Data Sheet

AR18 and AR35 Series

Miniature Programmable Single-Turn Absolute Encoder with Resolution Ranging from 17 Bits to 21 Bits

Description

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

Features

- Miniature absolute encoder ASIC surface-mount DFN package: 10.9 mm (L) × 9.1 mm (W) × 1.5 mm (H)
- User-programmable resolution ranging from:
  - 17-bit, 19-bit, and 21-bit single turn (OD18).
  - 17-bit and 21-bit single turn (OD35).
- User-programmable incremental output (ABI) resolution ranging from 128 to 8192 CPR
- User-programmable commutation signal (UVW) ranging from 2, 3, 4, 5, 12, 30, 32 pole pair
- Differential output for ABI and UVW
- High temperature range of –40°C to 115°C suitable for most of the industrial operation.
- Dual-mode operating voltage of 3.3V and 5V, enabling handheld and portable device applications.
- Selectable SSI mode communication protocol.
- Selectable RS485 mode communication protocol.
- RoHs compliance.

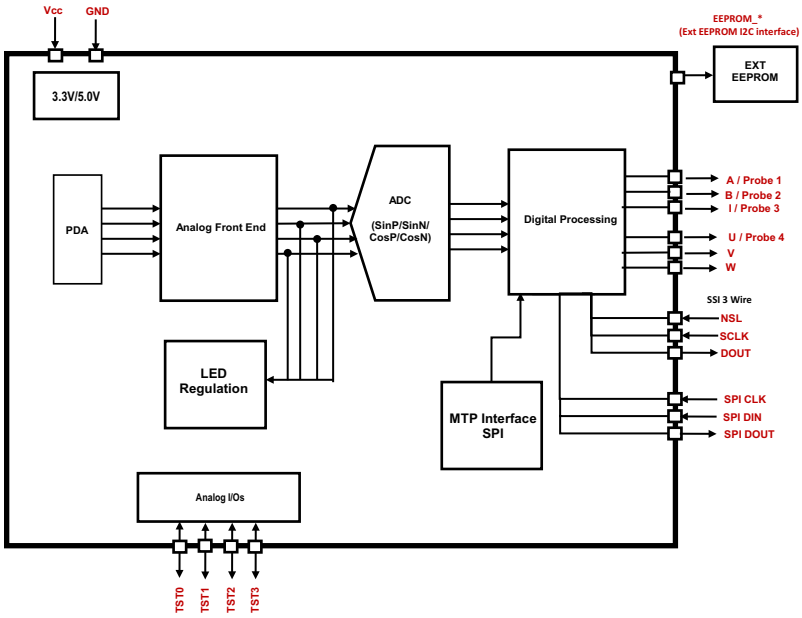
Applications

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

Functional Block Diagram

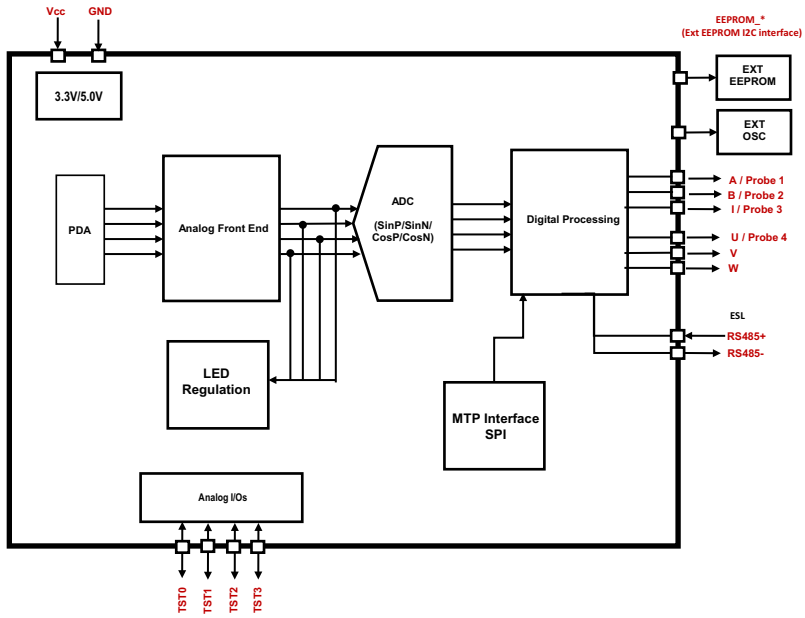
With SSI 3-Wire Communication Protocol Selection

Figure 1: SSI 3Wire Block Diagram



With ESL Communication Protocol Selection

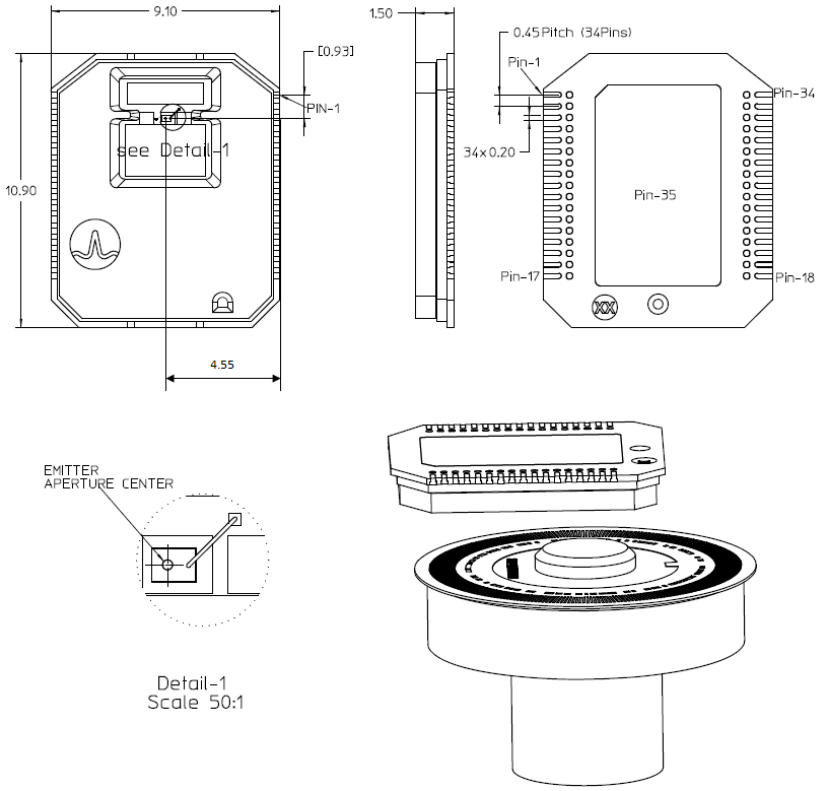
Figure 2: ESL Block Diagram



Mechanical Specifications

DFN Package Dimensions

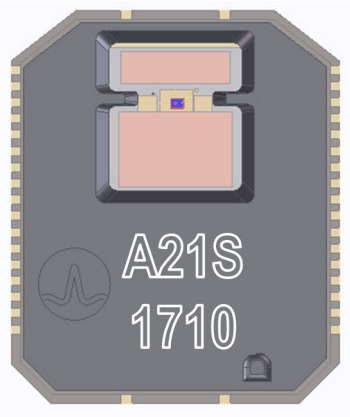
Figure 3: Overall Package Dimensions and Pinout



All dimensions given in mm. Tolerances of form and position according to JEDEC MO-220.

Package Markings

Figure 4: Product Marking Information



Part Type:

- A18S/E
- A21S

Date Code:

- YYWW (Year, Work Week)

Encoder Mounting

Figure 5: Encoder Mounting Guide

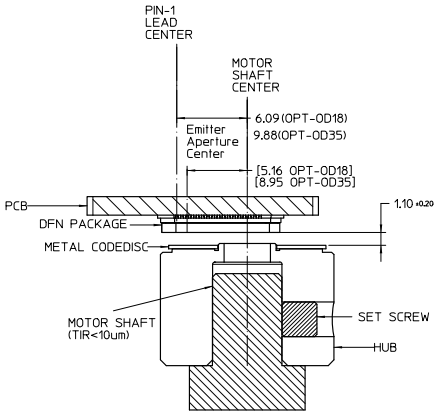


Figure 6: AR35

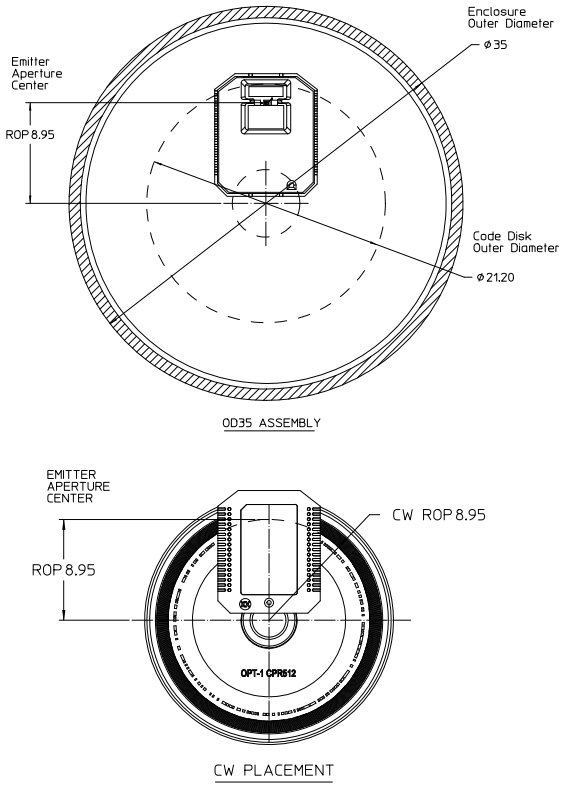
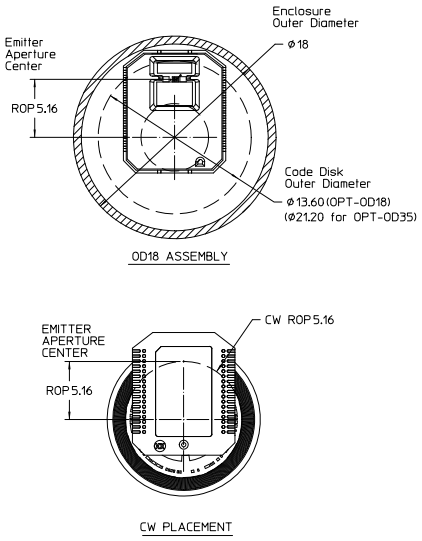


Figure 7: AR18



Notes of assembly:

- The assembly of the encoder needs clean room condition, Class 100k or better.
- The encoder needs to be enclosed with IP50 enclosure.

Recommended PCB Land Pattern

Figure 8: PCB Land Pattern

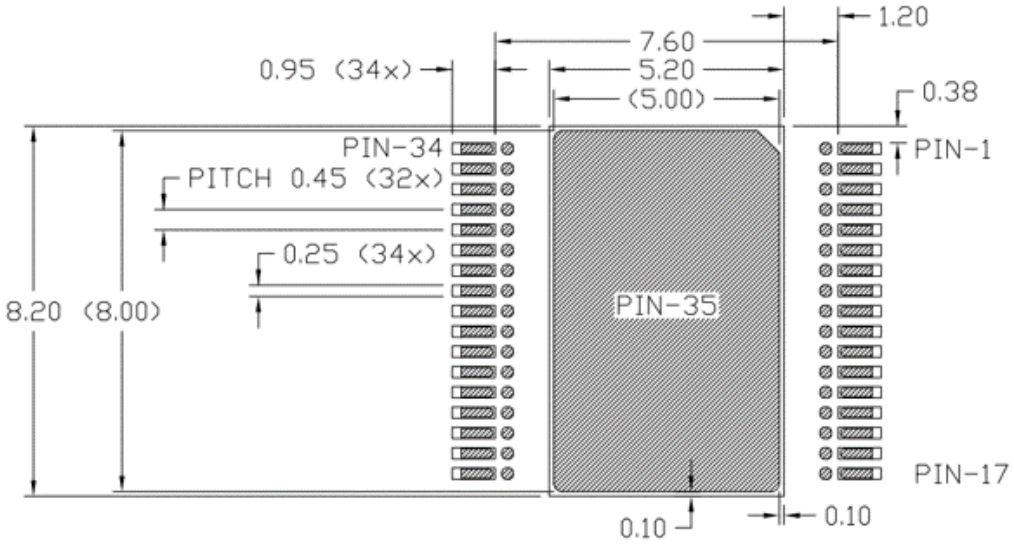
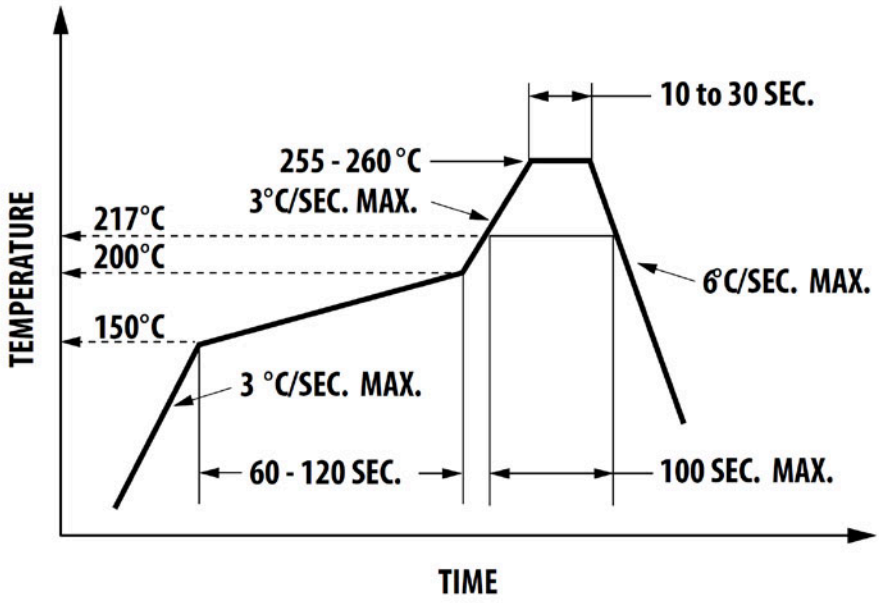


Figure 9: Recommended Pb-Free SMT Reflow Soldering Profile (According to JEDEC Pb-Free [J-STD-020D])



Electrical Specifications

Recommended Operating Conditions

Parameter	Symbol	Min.	Typical	Max.	Units	Notes
DC Supply Voltage	V_{dd}	+4.5	+5.0	+5.5	V	
DC Supply Voltage	V_{dd}	+3.0	+3.3	+3.6	V	
Ripple of Supply Voltage		—	—	100	mVpp	100 kHz
Output Current per channel		—	—	±5	mA	
Rise Time	t_r	—	30	—	ns	C_L = 50 pF, R_L = 1.2 kΩ
Fall Time	t_f	—	30	—	ns	
Ambient Temperature	T_{amb}	—	+25	—	°C	
Operational Temperature	T_A	–40	+25	+115	°C	
Storage Temperature	T_S	–40	+25	+115	°C	
Humidity	RH	—	—	85	%	Temperature = 40°C
INC Operating Frequency		—	—	128	kHz	Velocity (rpm) × CPR / 60
Radial Misalignment		–200	0	+200	µm	
Tangential Misalignment		–200	0	+200	µm	
Encoder Shaft Speed	SRPM	—	—	30,000	rpm	256CPR (AR18)
Encoder Shaft Speed	SRPM	—	—	15,000	rpm	512CPR (AR35)

Recommended Codewheel Characteristics

Parameter	Symbol	Min.	Typical	Max.	Units	Notes
Specular Reflectance	R_f	60%	—	—		Reflective Area
		—	—	5%		Non-Reflective Area

NOTE: Characteristics based on BRCM qualified codewheel supplier. Refer to BRCM for qualified reflective codewheel supplier.

Absolute Maximum Ratings

Parameter	Symbol	Value
Storage Temperature	T_S	–40°C to 115°C
Operating Temperature	T_A	–40°C to 115°C
Supply Voltage	V_{dd}	7V
ESD (HBM), JS-001-2014		± 2kV
Moisture Sensitive Level		3 (Maximum floor life = 168h)

DC Characteristics

DC characteristics over recommended operating range, typical at 25°C.

Parameter	Symbol	Conditions	Value			Units	Notes
			Min.	Typ.	Max.		
Vdd Supply Current	I_{dd}	V_{dd} = 3.3V/5V	—	70	—	mA	
Absolute Single Turn Resolution (AR18)			—	17, 19 and 21	—	Bit	
Absolute Single Turn Resolution (AR35)			—	17 and 21	—	Bit	
Incremental Resolution			—	2^n	—	CPR	n = 7, 8, 9, 10, 11, 12, 13

Encoder Characteristics

Incremental encoder characteristics over recommended operating conditions, at 25°C.

ABI Parameter	Symbol	Min	Typ.	Max[a]	Units
Cycle Error	ΔC	—	—	45	°e
State Error	ΔS	—	—	45	°e
Index Pulse Width	Po	—	90,180, 360	—	°e

a. Maximum values represent the encoder performance across the range of recommended mounting tolerance.

Commutation (UVW) Parameter	Symbol	Min	Typ.	Max[a]	Units
Commutation Accuracy (middle of channel I to channel U)	ΔI	–0.1	—	+0.1	°mechanical
Commutation Accuracy (Channel U,V and W)	ΔUVW	–0.1	—	+0.1	°mechanical

a. Maximum values represent the encoder performance across the range of recommended mounting tolerance.

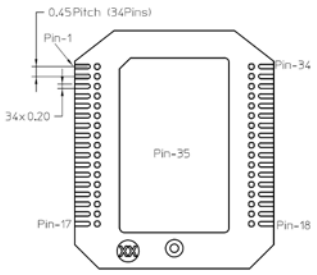
Encoder raw accuracy characteristics over recommended operating conditions, at 25°C.

Parameter	Symbol	Min	Typ.	Max[a]	Units
Raw Accuracy (AR18)	—	—	±500	—	Arc-sec
Raw Accuracy (AR35)	—	—	±250	—	Arc-sec

a. Typical values represent the encoder performance with shaft TIR < 10 µm, ϕ5.991 mm ~ 5.996 mm; CW hub ID = 6.000 mm ~ 6.008 mm.

Encoder Pin Functions

Figure 10: Pinouts



SSI 3-Wire Option Pinout Configuration

NOTE: Pin 35 must be grounded to VSSA and pin 17 connect to common GND.

Table 1: SSI 3-Wire Pinout

Pin	Name	Function	Pad type	Analog/Digital	Input/Output
1	CN/TST3	Analog Voltage Output NCOS	5V/3.3V pads	Analog	I/O
2	CP/TST2	Analog Voltage Output PCOS	5V/3.3V pads	Analog	I/O
3	SN/TST1	Analog Voltage Output NSIN	5V/3.3V pads	Analog	I/O
4	SP/TST0	Analog Voltage Output PSIN	5V/3.3V pads	Analog	I/O
5	SPI DOUT	SPI Data Output	3.3V / 5V (VDDPAD)	Digital	Output
6	SPI DIN	SPI Data Input	3.3V / 5V (VDDPAD)	Digital	Input
7	SPI CLK	SPI Clock	3.3V / 5V (VDDPAD)	Digital	Input
8	VDD	Digital Supply Voltage	3.3V / 5V (VDDPAD)	Digital	Power
9	VSS	Digital GND	Digital ground	Digital ground	Ground
10	+ SSI DOUT	SSI Data Output (+)	3.3V / 5V (VDDPAD)	Digital	I/O
11	- SSI DOUT	SSI Data Output (-)	3.3V / 5V (VDDPAD)	Digital	I/O
12	+ SSI NSL	SSI Input (+)	3.3V / 5V (VDDPAD)	Digital	I/O
13	- SSI NSL	SSI Input (-)	3.3V / 5V (VDDPAD)	Digital	Input
14	+ SSI SCL	SSI Clock (+)	3.3V / 5V (VDDPAD)	Digital	Input
15	- SSI SCL	SSI Clock (-)	3.3V / 5V (VDDPAD)	Digital	Input
16					
17	ESL SEL	Protocol Selection	Selection (GND)	Ground	Ground
18	EEPROM SCL	EXT EEPROM Clock	3.3V / 5V (VDDPAD)	Digital	I/O
19	EEPROM SDA	EXT EEPROM Data	3.3V / 5V (VDDPAD)	Digital	I/O
20	EEPROM WP	EXT EEPROM Write Protect	3.3V / 5V (VDDPAD)	Digital	Output
21	-A	Incremental -A Output	3.3V / 5V (VDDPAD)	Digital	Output
22	+A/PROBE1	Incremental +A Output	3.3V / 5V (VDDPAD)	Digital	Output
23	-B	Incremental -B Output	3.3V / 5V (VDDPAD)	Digital	Output
24	+B/PROBE2	Incremental +B Output	3.3V / 5V (VDDPAD)	Digital	Output
25	-I	Incremental -Index Output	3.3V / 5V (VDDPAD)	Digital	Output
26	+I/PROBE3	Incremental +Index Output	3.3V / 5V (VDDPAD)	Digital	Output
27	VSSA	Analog GND	Analog ground	Analog ground	Ground
28	VDDA	Analog Supply Voltage	3.3V / 5V (VDDPAD)	Analog	Power
29	-U	Incremental -U Output	3.3V / 5V (VDDPAD)	Digital	Output
30	+U/PROBE4	Incremental +U Output	3.3V / 5V (VDDPAD)	Digital	Output
31	-V	Incremental -V Output	3.3V / 5V (VDDPAD)	Digital	Output
32	+V	Incremental +V Output	3.3V / 5V (VDDPAD)	Digital	Output
33	-W	Incremental -W Output	3.3V / 5V (VDDPAD)	Digital	Output
34	+W	Incremental +W Output	3.3V / 5V (VDDPAD)	Digital	Output
35	Common GND (VSSA)	Ground to VSSA	Analog ground	Analog ground	Ground

ESL Option Pinout Configuration

NOTE: Pin 35 must be grounded to VSSA and pin 17 connected to VDD (5V/3.3V).

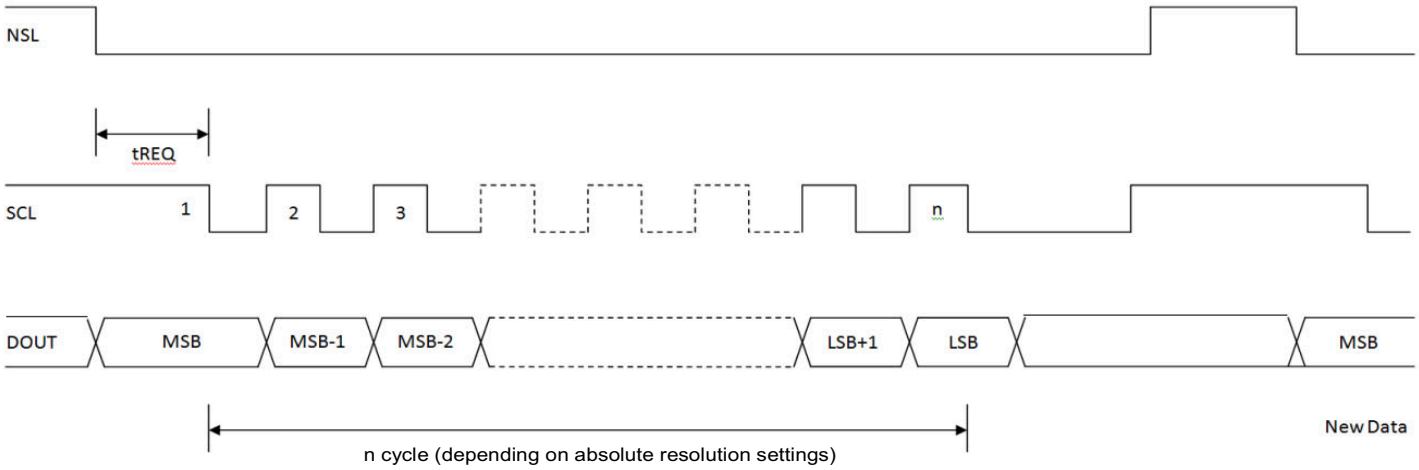
Table 2: ESL Pinout

Pin	Name	Function	Pad type	Analog/Digital	Input/ Output
1	CN/TST3	Analog Voltage Output NCOS	5V/3.3V pads	Analog	I/O
2	CP/TST2	Analog Voltage Output PCOS	5V/3.3V pads	Analog	I/O
3	SN/TST1	Analog Voltage Output NSIN	5V/3.3V pads	Analog	I/O
4	SP/TST0	Analog Voltage Output PSIN	5V/3.3V pads	Analog	I/O
5					
6					
7					
8	VDD	Digital Supply Voltage	3.3V / 5V (VDDPAD)	Digital	Power
9	VSS	Digital GND	Digital ground	Digital ground	Ground
10	+ RS485	RS485 Data Output (+)	3.3V / 5V (VDDPAD)	Digital	I/O
11	- RS485	RS485 Data Output (-)	3.3V / 5V (VDDPAD)	Digital	I/O
12					
13					
14					
15					
16	OSC_EXT	External Oscillator	3.3V pads	Digital	Input
17	ESL SEL	Protocol Selection	Selection (VDD)	Digital	Power
18	EEPROM SCL	EXT EEPROM Clock	3.3V / 5V (VDDPAD)	Digital	I/O
19	EEPROM SDA	EXT EEPROM Data	3.3V / 5V (VDDPAD)	Digital	I/O
20	EEPROM WP	EXT EEPROM Write Protect	3.3V / 5V (VDDPAD)	Digital	Output
21	-A	Incremental -A Output	3.3V / 5V (VDDPAD)	Digital	Output
22	+A/PROBE1	Incremental +A Output	3.3V / 5V (VDDPAD)	Digital	Output
23	-B	Incremental -B Output	3.3V / 5V (VDDPAD)	Digital	Output
24	+B/PROBE2	Incremental +B Output	3.3V / 5V (VDDPAD)	Digital	Output
25	-I	Incremental -Index Output	3.3V / 5V (VDDPAD)	Digital	Output
26	+I/PROBE3	Incremental +Index Output	3.3V / 5V (VDDPAD)	Digital	Output
27	VSSA	Analog GND	Analog ground	Analog ground	Ground
28	VDDA	Analog Supply Voltage	3.3V / 5V (VDDPAD)	Analog	Power
29	-U	Incremental -U Output	3.3V / 5V (VDDPAD)	Digital	Output
30	+U/PROBE4	Incremental +U Output	3.3V / 5V (VDDPAD)	Digital	Output
31	-V	Incremental -V Output	3.3V / 5V (VDDPAD)	Digital	Output
32	+V	Incremental +V Output	3.3V / 5V (VDDPAD)	Digital	Output
33	-W	Incremental -W Output	3.3V / 5V (VDDPAD)	Digital	Output
34	+W	Incremental +W Output	3.3V / 5V (VDDPAD)	Digital	Output
35	Common GND (VSSA)	Ground to VSSA	Analog ground	Analog ground	Ground

Communication Protocol

SSI 3-Wire

Figure 11: SSI 3-Wire Timing Diagram

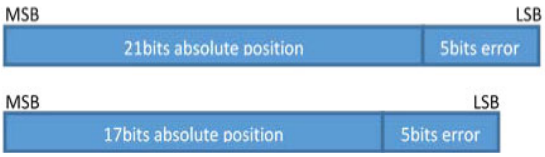


NOTE:

- NSL Toggle 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.

Figure 12: AR18 SSI 3-Wire Format Output

Figure 13: AR35 SSI 3-Wire Format Output

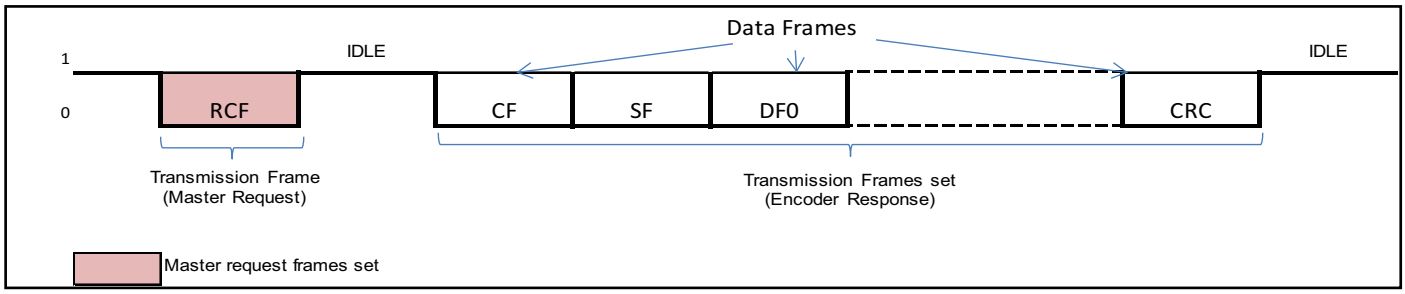


[4]	[3]	[2]	[1]	[0]
ST Error	MLS Error	LIS Error	MEM Error	LED Error

Error	Description
ST Error	Synchronization Error
MLS Error	Absolute Code Error
LIS Error	Lissajous > 1.2
MEM Error	Memory LRC Check Error
LED Error	LED Overcurrent

ESL

Figure 14: General Transmission Frames Format on Half-Duplex Line



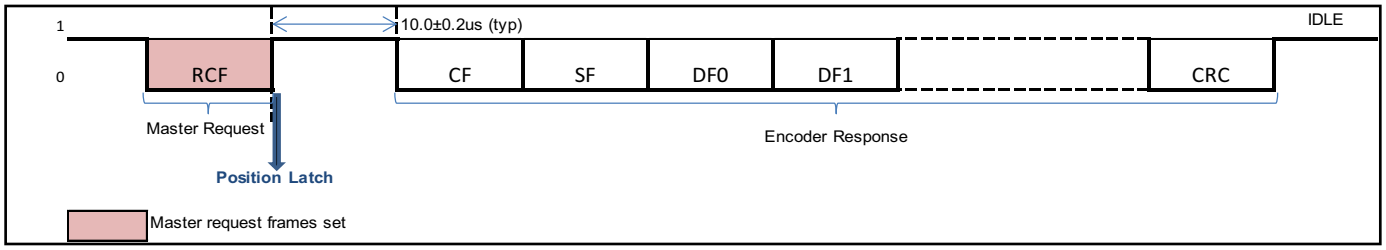
Start of transmission frames set: Upon detected the first logic of Low state "0" on the transmission line after idling state, and if the following 3 bit conforms to command identifier, the encoder will acknowledge as a valid Request Command Frame (RCF), indicating the start of transmission frame set, else, it will continue to search for next available logic of low state"0".

End of transmission frames set: After the Request 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”.

Encoder Data Read Out Frame Sets Format and Timing

Figure 15: Encoder Data Read Out Frames Set



Upon the master issue a RCF frame request, after 10.0 µs (typ.), the encoder shall respond with encoder data frames set with the following content.

1. CF: Corresponds to the Request Command Frame (RCF) issued from Master.
2. SF: Status Frame.
3. DF0~DF7: Data Frames.
4. CRC: Cyclic Redundancy Check (CRC) Frame.

Encoder position calculation will be completed within 10.0 µs (typ.) after the end bit of Master Request Command Frame (RCF).

The Encoder Response data frames set format are dependent on the requested operation by the master, see Table 3.

Table 3: Data Frames Content with Respective Command ID

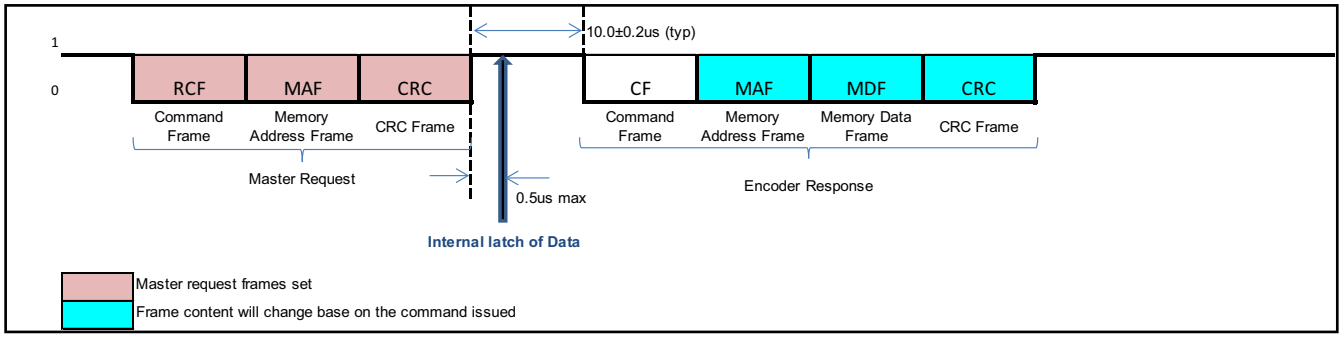
Command ID	DF0	DF1	DF2	DF3	DF4	DF5	DF6	DF7
Command ID 4	ALMC	ABS0	ABS1	ABS2	ABS3			
Command ID 6	ABS0	ABS1	ABS2	ABS3				
Command ID 8	ENID							
Command ID A	ALMC							
Command ID B	ALMC	ABS0	ABS1	ABS2	ABS3			
Command ID C	ALMC	ABS0	ABS1	ABS2	ABS3			

Key for Table 3:

- **ALMC**: Encoder alarm flags.
- **ABSn**: Single-turn counts, LSB of the single-turn counts are located in ABS0 and MSB of the counts data are located in ABS3. Combining ABS0~ABS3 will provide total to 32 bits of single-turn data. For the single-turn 25 bits encoder option, the 7 MSB of ABS3 is fixed to "0", thus giving total 25 bits single turn-data.
- **ENID**: Encoder Single-turn bits identification. For the single-turn 25 bits encoder option, ENID is fixed as "19h".

Memory Data Read Out Frames Set Format and Timing

Figure 16: Memory Data Read Out Frames Set

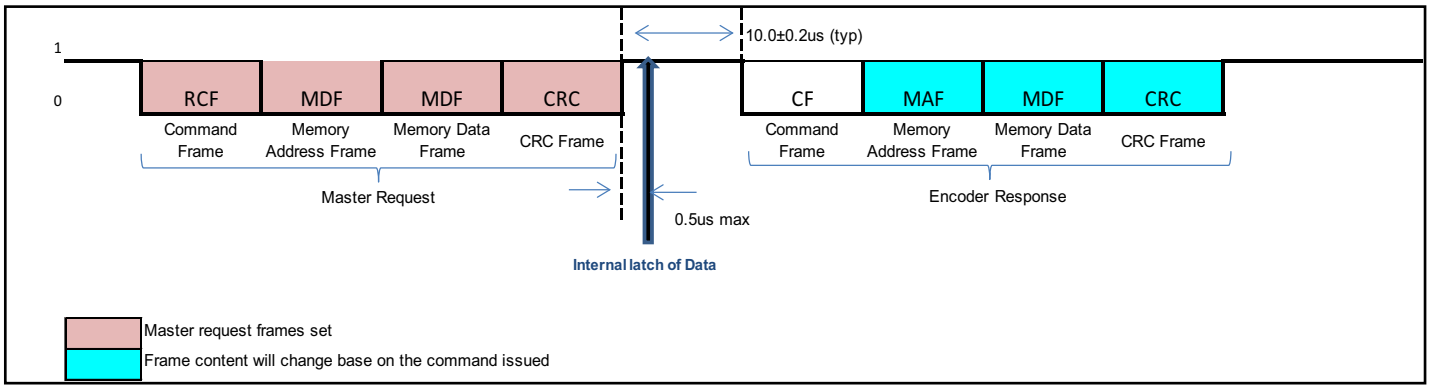


Content of transmission frames:

1. RCF: Request Command Frame from Master.
2. CF: Corresponds to the Request Command Frame (RCF) issued from Master.
3. MAF: Memory Address Frame indicates the Memory location to Read.
4. MDF: Memory Data Frame contains the data read from Memory.
5. CRC: Cyclic Redundancy Check (CRC) Frame.

Memory Data Write Frames Set Format and Timing

Figure 17: Memory Data Write Frames Set



Content of transmission frames:

1. RCF: Request Command Frame from Master.
2. CF: Corresponds to the Request Command Frame (RCF) issued from Master.
3. MAF: Memory Address Frame indicates the Memory location to Write.
4. MDF: Memory Data Frame contains the data write from Memory.
5. CRC: Cyclic Redundancy Check (CRC) Frame.

Configurations and Signal Output

Customer Configurations

Table 4: Encoder Configuration Settings

Page (Hex)	Address	Bit(s)	Name	Settings	Output	Default (Hex)
0x08	0x00	0–7	Register Unlock	Unlock (Write 0xAB)	Unlock register	8'h00
0x0E	0x09	7	EEPROM Disable	0	Enable EEPROM	8'h00
				1	Disable EEPROM	
		5	CW Direction	0	Count UP (CCW)	
				1	Count UP (CW)	
		3–4	RS485 Baud Rate Setting	0	SSI 3W/ESL	
				1	2.5-MHz ESL	
				11	10.0-MHz ESL	
		0–2	RS485 Encoder ID	000	Default	
	0x0A	5–7	UVW Setting [2:0]	0	2 pole-pairs	8'hC0
				1	3 pole-pairs	
				10	4 pole-pairs	
				11	5 pole-pairs	
				100	12 pole-pairs	
				101	30 pole-pairs	
				110	32 pole-pairs	
				111	32 pole-pairs	
		3–4	I-width Setting	0	90 edeg	
				1	180 edeg	
				10	360 edeg	
				11	90 edeg	
		0–2	CPR Setting	0	8192	
				1	4096	
				10	2048	
				11	1024	
				100	512	
				101	256	
				110	128	
				111	128	
	0x0B	0–1	Abs Resolution	AR35 Bit: 00	17 Bit	8'h3F
				AR35 Bit: 01	21 Bit	
				AR18 Bit: 00	17 Bit	
				AR18 Bit: 01	19 Bit	
				AR18 Bit: 10	21 Bit	

Customer Reserved Zero Offset and Calibration Registers

Table 5: Customer Zero Offset and Calibration

Page	Address	Bits	Name	Description
0x0E	0x09	0–5	Customer Configuration 1	User Programmable
	0x0A	0–7	Customer Configuration 2	User Programmable
	0x0C	0–7	Zero Reset 0	Zero Reset Position [7:0]
	0x0D	0–7	Zero Reset 1	Zero Reset Position [15:8]
	0x0E	0–7	Zero Reset 2	Zero Reset Position [23:16]
	0x00	0–7	Ext Gain Calibration	Calibration
	0x0B	2–7	Mon Calibration	Calibration
	0x08	2–7	Phase Calibration (Config_Sync)	Calibration
	0x10	0–5	Probe & PMUX	Calibration
	0x19	1 and 5	Calibration & Function ON	Calibration
	0x14	7	Safety Nrst	Alarm Clear

Incremental Output Format

Figure 18: ABI Signals Output (Based on Codewheel Direction Settings = 0)

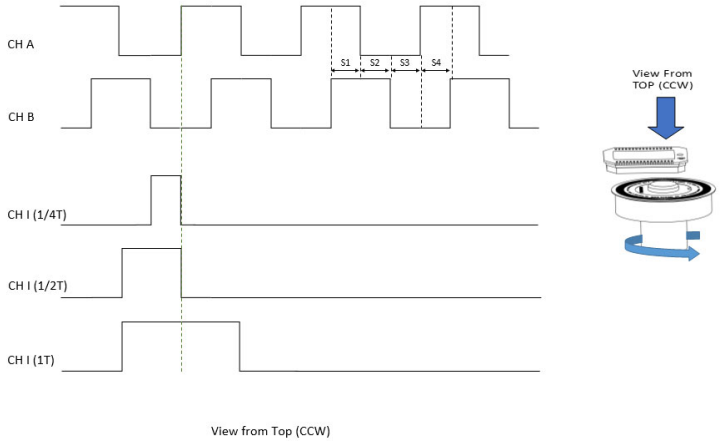
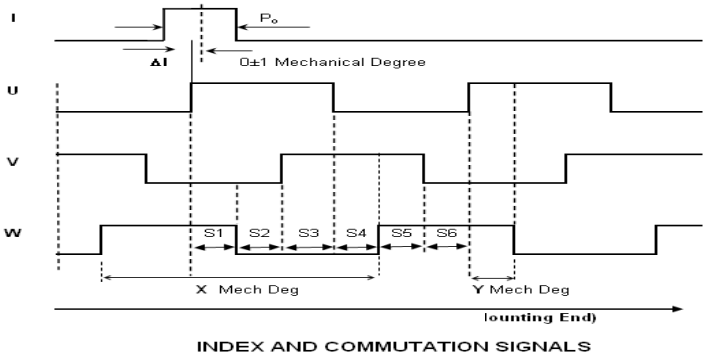


Figure 19: UVW Signals Output (Based on Codewheel Direction Settings = 0)

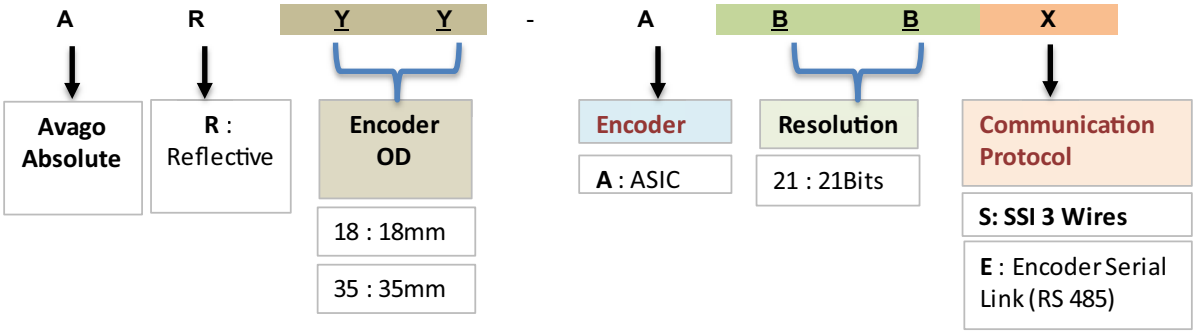


	X	Y
2pp	180	30
3pp	120	20
4pp	90	15
5pp	72	12
12pp	30	5
30pp	12	2
32pp	11.25	1.875

Ordering Information

Encoder Ordering Information

Figure 20: Enocder Ordering Information



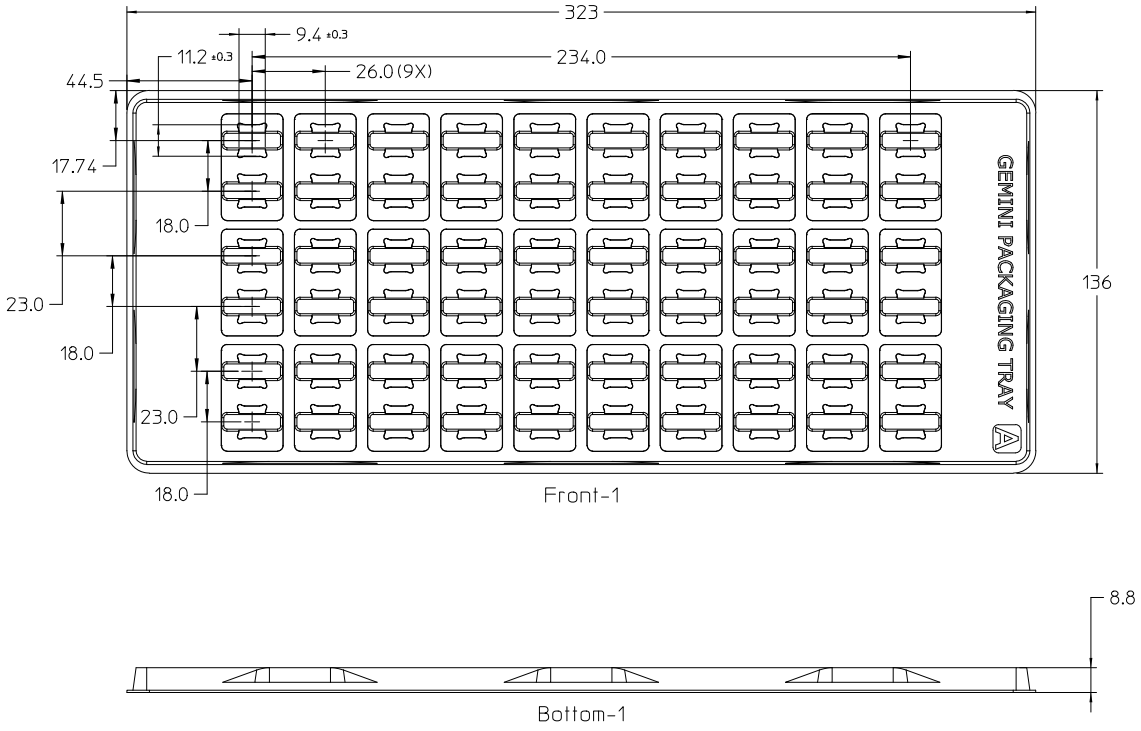
Calibration Kit

- Ordering Part No: A21E-0010
- Description: AR18/35 Electronic Calibration Kits

Packaging

- Encoder Packaging Information (Tray): 60 units per tray
- Codewheel Packaging Information (Tray): 30 units per tray

Figure 21: Encoder Tray Packaging Information



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