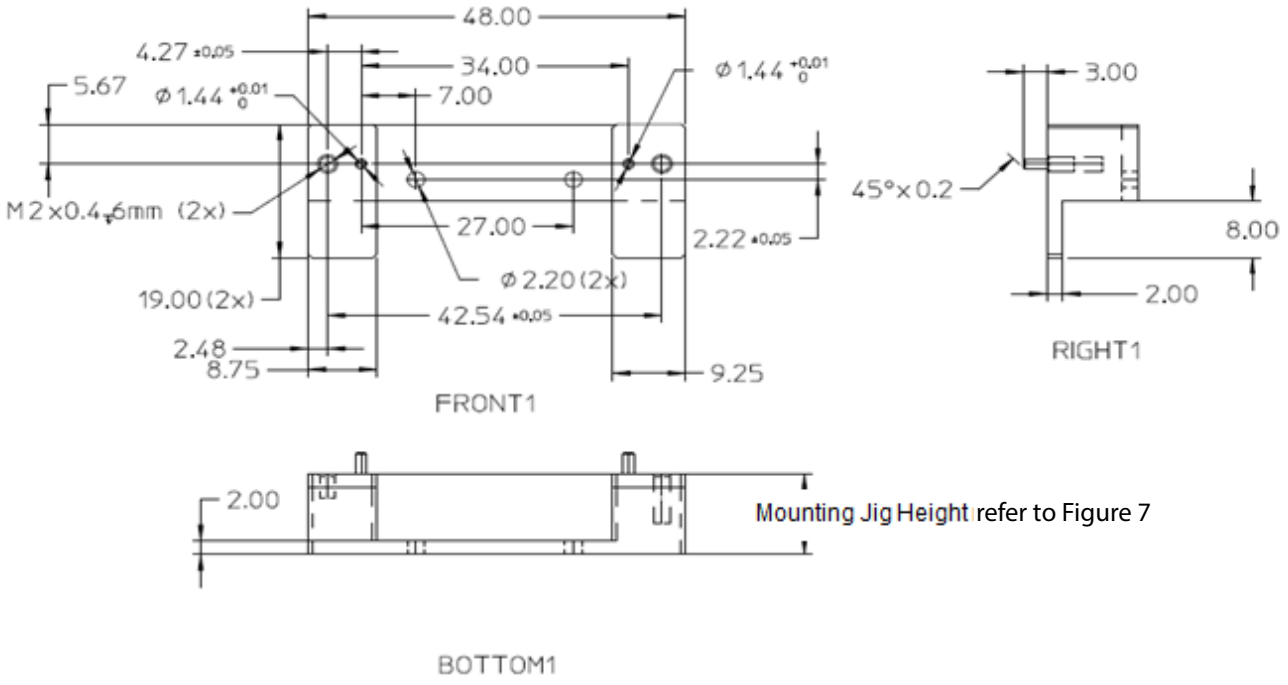


Figure 5: Alignment Jig Mechanical Dimensions (Radial and Tangential)

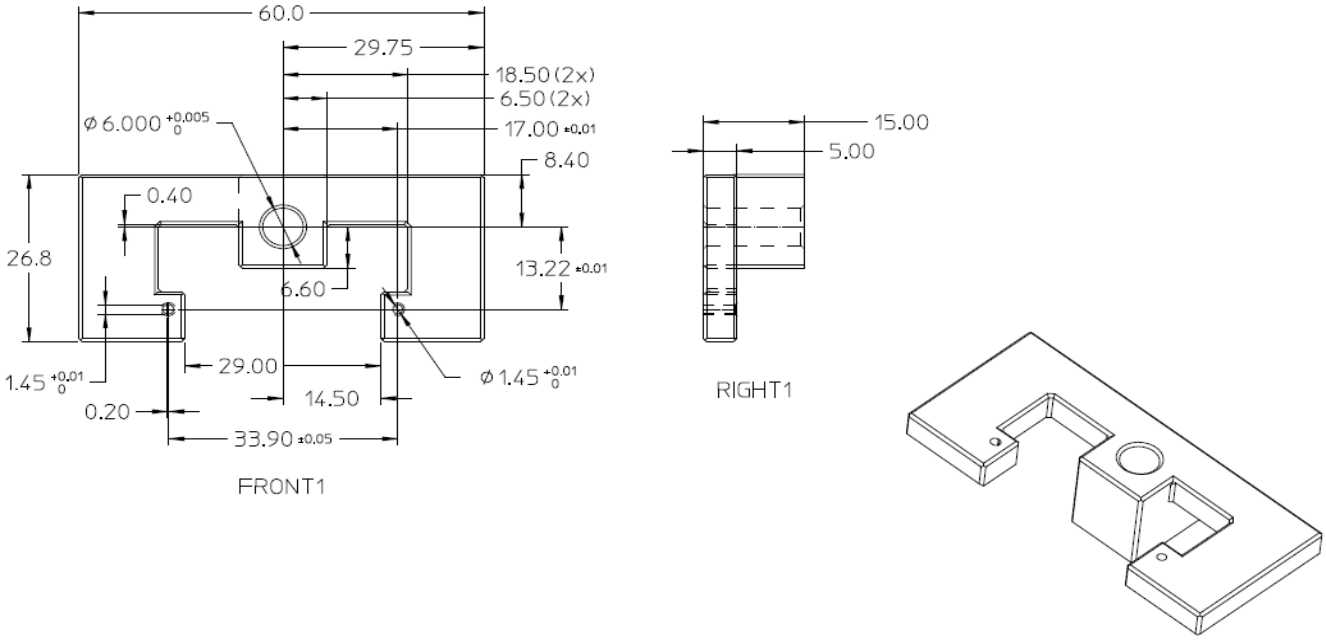


Figure 6: Set Height Jig Mechanical Dimensions

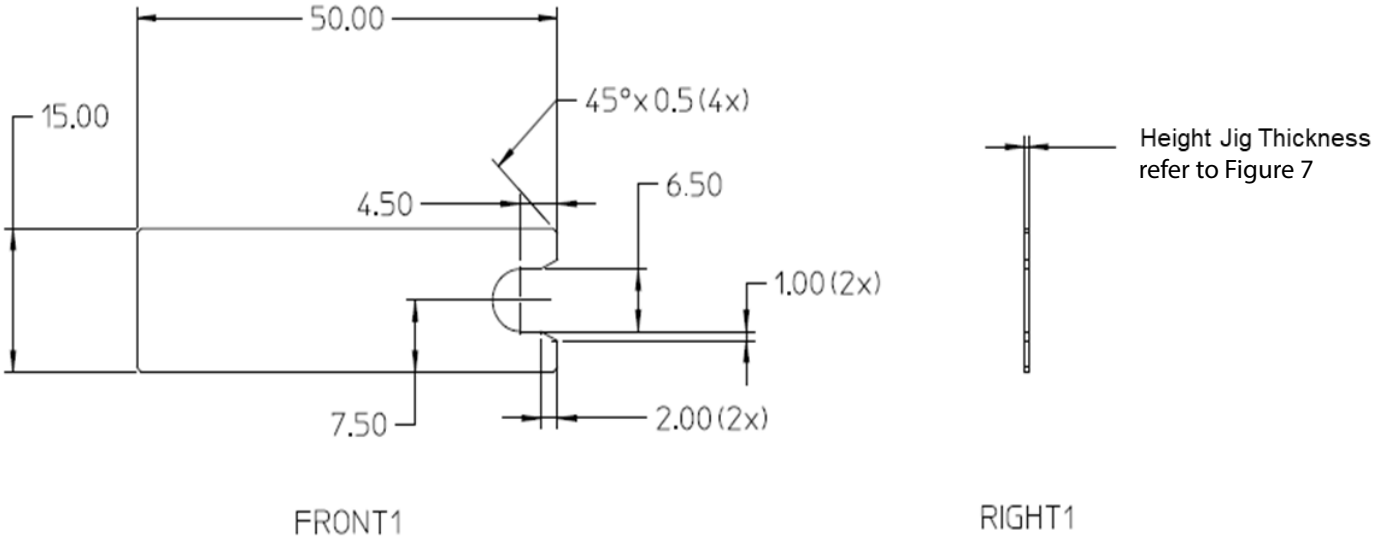
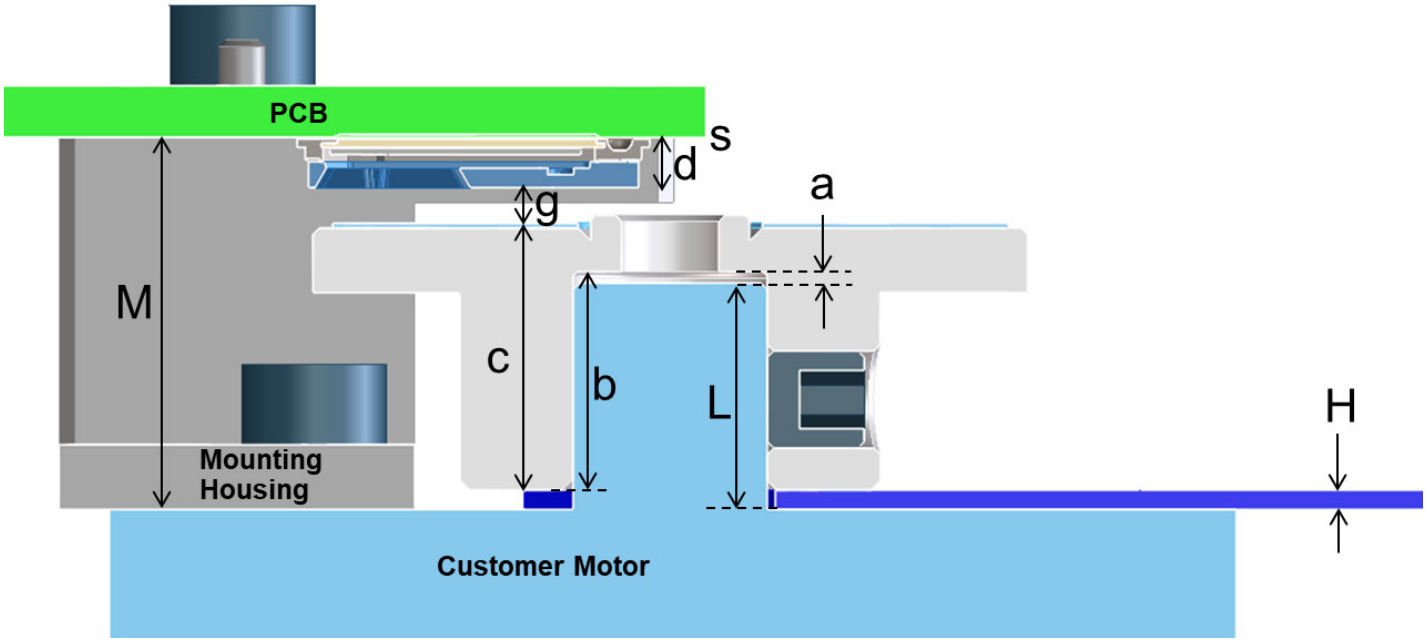


Figure 7: Jig Design Dimensions



	Parameter	Symbol	AR 18 (Nominal Dimension)	AR35 (Nominal Dimension)
1	Mounting Jig Height	M	M = H + c + g + d + s	M = H + c + g + d + s
2	Height Jig Thickness	H	H = L – (b – a)	H = L – (b – a)
3	Gap DFN and Code Wheel	g	1.10 mm	1.10 mm
4	Shaft to Hub Clearance	a	0.30 mm to 0.60 mm	0.30 mm to 0.60 mm
5	Code Wheel – Hub Height	c	6.75 mm	8.25 mm
6	Motor Shaft Height	L	Based on Customer Shaft Height	
7	DFN Package Height	d	1.50 mm	1.50 mm
8	Solder Paste Thickness	s	0.05 mm	0.05 mm
9	Hub Inner ID Depth	b	5.00 mm	6.50 mm

Recommended Shaft Tolerances

Table 1: Shaft Tolerances

Hub ID (mm)	Hole Tolerance			Set Screw Size	Shaft OD (mm)	Shaft Tolerance		
	Lower	Upper	Hole Basis			Lower	Upper	Shaft Basis
2	0	0.008	H6	#2-56	2	–0.004	–0.009	g5
3	0	0.008	H6	#2-56	3	–0.004	–0.009	g5
4	0	0.008	H6	M3	4	–0.004	–0.009	g5
6	0	0.008	H6	M3	6	–0.004	–0.009	g5
8	0	0.009	H6	M3	8	–0.005	–0.011	g5
10	0	0.009	H6	M3	10	–0.005	–0.011	g5

Code-Wheel Handling

- Wear a finger cot when touching the active area.
- Use a lint-free wiper (cleanroom grade) with IPA to clean the code wheel. Do not use cotton buds (non-lint-free) because they can scratch the code wheel.

Figure 8: Code-Wheel Handling

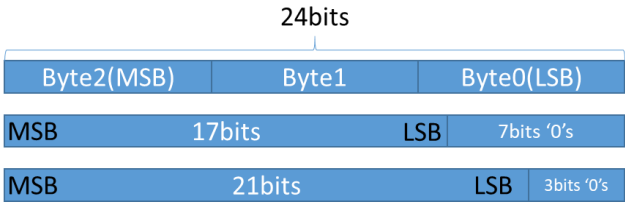
Encoder Zero Offset

Zero Offset with SSI 3-Wire and SPI

Table 2: Reference Memory Map (SPI) for Zero Offset

Number	Item	Address	Bits							
		Page 14	7	6	5	4	3	2	1	0
1	ST_Zero_Reset_0 (Byte 0)	0x0C	ST_ZR[7:0]							
2	ST_Zero_Reset_1 (Byte 1)	0x0D	ST_ZR[15:8]							
3	ST_Zero_Reset_2 (Byte 2)	0x0E	ST_ZR[23:16]							

Figure 9: Resolution Bits



AR35

1. With a static motor, read the position (using Figure 18) that SSI outputs, and patch with zeros to make it up to 24 bits.
   – If the readout is in the 21 bits position, patch 3 zero at LSB.
   – If the readout is in the 17 bits position, patch 7 zero at LSB.
   – Split into 3 bytes as shown in Figure 9.

2. SPI Write offset value operation.
   - SPI write address 0x7F, value 0x08 (switch to EEPROM page 8).
   - SPI write address 0x00, value 0xAB (unlock write access).
   - SPI write address 0x7F, value 0x0E (switch to EEPROM page 14).
   - SPI write address 0x0C, value of Byte 0.
   - SPI write address 0x0D, value of Byte 1.
   - SPI write address 0x0E, value of Byte 2.
   - SPI write address 0x1B, value 0x0F (unlock MTP for the programming the offset value).
   - SPI write address 0x40, value 0xC0 (perform MTP programming).
3. After ~30 ms, read the position that SSI outputs, and get to position value 0.

AR18

1. With a static motor, read the position that SSI ouputs, and patch with zeros to make it up to 24 bits.
   - If the readout is in the 21 bits position, patch 3 zero at LSB.
   - If the readout is in the 19 bits position, patch 5 zero at LSB.
   - If the readout is in the 17 bits position, patch 7 zero at LSB.
   - Split into 3 bytes as shown in Figure 9.
2. SPI write offset value operation.
   - SPI write address 0x7F, value 0x08 (switch to EEPROM page 8).
   - SPI write address 0x00, value 0xAB (unlock write access).
   - SPI write address 0x7F, value 0x0E (switch to EEPROM page 14).
   - SPI write address 0x0C, value of Byte 0.
   - SPI write address 0x0D, value of Byte 1.
   - SPI write address 0x0E, value of Byte 2.
   - SPI write address 0x1B, value 0x0F (unlock MTP for programming the offset value).
   - SPI write address 0x40, value 0xC0 (perform MTP programming).
3. After ~100 ms, read the position that SSI outputs, and get to position value 0.

Zero Offset with ESL

Use Table 2 or Table 10 using ESL protocol in the Memory Read/Write Frame.

Table 3: ESL Command ID List

	CF	SF	DF0	DF1	DF2	DF3	DF4	DF5	DF6	DF7	CRC	Remark	Frame Size
Data ID 4	Include CF and SF Status		ALMC	ABS0	ABS1	ABS2	ABS3				Include CRC	Position Read Command	8
Data ID 6			ABS0	ABS1	ABS2	ABS3							7
Data ID 8			ENID									Encoder ID Read Command	4
Data ID A			ALMC									Alarm Read Command	4
Data ID B			ALMC	ABS0	ABS1	ABS2	ABS3					Perform continuous 8× for ST clear command	8
Data ID C			ALMC	ABS0	ABS1	ABS2	ABS3					Perform continuous 8× for alarm clear command	8
Data ID E	CF	ADF	EDF									Memory or Register Read command	4
Data ID F	CF	ADF	EDF									Memory or Register Write Command	4

Method 1

AR35

1. With a static motor, read the position that ESL (ID4) outputs, and patch with zeros to make it up to 24 bits.
   – If the readout is in the 21 bits position, patch 3 zero at LSB.
   – If the readout is in the 17 bits position, patch 7 zero at LSB.
   – Split into 3 bytes as shown in Figure 9.
2. ESL Write (IDF) offset value operation.
   – ESL write address 0x7F, value 0x08 (switch to EEPROM page 8).
   – ESL write address 0x00, value 0xAB (unlock write access).
   – ESL write address 0x7F, value 0x0E (switch to EEPROM page 14).
   – ESL write address 0x0C, value of Byte 0.
   – ESL write address 0x0D, value of Byte 1.
   – ESL write address 0x0E, value of Byte 2.
   – ESL write address 0x1B, value 0x0F (unlock MTP for programming the offset value).
   – ESL write address 0x40, value 0xC0 (perform MTP programming).
3. After ~30 ms, read the position that ESL (ID4) outputs, and get position value 0.

AR18

1. With a static motor, read the position that ESL (ID4) outputs, and patch with zeros to make it up to 24 bits.
   – If the readout is in the 21 bits position, patch 3 zero at LSB.
   – If the readout is in the 19 bits position, patch 5 zero at LSB.
   – If the readout is in the 17 bits position, patch 7 zero at LSB.
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   – ESL write address 0x0D, value of Byte 1.
   – ESL write address 0x0E, value of Byte 2.
   – ESL write address 0x1B, value 0x0F (unlock MTP for programming the offset value).
   – ESL write address 0x40, value 0xC0 (perform MTP programming).
3. After ~30 ms, read the position that ESL (ID4) outputs, and get position value 0.

NOTE: The value of the position readout after a zero offset might fluctuate around 0 due to motor vibration at static.

Method 2

AR35

1. With a static motor, read the position that ESL (ID4) outputs for reference only.
2. Execute the ST clear command.
   – See Table 3, and use ESL (IDB) to send the command eight times continuously.
3. After ~30 ms, read the position that ESL (ID4) outputs, and get position value 0 (see note).

NOTE: The value of the position readout after a zero offset might fluctuate at 0 due to motor vibration at static.

AR18

1. With a static motor, read the position that ESL (ID4) outputs for reference only.
2. Execute the ST clear command.
   – See Table 3, and use ESL (IDB) to send the command eight times continuously.
3. After ~30 ms, read the position that ESL (ID4) outputs, and get position value 0 (see note).

NOTE: The value of the position readout after a zero offset might fluctuate at 0 due to motor vibration at static.

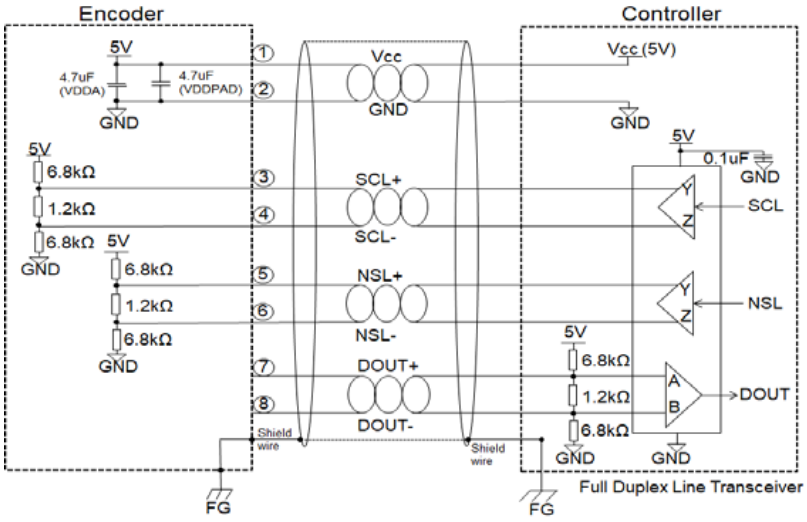
Recommended I/O Connection

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

ESL/SSI 3-Wire Differential Connection

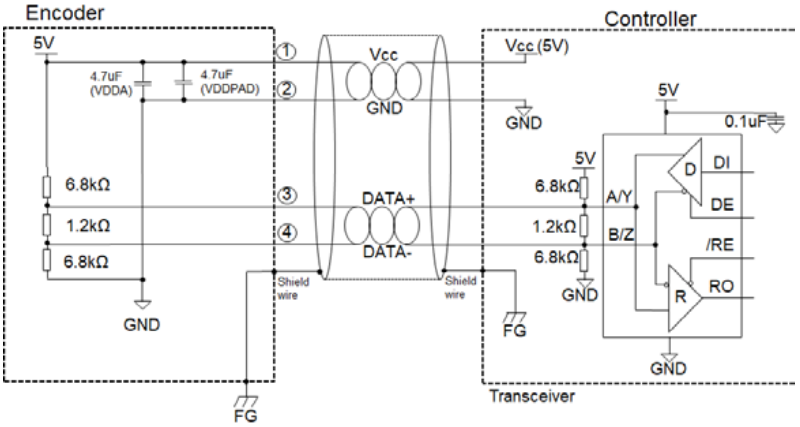
1. Provide the following encoder power supply:
   - For the 5.0V supply, V_{CC} should be within the range of 4.5V ~ 5.5V.
   - For the 3.3V supply, V_{CC} should be within the range of 3.0V ~ 3.6V.
2. For best noise immunity, use a twisted-pair shielded cable for connection to the servo driver.
3. To prevent undesirable signal reflection, terminate with 1200Ω resistors.

Figure 10: SSI Differential I/O Connections



ESL Half-Duplex Connection

Figure 11: ESL Half-Duplex I/O Connections

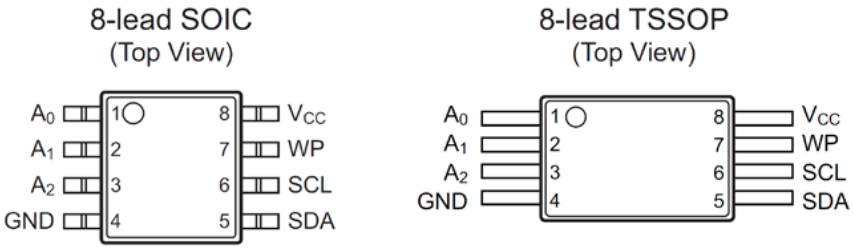


Recommended External EEPROM

Table 4: Recommended External EEPROM

Description	Part Number
Microchip, 2-wire Automotive Temperature Serial EEPROMs	AT24C08C-XPD

Figure 12: Recommended External EEPROM

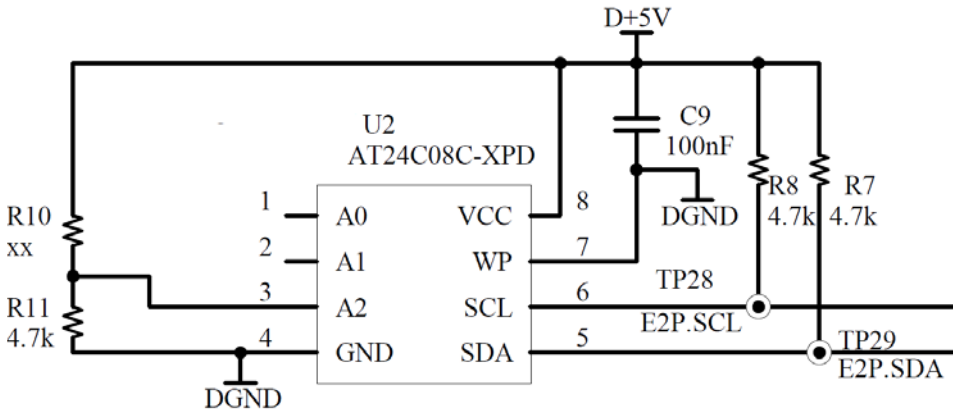


Note: Drawings are not to scale.

Table 5: Pin Name and Function

Pin Name	Function
A_0	Address Input (1K and 2K)
A_1	Address Input (1K, 2K, and 4K)
A_2	Address Input (1K, 2K, 4K, and 8K)
GND	Ground
SDA	Serial Data
SCL	Serial Clock Input
WP	Write Protect
V_{CC}	Device Power Supply

Figure 13: Recommended External EEPROM Connections



Recommended External Oscillator Device

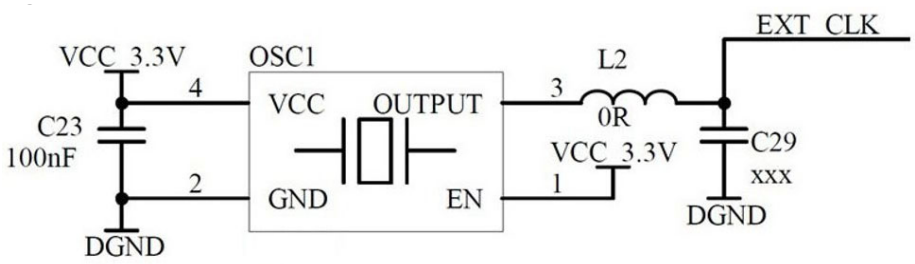
Table 6: Recommended External Oscillator Device

Description	Part Number
EPSON, 50-MHz Crystal Oscillator	SG-8101CGA 50.000000 MHz TJJSB
KYOCERA AVX, 50-MHz Crystal Oscillator	MC2016Z50.0000C19XSH

Table 7: Pin Description

Pin	Connection
1	$\overline{ST}$
2	GND
3	OUT
4	Vcc

Figure 14: Recommended Oscillator Connection



ESL: Half-Duplex

Table 8: ESL Interface

Interface	Circuit
ESL Serial Data (DATA +)	Transceiver (part number: ISL8485E)
ESL Serial Data (DATA –)	Transceiver (part number: ISL8485E)

Table 9: Timing Characteristics

Parameter	Min.	Typ.	Max.	Units
Communication Baud Rate	—	—	2.5 or 10.0	MHz
Frame Length	—	10	—	Bits/Frame

Position Read Frame (10 µs Wait Time)

Figure 15: Position Read Frame (2.5 Mb/s)

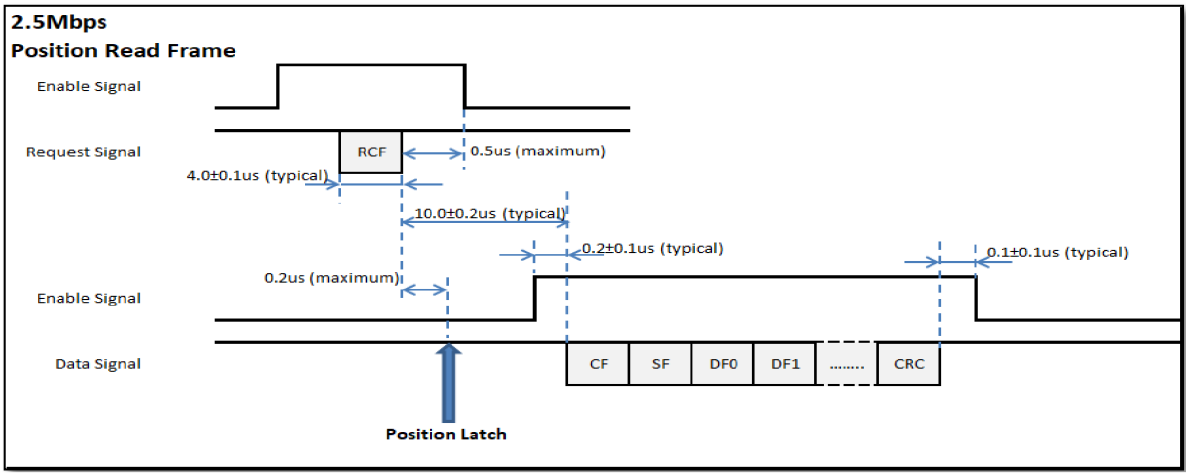
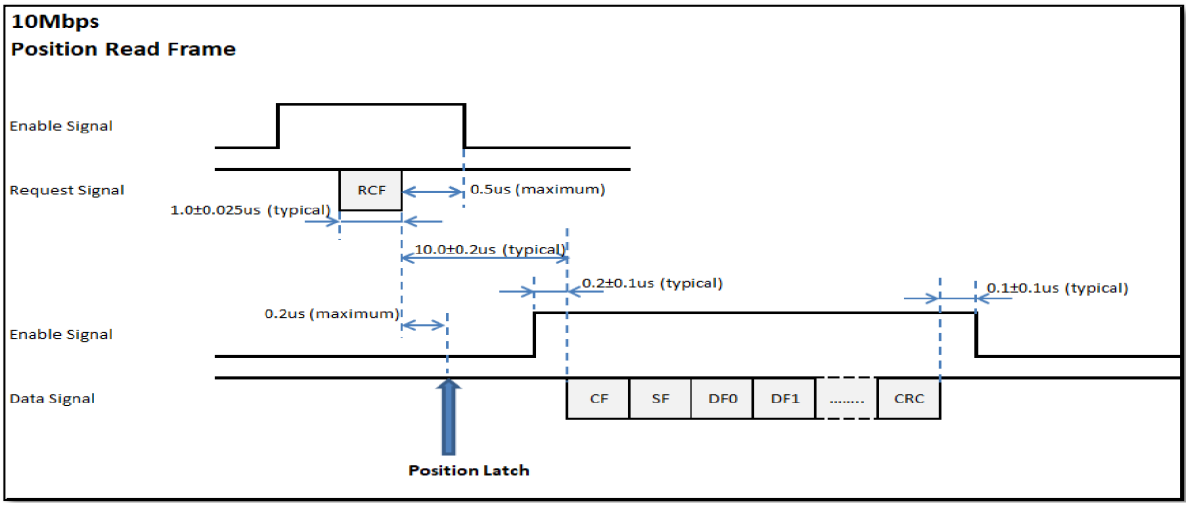


Figure 16: Position Read Frame (10 Mb/s)



Memory Read/Write Frame

Figure 17: Timing Characteristics of Enable, Request, and Data Signals (2.5 Mb/s)

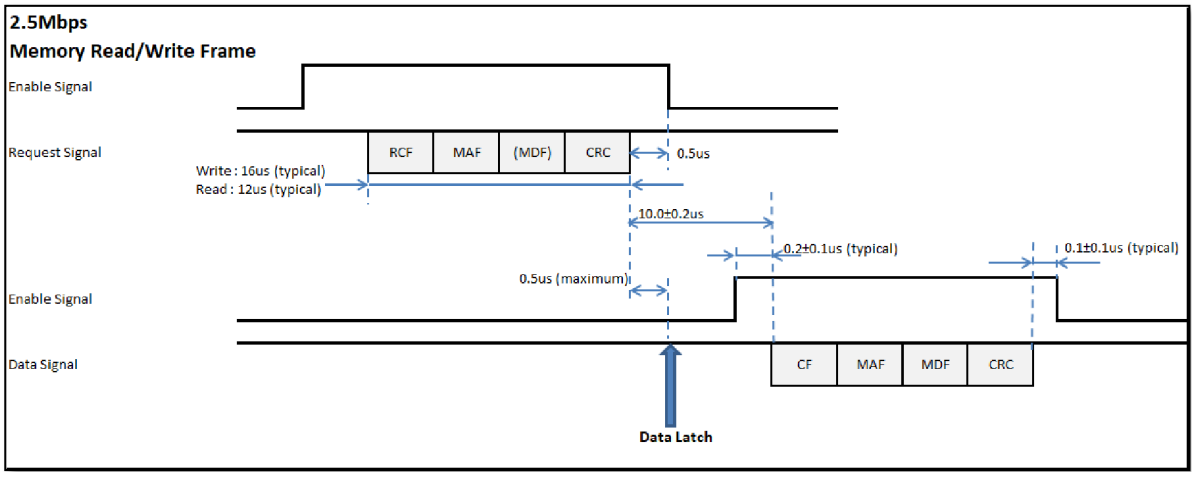
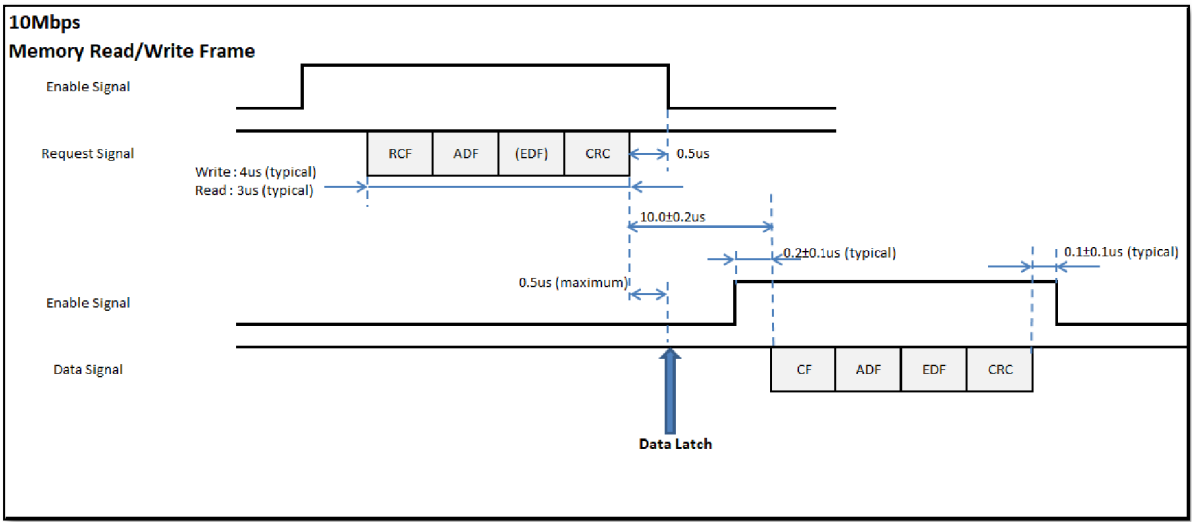


Figure 18: Timing Characteristics of Enable, Request, and Data Signals (10 Mb/s)



Register Communication and Assignment

Refer to the AR18/AR35 software specification document for detailed information.

Memory Map

NOTE: Enable the EEPROM write at Bank14 Add 0x1B followed by Program EEPROM.

Table 10: Memory Map

No.	Items	Address	Bits							
			7	6	5	4	3	2	1	0
1	Customer Configuration0	0x08	CFGSYNC[7:2]						N/A	N/A
2	Customer Configuration1	0x09	EEPROM Disable	MLS Segment Select	CW Direction	ESL Baud Rate Setting		ESL Encoder ID		
3	Customer Configuration2	0x0A	UVW Setting			I-width Setting		CPR Setting		
4	Customer Configuration3	0x0B	Mon Select						abs resolution[1:0]	
5	ST_Zero_Reset_0	0x0C	ST_ZR[7:0]							
6	ST_Zero_Reset_1	0x0D	ST_ZR[15:8]							
7	ST_Zero_Reset_2	0x0E	ST_ZR[23:16]							
8	Unlock Programming	0x1B	N/A	Address 0x0E	Address 0x0D	Address 0x0C	Address 0x0B	Address 0x0A	Address 0x09	Address 0x08

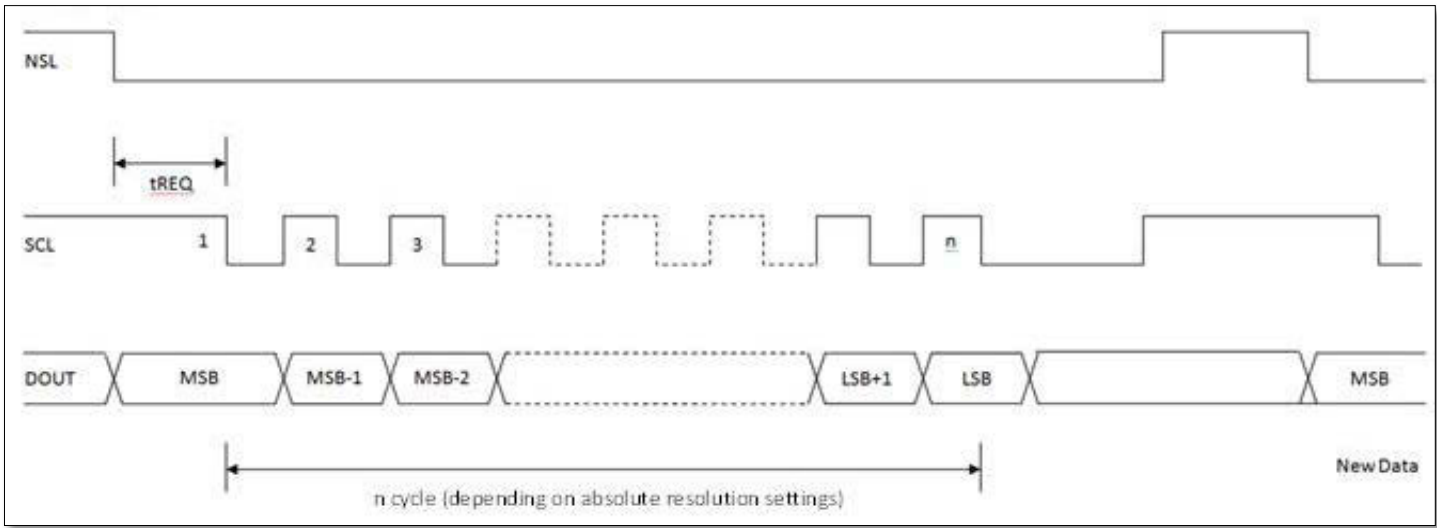
NOTE:

1. Unlock EEPROM is required before perform any changes on the Memory Map addresses. See Unlock EEPROM.
2. Unlock Programming is required by writing respective bit to "0" before perform any programming on desired setting. See Program EEPROM.

SSI 3-Wire Differential Output

SSI 3-Wire Timing

Figure 19: Timing Diagram



NSL toggles from high to low to start request position data.

SCL maximum frequency is 10 MHz.

tREQ = 10 µs is the time of data request processing.

SSI 3-Wire Pinout and Relevant Registers

Figure 20: SSI 3-Wire Pinout

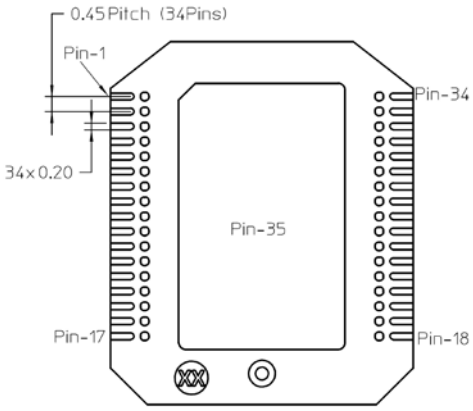


Table 11: SSI 3-Wire Pinout

Pin	Name	Function
10	SSI DOUT	SSI Data Output
12	SSI NSL	SSI Input
14	+ SSI SCL	SSI Clock (+)

AR18 SSI 3-Wire Output

Figure 21: AR18 Output

AR35 SSI 3-Wire Output

Figure 22: AR35 Output

Alarm Bit Definition

[4]	[3]	[2]	[1]	[0]
ST Error	MLS Error	LIS Error	MEM Error	LED Error

Encoder Calibration

Perform encoder calibration after installing the code wheel and encoder. Perform encoder calibration using the SPI interface.

NOTE: Do not power-cycle the encoder during calibration. Power-cycle the unit *only* after calibrating and programming the EEPROM.

SPI Communication Pinout (for Calibration)

Table 12: Calibration Pinout

Pin	Name	Function
5	SPI DOUT	SPI Data Output
6	SPI DIN	SPI Data Input
7	SPI CLK	SPI Clock

SPI Read and Write Timing Diagram (Maximum Clock Frequency 1 MHz)

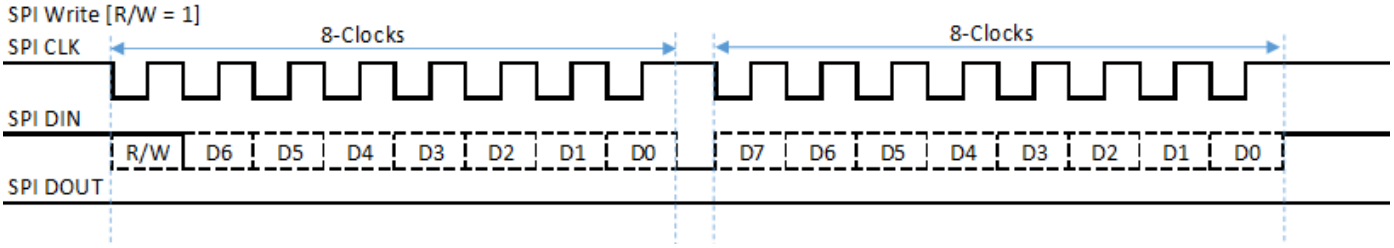
Memory Map

Table 13: SPI Read and Write Memory Map

Bit	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Read	0	Address[6:0]							Data[7:0]							
Write	1	Address[6:0]							Data[7:0]							

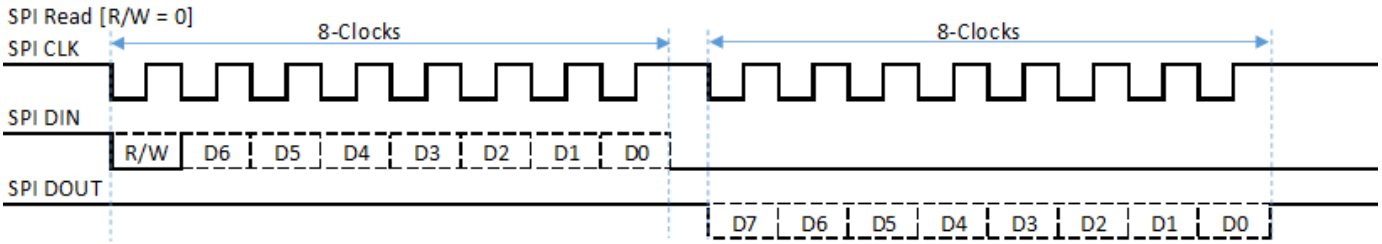
SPI Write: <Write Command = 1><7bits address><8bits data>

Figure 23: SPI Write Timing Diagram



SPI Read: <Read Command = 0><7bits address>

Figure 24: SPI Read Timing Diagram



Unlock EEPROM

1. Write to SPI address 0x7F with the value 08 (hexadecimal), to go to EEPROM page 8.
2. Write to SPI address 0x00 with value AB (hexadecimal), to unlock Level 1.
3. Write to SPI address 0x7F with value 0E (hexadecimal), to go to EEPROM page 14.

NOTE: Only required 1 time unlock per power cycle.

Program EEPROM

1. Write to SPI address 0x7F with value 08 (hexadecimal).
2. Write to SPI address 0x00 with value AB (hexadecimal).
3. Write to SPI address 0x7F with value 0E (hexadecimal).
4. Write to SPI address 0x1B [6:0] Unlock Programming bits to “0” based on address of changes. See Table 10, No. 8.
5. Write to SPI address 0x40 with value C0 (hexadecimal), to program EEPROM.
6. Read from SPI Address 0x13, Bit [0] and Bit [1].
   – From Address 0x13, if Bit [0] = 1 and Bit [1] = 0, the program is successful.

Calibration Description

1. AR18/35 is an absolute encoder that also generates incremental signals (ABIUVW).
2. Calibration (MLS Calibration) is a *required* process after assembly of the code wheel and encoder in order to operate normally without error.

Three calibration steps are required after encoder assembly into the motor/customer rotating fixture:

1. MLS segment select – Selects the matching MLS PD suitable for each encoder and code-wheel assembly.
2. Phase calibration – Synchronizes the absolute MLS signals to incremental signals.
3. MON total phase calibration – Optimizes the MLS pulse width in response to the incremental signals.

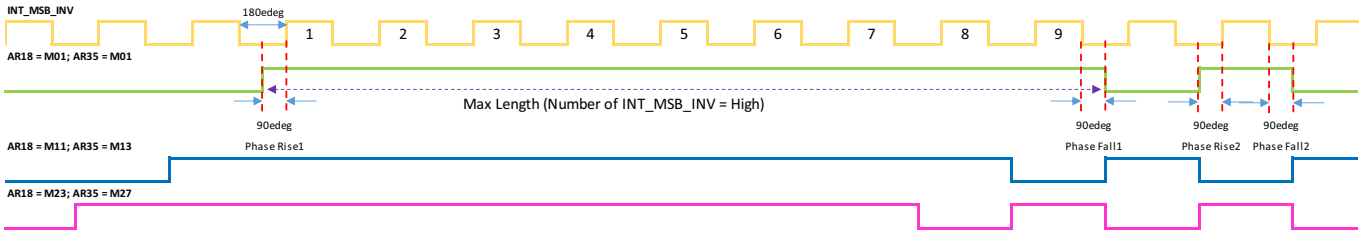
Concept of MLS Segment Select

1. MLS segment select – Enhances the spatial tolerance of an encoder.
2. MLS segment select 1 – Turns on both sets of MLS photodiodes (PDs) on the ASIC.
3. MLS segment select 0 – Turns on only one set of MLS photodiodes (PDs) on the ASIC.
4. When spatial displacement of the ASIC relative to the code wheel is off-centered and it hits the SET1 of MLS PD, MLS segment select 0 is chosen to minimize the crosstalk from Incremental track.

Concept of MLS-Incremental Phase Calibration

1. MLS-incremental phase calibration – Aligns and synchronizes digitized MLS (for example, M01, M13, M27) to incremental phase rise to 90 edeg.

Figure 25: Calibration



Concept of MON Total Phase Calibration

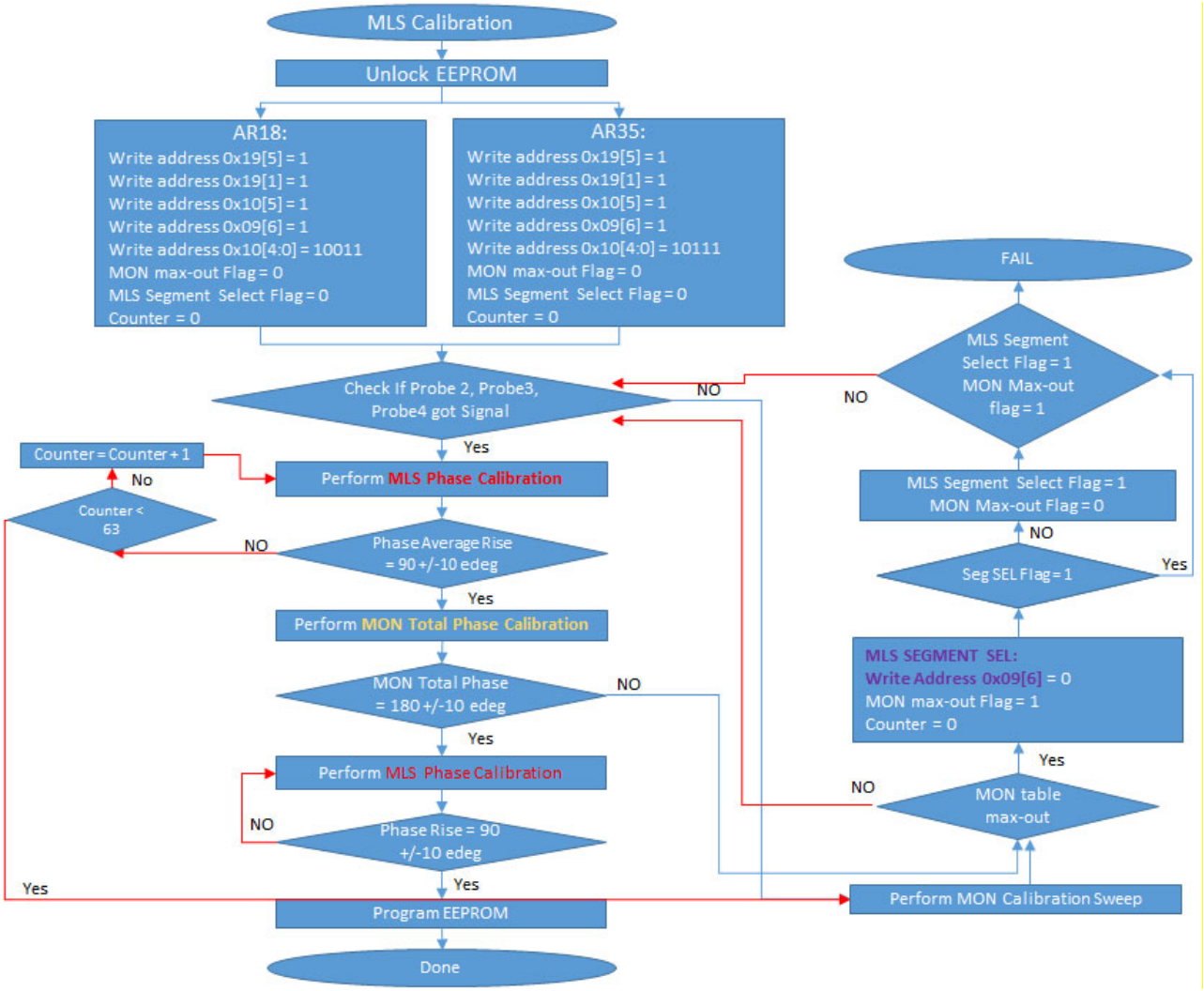
1. MON total phase calibration – Calibrates digitized MLS to incremental phase (rise + fall) to 180 edeg.

NOTE:

1. If MON NOT CROSSING MLS signal, *no* MLS digitized signal is generated (due to a spatial or calibration error).
2. MON level changes are required to get a digitized MLS signal.

Calibration Flow Chart

Figure 26: Calibration Flow Chart



Concept of MLS Calibration

1. Calibrate digitized MLS (for example, M01, M13, M27) to 90 edeg with MON total phase of 180 edeg and MLS phase of 90 edeg.
2. Perform MLS phase calibration by changing memory address page 14 address 0x08[7:2] with resolution of 5.625 edeg per step change.
3. Perform MON total phase calibration by changing memory address page 14 address 0x0b[7:2] with resolution of ~8 edeg per step change.
4. Perform MLS segment select when the preceding conditions cannot be meet.

NOTE:

1. The flow provided does not require an analog MLS signal to perform MLS calibration.
2. Only one time unlock and one time programming if it is on the same power cycle.

MLS Segment Select

1. Unlock EEPROM (see Unlock EEPROM).
2. Write to SPI address 0x09, with Bit [6] = 1 (Table 14).
3. Program EEPROM (see Program EEPROM).

Table 14: Memory Map for MLS Segment Selection

Register Name	Customer Configuration3							
Page	14			**Address**		0x09		
Access	RW			**Value**		Bit [6] = 1		
Bit Field	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
	N/A	MLS Segment	N/A	N/A	N/A	N/A	N/A	N/A
Description	For MLS Selection							

Mon Calibration

1. Unlock EEPROM (see Unlock EEPROM).
2. Write to SPI address 0x0B, with Bit [7:2] = 1 (Table 15).
3. Program EEPROM (see Program EEPROM).

Table 15: Memory Map for MON Calibration

Register Name	Customer Configuration3							
Page	14			**Address**		0x0B		
Access	RW			**Value**		Bit [7:2]		
Bit Field	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
	Mon Select [7:2]						N/A	N/A
Description	For MON Calibration							

Table 16: Mon Reference Table

Mon	
000101	0.866
000100	0.892
000011	0.918
000010	0.944
000001	0.97
000000	0.996
000110	1.022
000111	1.049
001000	1.075
001001	1.1
001010	1.126
001011	1.153
001100	1.179
001101	1.206
001110	1.231
001111	1.258
010101	1.285
010100	1.311
010011	1.337
010010	1.363
010001	1.389
010000	1.417
010110	1.441
010111	1.468
011000	1.495
011001	1.522
011010	1.548
011011	1.572
011100	1.6
011101	1.625
011110	1.652
011111	1.68

Mon	
100101	1.703
100100	1.728
100011	1.757
100010	1.782
100001	1.808
100000	1.833
100110	1.86
100111	1.885
101000	1.912
101001	1.94
101010	1.965
101011	1.992
101100	2.019
101101	2.043
101110	2.069
101111	2.094
110101	2.122
110100	2.15
110011	2.176
110010	2.202
110001	2.227
110000	2.254
110110	2.281
110111	2.308
111000	2.332
111001	2.36
111010	2.384
111011	2.41
111100	2.439
111101	2.465
111110	2.49
111111	2.518

MLS-Incremental Phase Calibration

1. Unlock EEPROM (see Unlock EEPROM).
2. Write to SPI address 0x19, with Bit [1] and Bit [5] =1 as shown in Table 18.
3. Write to SPI address 0x10, with Bit [5] = 1 as shown in Table 19.
4. Write to SPI address 0x10, with Bit [4:0] from Table 19 based on the following configuration:
   – AR18: 10011
   – AR35: 10111
5. Connect Pin 22, Pin 24, Pin 26, and Pin 30 to oscilloscope (Table 17).
6. Measure the following and calibration per bit step is 5.625V (Table 20):
   – Rising edge of 3 Digital MCODE to Incremental (INT_MSB_INV) as shown in Figure 27.
   – Phase target = 90 edeg ± 10 edeg.
7. Program EEPROM (see Program EEPROM).

Table 17: Signals Pinout

AR18		
Pin	**Name**	**Function**
22	PROBE1	INT_MSB_INV
24	PROBE2	M01
26	PROBE3	M11
30	PROBE4	M23

AR35		
Pin	**Name**	**Function**
22	PROBE1	INT_MSB_INV
24	PROBE2	M01
26	PROBE3	M13
30	PROBE4	M27

Table 18: Memory Map for Probe ON and MLS Selection Mode

Register Name	**Calibration and Function ON**							
Page	14			**Address**		0x19		
Access	RW			**Value**		Bit [1] and Bit [5] = 1		
Bit Field	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
	N/A	N/A	MLS SEL	N/A	N/A	N/A	PROBE ON	N/A
Description	For PROBE ON and MLS Selection Mode							

Table 19: Memory Map for Probe and PMUX Selection

Register Name	**Probe PMUX and LED Select**							
Page	14			**Address**		0x10		
Access	RW			**Value**		AR18: Bit [5] = 1, Bit [4:0] = 10011 AR35: Bit [5] = 1, Bit [4:0] = 10111		
Bit Field	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
	N/A	N/A	PROBE	PMUX[4:0]				
Description	For PROBE and PMUX selection							

Table 20: Memory Map for Calibration Bit

Register Name	Chip_Settings							
Page	14			Address		0x08		
Access	RW			Value		Bit [7:2]		
Bit Field	7	6	5	4	3	2	1	0
	CFGSYNC[7:2]						N/A	N/A
Description	For MLS-INC Phase Calibration							

Figure 27: Digital MCODE Signals (M01, M11/M13, and M21/M27) to Incremental Signals (INC)

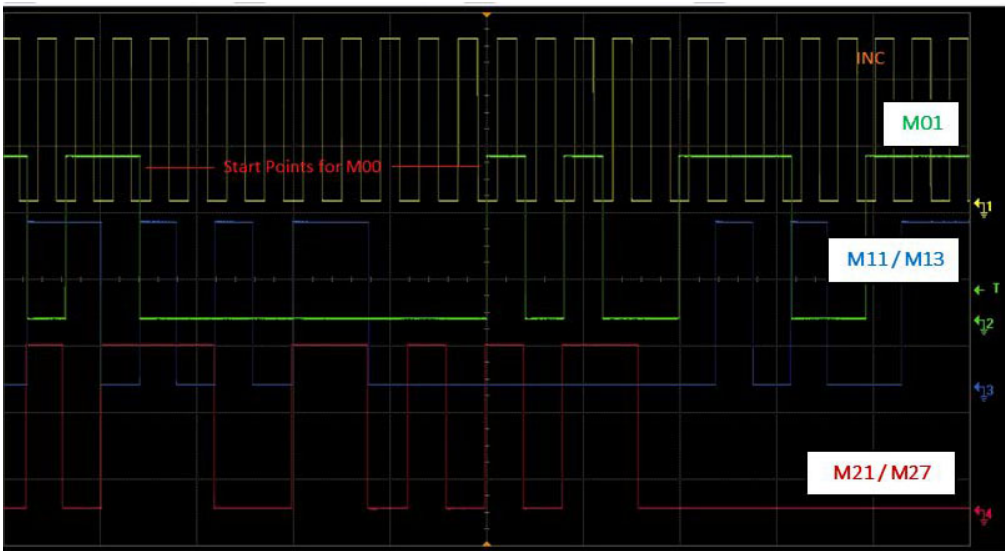


Table 21: Absolute Code Bit Length

Product	AR18	AR35
Total Number of Phase Rise (per revolution)	64	128
Total Number of Phase Fall (per revolution)	64	128
Max Length (Number of INT_MSB_INV = High)	8	9

NOTE:

1. Max. length is unique and only happens once per revolution.
2. It is required to spin the motor (100 RPM to 1000 RPM) to capture the phase rise/phase fall/max. length.

MLS-Incremental Phase Calibration:

Targeted Phase Average Rise: 90 edeg ± 10 edeg
Phase Rise= α
Number of Phase Rise = *r*

Figure 28: Equation

$$Phase\ Rise_{(Mxx)} = \frac{(\sum_{n=1}^{r} \alpha_n)}{r}$$

Phase Average Rise(AR18) = (Phase Rise(M01) + Phase Rise(M11) + Phase Rise(M23)) / 3
Phase Average Rise(AR35) = (Phase Rise(M01) + Phase Rise(M13) + Phase Rise(M27)) / 3

MLS-incremental phase calibration: Change the value of Page 14 Address 0x08 [7:2], per increment is ± 5.625 edeg depending on the motor turning direction.

Mon Total Phase Calibration

1. Unlock EEPROM (see Unlock EEPROM).
2. Write to SPI address 0x19, with Bit [1] and Bit [5] =1 as shown in Table 18.
3. Write to SPI address 0x10, with Bit [5] =1 as shown in Table 19.
4. Write to SPI address 0x10, with Bit [4:0] from Table 19 based on this configuration:
   – AR18: 10011 and AR35: 10111.
5. Connect Pin 22, Pin 24, Pin 26, and Pin 30 to the oscilloscope (Table 17).
6. Measure the following and calibrate using register address 0x08 and 0x0B as shown Table 22.
   – Rising edge *and* falling edge of 3 Digital MCODE to Incremental (INT_MSB_INV).
   – Total phase target = 180 edeg ± 10 edeg. Enable the EEPROM write at Bank14 Add 0x1B.
7. Program EEPROM (see Program EEPROM).

Table 22: Memory Map for Calibration Bit

Register Name	**Chip_Settings**							
Page	14			**Address**		0x08		
Access	RW			**Value**		Bit [7:2]		
Bit Field	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
	CFGSYNC[7:2]						N/A	N/A
Description	For MLS-INC Phase Calibration							

Register Name	**Customer Configuration3**							
Page	14			**Address**		0x0B		
Access	RW			**Value**		Bit [7:2]		
Bit Field	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
	Mon Select [7:2]						N/A	N/A
Description	For MON, Vmid and MON Total Phase Calibration							

Mon Total Phase Calibration:

Targeted Mon Total Phase: 180 edeg ± 10 edeg
Phase Rise= α
Phase Fall= *b*
Number of Phase Rise = *r*
Number of Phase Fall = *f*

Figure 29: Equations

$$Phase\ Rise_{(Mxx)} = \frac{(\sum_{n=1}^{r} \alpha_n)}{r} \qquad Phase\ Fall_{(Mxx)} = \frac{\left(\sum_{n=1}^{f} b_n\right)}{f}$$

Phase Average Rise(AR18) = (Phase Rise(M01) + Phase Rise(M11) + Phase Rise(M23)) / 3
Phase Average Fall(AR18) = (Phase Fall(M01) + Phase Fall(M11) + Phase Fall(M23)) / 3
Mon Total Phase = Phase Average Rise(AR18) + Phase Average Fall(AR18)

Phase Average Rise(AR35) = (Phase Rise(M01) + Phase Rise(M13) + Phase Rise(M27)) / 3
Phase Average Fall(AR35) = (Phase Fall(M01) + Phase Fall(M13) + Phase Fall(M27)) / 3
Mon Total Phase = Phase Average Rise(AR35) + Phase Average Fall(AR35)

NOTE:

1. Mon Total Phase Calibration: Change the value of Page14 Address 0x0B [7:2], per increment is ~7 edeg.
2. Number of Phase Rise(*r*) and Fall(*f*) is 128 for AR35 per revolution.
3. Number of Phase Rise(*r*) and Fall(*f*) is 64 for AR18 per revolution.

Encoder Configuration

The allowable encoder configurations for both incremental output and absolute resolution are based on the memory map in Table 23.

Table 23: Memory Map for Incremental Output and Absolute Resolution Settings

Register Name	Customer Configuration2							
Page	14			Address		0x0A		
Access	RW			Value		Bit [7:0] as per Table 24		
Bit Field	7	6	5	4	3	2	1	0
	UVW Setting [7:5]			I Width Setting [4:3]		CPR Setting [2:0]		
Description	For Incremental Output Settings							

Register Name	Customer Configuration3							
Page	14			Address		0x0B		
Access	RW			Value		Bit [1:0] as per Table 25		
Bit Field	7	6	5	4	3	2	1	0
	N/A	N/A	N/A	N/A	N/A	N/A	Abs resolution [1:0]	
Description	For Absolute Resolution Settings							

Incremental Output Settings

1. Unlock EEPROM (see Unlock EEPROM).
2. Write to SPI address 0x0A with values based on Table 24.
3. Program EEPROM (see Program EEPROM).

Table 24: Incremental Output Settings

Address	Bits	Name	Settings	Output
0x0A	5–7	UVW Setting [2:0]	000	2 pole-pairs
			001	3 pole-pairs
			010	4 pole-pairs
			011	5 pole-pairs
			100	12 pole-pairs
			101	30 pole-pairs
			110	32 pole-pairs
			111	32 pole-pairs
	3–4	I-width Setting	00	90 edeg
			01	180 edeg
			10	360 edeg
			11	90 edeg
	0–2	CPR Setting	000	8192
			001	4096
			010	2048
			011	1024
			100	512
			101	256
			110	128
			111	128

Absolute Resolution Settings

1. Unlock EEPROM (see Unlock EEPROM).
2. Write to SPI address 0x0B with values based on Table 25.
3. Program EEPROM (see Program EEPROM).

Table 25: Absolute Resolution Settings

Address	Bits	Name	Settings	Output
0x0B	0–1	Abs Resolution	AR35 Bit: 00	17 Bit
			AR35 Bit: 01	21 Bit
			AR18 Bit: 00	17 Bit
			AR18 Bit: 01	19 Bit
			AR18 Bit: 10	21 Bit

Calibration Kit

You can perform encoder calibration with the Broadcom Calibration Kit. The kit part number is A21E-0010 – 21 Bits, AR18/35 Programming Calibration Kit.

Calibration Kit Pinout

Connect the supplied ribbon cable to encoder as shown in Table 26.

Table 26: CN8 (Ribbon Cable)

Calibration Kit	Connector's Pin	Connection to Encoder Pin
1	VDD_PAD	8
2	VSSA	27
3	VDDA	28
4	VSS	9
9	SN_TST1	3
10	CN_TST3	1
11	SP_TST0	4
12	CP_TST2	2
13	SSI SCL	14
14	ESL_SEL	17
15	SSI NSL	12
16	SSI DOUT– / ESL Dout–	11
17	SSI DOUT+ / ESL Dout+	10
18	SPI_CLK	7
19	SPI_IN	6
20	SPI_DOUT	5
22	I+	26
24	B+	24
25	PROBE4+	30
26	A+	22

Calibration Kit Interface

1. Log in using the user login and password provided.
2. Select the encoder type from the **Encoder Selection** drop-down menu (AR18/AR35) as shown in Figure 30.
3. Configure the encoder using the **User Config** tab shown in Figure 31. After configuration, click **Write** and then **Save Configuration**.
4. Set up the encoder to the motor.
5. Run the encoder at 60 rpm only.
6. Click **Start** as shown in Figure 32, and wait for calibration to end (green circle).

Figure 30: Login Menu

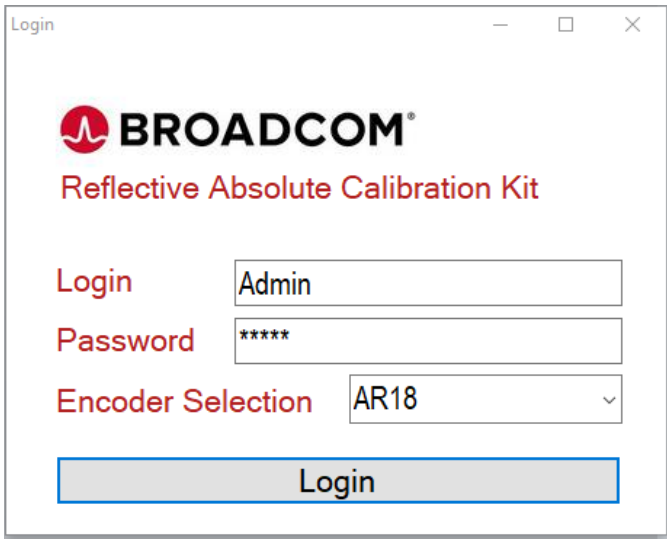


Figure 31: User Configuration Interface

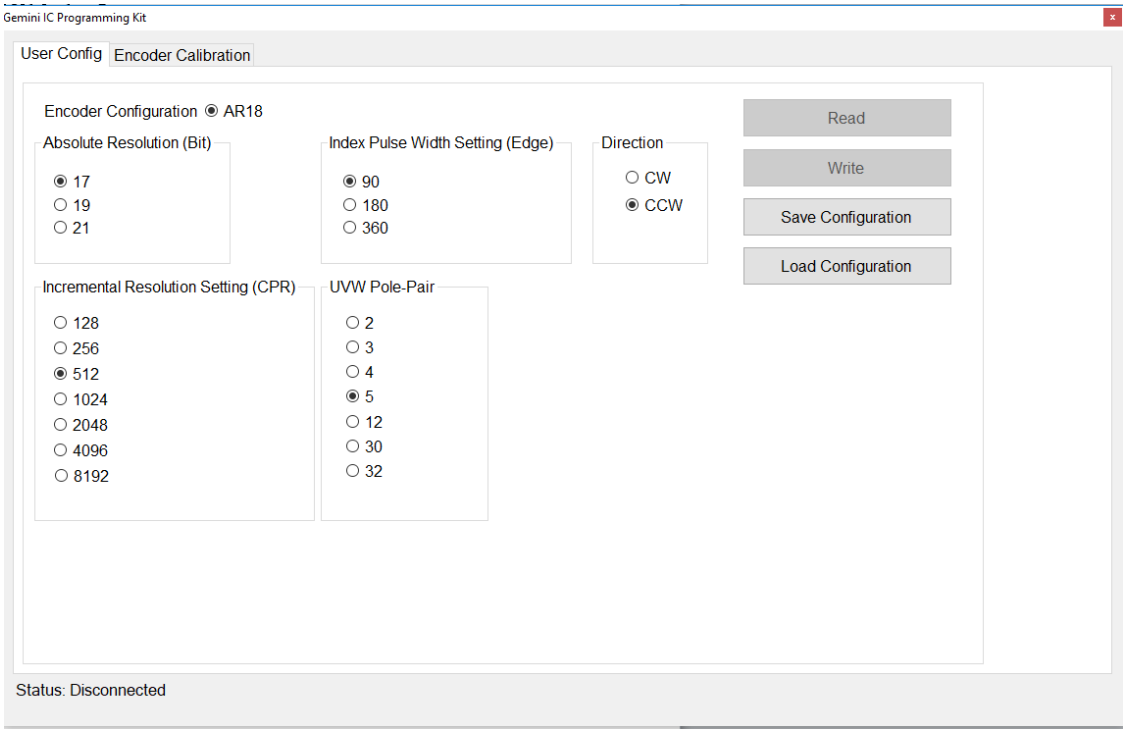
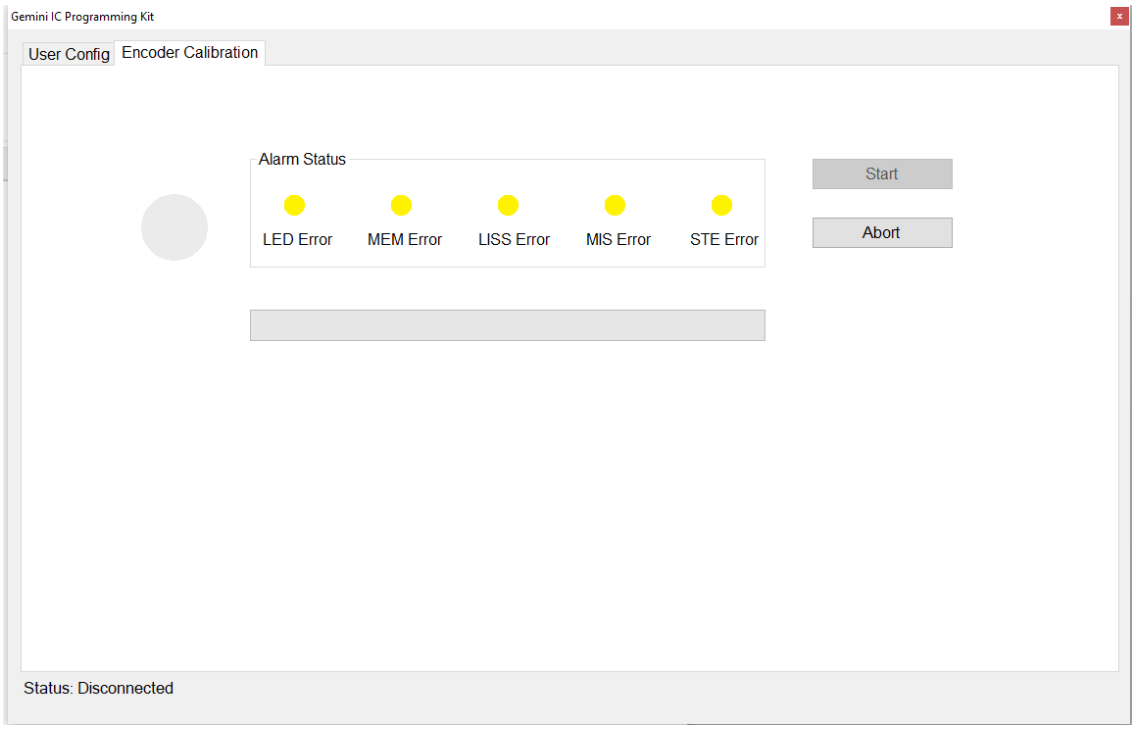


Figure 32: Encoder Calibration Interface



Acronyms Used in This Document

CFGSYNC	MCODE phase configuration synchronization
edeg	Electrical degree
ESL	Encoder serial link
MCODE	Digitized MLS signs
MLS	Maximum length sequence
MLS SEL	MLS photodiode segment selection
MON	MLS monitoring signal
MTP	Multiple time programming EEPROM
Vmid	Vmiddle of an analog signal
Vpp	Vpeak to peak of an analog signal

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