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## AR18 and AR35 Series

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



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## Description

The Broadcom<sup>®</sup> AR18 and AR35 Series are the miniature Absolute Encoder ASIC designed to cater for the growing demand on the space constraint application.

The AR18 encoder is designed for an overall diameter of 18 mm and offers user-programmable resolution ranging from 17, 19, and 21 bit single-turn absolute output. The AR35 encoder is designed for an overall diameter of 35 mm and offers 17 and 21 bits single-turn absolute output.

Both the AR18 and AR35 series provide the incremental ABI and UVW in differential mode. Both come with a recommended high temperature range of  $-40^{\circ}\text{C}$  to  $115^{\circ}\text{C}$  suitable for most industrial applications. Dual-mode operating voltage of 3.3V and 5V enable handheld and portable device applications.

Employing Broadcom patented Reflective Optical Encoding Theory, the AR18 and AR35 series offer a high accuracy with correction, which is unattainable by the magnetic encoder.

## Features

- Miniature absolute encoder ASIC surface mount DFN package: 10.9 mm (L) x 9.1 mm (W) x 1.5 mm (H)
- User-programmable resolution ranging from:
  - 17, 19, and 21 bit single turn (OD18).
  - 17 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  $-40^{\circ}\text{C}$  to  $115^{\circ}\text{C}$  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.

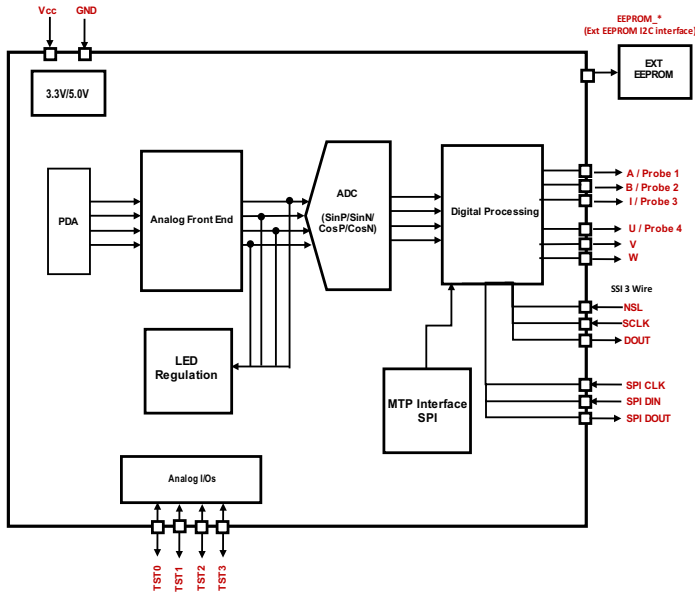
## Applications

- 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

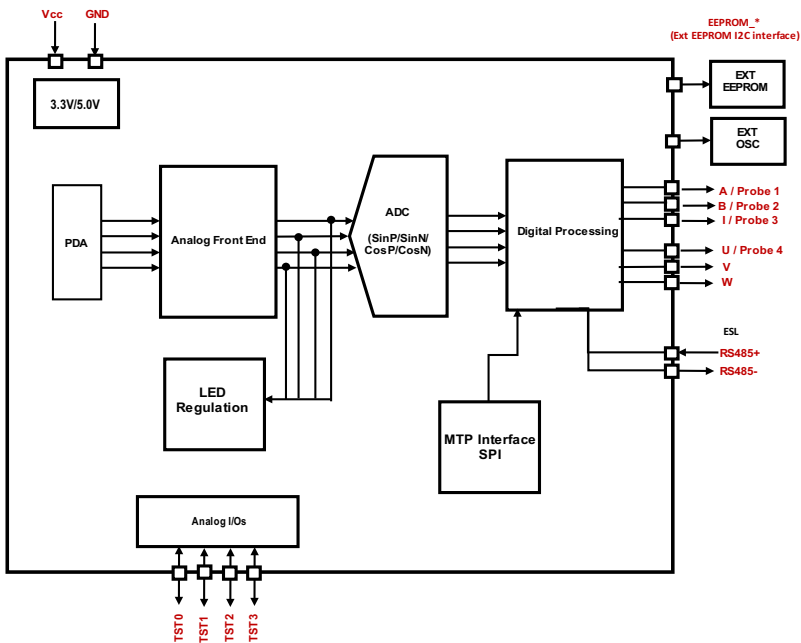
## With SSI 3-Wire Communication Protocol Selection

Figure 1: SSI 3-Wire Block Diagram



## With ESL Communication Protocol Selection

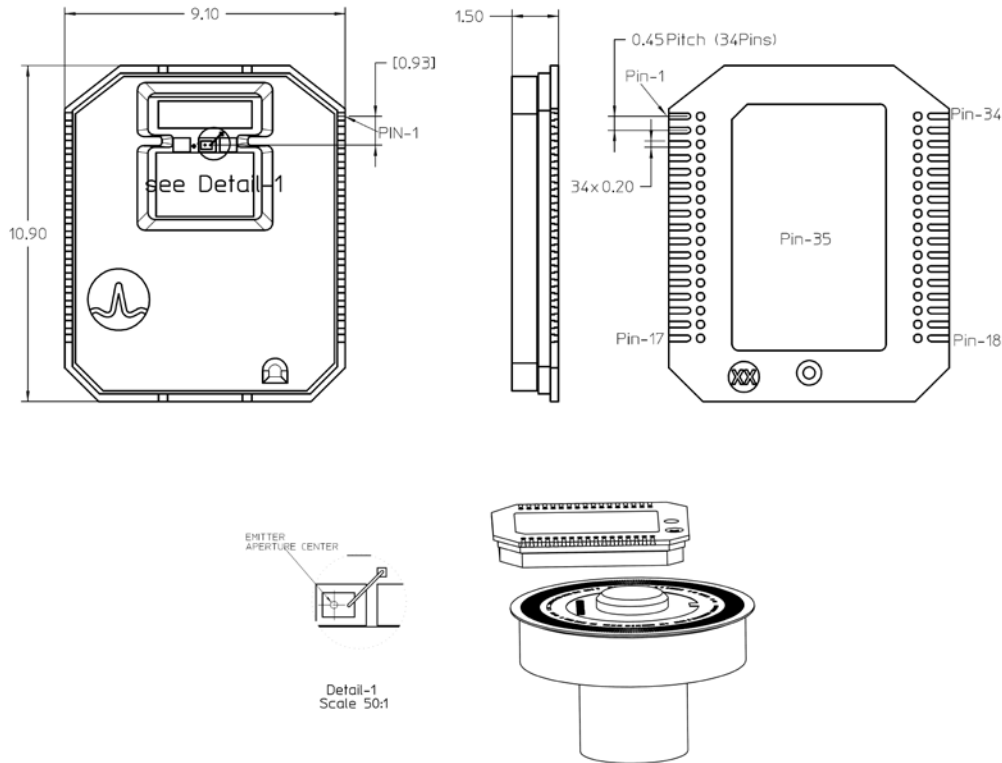
Figure 2: ESL Block Diagram



# Mechanical Specifications

## DFN Package Dimensions

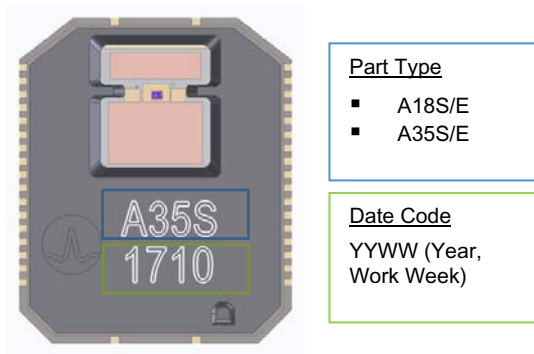
Figure 3: Overall Package Dimensions and Pinout



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

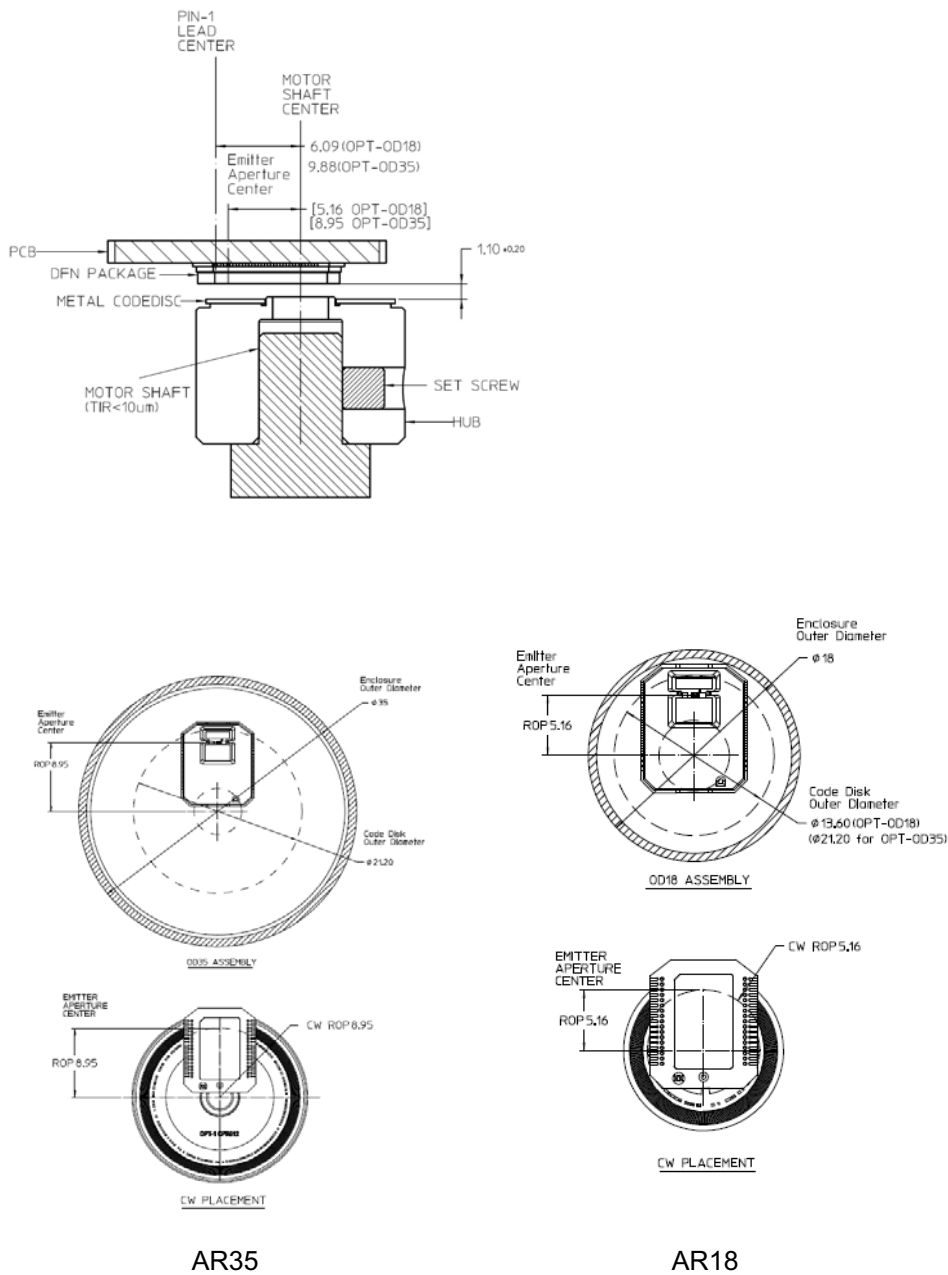
## Package Markings

Figure 4: Product Marking Information



# Encoder Mounting

Figure 5: Encoder Mounting Guide

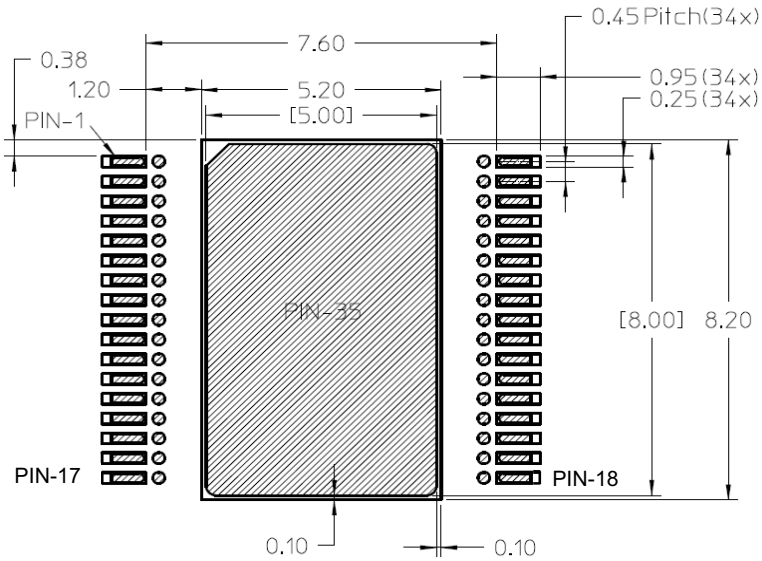


Notes of assembly:

- 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 6: PCB Land Pattern



SMT Reflow Profile: JEDEC Pb-Free (J-STD-020D)

## Electrical Specifications

### Recommended Operating Conditions

| Parameter                | Symbol    | Value |         |       | Unit | Notes                   |
|--------------------------|-----------|-------|---------|-------|------|-------------------------|
|                          |           | Min   | Typical | Max   |      |                         |
| 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                 |
| 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    | %    | Temp = 40°C             |
| INC Operating Frequency  |           | —     | —       | 128   | kHz  | Velocity (rpm) x CPR/60 |
| Radial Misalignment      |           | -200  | 0       | +200  | μm   |                         |
| Tangential Misalignment  |           | -200  | 0       | +200  | μm   |                         |
| Encoder Shaft Speed      | SRPM      | —     | —       | 30000 | rpm  | 256CPR (AR18)           |
| Encoder Shaft Speed      | SRPM      | —     | —       | 15000 | rpm  | 512CPR (AR35)           |

## 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                            |
| Moisture Sensitive Level |          | 3 (Maximum floor life = 168h) |

## DC Characteristics

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

| Parameter                              | Symbol   | Conditions         | Value |                |     | Unit | Notes                      |
|--|----------|--------------------|-------|----------------|-----|------|----------------------------|
|  |          |                    | Min   | Typ.           | Max |      |                            |
| $V_{dd}$ 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

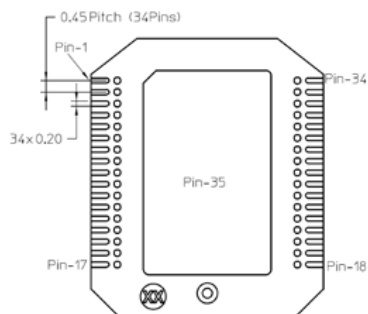
Incremental encoder characteristics over recommended operating range, at 25°C.

| Parameter         | Symbol     | Min | Typ         | Max <sup>a</sup> | Unit |
|-------------------|------------|-----|-------------|------------------|------|
| Cycle Error       | $\Delta C$ | —   | —           | 45               | °e   |
| State Error       | $\Delta S$ | —   | —           | 45               | °e   |
| Index Pulse Width | $P_o$      | —   | 90,180, 360 | —                | °e   |

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

## Encoder Pin Functions

Figure 7: Pinouts from Top View



## 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 connect to VDD (5V/3.3V).

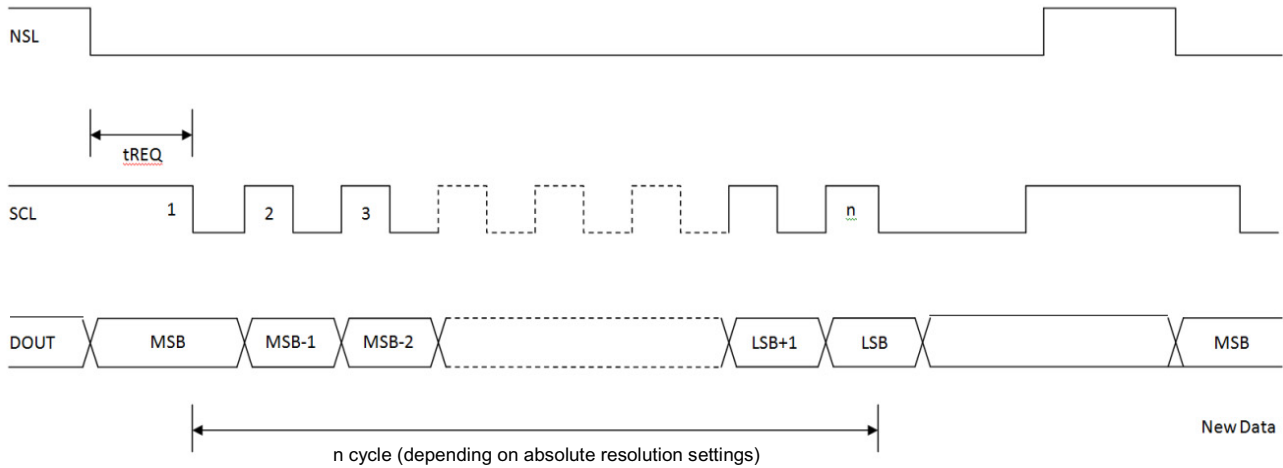
**Table 2: ESL Pinout**

| 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 8: SSI 3-Wire Timing Diagram

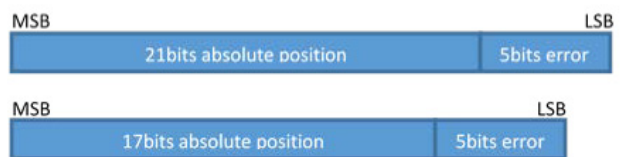


- Notes:
- NSL toggles from high to low to start request position data.
  - SCL maximum frequency is 10 MHz.
  - tREQ = 10  $\mu$ s is the time of data request processing.

Figure 9: AR18 SSI 3-Wire Format Output

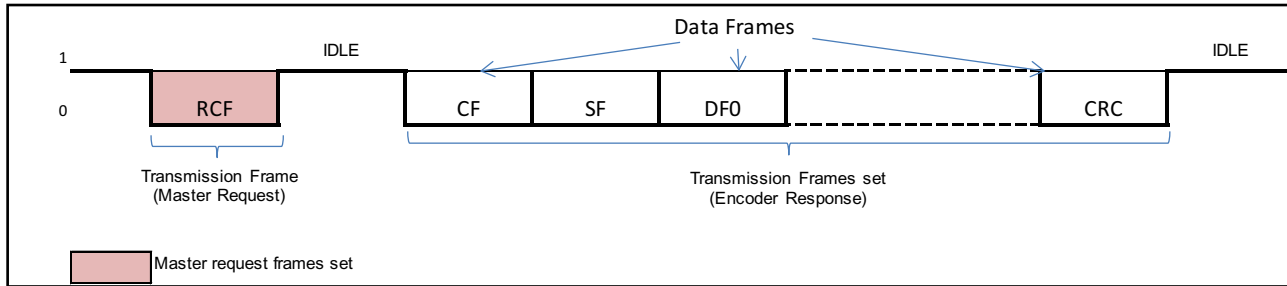


Figure 10: AR35 SSI 3-Wire Format Output



## ESL

Figure 11: 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 12: Encoder Data Read Out Frames Set



Upon the master issue a RCF frame request, after  $10.0\ \mu\text{s}$  (typ.), the encoder will 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  $10.0\ \mu\text{s}$  (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**

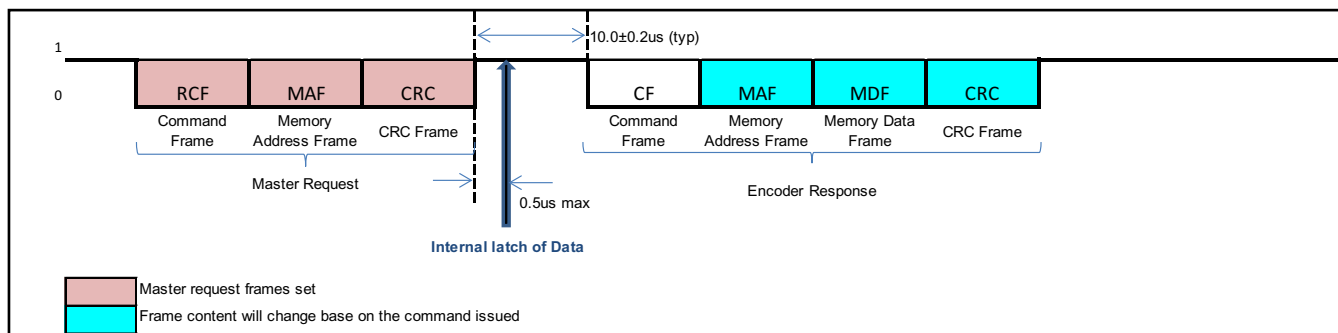
| Command ID   | DF0               | DF1               | DF2  | DF3  | DF4  | DF5 | DF6 | DF7 |
|--------------|-------------------|-------------------|------|------|------|-----|-----|-----|
| Command ID 4 | ALMC <sup>a</sup> | ABS0 <sup>b</sup> | ABS1 | ABS2 | ABS3 |     |     |     |
| Command ID 6 | ABS0              | ABS1              | ABS2 | ABS3 |      |     |     |     |
| Command ID 8 | ENID <sup>c</sup> |                   |      |      |      |     |     |     |
| Command ID A | ALMC              |                   |      |      |      |     |     |     |
| Command ID B | ALMC              | ABS0              | ABS1 | ABS2 | ABS3 |     |     |     |
| Command ID C | ALMC              | ABS0              | ABS1 | ABS2 | ABS3 |     |     |     |

a. **ALMC**: Encoder Alarm Flags.

b. **ABS<sub>n</sub>**: 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 single-turn 25 bits encoder option, the 7 MSB of ABS3 is fixed to 0, hence giving total 25 bits single turn-data.

c. **ENID**: Encoder Single-turn bits identification.

## Memory Data Read Out Frames Set Format and Timing

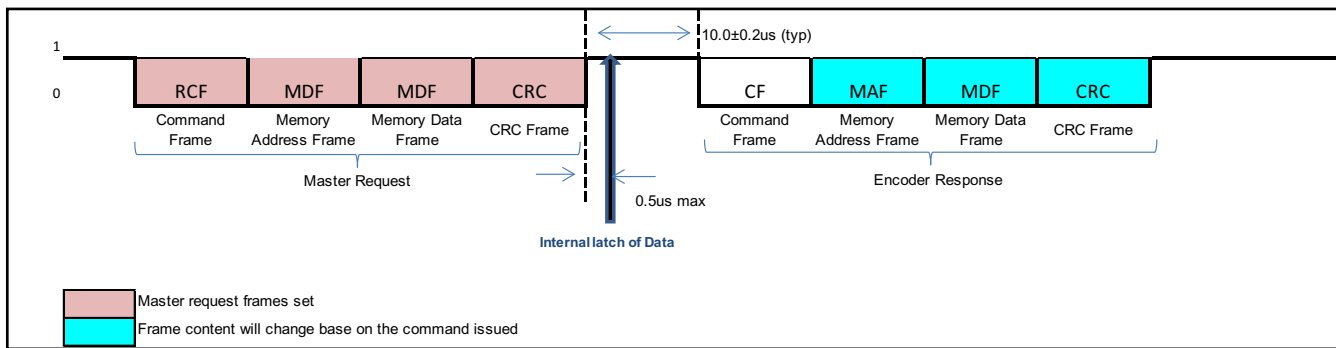
**Figure 13: Memory Data Read Out Frames Set**

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 14: 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                   | Disable EEPROM  | 8'h00         |          |
|            |         |                  |                         | 1                   | Enable EEPROM   |               |          |
|            |         | 5                | CW Direction            | 0                   | Count UP (CCW)  |               |          |
|            |         |                  |                         | 1                   | Count UP (CW)   |               |          |
|            |         | 3-4              | RS485 Baud Rate Setting | 0                   | SSI 3W          |               |          |
|            |         |                  |                         | 1                   | 2.5MHz ESL      |               |          |
|            | 11      |                  |                         | 10MHz 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 | Bit (s) | 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 [8:1]   |
|      | 0x0D    | 0-7     | Zero Reset 1                    | Zero Reset Position [16:9]  |
|      | 0x0E    | 0-7     | Zero Reset 2                    | Zero Reset Position [24:17] |
|      | 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 and PMUX                  | Calibration                 |
|      | 0x19    | 1 and 5 | Calibration and Function ON     | Calibration                 |
|      | 0x14    | 7       | Safety Nrst                     | Alarm Clear                 |

## Incremental Output Format

Figure 15: ABI Signals Output (based on codewheel direction settings = 0)

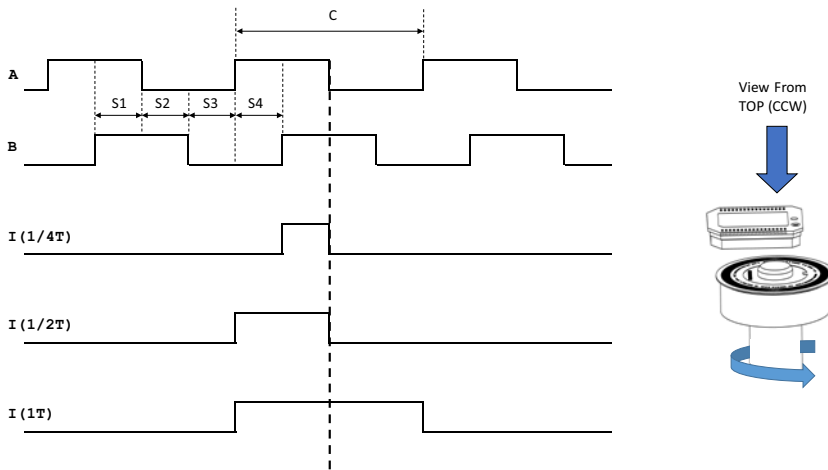
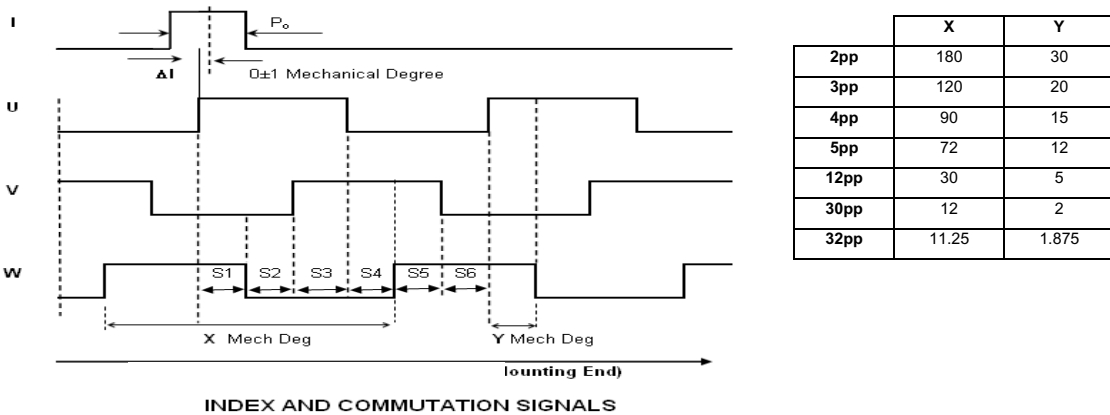
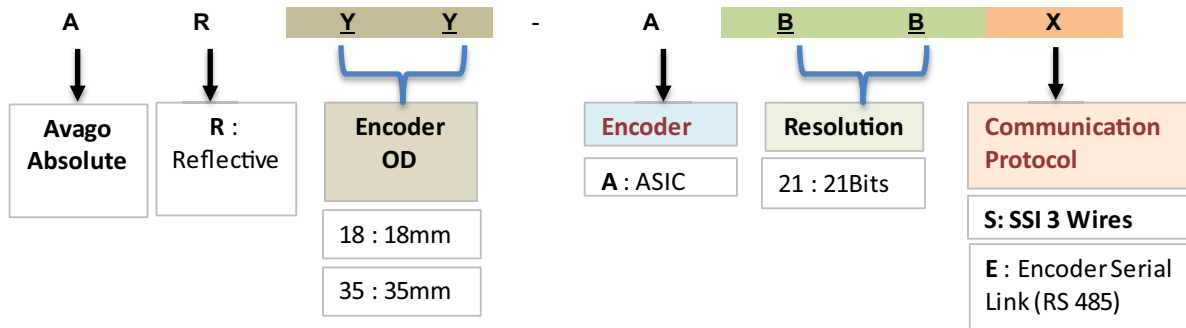


Figure 16: UVW Signals Output (based on codewheel direction settings = 0)



# Ordering Information

## Encoder 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



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