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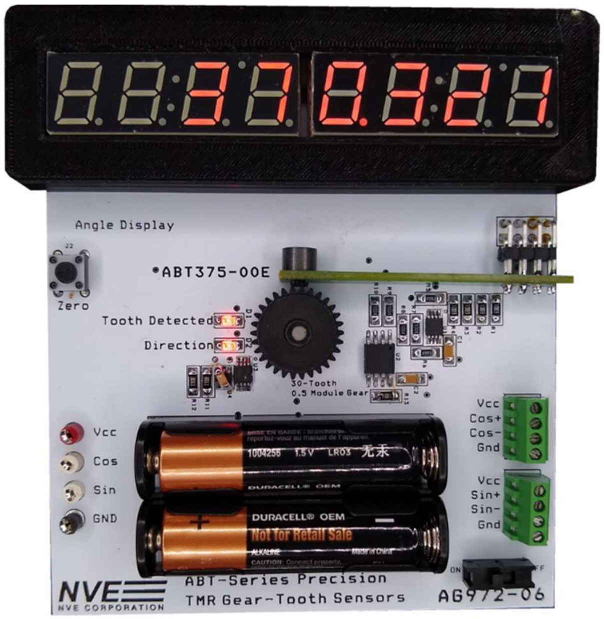
AG972-07E

ABT375-00E Precision TMR Gear-Tooth Sensor Demonstration



SB-00-141

Overview

The demonstration includes:

- ABT375-00E TMR Gear-Tooth Sensor with 0.375 mm element spacing
- NVE part number 12217, ceramic C8 back-biasing magnet
- 0.5 module carbon steel gear with low-friction ball bearing
- Low-cost dual op-amp and microcontroller interface
- Eight-digit LED micron display
- Simple analog tooth and direction detection circuit with LED indicators
- Sensor test points and screw terminals
- 3.5" (89 mm) x 4" (102 mm) printed circuit board
- Two AAA batteries to power the board

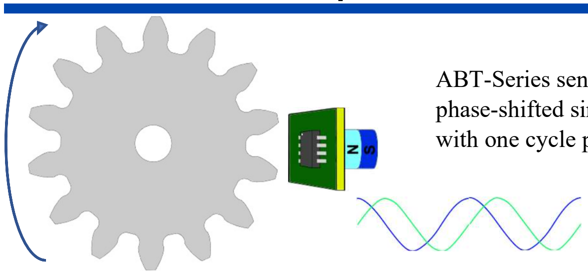
ABT375-00E Features:

- 400 mVpp/V typical max output
- Low noise, up to 0.001° resolution
- High Accuracy: 1% typical hysteresis / 1% typical linearity
- −40 °C to 150 °C
- Miniature 3 x 3 mm MSOP8 package

Quick Start

➔ Turn on the power and rotate the gear
➔ Observe the signed, multiturn angular display, from -9999.999 to 99999.999
➔ Press the zero button to set the index angle

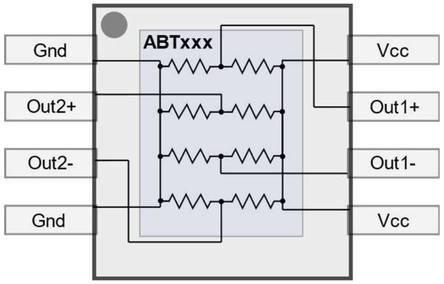
Sensor Operation and Structure



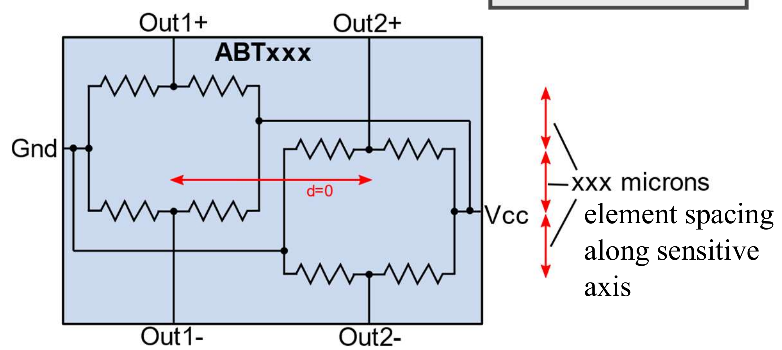
ABT-Series sensors produce phase-shifted sinusoidal outputs with one cycle per tooth

The ABT375 is an ultraprecise gear-tooth sensor that detects the periodic magnetic fields produced by magnetized gear teeth. The gear teeth are magnetized by fixing a back-biasing ceramic magnet symmetrically behind the sensor. The sensor is single-axis sensitive, and its spaced TMR elements are optimized for 1.5 mm pole pitch.

The ABT-Series GT Sensors consist of two Wheatstone bridges wired with common Vcc and GND.



The structure is equivalent to four half-bridge magnetometers, equally spaced from the center of the package by a distance known as the 'element spacing'.



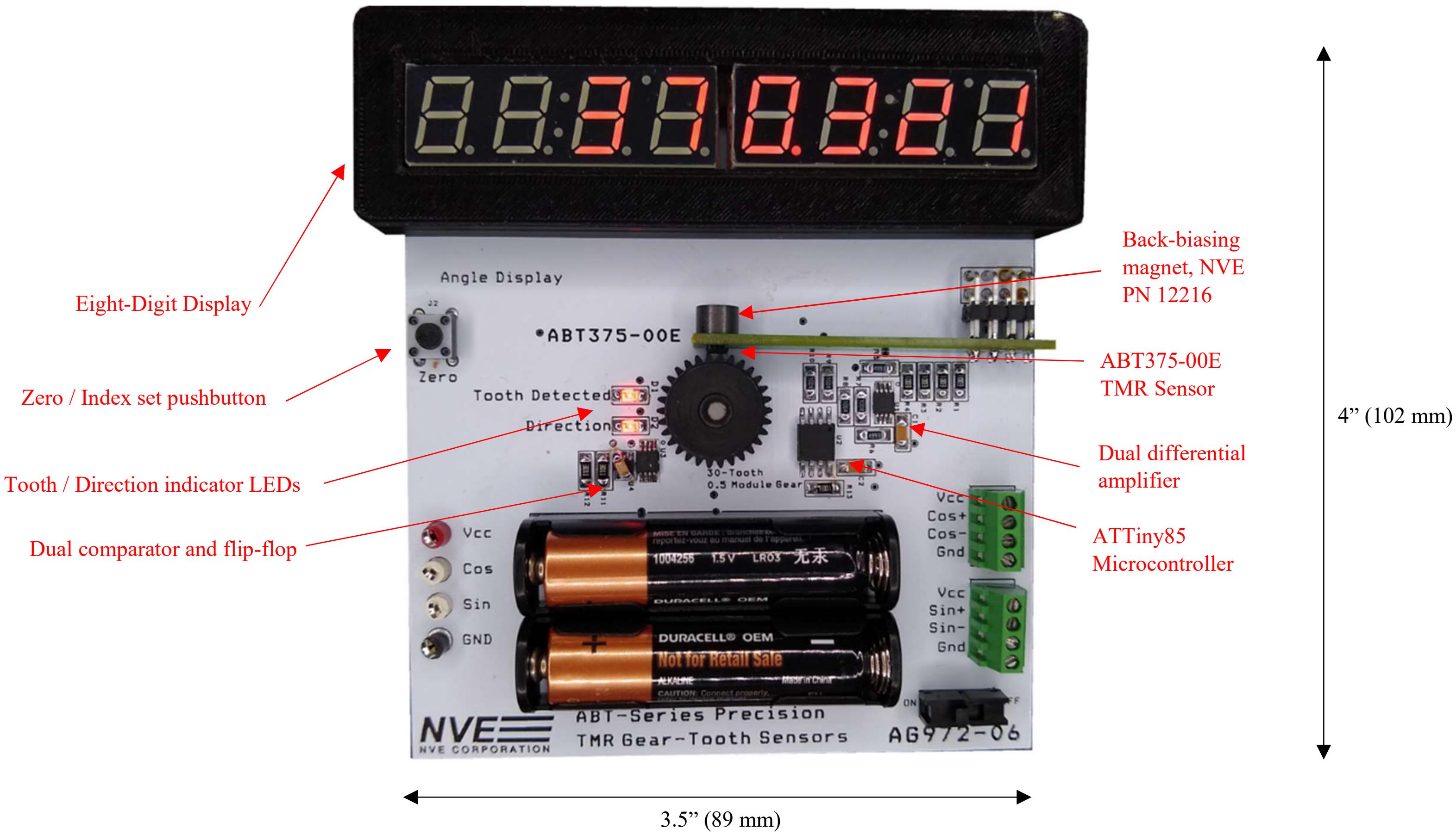
When a magnetic field gradient is swept along the sensor's sensitive axis, the four half-bridges produce identical, phase-shifted outputs corresponding to the pitch of the field gradient. In the case of a gear, the phase-shifted magnetic field is due to the gear-tooth pitch:

$$\text{Half-Bridge Phase Shift} = 360 \cdot \left(\frac{\text{Element Spacing}}{\text{Gear Pitch}}\right)$$

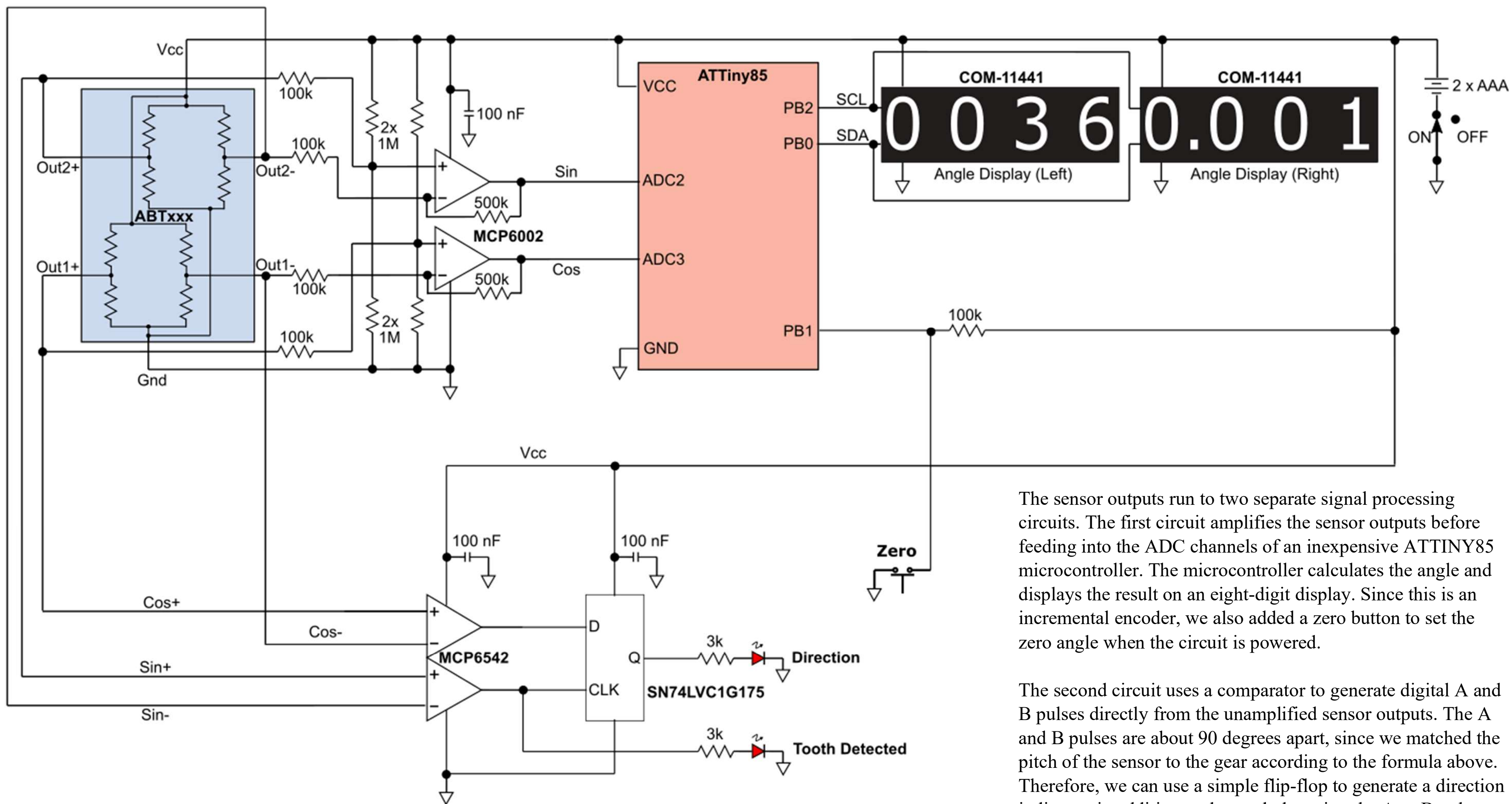
When the gear pitch is one-fourth the element spacing, the four half-bridge outputs are each 90 degrees out of phase. In this case, Out1 and Out2 are fully differential Wheatstone bridge outputs, since the phase shift between Out1+, Out1- is 180 degrees (and likewise for Out2).

In this demonstration, we're detecting a 0.5 module (1.57 mm pitch) gear. The half-bridge phase shift is therefore $360 \cdot \left(\frac{0.375}{1.57}\right) = 86°$. In this case, the phase error is small enough to be ignored, so we treat Out1 and Out2 as fully differential sine and cosine signals to calculate the angular position

Demonstration Board Layout (Actual Size)



Demonstration Board Schematic



The sensor outputs run to two separate signal processing circuits. The first circuit amplifies the sensor outputs before feeding into the ADC channels of an inexpensive ATTINY85 microcontroller. The microcontroller calculates the angle and displays the result on an eight-digit display. Since this is an incremental encoder, we also added a zero button to set the zero angle when the circuit is powered.

The second circuit uses a comparator to generate digital A and B pulses directly from the unamplified sensor outputs. The A and B pulses are about 90 degrees apart, since we matched the pitch of the sensor to the gear according to the formula above. Therefore, we can use a simple flip-flop to generate a direction indicator, in addition to the tooth detection the A or B pulse gives us.

Microcontroller Firmware

AG972-Gear-Tooth-Encoder | Arduino 1.8.10

File Edit Sketch Tools Help

AG972-Gear-Tooth-Encoder §

```
#include <math.h> // needed for atan2
#include <Wire.h> // Arduino library for I2C
const byte s7sAddressR = 0x71; //right display I2C address
const byte s7sAddressL = 0x50; //left display I2C address
char tempString[10]; // Will be used with sprintf to create strings
int sine=1; // initialized to 1 to avoid 0/0
int cosine=1;
long angle=1;
long oldangle=1;
long anglezero=0;
long toothnumber=0;

void setup()
{
  Wire.begin(); // Initialize hardware I2C pins

  Wire.beginTransmission(s7sAddressR); // Clears right display, resets cursor
  Wire.write(0x76); // Clear display command
  Wire.endTransmission();

  Wire.beginTransmission(s7sAddressL); // Clears left display, resets cursor
  Wire.write(0x76); // Clear display command
  Wire.endTransmission();

  Wire.beginTransmission(s7sAddressR); // set decimal for 1/1000 degree resolution
  Wire.write(0x77); // decimal control command
  Wire.write(0x01); // set thousandths decimal point
  Wire.endTransmission();
}
```

The firmware is simple. We read the sine and cosine signals and calculate the angle, scaling the -180 to 180° atan2 output to 12,000 counts per tooth. We're using two four-digit displays in parallel via I2C to get resolution to thousandths of a degree.

AG972-Gear-Tooth-Encoder | Arduino 1.8.10

File Edit Sketch Tools Help

AG972-Gear-Tooth-Encoder §

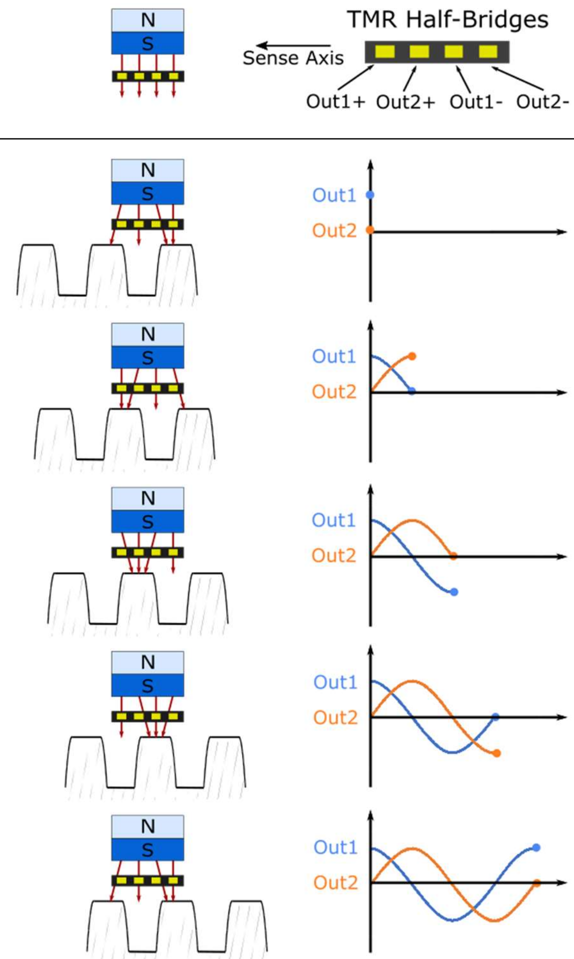
```
void loop()
{
  sine = analogRead(A2)-512; // read sine and cosine and calculate the angle
  cosine = analogRead(A3)-512;
  angle = atan2(sine,cosine)*180/3.14159*12000/360+6000; // 30-tooth gear => 12,000 thousandths/tooth
  angle = (long) angle;

  if(angle-oldangle>11000) // routine to detect transition to a new tooth
    toothnumber--;
  if(angle-oldangle<-11000)
    toothnumber++;
  oldangle=angle;

  angle=angle+12000L*toothnumber; // for counting multi-tooth, multi-turn

  if(digitalRead(1)==LOW) // zero the display when the zero button is pushed
    anglezero=angle;
  angle=angle-anglezero;

  sprintf(tempString, "%8ld", angle); //create string for display (%8ld creates an 8-digit signed long)

  Wire.beginTransmission(s7sAddressL); //display four most significant digits on the left display
  for (int i=0; i<4; i++)
    Wire.write(tempString[i]);
  Wire.endTransmission();

  Wire.beginTransmission(s7sAddressR); //display four least significant digits on the right display
  for (int i=4; i<8; i++)
    Wire.write(tempString[i]);
  Wire.endTransmission();
}
```

A conditional statement looks for transitions to the next tooth and tracks them, allowing us to count multiple turns. There's a simple routine to reset the displayed angle when the "zero" button is pressed.

Bill of Materials

Reference	Manufacturer	Part Number	Description
N/A	NVE Corporation	ABT375-00E	SENSOR TMR GEAR TOOTH 8MSOP
U1	Microchip Technology	MCP6002	IC OPAMP GP 2 CIRCUIT 8MSOP
U2	Microchip Technology	ATTiny85	IC MCU 8BIT 8KB FLASH 8SOIC
U3	Microchip Technology	MCP6542	IC COMP PUSHPULL 1.6V DUAL 8MSOP
U4	Texas Instruments	SN74AUP1G79DBVR	IC FF D-TYPE SNGL 1BIT SOT23-5
R1, R2, R3, R4, R13	N/A	Generic	RES SMD 100K OHM 1% 1/8W 1206
R5, R6	N/A	Generic	RES SMD 499K OHM 1% 1/8W 1206
R7, R8, R9, R10	N/A	Generic	RES SMD 1M OHM 1% 1/8W 1206
R11, R12	N/A	Generic	RES SMD 3K OHM 1% 1/8W 1206
C1, C2, C3, C4	N/A	Generic	CAP CER 0.1UF 50V X7R 0805
D1, D2	Kingbright	APT3216LSECK/J3-PRV	LED CLEAR CHIP 2SMD
	Keystone Electronics	500x	PC TEST POINT COMPACT
	TE Connectivity	282834-4	TERM BLK 4P SIDE ENT 2.54M M
	E-Switch	EG1218	SWITCH SLIDE SPDT 200MA 30V
	Keystone Electronics	2466	BATTERY HOLDER AAA PC PIN
	Energizer Battery Company	EN92	BATTERY ALKALINE 1.5V AAA
	Sparkfun Electronics	COM-11441	ADDRESS LED 7 SEG I2C RED
	TE Connectivity ALCOSWITCH Switches	1825910-6	SWITCH TACTILE SPST-NO 0.05A 24V
N/A	NVE Corporation	12216	MAGNET 6MM DIA 4MM THICK

Gear-Tooth Sensor Magnetic Operation



Cycling gear teeth create a sinusoidally varying field pattern from a fixed bias magnet. The ABT-Series sensors operate on this principle by detecting the tangential field gradient. For more information about AET-Series operation, read the datasheet and visit the sensor applications page:

www.nve.com/Downloads/ABT-Series-Datasheet.pdf
www.nve.com/SensorApps.php