TMR3365

Automotive Digital TMR Magnetic Angle Sensor

Description

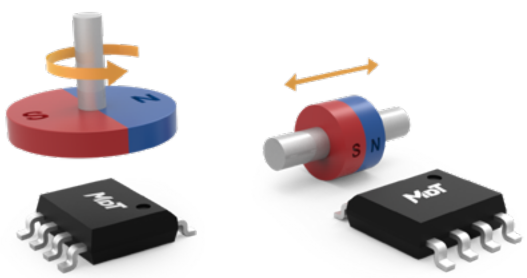
TMR3365 is a non-contact, high-speed, high-precision digital magnetic angle sensor from MultiDimension Technology (MDT). It captures the magnetic field signal and calculates the rotation angle by sensing the rotation of the magnet above the sensor. The sensor integrates a tunneling magnetoresistance (TMR) sensor and a signal processing ASIC, providing a rich set of working parameter configurations and various output interfaces for customers to choose from.

The TMR3365 provides three output modes: analog, PWM, and SENT (supports enhanced protocol). It can achieve the best absolute position angle detection performance when the magnetic field is in the range of 200 Gs to 800 Gs. The sensor has a built-in self-diagnostic and alarm function, providing safety assurances.

The TMR3365 features a built-in 5-point/17-point non-linear calibration function, which is simple to operate, allowing customers to easily compensate for non-linear errors caused by mounting. It also supports programmable angle measurement range functions to meet customer needs. The sensor supports a one-wire communication protocol (OWI).

The TMR3365 is available in SOP8 package.

SOP8



Features and Benefits

- Tunneling magnetoresistance (TMR) technology
- Adaptable supply voltage: 4.5 V to 18 V
- Supply current down to 10 mA
- Supports reverse pin voltage protection
- Supports one-wire communication protocol (OWI)
- Output modes: SENT / PWM / Analog
- Piecewise linear calibration mode:
  5-point or 17-point calibration
- Programmable angle measurement range
- Built-in self-diagnosis and alarm function
- Built-in EEPROM, over 10,000 write cycles
- Operating temperature range: -40°C to 160°C
- Excellent resistance to environmental magnetic fields
- AEC-Q100 compliant
- RoHS & REACH compliant

Applications

- Absolute value rotary position sensor
- Steering wheel angle sensor
- Throttle position sensor
- Ride height position sensor
- Floating liquid level sensor
- Non-contact potentiometer

Selection Guide

Part Number	Output Interface	Supply Voltage	Operating Temperature	Package	Packing Form
TMR3365P	SENT/PWM/Analog	4.5 V to 18 V	-40 °C to 160 °C	SOP8	Tape & Reel

Catalogue

1. Functional Block Diagram

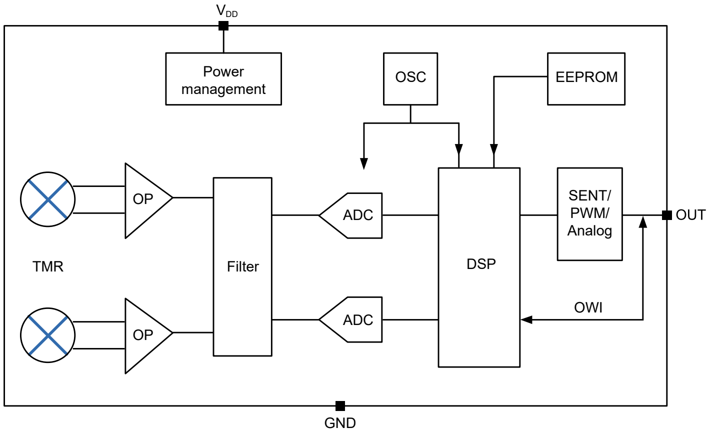


Figure 1. Block diagram

2. Pin Configuration

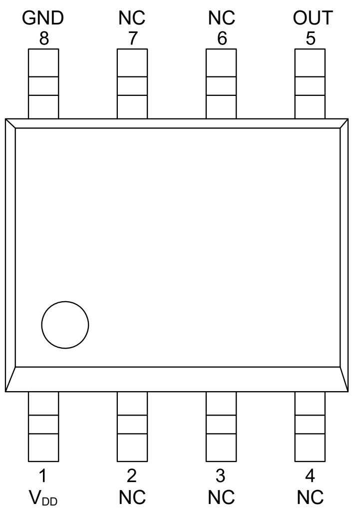


Figure 2. Pin configuration (SOP8)

Number	Name	Function
1	V_{DD}	Supply voltage
2	NC	Grounding recommended
3	NC	Grounding recommended
4	NC	Grounding recommended
5	OUT	Output signal / OWI
6	NC	Grounding recommended
7	NC	Grounding recommended
8	GND	Ground

3. Absolute Maximum Ratings

Parameters	Symbol	Min.	Max.	Unit
Supply voltage[1)]	V_{DD}	-	35	V
		-	6	
Reverse voltage protection	V_{DD-REV}	-18[2)]	-	V
OUT pin voltage	V_{OUT}	-	35	V
Reverse out pin voltage	$V_{OUT-REV}$	-18[2)]	-	V
External magnetic field	B	-	4000	Gs
Operating ambient temperature	T_A	-40	160	°C
Storage ambient temperature	T_{STG}	-55	160	°C

Note:
1) When configured for analog output, V_{DD} should not exceed 6 V; when configured for PWM/SENT output, V_{DD} should not exceed 35 V.
2) Under test conditions, V_{DD} is connected to 0V, and GND is connected to 18 V.

4. Electrical Specifications

V_{DD} = 5 V, T_A = 25 °C, 100 nF capacitor connected between VDD and GND unless specified otherwise

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Supply voltage	V_{DD}	Analog	4.5	-	5.5	V
		Digital	4.5	-	18	V
Supply current	I_D	No load	-	10	-	mA
Output load	R_L	Analog pull-up/pull-down	5	-	10	kΩ
		Push-pull PWM	5	-	100	kΩ
		Push-pull PWM with pull-up	10	-	55	kΩ
		Open-drain, pull-up/pull-down	1	-	100	kΩ
Digital open drain output	V_{sat_loOD}	Pull-up to external V_{EXT} ≤ 18V, I ≤ 3mA	0	-	10	$\%V_{EXT}$
	V_{sat_hiOD}	Pull-down to ground V_{EXT} ≤ 18V, I ≤ 3mA	90	-	100	$\%V_{EXT}$
Analog saturation output voltage	V_{satA_lo}	Pull-up load ≥ 10 kΩ	-	0.7	-	$\%V_{DD}$
	V_{satA_hi}	Pull-down load ≥ 10 kΩ	-	96	-	$\%V_{DD}$
Push-pull digital output	V_{satD_lopp}	Pull-up load ≥ 10 kΩ	-	-	0.2	V
	V_{satD_hipp}	Pull-down load ≥ 10 kΩ	V_{DD} - 0.2	-	-	V
Simulated step response	T_{res}	No load	-	-	380	μs
Slew rate	SR	C = 100 nF	-	-	120	V/ms
Push-pull mode rise time	T_{up}	V_{DD} = 4.5 V to 5.5 V, C = 10 nF	-	-	5	μs
Push-pull mode falling time	T_{down}	V_{DD} = 4.5 V to 5.5 V, C = 10 nF	-	-	4.5	μs
NMOS fall time in open-drain mode	TP_{down}	V_{DD} = 4.5 V to 5.5 V, R_L = 10 kΩ	-	-	200	μs
PMOS rise time in open-drain mode	TP_{up}	V_{DD} = 4.5 V to 5.5 V, R_L = 10 kΩ	-	-	200	μs

5. Magnetic Specifications

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Measurement range	A_{range}	-	0	-	360	Deg
Nonlinearity error	INL_{OPT}	Room temperature	-	-	±0.3	Deg
		@ -40°C and 160°C	-	-	±0.5	Deg
Differential nonlinearity	DNL	-	-	-	±0.1	Deg
Hysteresis	HYS	-	-	-	±0.176	Deg
Repeatability	A_{repeat}	-	-	-	±0.088	Deg
Tick	Tick	-	1	3	5	μs
SENT frame period	T_{frame}	-	-	900	-	μs

6. Magnetic Field Specification

Recommended magnet: cylindrical neodymium magnet (N35SH), Φ 9mm × 2.5 mm, radial magnetization

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Diameter of magnet	d_{mag}	-	6	9	20	mm
Thickness of magnet	t_{mag}	-	-	2.5	-	mm
Mounting distance	D_{in}	Recommended magnet(9 mm)	-	3	-	mm
Magnetic field	H_{ext}	Sensor surface	-	300	-	Gs
Center deviation between magnet and sensor	x_{dis}	-	-	-	0.5	mm
Angle deviation between magnet and sensor	φ_{pac}	-	-3	-	3	Deg

7. OUT Pin Function Description

The 'OUT' pin (Pin 5 of the SOP8 package) on the TMR3365 can be multiplexed for various functions, including analog output, PWM output, SENT output, and a single-wire communication interface (OWI). Users can configure their desired output mode through the mode_sel [3:0] register. By default, if the output mode is not specifically activated, the sensor will operate in single-wire communication (OWI) mode, allowing users to read/write internal register values and perform EEPROM data burning operations.

Once the output mode configuration of the TMR3365 is activated, users can seamlessly transition between OWI communication mode and the standard operating mode by adjusting the V_{DD} voltage level. Specifically, when the output mode is set to PWM/SENT and V_{DD} exceeds V_{DH}, the OWI communication mode is engaged. If V_{DD} drops below V_{DL}, it reverts to the PWM/SENT output. Similarly, for analog output mode, if V_{DD} surpasses V_{AH}, OWI communication mode is initiated. When V_{DD} falls below V_{AL}, the sensor returns to analog output. To assist users, MDT offers the "TMR336x Demonstration Board" designed around the OWI interface, along with compatible host software, to simplify user interactions and configurations.

7.1 Analog voltage output

The TMR3365 has a built-in high-precision digital-to-analog converter (DAC) that converts angular position information into a linear analog voltage output. The corresponding output voltage from 0° to 360° is 0 to 100%V_{DD} (factory default value). As shown in Figure 3, the analog output voltage can be programmed through the built-in 5-point/17-point piecewise linear calibration function to set different voltage gains. Piecewise linear calibration is detailed in Section 8.

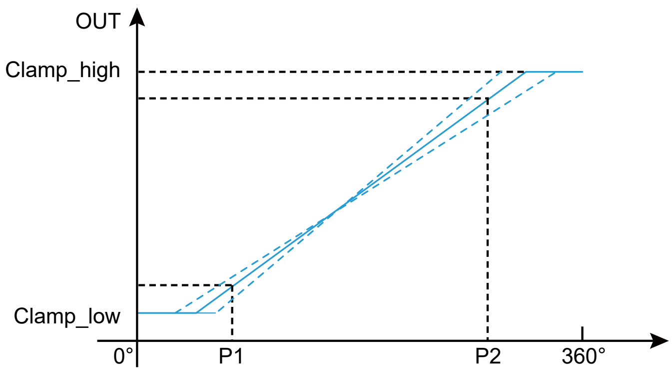


Figure 3. Analog voltage output (with clamp functions)

The analog output provides Clamp_low / Clamp_high level clamping function, which can be configured by customers according to the MCU input voltage requirements.

7.2 PWM Output

The TMR3365 supports pulse width modulation signal (PWM) output. PWM is a logic signal (duty cycle proportional to magnetic field angle) with a resolution of 12 bits. Figure 4 shows a cycle of the PWM signal, which contains 4119 minimum clock cycles. The entire cycle starts with a fixed high level of 16 minimum clock cycles and ends with a low level of 8 minimum clock cycles, with a total length of 12-bit angle data in the middle of 4095 minimum clock cycles.

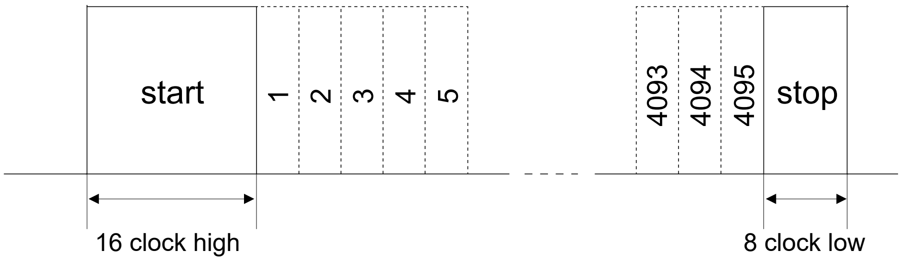


Figure 4. PWM output

The minimum clock cycle is programmable by the customer and is divided into 4 levels. The PWM output type can be set to push-pull or open-drain.

7.3 SENT Output

7.3.1 SENT Protocol

The TMR3365 SENT output is provided in compliance with SAE J2716 APR2010 protocol. The SENT protocol is defined by the minimum time unit Tick. The transmitted data is composed of Nibble (half byte). The nibble is 4-bit data encoded between two falling edges in the time domain level. It consists of 12 to 27 Ticks. Tick The number 12 to 27 defines the nibble data as 0x00 to 0x0F. The pulse transmission sequence of single frame data is shown in Figure 5.

- Synchronous calibration (Calibration/Synchronization): Synchronous calibration pulse composed of 56 ticks
- STATUS: Contains 2-bit serial information bits SM[1:0] and 2-bit status bits S[1:0]
- Data Nibble: The 1st to 3rd Nibble represents 12-bit angle output data
  The 4th to 5th Nibble represents the 8-bit cyclic rolling counter
  The 6th Nibble represents the complement of the 12-bit angle output [11:8]
- CRC check bit: 4bit CRC check code
- Pause: Pause pulse (this function can be disabled/enabled, and the pause duration can be configured)

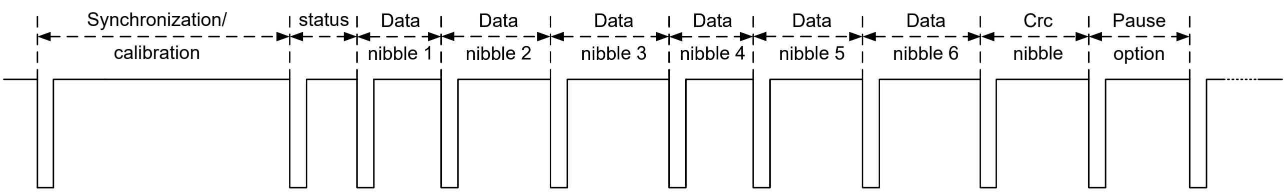


Figure 5. SENT protocol

Item	Description
Calibration	56 ticks check digits
Status	Status bit, used by enhance protocol
Nibble1	Angle_bit <11:8>
Nibble2	Angle_bit <7:4>
Nibble3	Angle_bit <3:0>
Nibble4	Roll_bit <7:4>
Nibble5	Roll_bit <3:0>
Nibble6	Angle_bit <11:8> complement
CRC	CRC check sum from Nibble1 to Nibble6
Pause	Pause (optional) to ensure consistency of SENT data frame length

Note: Angle_bit is a 12-bit absolute angle value

Roll_bit is an automatic count of SENT frames. It automatically adds 1 at the end of each frame and counts in a loop from 0 to 255.

CRC polynomial: $X^4 + X^3 + X^2 + 1$, initial value is 4’b0101

7.3.2 Enhanced SENT Protocol

The TMR3365 is compatible with the enhanced serial message format, which can be activated through register configuration. The serial data consists of bit3 and bit2 of the status bit. As shown in Figure 6, an enhanced model serial message contains 18 consecutive SENT message frames. When all 18 frames of SENT data are successfully received (without errors, no calibration pulse changes, no CRC check errors, etc.), forming an enhanced serial frame. When the status bit 3 appears 6 times "1" in a row indicates the beginning of the serial message frame.

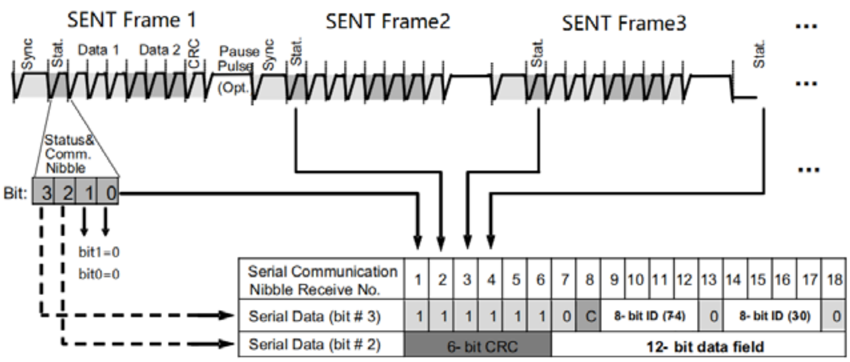


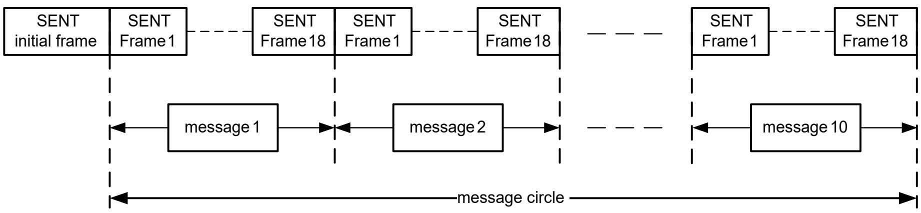
Figure 6. Enhanced SENT protocol

The enhanced SENT protocol message consists of an 8-bit message ID and a 12-bit message data. Message ID and message data complies with SAE J2716 APR2010 protocol. See the table below for specific instructions:

Message ID	Description	Message Data	Description
0x01	Diagnostic error code	0x820	Analog V_{DD} error
		0x840	Digital V_{DD} error
		0x800	No error
0x05	Manufacturer code	manufacturer code [11:0]	Manufacturer defined
0x29	Sensor ID1	sensor id1 [11:0]	Customizable
	Sensor ID2	sensor id2 [11:0]	
0x90	Customer code 1	OEM id1 [11:0]	Customizable
	Customer code 2	OEM id2 [11:0]	

Note: CRC polynomial: $X^6 + X^4 + X^3 + 1$, the initial value is 6’b010101

When the enhanced SENT mode of the TMR3365 is active, the message information is output in a loop as shown in Figure 7.



Message1 Message ID = 0x05 (manufacturer code)	Message6 Message ID = 0x01 (error diagnosis code)
Message2 Message ID = 0x01 (error diagnosis code)	Message7 Message ID = 0x90 (customer code 1)
Message3 Message ID = 0x29 (sensor ID1)	Message8 Message ID = 0x01 (error diagnosis code)
Message4 Message ID = 0x01 (error diagnosis code)	Message9 Message ID = 0x90 (customer code 2)
Message5 Message ID = 0x29 (sensor ID2)	Message10 Message ID = 0x01 (error diagnosis code)

Figure 7. Enhanced SENT protocol message output sequence

The tick cycle is user programmable, and the SENT output type can be set to push-pull or open-drain.

8. Piecewise Linear Calibration

TMR3365 has completed initial calibration before leaving the factory. In order to facilitate customers to compensate for non-linear errors caused by mounting, the sensor provides 5-point/17-point non-linear calibration functions and programmable angle measurement range functions. Customers can program and configure the linear interval, angle gain and output clamp parameter configuration according to demand.

8.1 5-Point Piecewise Linear Programming

The parameters of 5-point piecewise linear programming are clamp_high, clamp_low, 5P_a_x to 5P_d_x, 5P_a_y to 5P_d_y, slope0, slope_a to slope_d.

Customers can choose the appropriate 5P_a_x to 5P_d_x, 5P_a_y to 5P_d_y according to the actual angle detection range and calculate the corresponding slope. Rates slope0 and slope_a to slope_d are written into the sensor, and processed by the internal algorithm to optimize the nonlinearity and gain of the angle detection range.

The principle of TMR3365 5-point piecewise linear calibration is shown in Figure 8.

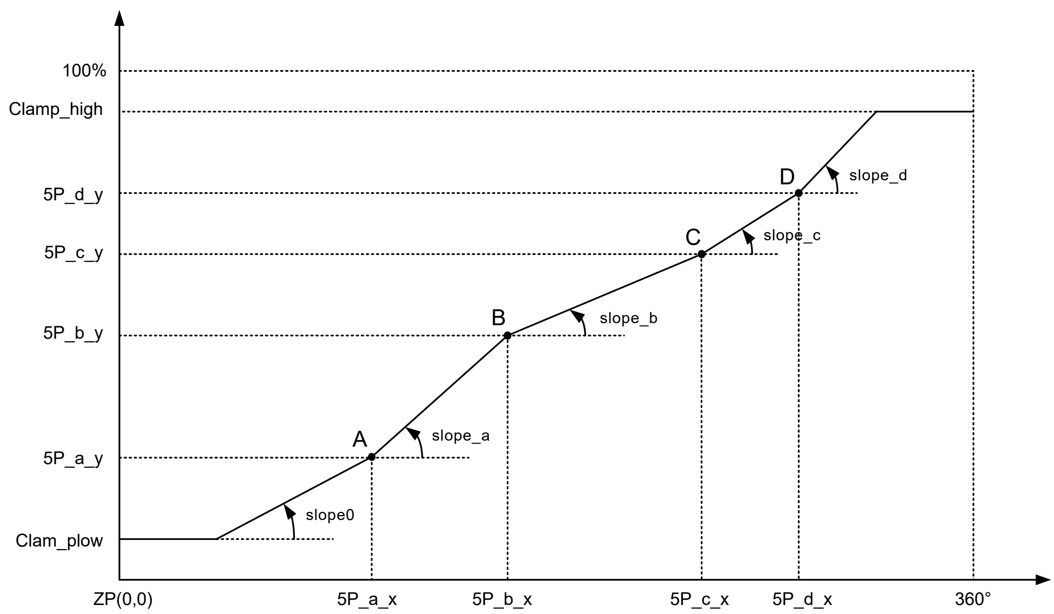
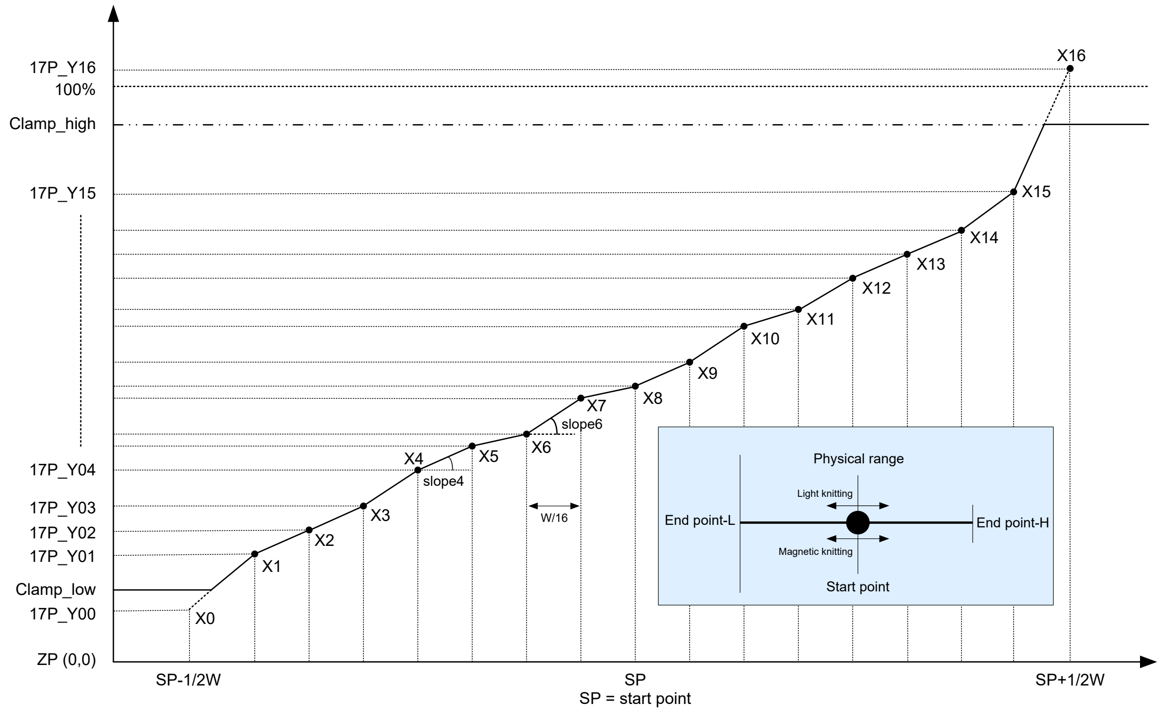


Figure 8. Schematic of 5-point calibration

8.2 17-Point Piecewise Linear Programming

The 17-point piecewise linear programming parameters are composed of Work_rang, Sp, clamp_high, lamp_ low, 17P_Y00 to 17P_Y16. Customers can determine the work_rang [11:0] and sp [11:0] parameters based on the actual angle detection range, and refer to the customer application manual to write into the EEPROM. Internal algorithm will optimize the nonlinearity and gain of the angle detection range.

The principle of TMR3365 17-point piecewise linear calibration is shown in Figure 9.



W = (4095 × 16) / work_range

Figure 9. Schematic 17-point calibration

9. Register List

EEPROM Definition	Description
zero_reg [13:0]	Set zero point
dis_error [2:0]	Disable/enable on error alarm
ccw	Set forward/reverse
owi_hys [4:0]	Set angle hysteresis
pwm_sel [1:0]	Select PWM output frequency
manufacturer code [11:0] sensor id1 [11:0] sensor id2 [11:0] OEM id1 [11:0] OEM id2 [11:0]	SENT message output message
Pause	Disable/enable SENT pause func-tion
Protocol	Disable/enable SENT enhanced function
pause length [9:0]	Set pause length
tick_accuracy [8:0]	Set tick time
lnr_type	5-point piecewise linear calibration
	17-point piecewise linear calibration
mode_sel [3:0]	Select output mode (analog/sent/pwm)
5p_a_x [11:0]........5p_a_d [11:0] 5p_a_y [11:0]........5p_a_y [11:0] slope_0 [11:0]........slope_d [11:0]	5-point piecewise linear calibration parameters
work_rang [11:0] sp [11:0] 17P_Y00 [11:0]........17P_Y05 [11:0]	17-point piecewise linear calibration parameters
clamp_high [11:0] clamp_low [11:0]	Set clamp voltage

10. Functional Safety Manual

A functional safety manual for the TMR3365 is provided to meet user needs. This manual details various alarm mechanisms and self-diagnostic functions that safeguard the reliability of the TMR3365, ensuring that the sensor promptly addresses and responds to specific failure causes. This proactive approach prevents the sensor from emitting erroneous signals that could impact its usage.

In most instances, when the sensor enters a fault mode, it can return to normal state once when the factors that triggered the failure disappear. However, there are scenarios where the sensor requires a power cycle to regain its normal functionality. An example of this is when an error occurs during the loading of data from the EEPROM into the register.

In case of such errors, the fault code will persist until the sensor is restarted, and the data from the EEPROM is correctly loaded. Below, we will outline the TMR3365's error code alarm and self-diagnostic functions.

Diagnostic alarm register

Alarm register bit sequence number	Description
0	Angle calculation error
1	Magnetic field exceeds limit
2	EEPROM data error
3	Any error above

Diagnosis alarm output and recovery conditions

Alarm Conditions	Alarm Output Method	Recovery Mechanism
Angle calculation error	Analog / PWM / SENT / OWI	Automatic reset upon angle output
Magnetic field exceeds limit	OWI	Failure condition ends
EEPROM data error	OWI	Power cycle
Any error above	OWI	All alarms disarmed
Abnormal power supply of sensor analog circuit	SENT	Failure condition ends
Abnormal power supply of sensor digital circuit	SENT	Failure condition ends

11. Typical Application

The reference circuit is shown in Figure 10. The NC pin connects to GND, and an external decoupling capacitor C1 (typical value 100nF, not exceeding 220nF) is connected, which should be placed as close as possible to the V_{DD} and GND pins. A filtering capacitor C2 connecting to the OUT pin can be 10nF (or selected by the customer).

R1, R2, C3, and C4 are to be selected by the customer based on actual needs.

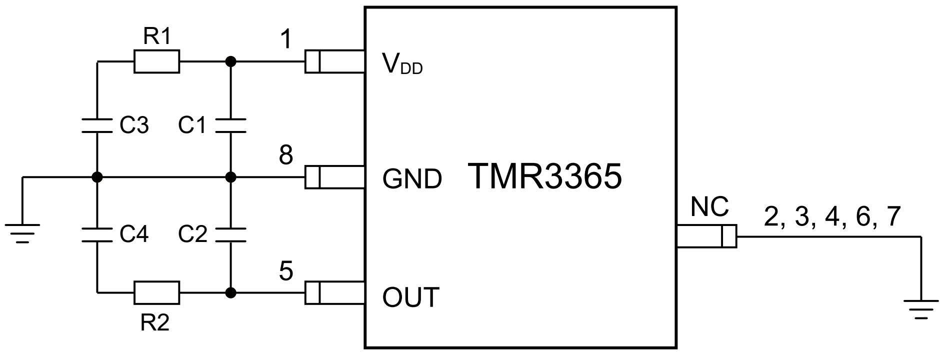


Figure 10. Typical application diagram

To facilitate customer use, MDT can offer the "TMR336x Demonstration Board" along with host software, which allows for the setting of output modes, parameter configuration, and operation of piecewise linear calibration functions.

12. Mechanical Angle Orientation

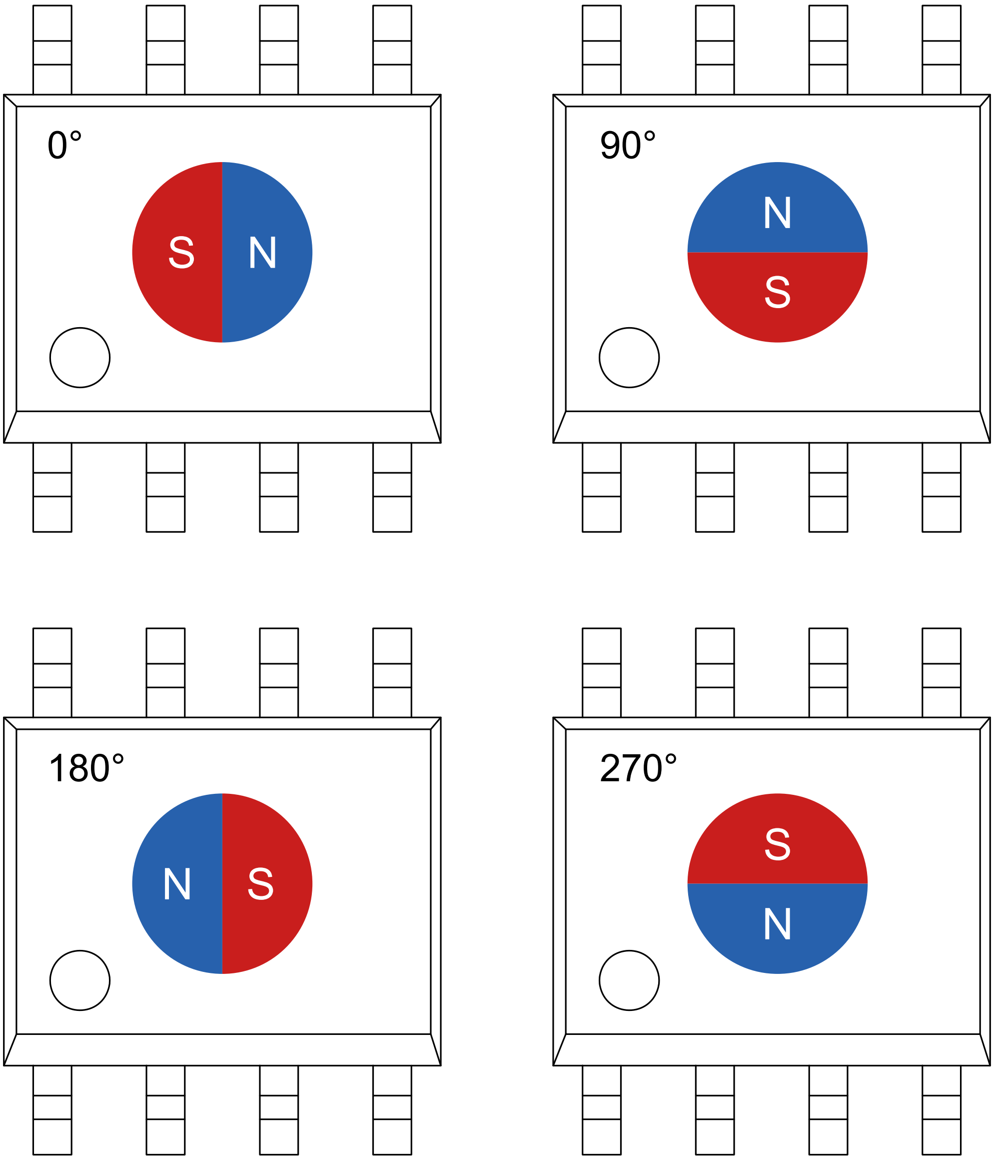


Figure 11. Definition of the magnetic field orientation measured by TMR3365 (top view)

13. Dimensions

SOP8 Package

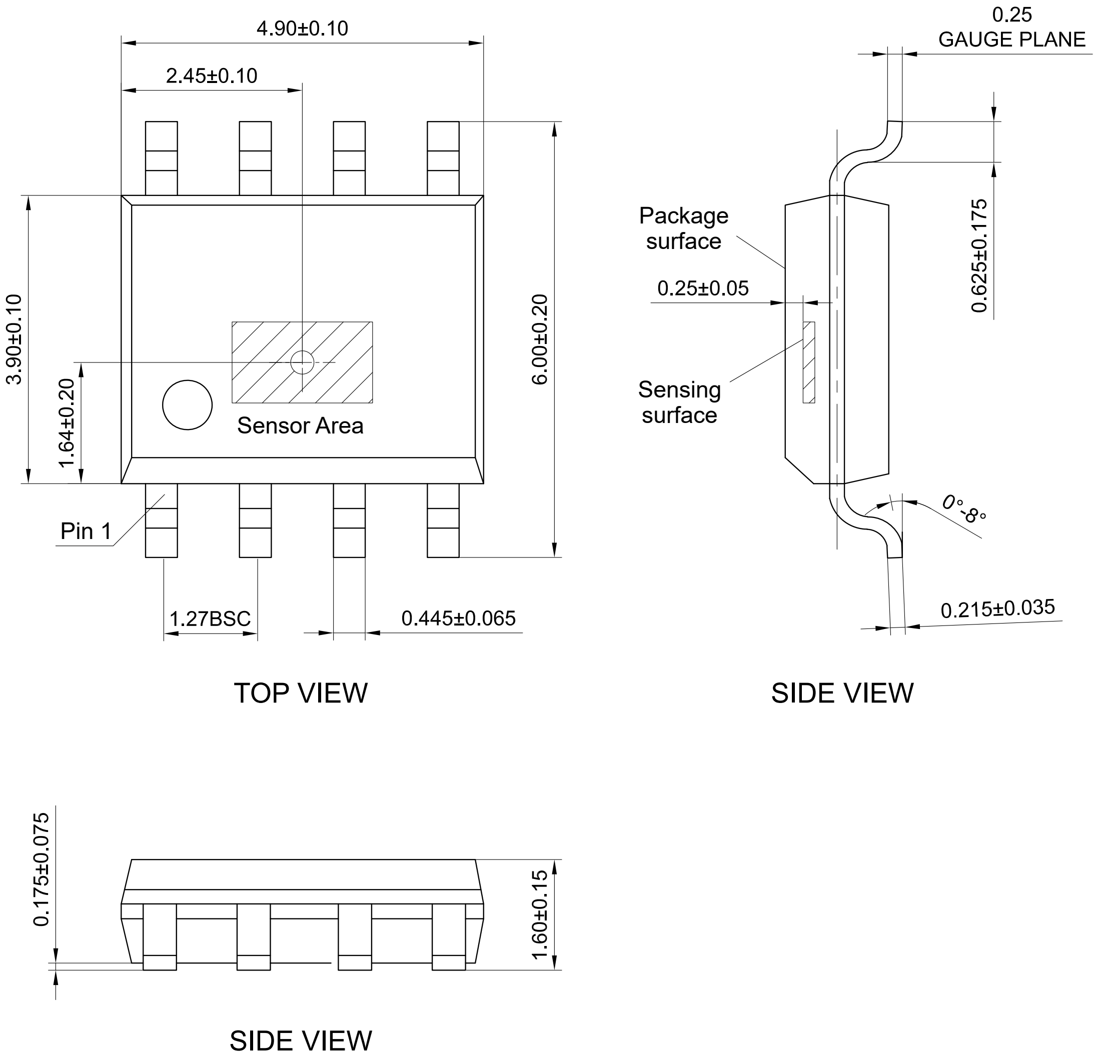


Figure 12. Package outline of SOP8 (unit: mm)

Absolute maximum ratings are the extreme limits the device will withstand without damage to the MDT product. However, the electrical and mechanical characteristics are not guaranteed as the maximum limits (above recommended operating conditions) are approached. MDT disclaims any and all warranties and liabilities of the MDT product will operate at absolute maximum ratings.

Specifications may change without notice.

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Recycling

The product(s) in this document need to be handed over to a qualified solid waste management services company for recycling in accordance with relevant regulations on waste classification after the end of the product(s) life.

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