Data Sheet

AEAT-6600-T16

10-Bit to16-Bit Programmable Angular Magnetic Encoder IC

Description

The Broadcom® AEAT-6600 angular magnetic encoder IC is a contactless magnetic rotary encoder for accurate angular measurement over a full turn of 360 degrees.

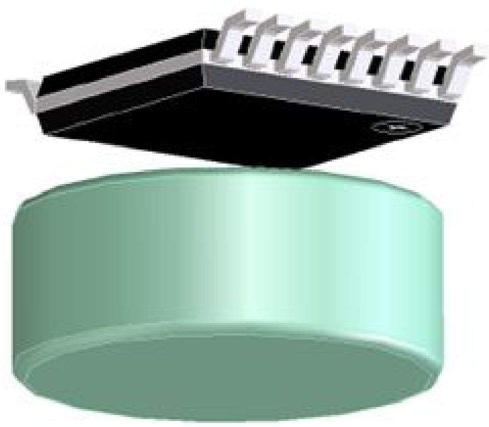
It is a system-on-a-chip, combining integrated Hall elements, an analog front end, and digital signal processing in a single device.

To measure the angle, only a simple two-pole magnet, rotating over the center of the chip, is required. The magnet may be placed above or below the IC.

The absolute angle measurement provides an instant indication of the magnet's angular position with a resolution of 0.005° = 65,536 positions per revolution. This digital data is available as a serial bit stream and as a PWM signal.

An internal voltage regulator allows the AEAT-6600 to operate at either 3.3V or 5V supplies.

Figure 1: AEAT-6600 Series TSSOP-16 IC Package



Features

- 5V or 3.3V operation
- 3-wire or 2-wire SSI interface mode for absolute output
- Incremental ABI or UVW, and PWM output modes
- User-programmable zero position, direction, and index pulse width
- Easy magnet alignment with magnetic field strength output and alignment mode
- Power-down mode to reduce current consumption
- TSSOP-16 IC package
- RoHS compliant

Specifications

- Absolute 10-bit to 16-bit resolution
- Incremental output resolutions 8 to 1024 CPR
- –40°C to 125°C operating temperature range

Applications

- 3-phase commutation for brushless DC motor
- Resolver and potentiometer replacement
- Industrial automation and robotics

NOTE: This product is not specifically designed or manufactured for use in any specific device. Customers are solely responsible for determining the suitability of this product for its intended application and are solely liable for all loss, damage, expense, or liability in connection with such use. The part is not suitable for those servo motors or applications that require a fast response clockwise to counterclockwise, or vice versa.

Definitions

Electrical Degree (°e): Resolution x 360 electrical degrees = 360 mechanical degrees.

Cycle (C): One cycle of the incremental signal is 360 mechanical degrees/resolution and is equal to 360 electrical degrees (°e).

Cycle Error (ΔC): The difference between the actual cycle width and the ideal cycle width corresponding to a shaft angle displacement of 1/resolution. The accumulated cycle error leads to position error.

Pulse Width (P): The number of electrical degrees that an output is high during one cycle, nominally 180°e or ½ a cycle.

Pulse Width Error (ΔP): The deviation in electrical degrees of the pulse width from its ideal value of 180°e.

State Width (S): The number of electrical degrees between a transition in the output of channel A and the neighboring transition in the output of channel B. There are 4 states per cycle, each nominally 90°e.

State Width Error (ΔS): The deviation in electrical degrees of each state width from its ideal value of 90°e.

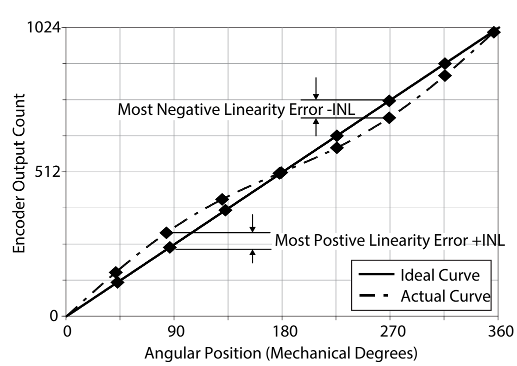
Phase (θ): The number of electrical degrees between the center of the high state on channel A and the center of the high state on channel B.

Phase Error (Δθ): The deviation in electrical degrees of the phase from its ideal value of 90°e.

Index Pulse Width (P_O): The number of electrical degrees that an index pulse is active within the cycle that coincides with the absolute zero position. The index pulse width is also expressed in terms of LSB (least significant bit) counts corresponding to the encoder resolution.

Integral Non-Linearity (INL): The maximum deviation between the actual angular position and the position indicated by the encoder's output count, over one revolution. It is defined as the most positive linearity error +INL or the most negative linearity error -INL from the best fit line, whichever is larger.

Figure 2: Integral Non-Linearity Example



Functional Description

The AEAT-6600 is manufactured with a CMOS standard process and uses Hall technology for sensing the magnetic field distribution across the surface of the chip. The integrated Hall elements are placed around the center of the device and deliver a voltage representation of the magnetic field at the surface of the IC. The digital signal processing (DSP) circuit converts the data from the Hall sensor into absolute angular position (DO/DI pin) as an absolute output or converted into digital output (A/U, B/V, I/W pins) by the incremental circuit.

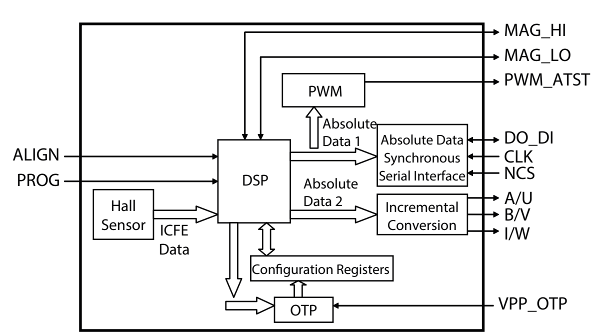
The DSP circuit also provides digital information at the outputs MagHi and MagLo that indicates movements of the used magnet toward or away from the device's surface. A small low-cost diametrically magnetized (two-pole) standard magnet provides the angular position information.

The AEAT-6600 senses the orientation of the magnetic field and calculates a 10-bit to 16-bit binary code. This code can be accessed via a Synchronous Serial Interface (SSI). In addition, an absolute angular representation is given by a pulse-width modulated signal at pin 8 (PWM). The AEAT-6600 is tolerant to magnet misalignment and magnetic stray fields due to a local measurement technique and Hall sensor conditioning circuitry.

The OTP block provides access to program to a specific resolution and output modes through a PROG pin (pin 13).

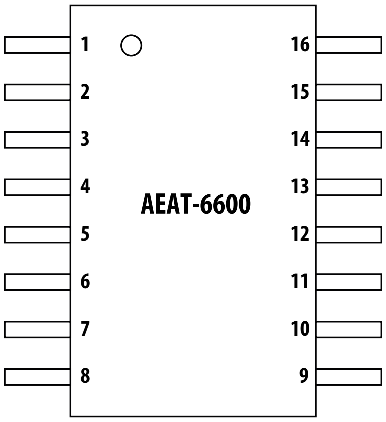
NOTE: For further information regarding the operating mode and application, refer to the application note (AV02-2791EN). For the programming tool and software application, refer to the user manual (AV02-2803EN).

Figure 3: Polaris Block Diagram



Pin Assignments

Figure 4: Pin Configuration TSSOP-16



Pinout Description

Pin	Symbol	I/O Type	Description
1	A/U	Output	Incremental A output (ABI mode)
			U Commutation output (UVW mode)
2	B/V	Output	Incremental B output (ABI mode)
			V Commutation output (UVW mode)
3	I/W	Output	Index output (ABI mode)
			W Commutation output (UVW mode)
4	MAG_HI/OTP_ERR	Output	1 indicates the magnetic field strength is too high (normal operation mode)
			1 indicates an OTP programming error (OTP program mode)
5	MAG_LO/OTP_PROG_STAT	Output	1 indicates the magnetic field strength is too low (normal operation mode)
			1 indicates OTP programming completed (OTP program mode)
6	GND	Ground	Supply Ground
7	ALIGN	Input (internal pull-down)	0: Normal operation mode
			1: Alignment mode
8	PWM	Output	PWM output
9	VDD	Supply	5V Supply input (connected to VDD_F for 3.3V operation)
10	VDD_F	Supply	Filtered VDD
11	PWRDOWN	Input	0: Normal operation mode
			1: Power-down mode
12	VPP	High Supply	6.5V voltage supply for OTP programming. VDD at normal operation mode
13	PROG	Input (internal pull-down)	0: Normal operation mode
			1: OTP programming mode
14	NCS	Input (internal pull-up)	SSI data strobe input
15	CLK	Input	SSI clock input
16	DO/DI	Input/Output (tristate)	SSI data output (Absolute Output mode)
			Serial data input (OTP Program mode)

Table 1: Absolute Maximum Ratings

Parameter	Symbol	Min.	Max.	Units	Notes
Storage Temperature	T_S	–40	125	°C	—
DC Supply Voltage VDD Pin VPP Pin	 VDD VPP	 –0.3 –0.3	 7 7	Volts	—
Input Voltage Range	V_{in}	–0.25	VDD + 0.25	Volts	—

CAUTION! Subjecting the product to stresses beyond those listed under this section may cause permanent damage to the devices. These are stress ratings only and do not imply that the devices will function beyond these ratings. Exposure to the extremes of these conditions for extended periods may affect product reliability.

Table 2: Recommended Operating Conditions

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes
Operating Ambient Temperature	T_A	–40	—	125	°C	—
DC Supply Voltage to VDD Pin 5V Operation 3.3V Operation	VDD	 4.5 3.0	 5.0 3.3	 5.5 3.6	Volts	VDD pin tied to VDD_F pin for 3.3V operation.
OTP Programming Voltage at VPP Pin	VPP	6.3	6.5	6.7	Volts	VPP tied to VDD during normal operation mode
Incremental Output Frequency	f_{MAX}	—	—	512	kHz	Frequency = Velocity (RPM) x Resolution/60 Max RPM = 30,000 RPM
Load Capacitance	C_L	—	—	50	pF	—

Table 3: Electrical Characteristics

Condition: Electrical characteristics over the recommended operating conditions. Typical values specified at VDD = 5.0V and 25°C.

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes
Current Consumption						
Supply Current						
Normal Operation Mode	I_{DD}	—	17	21	mA	—
Power-Down Mode	I_{PD}	—	—	100	µA	—
OTP Programming Current	I_{PP}	—	—	2	mA	VPP supply pin
Digital Outputs (DO)						
High-Level Output Voltage	V_{OH}	VDD – 0.5	—	—	Volts	Normal operation
Low-Level Output Voltage	V_{OL}	—	—	GND + 0.4	Volts	—
Output Leakage Current	I_{OZ}	–1	—	1	µA	—
Power-Up Time: 10-bits	t_{PwrUp}	—	—	11	ms	—
Absolute Output: 12-bits				11		
Incremental Output: 14-bits				11		
PWM Output: 16-bits				11		
Digital Inputs (DI)						
Input High Level	V_{IH}	0.7 x VDD	—	—	Volts	—
Input Low Level	V_{IL}	—	—	0.3 x VDD	Volts	—
Input Leakage Current	I_{LEAK}	–1	—	1	µA	CLK, DI pins
Pull-Up Low-Level Input Current	I_{IL}	—	—	30	µA	NCS pin
Pull-Down High-Level Input Current	I_{IH}	—	—	30	µA	ALIGN, PROG

Table 4: Encoding Characteristics

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes
Absolute Output						
Resolution	RES	10	—	16	Bit	10 and 16 bits (Slow Mode) 10 and 14 bits (Fast Mode)
Integral Non-Linearity (optimum)	INL_{nom}	—	±0.4	±0.9	Deg.	Maximum error with respect to the best line fit. Verified at the nominal mechanical magnet placement. Tamb = 25°C
Integral Non-Linearity	INL	—	—	±1.9	Deg.	Best line fit = $(Err_{max} – Err_{min})/2$ Over displacement tolerance with 9-mm diameter magnet, Tamb = –40 to +125°C
Output Sampling Rate	f_S	—	12	—	kHz	See Table 5 for the AEAT-6600-T16 internal sampling time
Incremental Output (Channel ABI)						
Resolution	R_{INC}	8	—	1024	CPR	Options 8, 16, 32, 64, 128, 256, 512, or 1024 CPR
Index Pulse Width	P_O	90	—	360	°e	Options: 90, 180, 270, or 360 ºe
Cycle Error	∆C	—	7	60 80 100	°e	8, 16, 32, 64, 128 CPR 256 CPR 512, 1024 CPR
Pulse Width Error	∆P	—	5	40 50 60	°e	8, 16, 32, 64, 128 CPR 256 CPR 512, 1024 CPR
State Width Error	∆S	—	3	40 50 60	°e	8, 16, 32, 64, 128 CPR 256 CPR 512, 1024 CPR
Phase Error	∆θ	—	2	20 25 30	°e	8, 16, 32, 64, 128 CPR 256 CPR 512, 1024 CPR
Index Pulse Width Error	P_O	60 150 240 330	90 180 270 360	120 210 300 390	°e	Index Pulse Width Gated 90ºe Index Pulse Width Gated 180ºe Index Pulse Width Gated 270ºe Index Pulse Width Gated 360ºe
Velocity	—	1	—	30,000	RPM	—
NOTE: The encoding characteristics above are based on 12-bit resolution.						—
Commutation Characteristic (Channel U, V, W)						
Commutation Format	Four-phase 1, 2, 4, or 8 pole pairs					
Commutation Accuracy	∆UVW	–2	—	+2	°mechanical	—
Velocity	1, 2, 4, 8 poles	1	—	30,000	RPM	—
PWM Output						
PWM Frequency 10 bits	f_{PWM}	3040	3800	4560	Hz	—
Minimum Pulse Width 10 bits	PW_{MIN}	0.8	1	1.2	µs	—
Maximum Pulse Width 10 bits	PW_{MAX}	210	263	315	µs	—
NOTE: The encoding characteristics are over the recommended operating range unless otherwise specified.						

Table 5: Encoding Timing Characteristics

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes
Absolute Output						
System Refresh Time						
10-bit	$t_{Refresh}$	—	—	111	µs	First SSI absolute output upon power-up
12-bit		—	—	111	µs	
14-bit		—	—	111	µs	
16-bit		—	—	111	µs	
System Reaction Time (Fast Mode)						
10-bit	t_{Fast}	—	—	111	µs	No averaging reaction time
12-bit		—	—	111	µs	
14-bit		—	—	111	µs	
System Reaction Time (Slow Mode)						
10-bit	t_{Slow}	—	—	111	µs	Averaging reaction time
12-bit		—	—	442	µs	
14-bit		—	—	7.1	ms	
16-bit		—	—	113	ms	
Incremental Output (ABI & UVW)						
System Reaction Time (Fast Mode)	$t_{Inc.}$	—	—	720	µs	(for 400 to 1800 RPM)
		—	—	310	µs	(for 1801 RPM and above)

NOTES:

The $t_{Refresh}$, t_{Fast}, t_{Slow}, $t_{Inc.}$ are the AEAT-6600-T16 internal sampling time.
Slow Mode is not recommended for incremental output. Contact the factory for Slow Mode application on incremental output.
Contact the factory for Fast Mode 16-bit application.

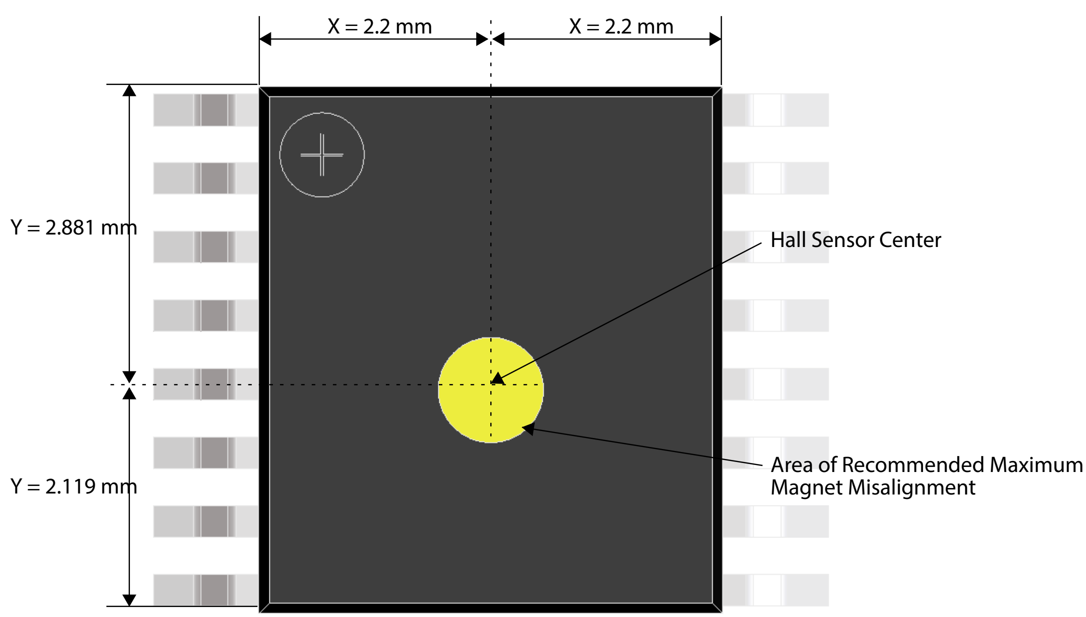
Table 6: Recommended Magnetic Input Specifications

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes
Diameter	d	—	9	—	mm	Recommended magnet: Cylindrical magnet, diametrically magnetized and one pole pair.
Thickness	t	—	3	—	mm	
Magnet Radial Magnetic Flux Density	B_radial	188	198	208	mT	Measured at 1.3 mm away from the center of the magnet radial surface. Magnet validation purpose.
Magnet Plane Magnetic Flux Density	B_plane	106	112	118	mT	B_plane at 1.3 mm from the magnet flat surface. Hall sensor required plane components magnetic field.
Magnetization Vector Tilt	Mag_Vec	—	—	±5	—	Magnet magnetization vector tilt.
Magnet Displacement Radius	R_m	—	—	0.1	mm	Displacement between the magnet axis and the rotational axis.
Hall Sensor Displacement Radius	R_s	—	—	0.5	mm	Displacement between the Hall sensor axis and the rotational axis.
Recommended Magnet Material and Temperature Drift	—	—	–0.11	—	%/°C	NdFeB (Neodymium Iron Boron), grade N35SH.

DISCLAIMER: The above information is based on the specification provided by the supplier of the magnet used for product characterization. The supplier of the magnet is solely responsible for the specification and performance of the magnet used.

Magnet and IC Package Placement

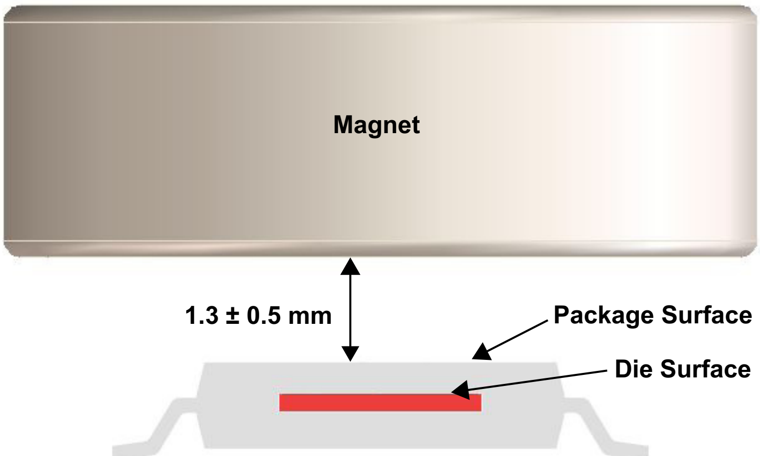
Figure 5: Magnet and IC Package Placement



The magnet's center axis should be aligned within a displacement radius of 0.5 mm from the defined Hall sensor center.

Defined Chip Sensor Center and Magnet Displacement Radius

Figure 6: Defined Chip Sensor Center and Magnet Displacement Radius



Vertical Placement of the Magnet

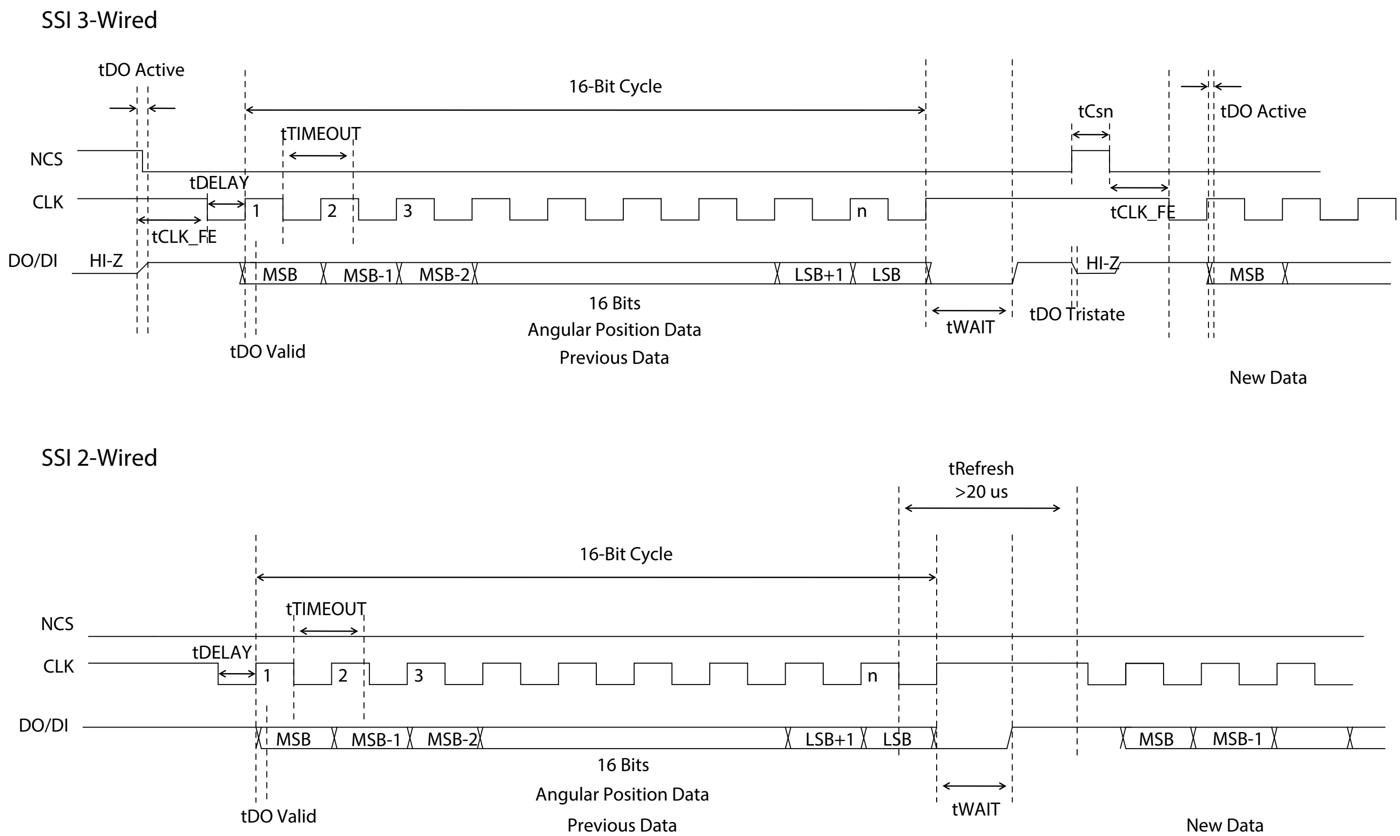
Table 7: SSI Timing Characteristics

Parameter	Symbol	Min.	Typ.	Max.	Units	Notes
fclk	—	—	—	1000	kHz	—
tCLK FE	—	—	—	500	ns	Minimum time required for the encoder to freeze data and prepare shift registers before receiving the first rising edge to prompt the MSB.
tDO Active	—	—	100	—	ns	—
tDO Valid	—	—	50	—	ns	—
tCSn	—	—	500	—	ns	—
tDO Tristate	—	—	100	—	ns	—
tDELAY	—	—	500	—	ns	Minimum time required for the encoder to freeze data and prepare shift registers before receiving the first rising edge to prompt the MSB.
tRefresh	—	20	—	—	µs	Required waiting time to refresh position data between subsequent position reads.
tTIMEOUT	—	—	—	20	µs	Every falling edge of the clock.
tWAIT	—	—	—	10	µs	Maximum time to hold DO to low.

NOTE: SSI timing characteristics are over the recommended operating range unless otherwise specified.

SSI Timing Diagram

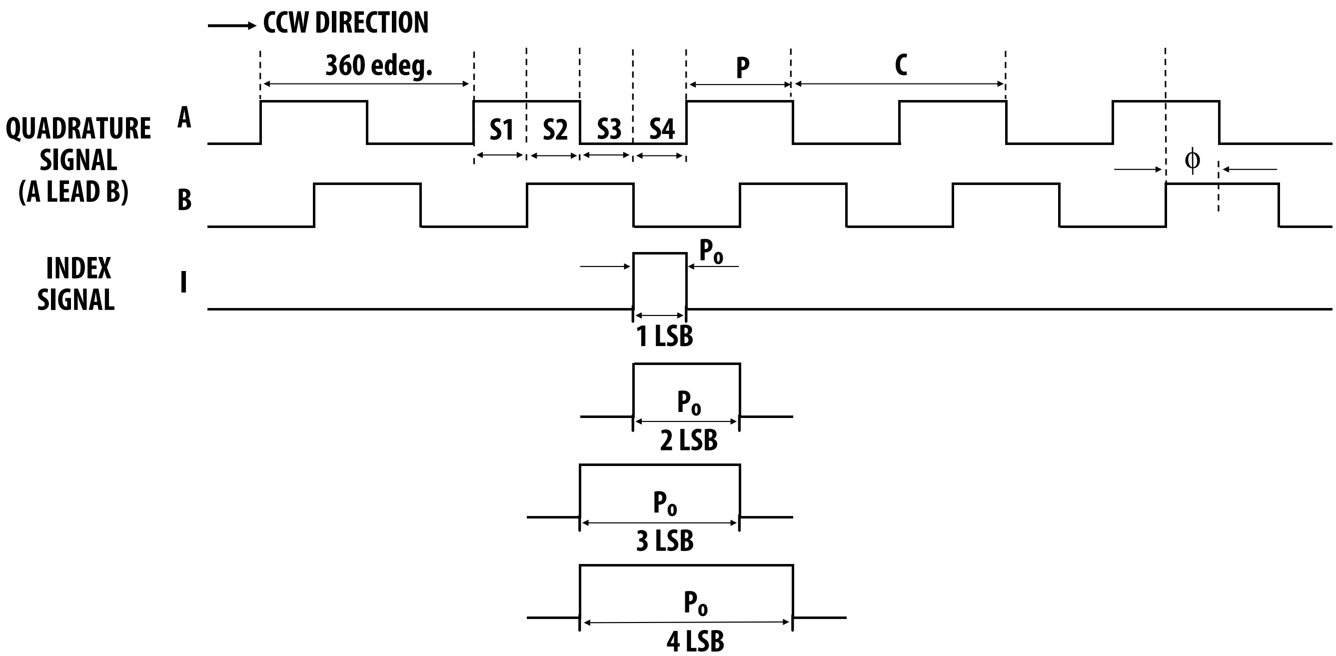
Figure 7: SSI Timing Diagram: 3-Wire and 2-Wire SSI Mode



Generally, the SSI protocol uses an initiator/receiver relationship, in which the initiator initiates the data frame. CLK is generated by the initiator (controller) and input to all receivers. In AEAT-6600-T16, position data is continually updated by the encoder (AEAT-6600-T16) and made available to the shift register.

Incremental ABI Output

Figure 8: Incremental ABI Signals



With Incremental ABI output enabled, AEAT-6600-T16 is able to provide position data and direction data with the resolution 8 to 1024 CPR. The index signal marks the absolute angular position and typically occurs once per revolution, with the options 90, 180, 270, 360. Lastly, the index signal clears the counter after each full rotation.

UVW Commutation Output

Figure 9: UVW Commutation Signals – 12-Bit Resolution, One Pole Pair

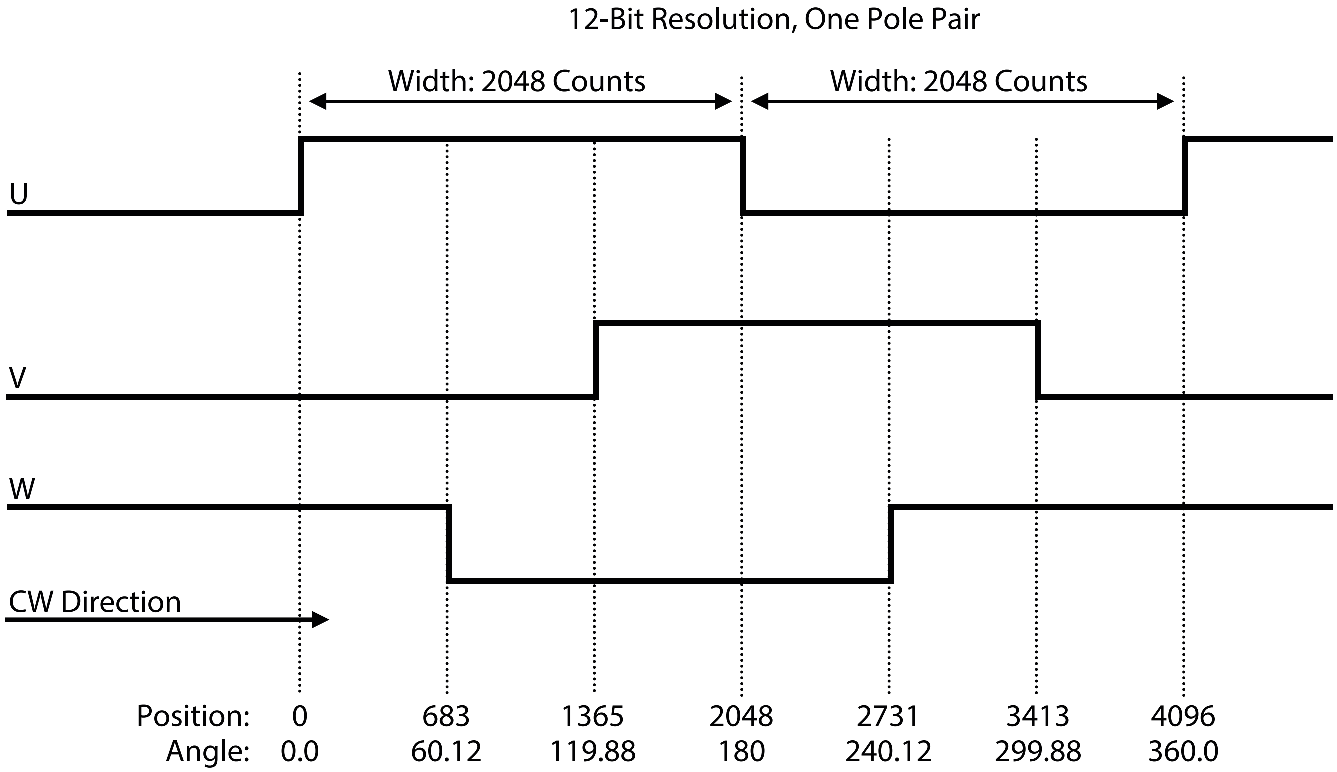
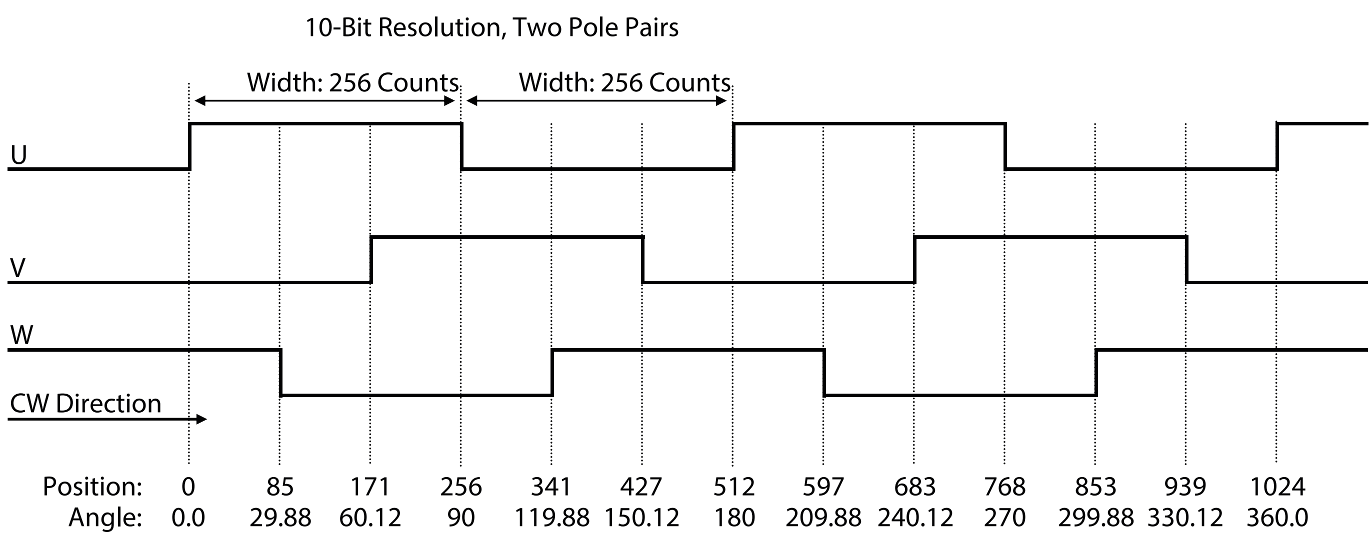


Figure 10: UVW Commutation Signals – 10-Bit Resolution, Two Pole Pairs

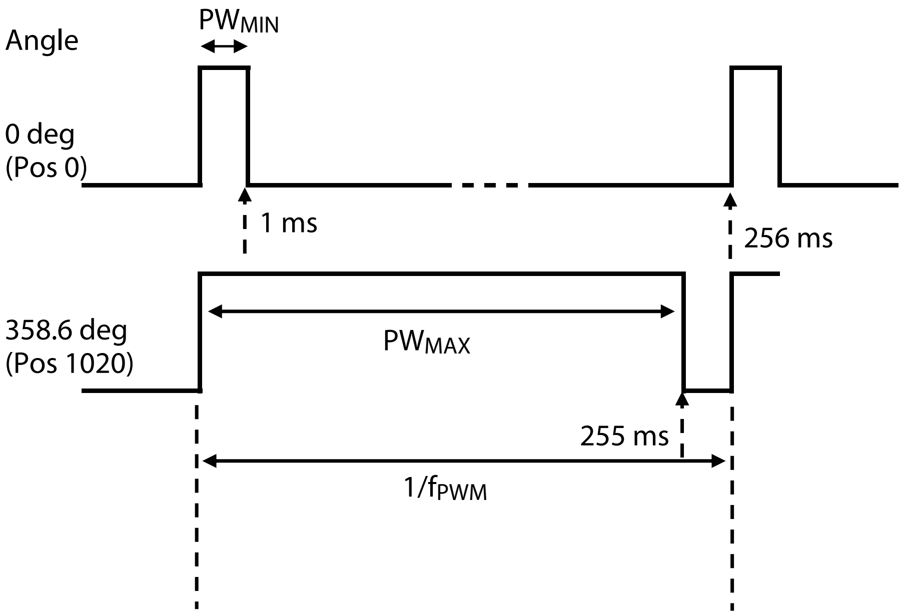


In this option, three-channel integrated commutation output (U, V, W) serves the purpose of emulating Hall sensor feedback. With this, AEAT-6600-T16 is able to align the commutation encoder signal to the correct phase of the motor. Generally, the more the pole pairs, the finer the commutation steps (AEAT-6600 up to 1, 2, 4, 8 pole pairs).

PWM Output

Figure 11: PWM Signals – 12-Bit Resolution

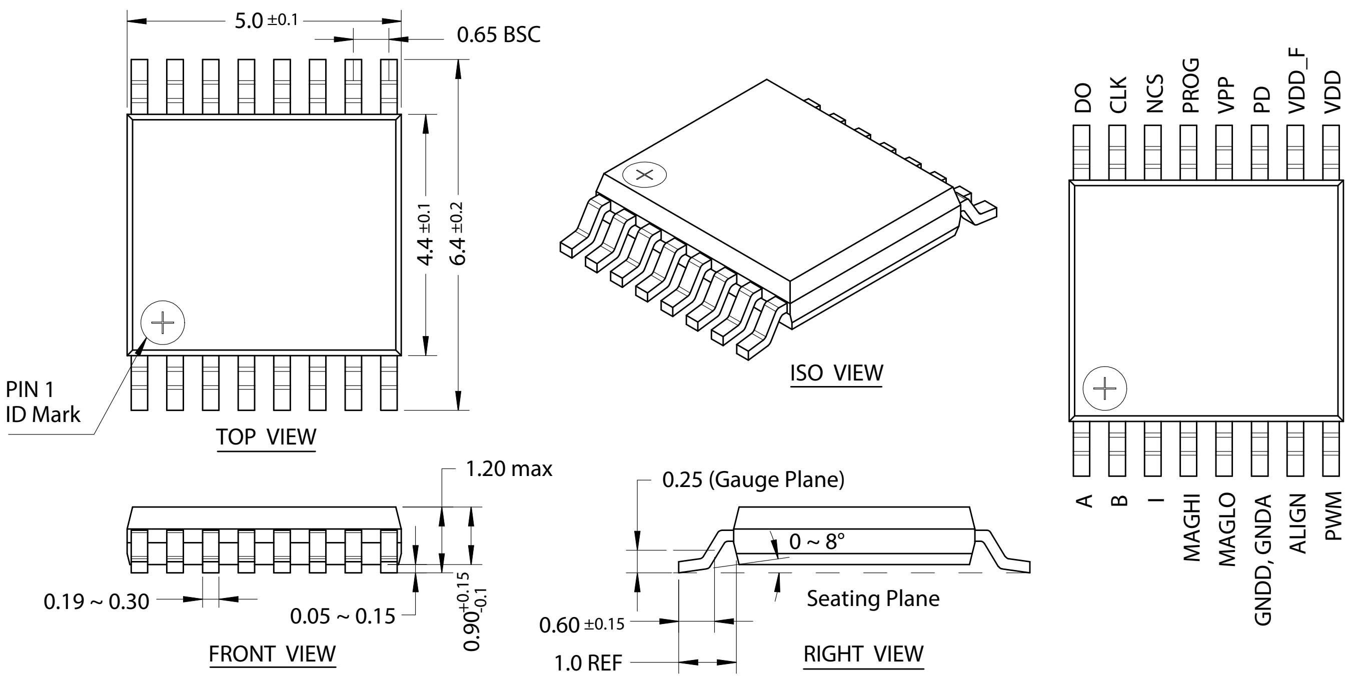
$$\text{Position} = \frac{t_{on} \times 1025}{(t_{on} + t_{off})} - 1$$



PWM output is considered as another absolute output besides SSI. In PWM mode, the duty cycle is proportional to the measured angle. For full rotation angle, 360 degrees is equivalent to position 0 to 1023. For instance, an angle position of 358.6° generates a pulse width t_{on} = 255 µs and a pause t_{off} of 1 µs, resulting in Position = 1020 after the calculation:
255 × 1025 / (255 + 1) – 1 = 1020

Package Drawings

Figure 12: AEAT-6600, 16-Lead TSSOP Dimensions



All Dimensions Unit: mm

Ordering Information

AEAT-6600-T16