
Chipsmall
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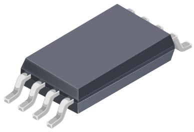
A1330

Programmable Angle Sensor IC with Analog and PWM Output

FEATURES AND BENEFITS

- Contactless 0° to 360° angle sensor IC, for angular position, rotational speed, and direction measurement
- Single and dual die options available in same package
- Non-volatile memory (EEPROM) for use in application trimming/calibration
- Circular Vertical Hall (CVH) technology provides a single-channel sensor system with air gap independence
- Angle Refresh Rate (output rate) configurable between 25 and 3200 µs through EEPROM programming
- Customer-programmable output clamp levels provide short-circuit diagnostic capabilities
- Open-circuit detection on ground pin (broken wire)
- Undervoltage lockout for V_{CC} below specification
- Fine angle scaling for short-stroke applications
- Missing Magnet Error flag for notifying controller of low magnetic field level
- EEPROM programmable angle reference (0°) position and rotation direction (CW or CCW)
- AEC-Q100 automotive qualified

PACKAGE: 8-pin TSSOP (LE package)



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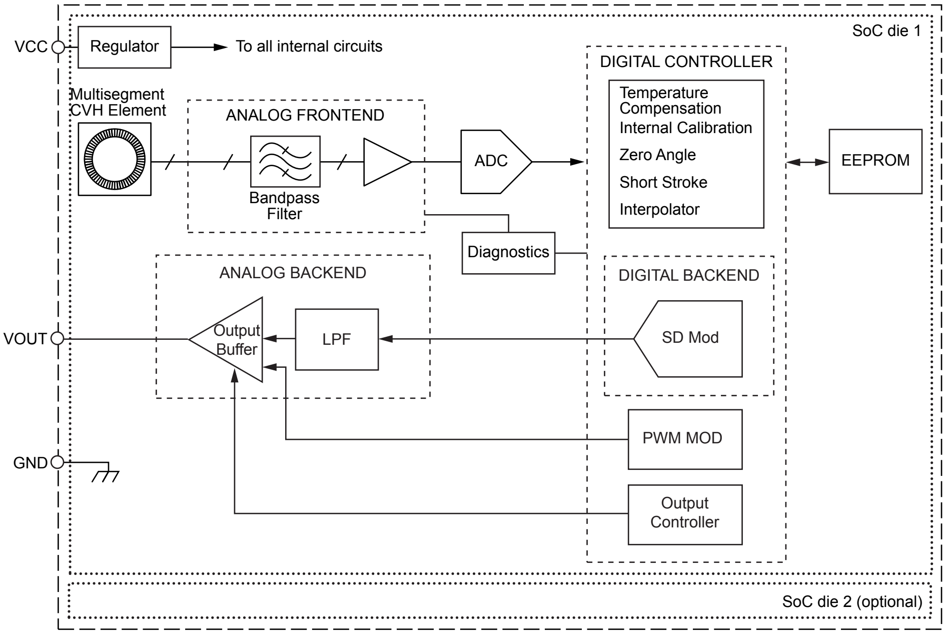
DESCRIPTION

The A1330 is a 360° angle sensor IC that provides contactless high-resolution angular position information based on magnetic Circular Vertical Hall (CVH) technology. It has a system-on-chip (SoC) architecture that includes: a CVH front end, digital signal processing, and an analog output driver. It also includes on-chip EEPROM technology, capable of supporting up to 100 read/write cycles, for flexible end-of-line programming of calibration parameters. Broken ground wire detection and user-selectable output voltage clamps make the A1330 ideal for high-reliability applications requiring high-speed 0° to 360° angle measurements.

The A1330 provides adjustable internal averaging, allowing response time to be traded for resolution. This is ideal for applications operating at low rotational velocities requiring high precision. For higher RPM applications, the A1330 provides industry-leading analog response time when no averaging is enabled.

With programmable angle scaling, the A1330 supports applications requiring short angular displacements, while maintaining full dynamic range on the output. Programmable minimum and maximum angle thresholds allow diagnosis of mechanical failures.

The A1330 is available as either a single or dual die option, in an 8-pin TSSOP. The package is lead (Pb) free with 100% matte-tin leadframe plating.



Functional Block Diagram

SELECTION GUIDE

Part Number	Application	Number of Die	Package	Packing [1]
A1330LLETR-T	Analog Output	Single Die	8-pin TSSOP	4000 pieces per 13-inch reel
A1330LLETR-P-T	PWM Output	Single Die		
A1330LLETR-DD-T	Analog Output	Dual Die		
A1330LLETR-P-DD-T	PWM Output	Dual Die		
A1330LLETR-T-C02	Analog Output [2]	Single Die		

[1] Contact Allegro™ for additional packing options.
[2] Increased Angle averaging and Analog hysteresis settings for reduced angle noise.

ABSOLUTE MAXIMUM RATINGS

Characteristic	Symbol	Notes	Rating	Unit
Forward Supply Voltage	V_{CC}	Not sampling angles	26.5	V
Reverse Supply Voltage	V_{RCC}	Not sampling angles	–18	V
Forward Output Voltage	V_{OUT}	$V_{OUT} < V_{CC} + 2$ V	16	V
Reverse Output Voltage	V_{ROUT}		0.5	V
Operating Ambient Temperature	T_A	L range	–40 to 150	°C
Maximum Junction Temperature	T_J(max)		165	°C
Storage Temperature	T_{stg}		–65 to 170	°C

THERMAL CHARACTERISTICS: May require derating at maximum conditions; see application information

Characteristic	Symbol	Test Conditions*	Value	Unit
Package Thermal Resistance	$R_{θJA}$	LE-8 single die package	145	°C/W
		LE-8 dual die package	277	°C/W

*Additional thermal information available on the Allegro website.

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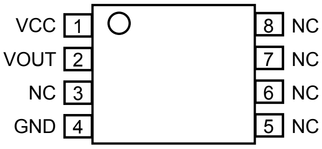
PINOUT DIAGRAMS AND TERMINAL LIST TABLES

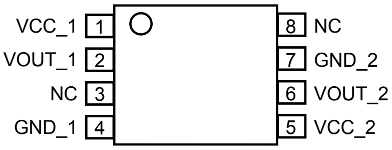


LE-8 Package Pinout (single die)

Terminal List Table (Single Die)

Pin Name	Pin Number	Function
VCC	1	Device power supply. Serves as Manchester communication input pin.
VOUT	2	Angle output (analog or PWM). Manchester output during serial communication. Input for EEPROM programming pulses.
NC*	3,5,6,7,8	Not connected; connect to ground for optimal ESD performance
GND	4	Ground

* NC pins must be tied to GND for optimum ESD performance.



LE-8 Package Pinout (dual die)

Terminal List Table (Dual Die)

Pin Name	Pin Number	Function
VCC_1	1	Device power supply. Serves as Manchester communication input pin. (die 1)
VOUT_1	2	Angle output (analog or PWM). Manchester output during serial communication. Input for EEPROM programming pulses. (die 1)
NC*	3, 8	Not connected; connect to ground for optimal ESD performance
GND_1	4	Ground (die 1)
VCC_2	5	Device power supply. Serves as Manchester communication input pin. (die 2)
VOUT_2	6	Angle output (analog or PWM). Manchester output during serial communication. Input for EEPROM programming pulses. (die 2)
GND_2	7	Ground (die 2)

* NC pins must be tied to GND for optimum ESD performance.

OPERATING CHARACTERISTICS: Valid over the full operating voltage and ambient temperature ranges, unless otherwise noted

Characteristics	Symbol	Test Conditions		Min.	Typ.	Max.	Unit[1]
ELECTRICAL CHARACTERISTICS							
Supply Voltage[2]	V_{CC}			4.5	–	5.5	V
Supply Current	I_{CC}	One die, analog output, unloaded output	$T_A \geq 25°C$	–	12	15	mA
			$T_A < 25°C$	–	12.6	16	mA
		One die, PWM output, unloaded output		–	8.5	10	mA
Undervoltage Lockout Threshold Voltage[3]	$V_{UVLO(H)}$	Maximum V_{CC}, dV/dt = 1 V/ms, $T_A = 25°C$, A1330 sampling enabled, rising V_{CC}		–	–	4.65	V
	$V_{UVLO(L)}$	Maximum V_{CC}, dV/dt = 1 V/ms, $T_A = 25°C$, A1330 sampling disabled, falling V_{CC}		3.9	–	4.5	V
Undervoltage Lockout Threshold Hysteresis	$V_{UVLO(HYS)}$	dV/dt = 1 V/ms, $T_A = 25°C$		–	180	–	mV
Overvoltage Lockout Threshold Voltage	$V_{OVLO(H)}$	Maximum V_{CC}, dV/dt = –1 V/ms, $T_A = 25°C$, A1330 sampling disabled		–	6.3	–	V
	$V_{OVLO(L)}$	Maximum V_{CC}, dV/dt = 1 V/ms, $T_A = 25°C$, A1330 sampling enabled		5.5	5.9	–	V
Overvoltage Lockout Threshold Hysteresis	$V_{OVLO(HYS)}$	dV/dt = –1 V/ms, $T_A = 25°C$		–	450	–	mV
Supply Zener Clamp Voltage	V_{ZSUP}	$I_{CC} = I_{CC} + 3$ mA, $T_A = 25°C$		26.5	–	–	V
Reverse-Battery Current	I_{RCC}	$V_{RCC} = 18$ V, $T_A = 25°C$		–	–	5	mA
Power-On Time[4]	t_{PO}			–	300	–	μs
ANALOG OUTPUT CHARACTERISTIC							
DC Output Resistance[4]	R_{OUT}			–	1	–	Ω
Output Load Resistance[4]	R_L	VOUT to VCC		4.7	–	–	kΩ
		VOUT to GND		4.7	–	–	kΩ
Output Current Limit	I_{LIMIT}	Minimum output, shorted to 5 V		24	29	34	mA
		Maximum output, shorted to GND		–	3	–	mA
Output Load Capacitance[4]	C_{OUT}			–	–	10	nF
Broken Wire Voltage	$V_{BRK(H)}$	$T_A = 25°C$, $R_{L(PU)} = 10$ kΩ to VCC		–	V_{CC}	–	V
	$V_{BRK(L)}$	$T_A = 25°C$, $R_{L(PD)} = 10$ kΩ to GND		–	130	–	mV
Output Slew Rate	SR	10 kΩ pull-up		–	100	–	V/ms
DAC Output Noise[4]	A_{NOISE}	DAC output, excluding angle measurement noise, 30 kHz BW setting		–	–	15	mV_{p-p}
		DAC output, excluding angle measurement noise, 15 kHz BW setting		–	–	10	mV_{p-p}
Average DAC Resolution[4]	Res(avg)	Across entire code range, theoretical noise-free input, 30 kHz BW		–	12	–	bits
Output Ratiometry Error[4]	Rat_{ERROR}			–	<±1	–	%
Analog Drift	$\lvert V_{DRIFT} \rvert$	Absolute change in analog output from 25°C to 150°C		–	10	30	mV
		Absolute change in analog output from 25°C to –40°C		–	10	–	mV

Continued on the next page…

OPERATING CHARACTERISTICS (continued): Valid over the full operating voltage and ambient temperature ranges, unless otherwise noted

Characteristics	Symbol	Test Conditions	Min.	Typ.	Max.	Unit[1]
ANALOG OUTPUT CHARACTERISTIC (continued)						
Output Saturation Voltage	$V_{OUT(MAX)}$	Max input angle position; V_{CC} = 5 V, HIGH_CLAMP = 0	4.65	4.75	–	V
	$V_{OUT(MIN)}$	0° input angle position; V_{CC} = 5 V, HIGH_CLAMP = 0	–	0.25	0.35	V
OUTPUT CLAMP PROGRAMMING						
Clamp High[4]	$V_{CLAMP(H)}$	Valid for Analog or PWM output, EEPROM programmable	32	–	95	% V_{CC} or DC
Clamp Low[4]	$V_{CLAMP(L)}$	Valid for Analog or PWM output, EEPROM programmable	5	–	68	% V_{CC} or DC
PWM INTERFACE SPECIFICATIONS						
PWM Carrier Frequency[4]	f_{PWM}	Programmable, 3 bit field	156.25	1250	20,000	Hz
Output Current Limit	I_{LIMIT}	Minimum output, shorted to 5 V	24	29	34	mA
Pull-up Load[5]	R_L		4.7	–	–	kΩ
PWM Duty Cycle Minimum[4]	$D_{PWM(MIN)}$	LOW_CLAMP = 0	–	5	–	%
PWM Duty Cycle Maximum[4]	$D_{PWM(MAX)}$	HIGH_CLAMP = 0	–	95	–	%
MAGNETIC CHARACTERISTICS						
Magnetic Field	B	Range of input field	–	–	1200	G
ANGLE CHARACTERISTICS						
Output[5]	RES_{ANGLE}		–	12	–	bit
Angle Refresh Rate[6]	t_{ANG}	ANG_AVE = 0	–	25	–	μs
Response Time[4]	$t_{RESPONSE}$	ANG_AVE = 0	–	120	–	μs
		ANG_AVE = 3	–	200	–	μs
Temperature Drift	$ANGLE_{DRIFT}$	Angle change from 25°C; T_A = 150°C, B = 300 G	–1.8	0.5	1.8	degrees
		Angle change from 25°C; T_A = –40°C, B = 300 G	–	0.8	–	degrees
Angle Error	ERR_{ANG}	T_A = 25°C, ideal magnet alignment, B = 300 G	–1.1	±0.4	1.1	degrees
		T_A = 150°C, ideal magnet alignment, B = 300 G	–1.5	±0.5	1.5	degrees
Angle Noise	N_{ANG}	T_A = 25°C, B = 300 G, no internal filtering, target rpm = 0, 3 sigma, PWM output	–	±0.6	–	degrees
		T_A = 150°C, B = 300 G, no internal filtering, target rpm = 0, 3 sigma, PWM output	–	±0.75	–	degrees
Angle Drift Over Lifetime[7]	$ANGLE_{DRIFT\_LIFE}$	B = 300 G, typical angle drift observed following AEC-Q100 qualification testing	–	±0.5	–	degrees

[1] 1 G (gauss) = 0.1 mT (millitesla).

[2] Operation guaranteed down to 4.5 V, once V_{CC} has risen above 4.65 V.

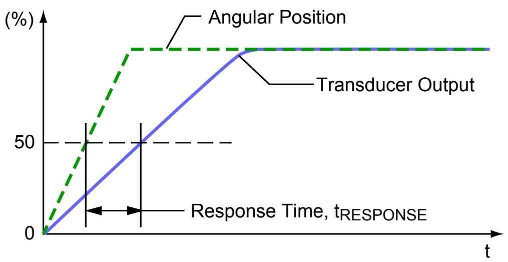
[3] At power-on, the sensor IC will not respond to commands until V_{CC} rises above $V_{UVLO(H)}$. After that, the sensor IC will perform and respond normally until V_{CC} drops below $V_{UVLO(L)}$.

[4] Parameter is not guaranteed at final test. Values for this characteristic are determined by design.

[5] RES_{ANGLE} represents the number of bits of internal angle information available.

[6] The rate at which a new angle reading will be ready.

[7] Maximum of 1.0 degree increase in angle error observed following AEC-Q100 stress.



Definition of Response Time

TYPICAL PERFORMANCE CHARACTERISTICS

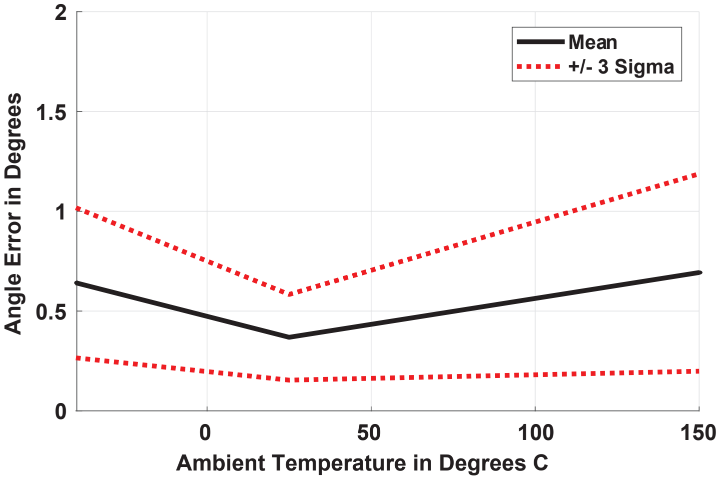


Figure 1: Peak Angle Error over Temperature (300 G)

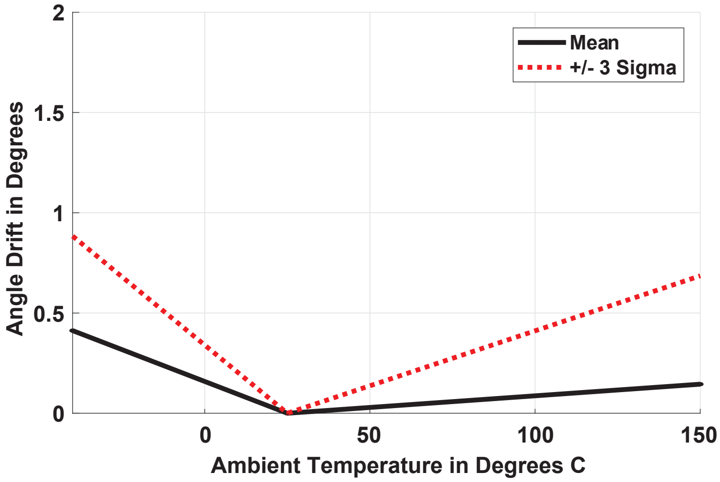


Figure 2: Maximum Absolute Drift from 25°C Reading (300 G)

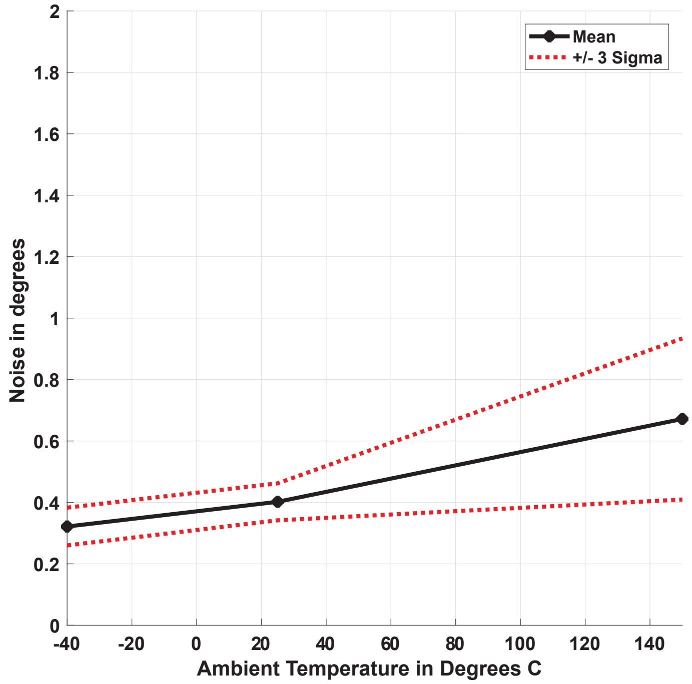


Figure 3: Noise Performance over Temperature (3 Sigma, 300 G, no internal filtering, Analog Output, 1 nF output capacitance)

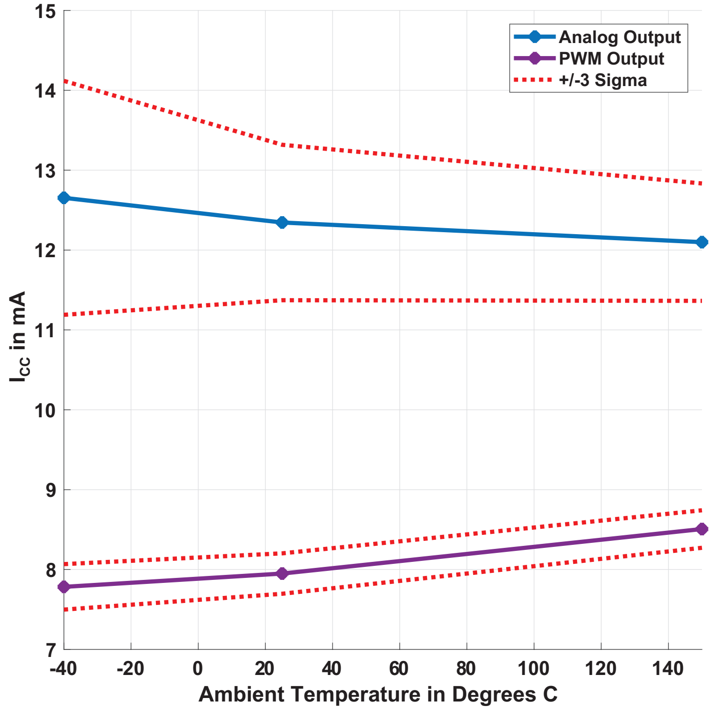


Figure 4: I_{CC} over Temperature (V_{CC} = 5.0 V)

FUNCTIONAL DESCRIPTION

Operational Modes

The A1330 is a rotary position Hall-effect-based sensor IC. The sensor IC measures the direction of the magnetic field vector through 360° in the x-y plane (parallel to the branded face of the device) and computes an angle measurement based on the actual physical reading, as well as any internal parameters that have been set by the user.

The device is a programmable system-on-chip (SoC). The integrated circuit includes a Circular Vertical Hall (CVH) analog front end, a high-speed sampling A-to-D converter, digital filtering, digital signal processing, and a high-speed Digital-to-Analog converter.

Internal averaging may be enabled to improve signal resolution.

Advanced offset and gain adjustment options are available in the A1330. These options can be configured in the onboard EEPROM, providing a wide range of sensing solutions in the same device. Device performance can be optimized by enabling individual functions or disabling them in EEPROM to minimize latency.

Angle Measurement

The A1330 can monitor the angular position of a rotating magnet at speeds ranging from 0 to more than 7,000 rpm.

The raw angle data is received in a periodic stream, and several samples may be accumulated and averaged, based on a user-selected EEPROM field. This feature increases the effective resolution of the system. The amount of averaging is determined by the user-programmable ANG_AVE field. The user can configure the quantity of averaged samples by powers of two to determine the refresh rate, the rate at which successive averaged angle values are fed into the post-processing stages. The available rates are set as follows:

ANG_AVE [2:0]	Quantity of Samples Averaged	Refresh Rate (µs)
000	1	25
001	2	50
010	4	100
011	8	200
100	16	400
101	32	800
110	64	1600
111	128	3200

Short Stroke

Short stroke (or fine angle scaling) allows for magnetic angle rotations smaller than 360 degrees to be represented by full-scale deflection. This feature is enabled in "Short Stroke" mode. In this mode, the raw angle reading is scaled via a programmable GAIN setting. Minimum and maximum angle thresholds may be programmed to detect hardware malfunctions. When a raw angle greater than the maximum angle threshold is detected, the sensor output will tri-state, alerting the host microprocessor of an unexpected condition. Programmable Clamp_High and Clamp_Low settings allow the maximum or minimum output level to be customizable.

Output Types

The A1330 is set at Allegro factory for either analog or PWM output.

ANALOG OUTPUT

The A1330LLETR-T and A1330LLETR-D-T feature an analog output, proportional to a 12-bit digital angle value. Angles 0.0 through 359.9 degrees are mapped to voltages between the default V_{CLAMPL} and default V_{CLAMPH}. The output voltage will increase linearly, between the clamp settings when a linearly increasing magnetic angle is detected.

Voltage values beyond the upper or lower clamps represent diagnostic regions. Output voltages within these two regions will only occur if the device detects an abnormal operating condition or internal error.

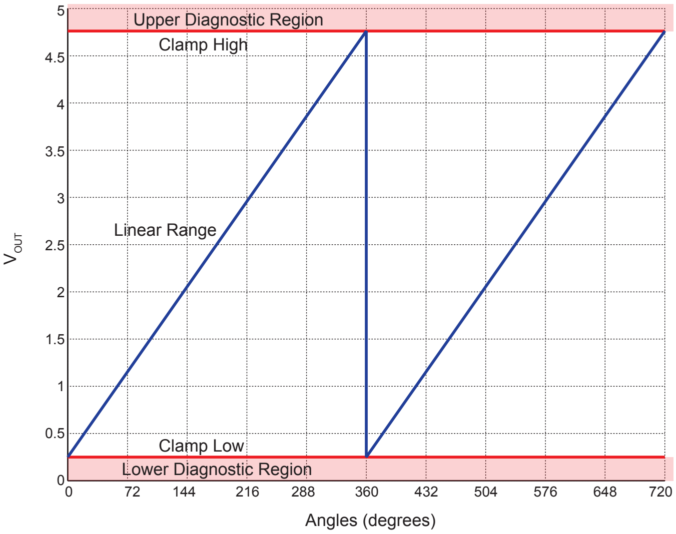


Figure 5: Output Value for a 0-720° Magnetic Input Signal

BACKEND DAC BW

The bandwidth of the backend analog filter is adjustable in EEPROM between two settings.

ABW	DAC Bandwidth
0	30 kHz
1	15 kHz

The default setting of 30 kHz is recommended for most applications, providing a good balance between low noise and fast response time. For applications especially sensitive to noise, it is recommend to choose the 15 kHz option and use the internal digital averaging to further reduce front end noise.

PWM OUTPUT

The A1330LLETR-P-T and A1330LLETR-P-DD-T provide a pulse-width-modulated open-drain output, with the duty cycle (D) proportional to measured angle. The PWM duty cycle is clamped at 5% and 95% by default and may be adjusted further for diagnostic purposes.

A 5% D corresponds to 0°; a 95% D corresponds to 360°.

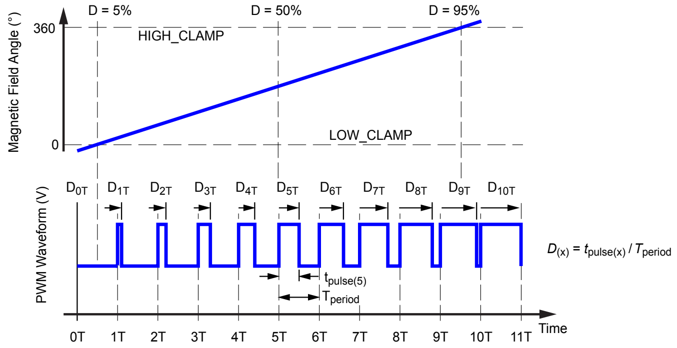


Figure 6: PWM Mode Outputs a Duty Cycle Proportional to Sensed Angle

Angle is represented in 12-bit resolution and can never reach a full 360° (0° and 360° are the same physical position). The maximum duty cycle high period with default clamp values is:

$$DutyCycleMax\ (\%) = (4095 / 4096) \times 90 + 5.$$

The derived angle (in degrees) from a given PWM duty cycle is:

$$Angle = (D - 5) / 90 \times 360.$$

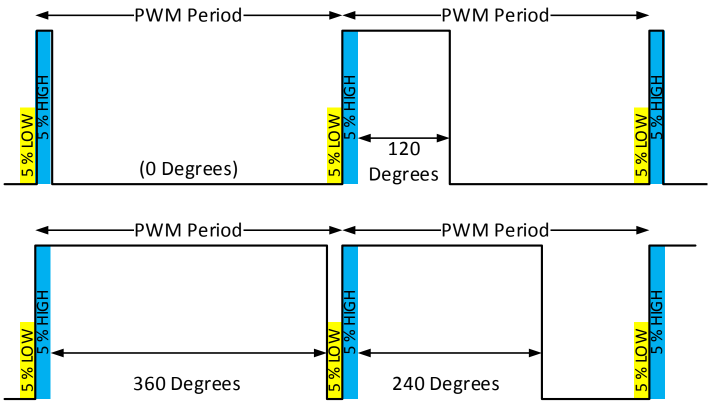


Figure 7: Pulse-Width Modulation (PWM) Examples

PWM CARRIER FREQUENCY

The PWM carrier frequency is controlled via a 3-bit EEPROM field.

PWM_FREQ	PWM Frequency
000	20 kHz
001	10 kHz
010	5 kHz
011	2.5 kHz
100	1.25 kHz
101	625 Hz
110	312.5 Hz
111	156.25 Hz

Undervoltage and Overvoltage Lockout

The Output pin state changes according to the V_{CC} level. This is shown in Figure 8, with typical threshold values highlighted. By using a pull-up/pull-down resistor, one is able to know the sensor is in high-impedance, as the output will be beyond the clamp values.

Hysteresis

The periodic behavior intrinsic to angle sensing results in output voltage swings from minimum to maximum deflection during 0/360 degree crossings. For some applications, this may be problematic, especially if a high-noise environment results in values close to 0 degrees intermittently appearing as 359.9 degrees.

To prevent oscillations between mininimum or maximum output, the A1330 features programmable hysteresis, specified by the 2-bit HYST EEPROM field. When hysteresis is enabled, the output will not change for angle variations smaller than the hysteresis setting.

As an alternate approach, the HYST_0/360 bit may be set in EEPROM, to enable hysteresis only around the 0/360 degree crossing.

Note: Unlike the typical description of ‘Hysteresis”, the implementation used in the A1330 is “two-sided”, meaning the hysteresis gap is independent of rotation direction. This effectively increases the output step size and as a result may not be desired. To apply this filtering method to only angle ranges of importance (in which a 0/360 crossover could occur), the HYST_0/360 bit can be set.

Table 1: HYST Settings in EEPROM

Code	Hysteresis (in LSB)	Angle Equivalent
00	0	0
01	4	0.352
10	8	0.703
11	16	1.406

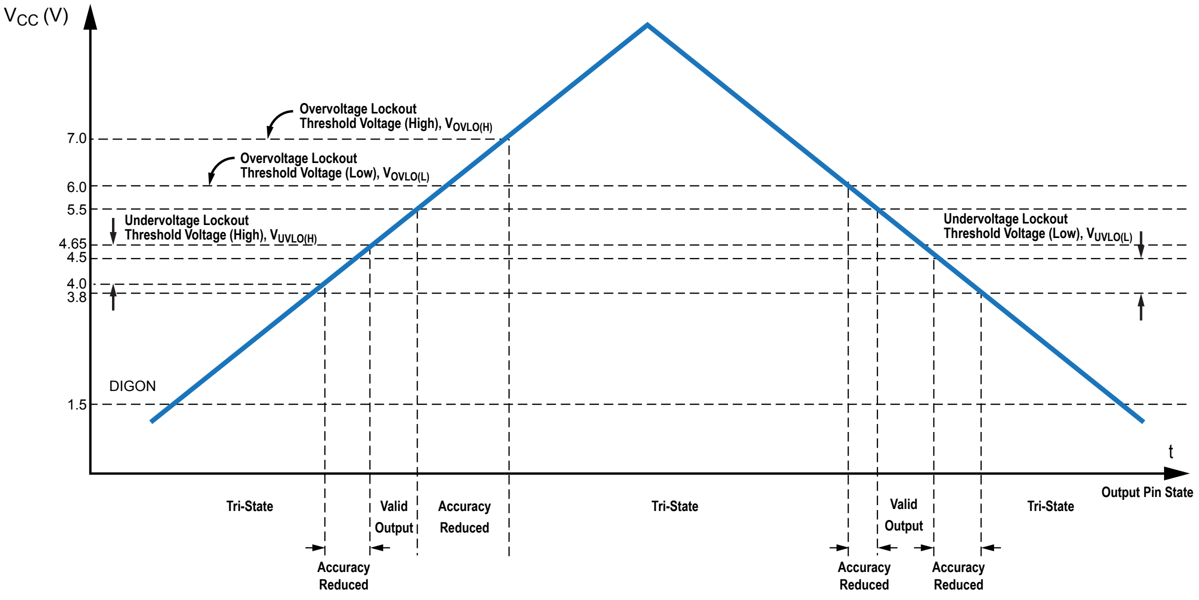


Figure 8: Relationship of V_{CC} and Output

PROGRAMMING SERIAL INTERFACE

The A1330 incorporates a serial interface that allows an external controller to read and write registers in the A1330 EEPROM and volatile memory. The A1330 uses a point-to-point communication protocol, based on Manchester encoding (a rising edge indicates a 0 and a falling edge indicates a 1), with address and data transmitted MSB first.

Transaction Types

Each transaction is initiated by a command from the controller; the A1330 does not initiate any transactions. Two commands are recognized by the A1330: Write and Read. There also are three special function Write commands: Write Access Code, Manchester Enable, and Manchester Disable. One response frame type is generated by the A1330, Read Acknowledge.

If the command is a read, the A1330 responds by transmitting the requested data in a Read Acknowledge frame. If the command is a write, the A1330 does not acknowledge.

As shown in Figure 9, The A1330 receives all commands via the VCC pin. It responds to Read commands via the VOUT pin. This implementation of Manchester encoding requires the communication pulses be within a high ($V_{MAN(H)}$) and low ($V_{MAN(L)}$) range of voltages for the VCC line and the VOUT line. The Write command pulses to EEPROM are supported by two high-voltage pulses on the VOUT line.

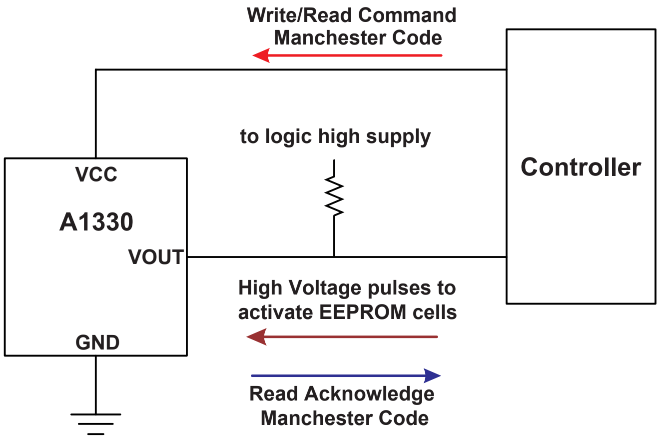


Figure 9: Top-Level Programming Interface

Writing the Access Code

If the external controller will write to or read from the A1330 memory during the current session, it must establish serial communication with the A1330 by sending a Write Access Command within 70 ms after powering up the A1330. If this deadline is missed, all write and read access is disabled until the next power-up.

Writing to EEPROM

When writing to non-volatile EEPROM, following the write command, the controller must also send two Programming pulses. These pulses are well-separated, long, high-voltage strobes transmitted on the VOUT pin. These strobes are detected internally, allowing the A1330 to boost the voltage on the EEPROM gates. The digital logic will automatically detect an impending EEPROM write and tri-state the output pin.

The required sequence is shown in Figure 12. The voltage pulse profile necessary for EEPROM programming is shown in Figure 10. Minimum and maximum times are described in Table 2.

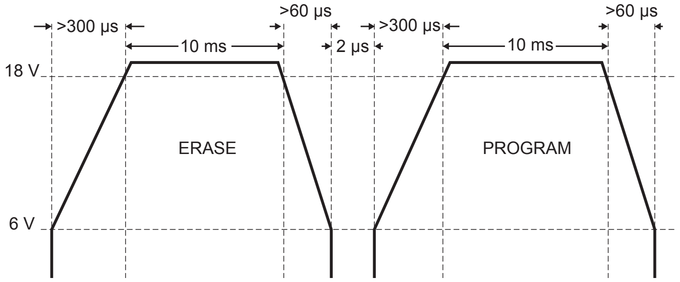


Figure 10: Top-Level Programming Interface

Table 2: EEPROM Pulse

Parameter	Comments	Min.	Typ.	Max.	Unit
Pulse High Time	Time above minimum pulse voltage	8	10	11	ms
Rise Time	10% to 90% of minimum pulse level	300	–	–	µs
Fall Time	10% to 90% of minimum pulse level	60	–	–	µs
Pulse Voltage		18	19	19.5	V
Separation time	Time between first pulse dropping below 6 V and 2nd pulse rising above 6 V	2 µs	–	50 ms	µs/ms

Writing to Volatile Registers

The three main volatile write commands (Write Access, Manchester Enable and Manchester Disable) are all accomplished by writing to register 0x1F.

In addition to these three commands, the PWM output version requires a PWM Disable command be written prior to performing a Manchester read and a PWM Enable command prior to going back to Normal Mode. These two commands are written to register 0x22.

Reading from EEPROM

To read from EEPROM, the Manchester mode must be entered. This is accomplished by sending the Manchester Enable code on VCC. For PWM parts, an additional PWM Disable command must also be sent.

After the Read Acknowledge frame has been received from the A1330, the controller must send a Manchester Disable command to restore VOUT to normal operation. The required sequence is shown in Figure 12.

Error Checking

The serial interface uses a cyclic redundancy check (CRC) for data-bit error checking (synchronization bits are ignored during the check).

The CRC algorithm is based on the polynomial

$$g(x) = x^3 + x + 1 \quad ,$$

and the calculation is represented graphically in Figure 11.

The trailing 3 bits of a message frame comprise the CRC token. The CRC is initialized at 111.

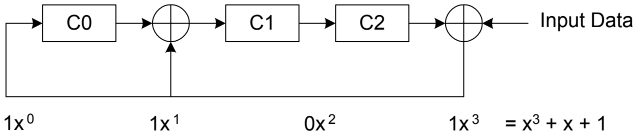


Figure 11: CRC Calculation

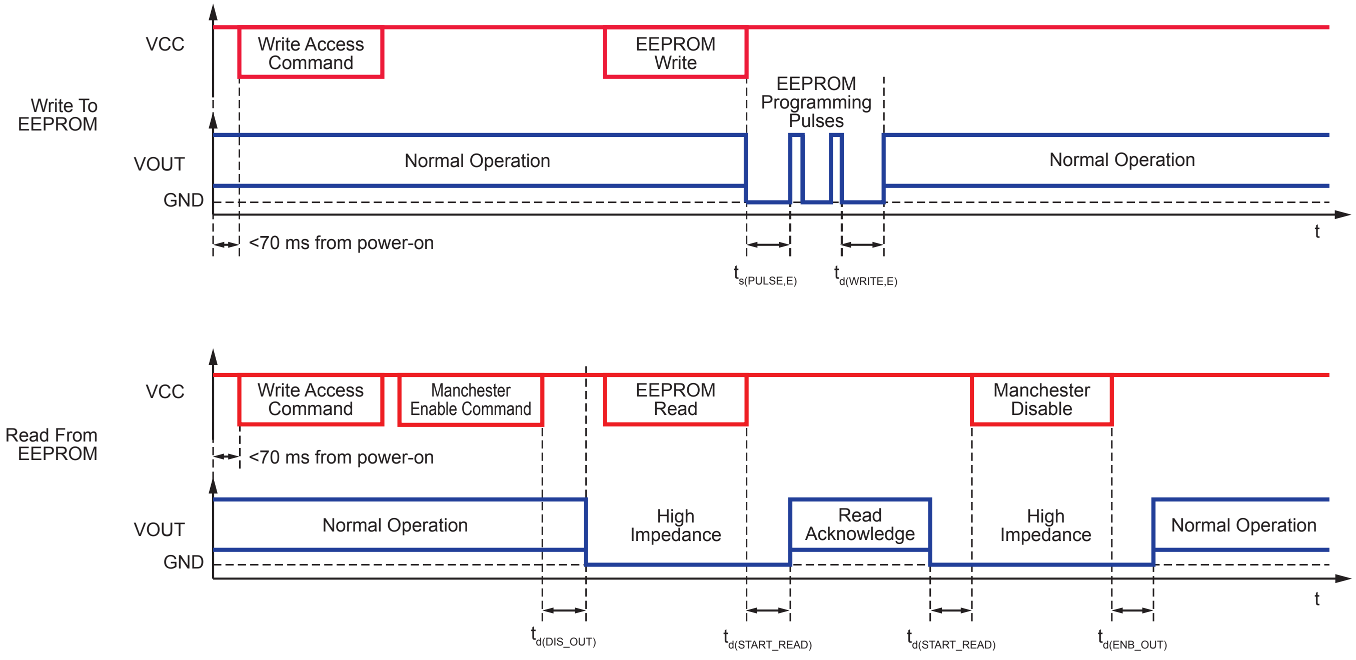


Figure 12: Programming Read and Write Timing Diagrams

SERIAL INTERFACE REFERENCE

Table 3: Serial Interface Protocol Characteristics [1]

Characteristics	Symbol	Note	Min.	Typ.	Max.	Unit
INPUT/OUTPUT SIGNAL TIMING						
Access Code Timeout	t_{ACC}	Customer Access Code should be fully entered in less than t_{ACC}, measured from when V_{CC} crosses $V_{CC(UVH)}$	–	–	70	ms
Baud Rate	f_s	Defined by the input message bit rate sent from the external controller	5	–	40	kbps
Bit Time Error	err_{TBIT}	Deviation in t_{BIT} during one command frame	–15	–	+15	%
Read Acknowledge Delay	$t_{d(READ)}$	Required delay from the trailing edge of a Read Acknowledge frame to the leading edge of a following command frame	2 × t_{BIT}	–	–	µs
Read Delay [2]	$t_{d(START\_READ)}$	Delay from the trailing edge of a Read command frame to the leading edge of the Read Acknowledge frame	–	2 × t_{BIT}	–	µs
Enable Manchester Delay [2]	$t_{d(DIS\_OUT)}$	Delay from the trailing edge of a Manchester Enable command frame to the device output going from normal operation to the high-impedance state	1 – ¼ × t_{BIT}	5 – ¼ × t_{BIT}	15 – ¼ × t_{BIT}	µs
Disable Manchester Delay [2]	$t_{d(ENB\_OUT)}$	Delay from the trailing edge of a Manchester Disable command frame to the device output going from the high-impedance state to normal operation	1 – ¼ × t_{BIT}	5 – ¼ × t_{BIT}	15 – ¼ × t_{BIT}	µs
EEPROM PROGRAMMING PULSE						
EEPROM Programming Pulse Setup Time	$t_{s(PULSE,E)}$	Delay from last bit cell of write command to start of EEPROM programming pulse	2 × t_{BIT}	–	–	µs
EEPROM Memory Write Delay	$t_{d(WRITE,E)}$	Required delay from the trailing edge of the second EEPROM Programming pulse to the leading edge of a following command frame	40	–	–	µs
INPUT SIGNAL VOLTAGE						
Manchester Code High Voltage	$V_{MAN(H)}$	Applied to VCC line	7.3	–	–	V
Manchester Code Low Voltage	$V_{MAN(L)}$	Applied to VCC line	–	–	6.3	V
OUTPUT SIGNAL VOLTAGE (APPLIED ON PWM LINE)						
Manchester Code High Voltage	$V_{MAN(H)}$	Minimum R_{pullup} = 5 kΩ	0.9 × V_S	–	–	V
		Maximum R_{pullup} = 50 kΩ	0.7 × V_S	–	–	V
Manchester Code Low Voltage	$V_{MAN(L)}$	5 kΩ ≤ R_{pullup} ≤ 50 kΩ	–	–	0.35	V

[1] Determined by design.

[2] In the case where a slower baud rate is used, the output responds before the transfer of the last bit in the command message is completed.

Serial Interface Message Structure

The general format of a command message frame is shown in Figure 13. Note that, in the Manchester coding used, a bit value of 1 is indicated by a falling edge within the bit boundary, and a bit value of zero is indicated by a rising edge within the bit boundary.

Each command is composed of two zero synchonization bits (“00”) followed by a Read/Write bit, 6 bit address, 32 data bits (only for write commands) and 3 bits of CRC. All field are interpreted MSB first.

The read acknowledged frame is composed of two zero synchronization bits, 32 bits of data, and a 3 bit CRC.

The bits are described in Table 4.

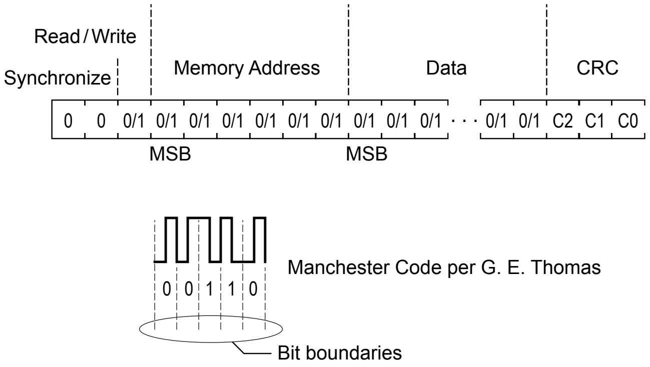


Figure 13: General Format for Serial Interface Commands

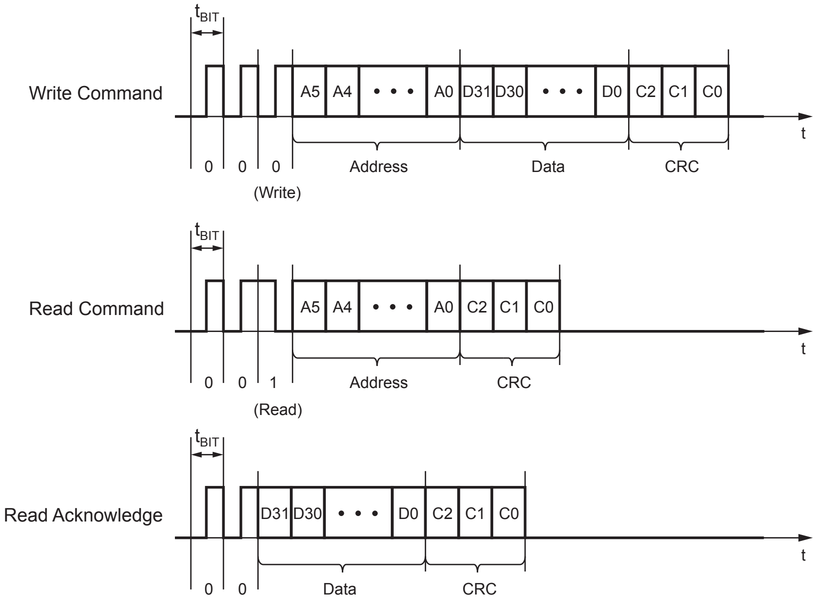


Figure 14: Manchester Format Example

Table 4: Serial Interface Command General Format

Quantity of Bits	Name	Values	Description
2	Synchronization	00	Used to identify the beginning of a serial interface command and communication bit time
1	Read/Write	0	[As required] Write operation
		1	[As required] Read operation
6	Address	0/1	[Read/Write] Register address (volatile memory or EEPROM)
variable	Data	0/1	[As required] 32 bits of data
3	CRC	0/1	Incorrect value indicates errors

Special Access Code Commands

There are two Manchester code commands: a write access code, which initiates serial communication and must be sent within t_{ACC} of power up; and a Disable Output Command, which toggles between mission mode (normal sensor behavior) and Manchester mode, allowing the part to respond to read requests. Both commands are written to volatile register 0x1F.

1. Write Access Code:
   Unlocks the customer address space.
2. Manchester Enable Command:
   Disables sensor output, allowing sensor to respond with a read acknowledge frame.
3. Manchester Disable Command:
   Exits Manchester mode and returns the sensor normal output mode.

The PWM varient requires two additional commands.

1. PWM Disable Code:
   Disables the PWM modulator, allowing Manchester logic to control the open drain output. Must be sent after the Manchester Enable pulse, and prior to a read request.
2. PWM Enable Code:
   Moves control of the output driver back to the PWM logic. Must be sent prior to Manchester Disable command.

Write Access Code

String	ASCII Code (hex)
“1330”	31 33 33 30

Manchester Enable Code

String	ASCII Code (hex)
“READ”	52 45 41 44

Manchester Disable Code

String	ASCII Code (hex)
“EXIT”	45 58 49 54

PWM Disable Code

Address	Hex Code
0x22	0x01E6C0D

PWM Enable Code

Address	Hex Code
0x22	0x21E6C0D

EEPROM Locking

The EEPROM contains an EELOCK bit. When set high, this bit prevents the writing of all EEPROM locations. This is a safety feature guaranteeing EEPROM content integrity during operation in the field.

Safety Features

Lockout and clamping features protect the A1330 internal circuitry and prevent spurious outputs when the supply voltage is out of specification. Open ground circuit detection is also provided.

Internal Detection Circuitry

Internal diagnostic circuitry monitors EEPROM ECC to ensure valid system configurations. Magnetic field amplitude is compared against a low field threshold to identify possible hardware malfunctions.

During short stroke mode, minimum and maximum angle values may be specified to identify unexpected behavior and place the output in a safe state.

These diagnostic modes may be disabled with an EEPROM mask bit.

Detecting Broken Ground Wire

If the GND pin is disconnected, node A becoming broken (Figure 15), the VOUT pin will go to a high-impedance state. Output voltage will go to $V_{BRK(H)}$ if a load resistor $R_{L(PU)}$ is connected to VCC or to $V_{BRK(L)}$ if a load resistor $R_{L(PD)}$ is connected to GND. The device will not respond to a magnetic field.

If the ground wire is reconnected, the A1330 will resume normal operation.

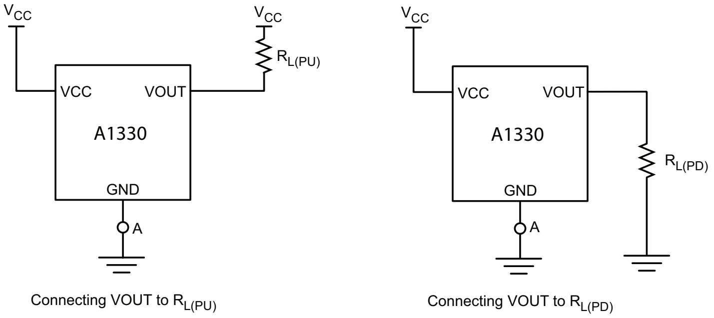


Figure 15: Connection for Detecting Broken Ground Wire

Table 5: Safety Features

Diagnostic/Protection	Description	Output State
Reverse VCC	Current limiting (VCCx pin)	–
Output to VCC	Current limiting (VOUT pin)	–
Output to Ground	Current limiting (VOUT pin)	–
UVLO	V_{CC} below expected range	Tri-state
OVLO	V_{CC} above expected range	Tri-state
EEPROM dual bit fault	Uncorrectable EEPROM bit fault. Proper device configuration cannot be guaranteed	Tri-state
Missing Magnet	Monitors magnet field level in case of mechanical failure (default of 100 G)	Tri-state
Angle Out of Range	During short-stroke operation, measured raw angle exceeds maximum specified angular displacement	Tri-state
Broken Ground Wire	Broken ground connection	Tri-state: output goes to $V_{BRK(H)}$ or $V_{BRK(L)}$
Digital Interpolation Error	Internal monitor of the DAC interpolation block detects unexpected internal register changes and resets the interpolator	Tri-state

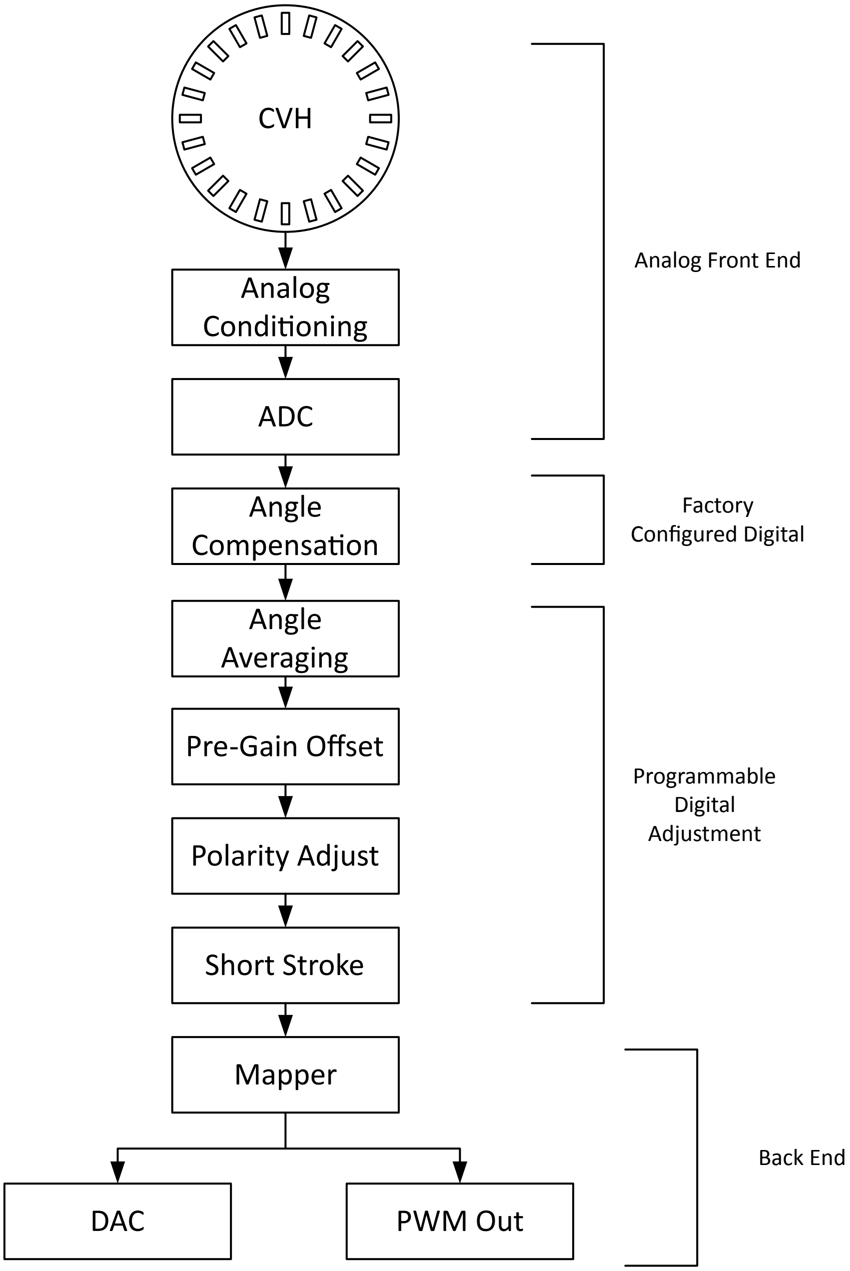


Figure 16: Digital Signal Path Description

Angle Compensation

The A1330 is capable of compensating for alterations in angle readings that result from changes in the device temperature or applied field strength. The device comes from the factory pre-programmed with coefficient settings to allow compensation of linear shifts of angle with temperature and applied field.

Angle Averaging

The raw angle data is received in a periodic stream, and multiple samples may be accumulated and averaged, based on the user-programmable ANG_AVE EEPROM field. This feature increases the effective resolution of the system. The user can configure the quantity of averaged samples by powers of two to determine the refresh rate, the rate at which successive averaged angle values are fed into the post-processing stages. The available rates are set as follows:

Table 6: Refresh Rate based on Averaged Samples

ANG_AVE [2:0]	Quantity of Samples Averaged	Refresh Rate (µs)
000	1	25
001	2	50
010	4	100
011	8	200
100	16	400
101	32	800
110	64	1600
111	128	3200

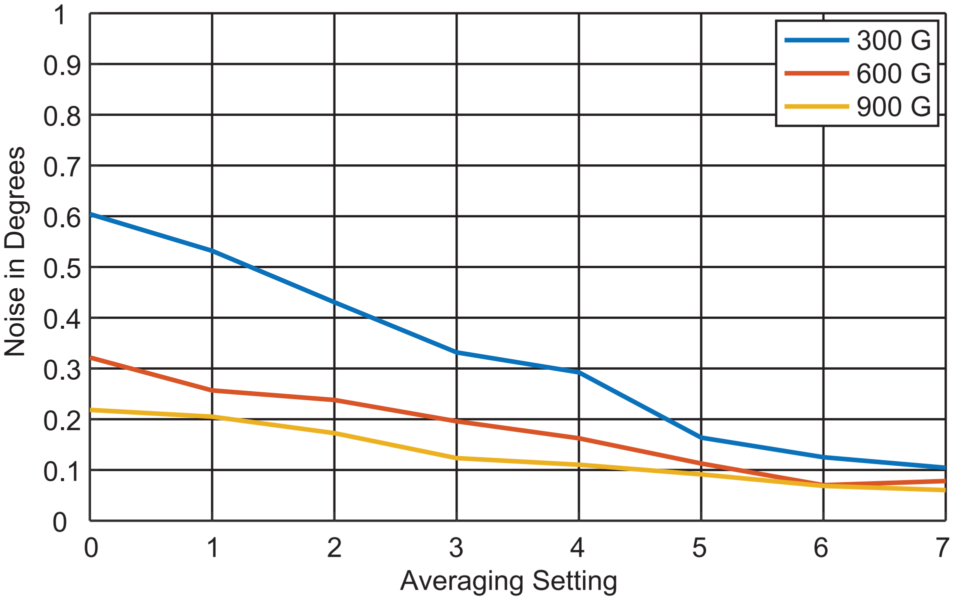


Figure 17: 3 Sigma Angle Noise Over Averaging Settings. PWM Output, 25°C, Multiple Field Levels.

Pre-Gain Offset

Allows zeroing of the angle prior to applying gain. Set via the PREGAIN_OFFSET field in EEPROM.

$$Angle = Angle - PREGAIN\_OFFSET$$

Polarity Adjust

Sets the polarity of the final angle output. When set to “1”, the angle is complemented.

$$Angle = 360° - Angle$$

Short Stroke

The A1330 features “short stroke” logic allowing a limited input signal to be gained up and use the full output range of the sensor. The short stroke logic consists of multiple steps. A high level block diagram is shown in Figure 18. Short stroke applies to both the PWM and analog output variants.

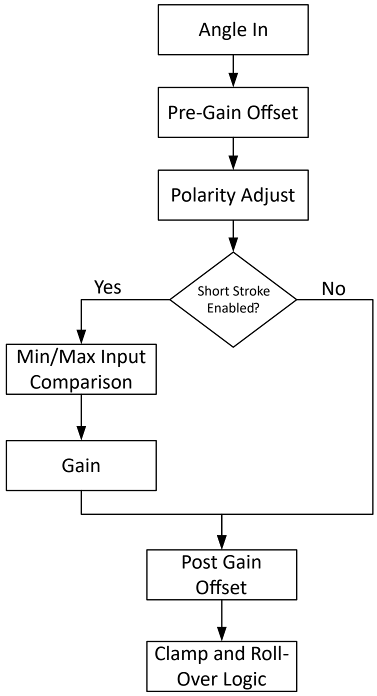


Figure 18: High Level Short Stroke Block Diagram

MIN/MAX INPUT ANGLE COMPARISON

The IC compares the pre-gained angle value to the boundaries set via the MIN_INPUT and MAX_INPUT EEPROM fields. If the angle is outside of the established boundaries the output will tristate to indicate an unexpected angle location. This feature is useful for applications where clamping is enabled and will otherwise mask excessive angular travel.

GAIN

Adjusts the output dynamic range of the device. Gain is applied digitally and capable of expanding an 11.25° input angle to a full scale output deflection.

It should be noted that with application of high gain, the front end noise will also be amplified. In such cases it is highly recommend to use the Angle Averaging feature to minimize the impact of noise.

When applying a non-integer gain, an asymetric transfer function will result, causing the output to jump to the minimum allowed output value before reaching the maximum allowed output value. As an example, if a gain of 4× is applied, with Clamp Enable (CE) and Roll-Over Enable (ROE) set to 0, the output angle will slew from 0-360° four times for a single 0-360° target rotation (this is shown in Figure 19 for 2 rotations of the target). However, if a gain of 4.5× is applied, the output will slew from 0-360° four and a half times. This results in a jump from 180° output to 0° output, at the 360° input position (shown in Figure 20).

POST-GAIN OFFSET

Provides a final, post-gain angle adjustment.

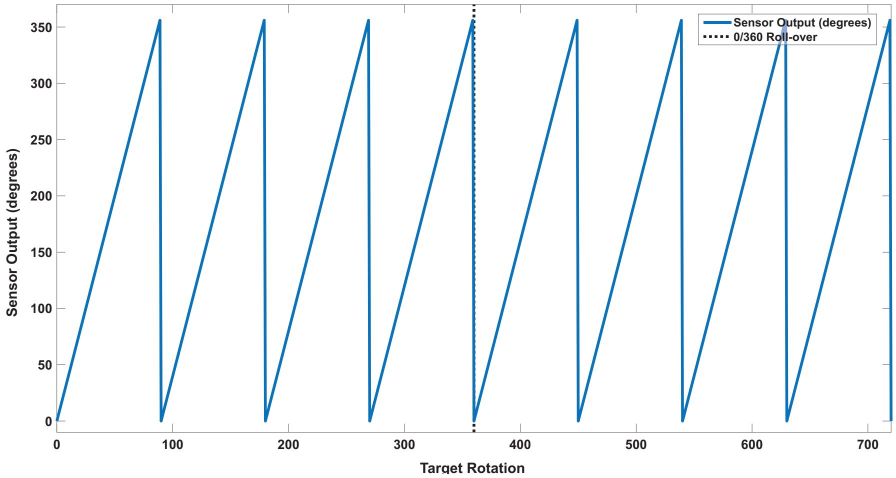


Figure 19: A1330 Output (in degrees) with 4.0× Gain

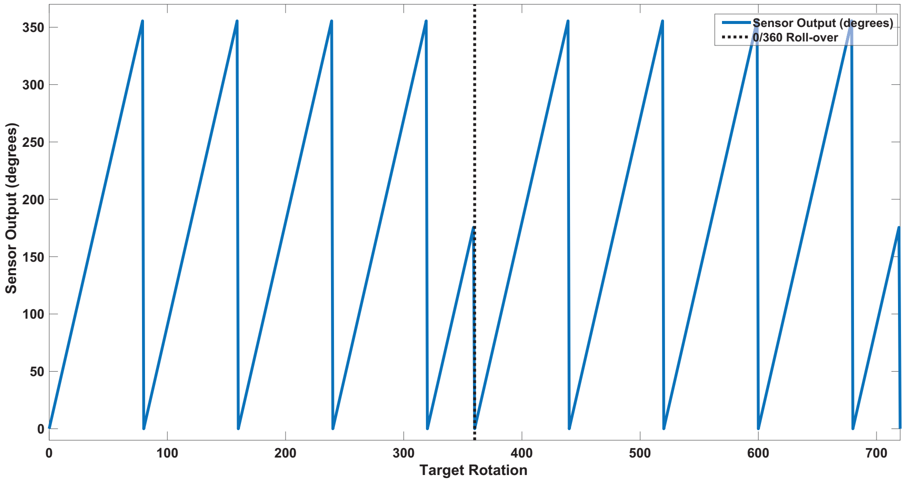


Figure 20: A1330 Output (in degrees) with 4.5× Gain

Clamp and Roll-Over Logic

Output behavior following gain and offset application is defined by the Clamp Enable (CE) and Roll-Over Enable (ROE) EEPROM bits. Together these two field select between four different output behavior types.

Below are figures depicting the output behavior with different clamp and roll-over settings.

CE	ROE	Description
0	0	Normal behavior. Roll-over at standard module 360.
0	1	Output rolls-over at the High and Low Clamp values.
1	0	Output clamps at the first encountered High/ Low Clamp value.
1	1	Roll-over occurs at standard module 360. Output is clamped to High/Low Clamps value.

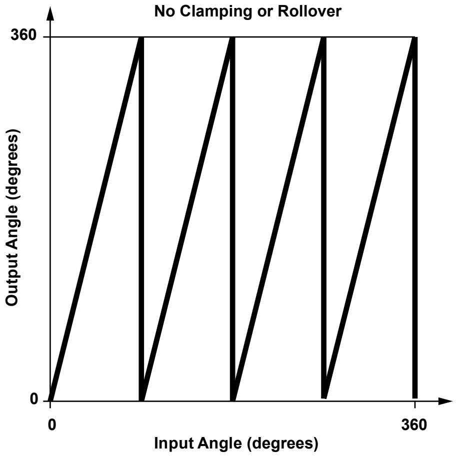


Figure 21: CE = 0, ROE = 0. Applied gain = 4×.

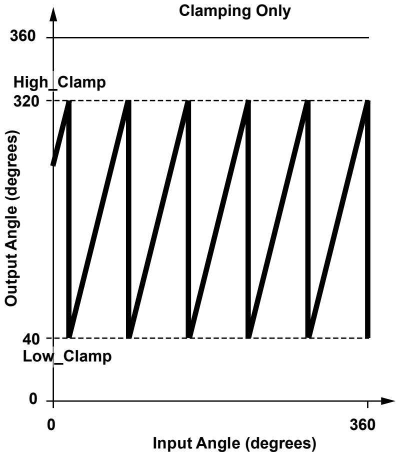


Figure 23: CE = 0, ROE = 1. Applied gain = 4×.
LOW_CLAMP = 10 (≈40°), HIGH_CLAMP = 10 (≈320°)

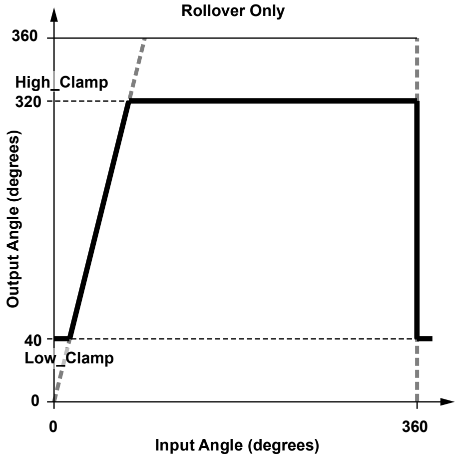


Figure 22: CE = 1, ROE = 0. Applied gain = 4×.
LOW_CLAMP = 10 (≈40°), HIGH_CLAMP = 10 (≈320°)

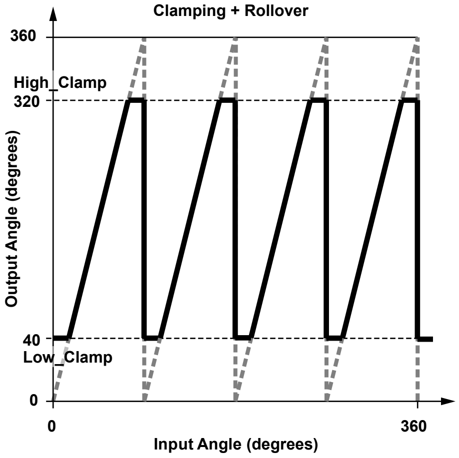


Figure 24: CE = 1, ROE = 1. Applied gain = 4×.
LOW_CLAMP = 10 (≈40°), HIGH_CLAMP = 10 (≈320°)

Additional Short Stroke Examples

To demonstrate short stroke, several possible scenarios are shown in the following figures.

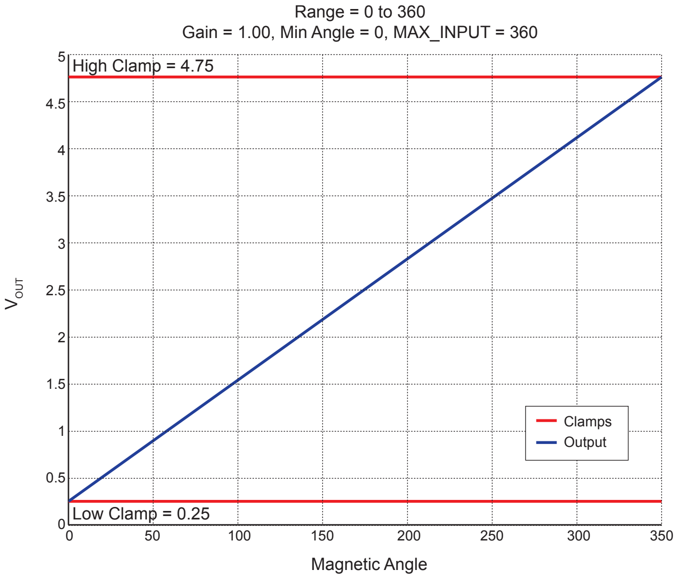


Figure 25: Scenario A.
Regular output for a 0-360 degree input angle.
Gain = 1. Clamps set to 95% and 5%.

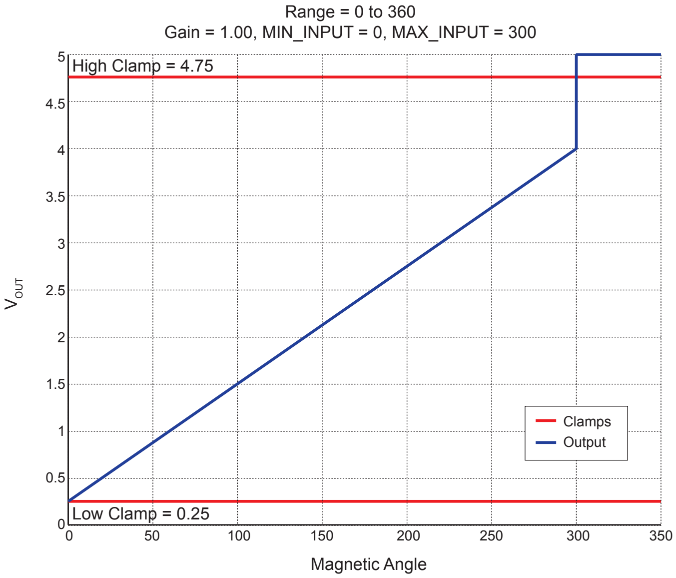


Figure 26: Scenario B.
Regular 0-360 degree input value. Gain = 1.
MAX_INPUT = 300. Clamps set to 95% and 5%.
Output goes into diagnostic region (in this case V_{CC}) when input angle exceeds the MAX_INPUT set point.

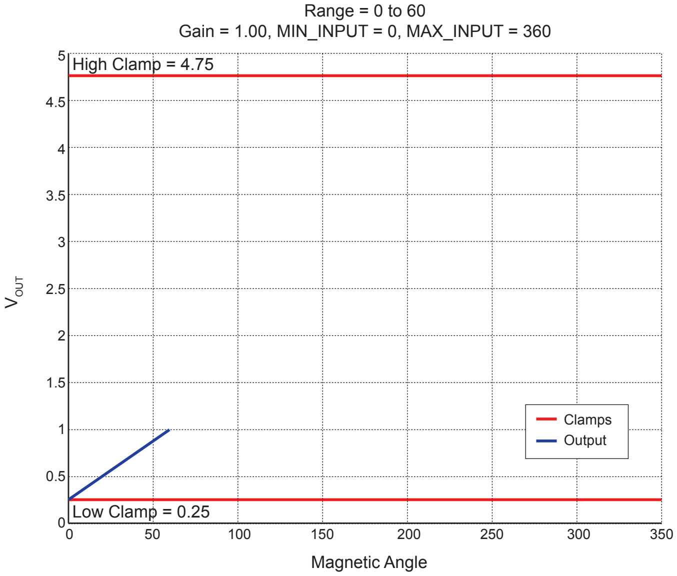


Figure 27: Scenario C.
0-60 degree input. Gain = 1.
With no gain, a 60-degree input angle results in an output signal 1/6th of V_{CC}.

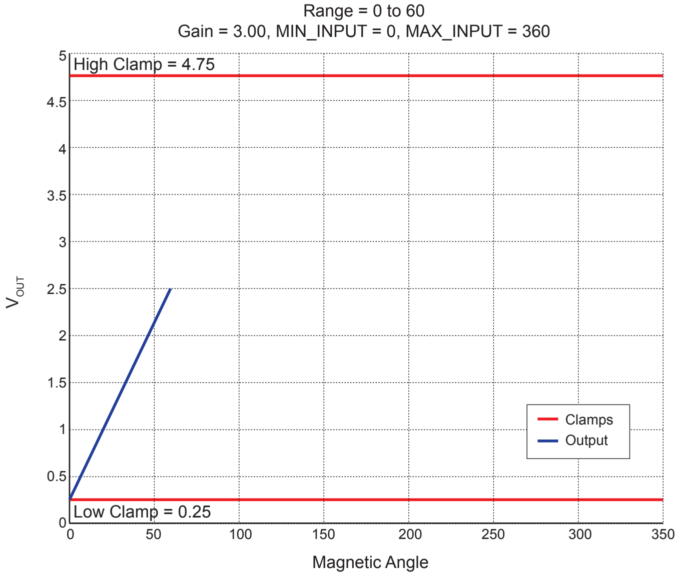


Figure 28: Scenario D.
0-60 degree input. Gain = 3.
With an increased Gain value of 3×, the same 60-degree input signal now results in 50% of V_{CC}. The output signal is still free to swing from 5% to 95% of V_{CC}.

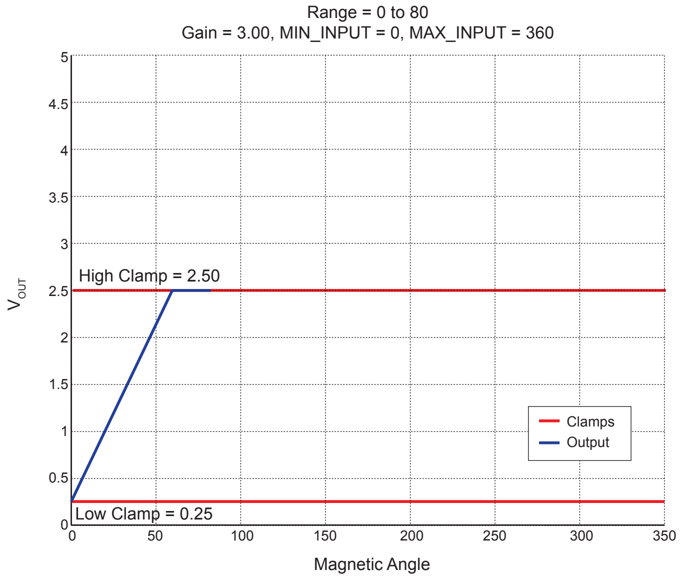


Figure 29: Scenario E.
0-80 degree input. Gain = 3.
High Clamp reduduced to 50% of V_{CC}.
60-degree input results in 50% output signal. With the reduced upper clamp value, maximum V_{OUT} is 50% of V_{CC}. Angle measurements greater than 60 degrees will be clamped to this 50% value.

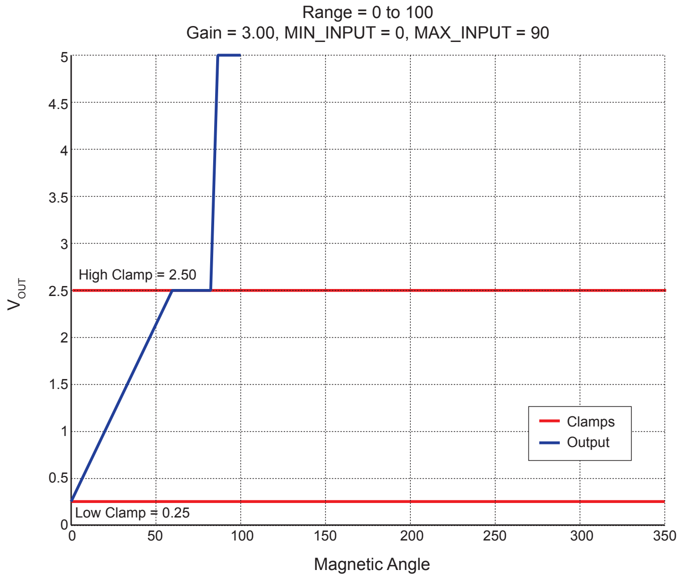


Figure 30: Scenario F.
0-100 degree input. Gain = 3. Clamp_High reduced to 50% V_{CC}. MAX_INPUT = 90°. Similar to the above scenario, output voltage is clamped at 50% of V_{CC} for any input angle greater than 60 degrees. However, when the input angle exceeds the MAX_INPUT threshold, output voltage goes to diagnostic state (V_{CC}). In this example, if the expected input range is 60 degrees, a mechanical failure resulting in 100 degrees of rotation will be detected.

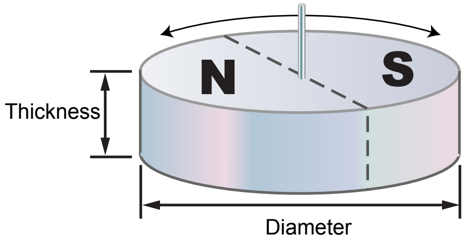
APPLICATION INFORMATION

Magnetic Target Requirements

The A1330 is designed to operate with magnets constructed with a variety of magnetic materials, cylindrical geometries, and field strengths, as shown in Table 7. Contact Allegro for more detailed information on magnet selection and theoretical error.

Table 7: Target Magnet Parameters

Magnetic Material	Diameter (mm)	Thickness (mm)
Neodymium (bonded)	15	4
Neodymium (sintered)*	10	2.5
Neodymium (sintered)	8	3
Neodymium / SmCo	6	2.5



*A sintered Neodymium magnet with 10 mm (or greater) diameter and 2.5 mm thickness is the recommended magnet for redundant applications.

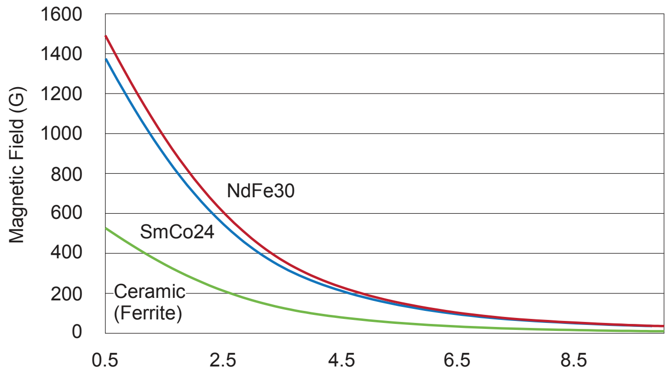


Figure 31: Magnetic Field versus Air Gap for a magnet 6 mm in diameter and 2.5 mm thick. Allegro can provide similar curves for customer application magnets upon request. Allegro recommends larger magnets for applications that require optimized accuracy performance.

Field Strength

The A1330 actively measures and adapts to its magnetic environment. This allows operation throughout a large range of field strengths (recommended range is 300 to 1000 G, operation beyond this range is allowed with no long-term impact). Due to the greater signal-to-noise ratio provided at higher field strengths, performance inherently increases with increasing field strength. Typical angle performance over applied field strength and temperature are shown in Figure 32 and Figure 33.

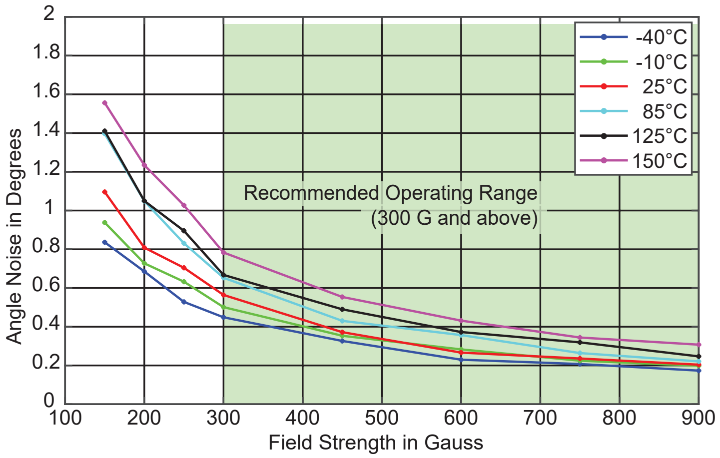


Figure 32: Typical Three Sigma Angle Noise Over Field Strength

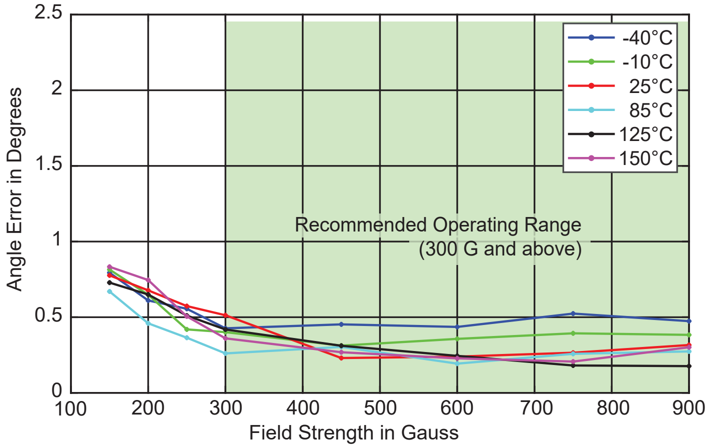


Figure 33: Typical Angle Error Over Field Strength

Setting the Zero-Degree Position

When shipped from the factory, the default angle value when oriented as shown in Figure 34 is ≈162° for die 1 and ≈342° for die 2. In some cases, the end user may want to program and angle offset to compensate for variations in magnetic assemblies, or for applications where absolute system level readings are required.

The A1330 features two different offset adjust field in EEPROM, which may be used to change the location of the 0/360°discontinuity point. Depending on application either the PREGAIN_OFFSET, the POSTGAIN_OFFSET or both may be used to such ends.

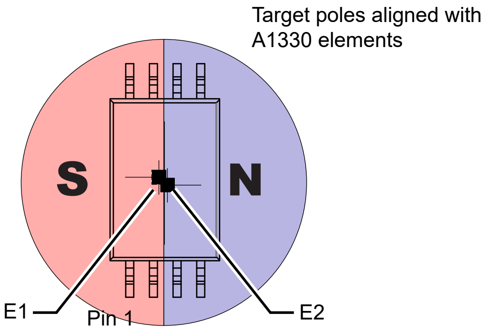


Figure 34: Orientation of Magnet Relative to Primary and Secondary Die

Magnet Misalignment

Magnetic misalignment with the A1330 package impacts the linearity of the observed magnetic signal and consequently the resulting accuracy. The influence of mechanical misalignment may be minimized by reducing the overall airgap and by choosing a larger magnet diameter. Figure 35 shows the influence of magnet diameter of eccentricity error.

The dual die variant of the A1330 uses a stacked die approach, resulting in a common eccentricity value for both die. This eliminates the "native misalignment" present in "side-by-side" packaging options.

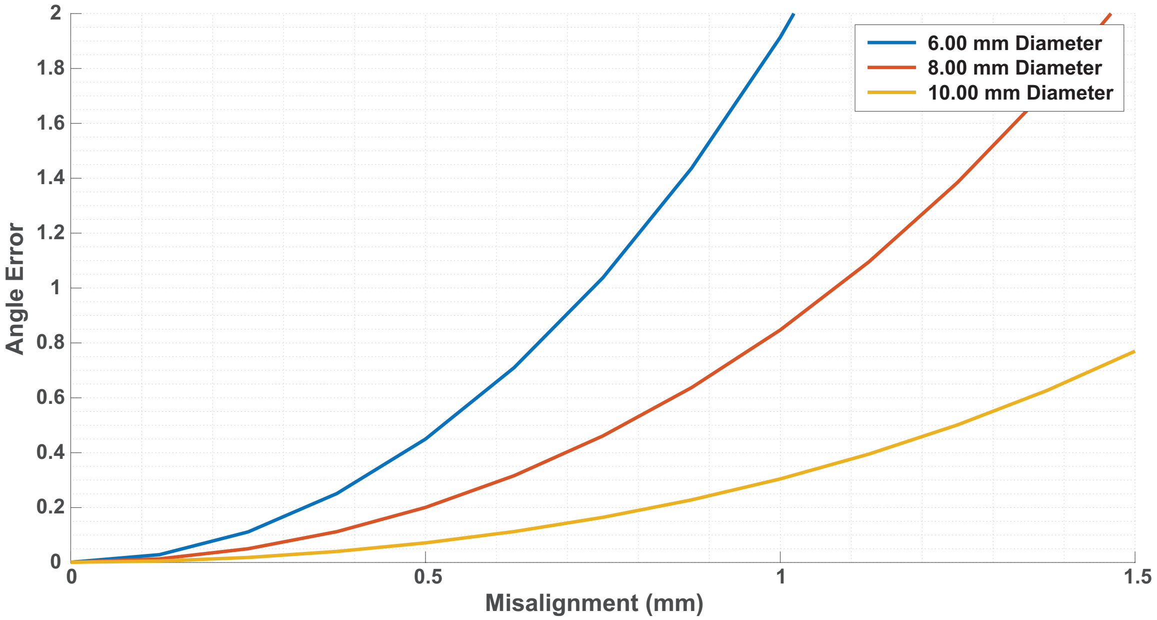


Figure 35: Simulated Error versus Eccentricity for different size magnet diameters, at 2.0 mm air gap

Typical Systemic Error versus magnet to sensor eccentricity (d_{axial}), Note: "Systemic Error" refers to application errors in alignment and system timing. It does not refer to sensor IC device errors. The data in this graph is simulated with ideal magnetization.