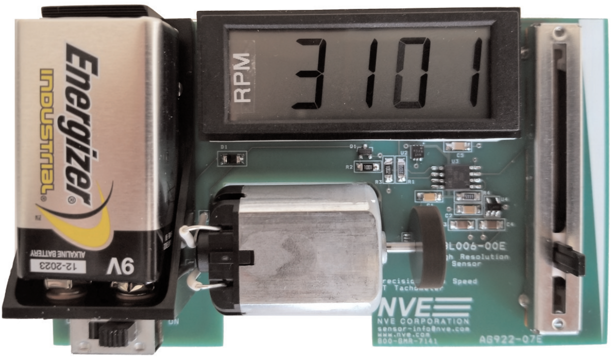
AG922-07E
Precision High-Speed "Tiny Gear" Tachometer Demonstration



SB-00-096

Overview

This demonstration board shows how to detect tiny gear teeth at high speed with ***GT Sensor***™ Precision Gear Tooth Sensors.

The demonstration gear has a submillimeter pitch, which demands a sensitive sensor. It also demands a high-speed sensor, since the gear has 56 teeth, so at 10,000 RPM, there are nearly 10,000 teeth per second.

This Demo includes a 4.5 by 2.63-inch (114 by 67 mm) circuit board with:

- a 56-tooth, 0.83 mm pitch (0.26 mm module) gear
- an ABL006-00E 0.3-mm element MSOP Precision Gear Tooth Sensor
- a low-cost ferrite disk bias magnet
- a low-cost comparator to detect sensor zero crossings
- a preprogrammed, onboard microcontroller
- a high-speed DC motor with speed control
- a digital meter to display the sensor-detected motor RPM
- a nine-volt battery to power the demonstrator

The 0.3-mm sensor element spacing makes it ideal for fine-tooth gears. ABL-Series Sensors are also available with other element spacings, and with dual bridges to provide direction and speed information.

These sensors use high-sensitivity, low-hysteresis GMR to detect even the smallest ferromagnetic gear teeth with wide airgap and temperature tolerances. Two sensor elements spaced a precise distance apart are arranged as a Wheatstone bridge.

Key ABL-Series features include:

- Large signal
- Single- and dual-bridge versions
- Up to 1 MHz operating frequency
- 0 to 30 volt supply
- 150°C operating temperature
- MSOP8 and ultraminiature 2.5 mm x 2.5 mm TDFN6 packages

Visit **www.nve.com** for complete product specifications.

Demonstrator Operation

⇒ Ensure the 9 volt battery is installed.

⇒ Turn the demonstrator ON
(slide to the right).

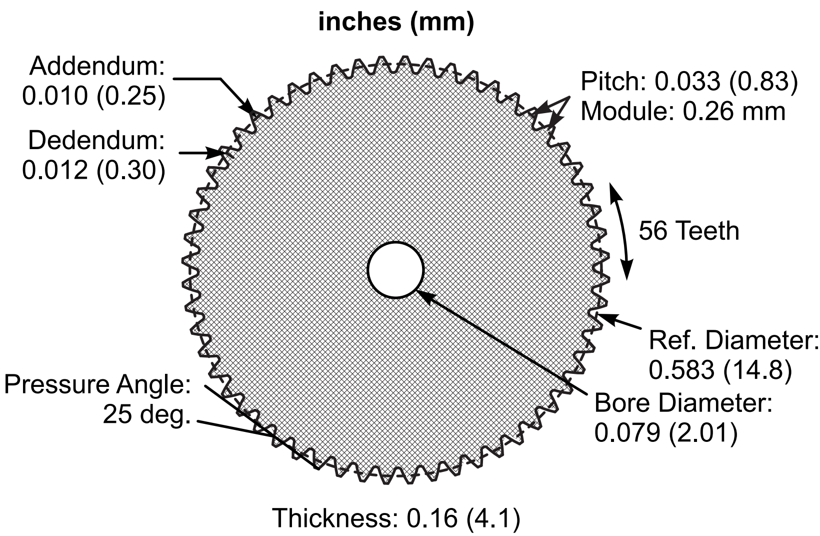
⇒ Adjust the motor speed using the slide control.

⇒ Observe the motor speed as detected by the sensor and calculated by the microcontroller on the meter.

⇒ Turn the demonstrator OFF when not in use to preserve battery life.

8380 RPM

The Demonstrator Gear



Visit **nve.com** or **YouTube/NveCorporation** for a demonstration.

Magnetic Design

Magnetic Design Considerations

The optimum GT Sensor™ design depends on several factors, which can be simplified using a few rules of thumb.

Choosing a GT Sensor

With three options for element spacings, ABL-Series GT Sensors can accommodate almost any size gear. Proper choice of element spacing maximizes the output signal. A rule of thumb starting point is an element spacing one-fourth the gear pitch.

Part No.	Element Spacing	Recommended Gear Pitch
ABL004	1 mm	2.5 to 6 mm
ABL005	0.5 mm	1.5 to 2.5 mm
ABL006	0.3 mm	0.6 to 1.5 mm

Sensor-to-Gear Airgap

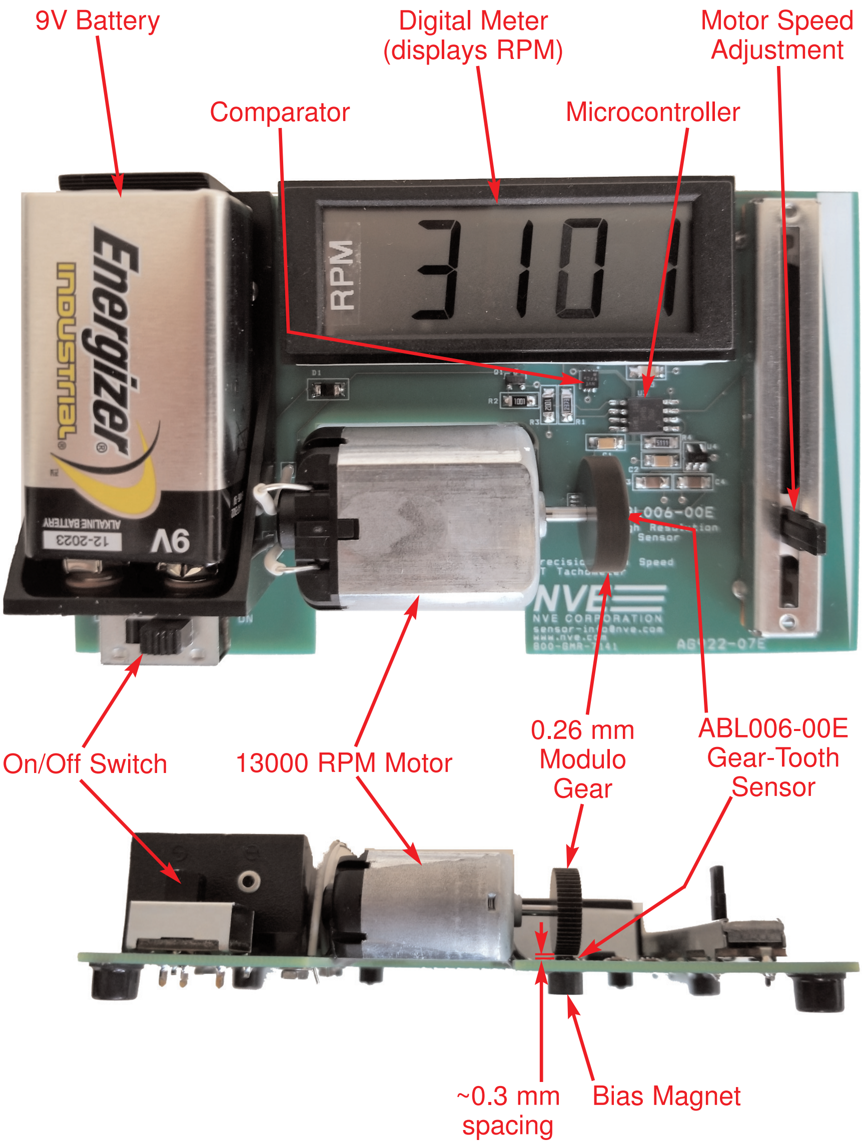
The sensor to gear airgap is determined by the size of the gear teeth, which sets the length scale of the magnetic flux distribution. As a guideline for spur and timing gears, the maximum airgap is approximately equal to the gear pitch.

Bias Magnet Selection

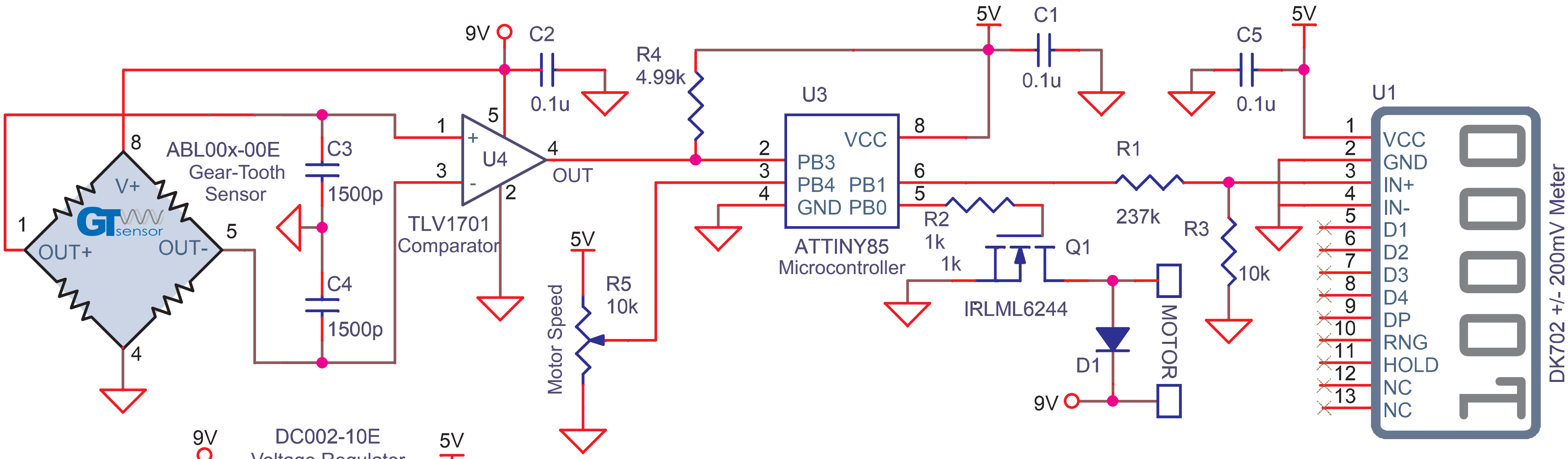
In most applications, a small inexpensive disk magnet on the back of a 1.5 mm PCB is ideal. NVE offers two magnets options: 6 mm diameter by 4 mm thick (part number 12216), and 3.5 mm diameter by 4 mm thick (part number 12217). We generally do not recommend rare-earth magnets since they tend to saturate the sensors.

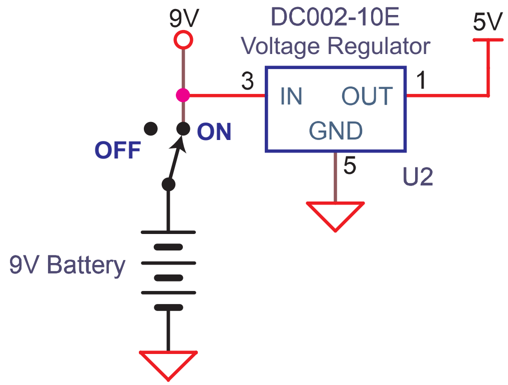
NVE engineers are experts in GT sensing and are eager to help.
E-mail sensor-apps@nve.com for help optimizing your application.

Demonstrator Components



Schematic Diagram





Part Number	Manufacturer	Reference Designator	Description
ABL006-00E	NVE Corporation	-	GMR GT Sensor
12216	NVE Corporation	-	Ferrite Disk Magnet, 6 mm dia. x 4
DC002-10E	NVE Corporation	U2	5V High Temp Regulator
DK702	C-Ton Industries	U1	Panel Voltmeter 200mVDC
PTA4543-2010CIB1	Bourns Inc.	R5	Slide Potentiometer 10kOhm
EN22	Energizer	-	9V Battery
BH9VPC	Memory Protection	-	9V Battery Holder
GF-124-0196	CW Industries	-	Slide Switch SPDT
IRLML6244TRPBF	Infineon	Q1	MOSFET N-CH 20V 6.3A SOT-23
TLV1701AIDBVR	Texas Instruments	U4	Comparator SOT23-5
PAN14EE12AA1	NMB Technologies	-	DC Motor 12850 RPM 12V DC
SD1206S100S1R0	AVX Corporation	D1	Schottky Diode 100V 1A 1206
ATTINY85-20SUR	Microchip	U3	Microcontroller
RMCF1206FT237K	Stackpole Electronics	R1	Resistor 237k Ohm 1% 1/8W 1206
RMCF1206FT1K00	Stackpole Electronics	R2	Resistor 1k Ohm 1% 1/8W 1206
RMCF1206FT10K0	Stackpole Electronics	R3	Resistor 10k Ohm 1% 1/8W 1206
RMCF1206FT4K99	Stackpole Electronics	R4	Resistor 4.99k Ohm 1% 1/8W 1206
-	Generic	C1, C2, C5	Bypass Capacitor 0.1uF
-	Generic	C3, C4	Filter Capacitor 1500pF

Electrical Operation

Sensor Output

The gear tooth sensor provides a sinusoidal output corresponding to the position of each gear tooth, with frequency of one cycle per tooth. Capacitors C3 and C4 provide a low-pass filter to improve the signal-to-noise ratio. The typical sensor bridge resistance is 5 kΩ, so the output impedance of each output is approximately 2.5 kΩ, and the 1500 pF filter capacitors provide a cutoff frequency of approximately 42 kHz.

Comparator

The comparator (U4) detects the sensor differential output zero crossings, corresponding to when the bridge is balanced over a tooth or gap. The comparator output is a square wave with one cycle per tooth. Because of the sensor's large signal, no preamplifier is required and a low-cost comparator can be used. A pullup resistor (R4) is used with the open-collector comparator. In some cases the sensor can be connected directly to a microcontroller comparator or analog input.

Motor Control

The speed adjustment potentiometer (R5) is read as an analog input by the microcontroller. The microcontroller generates a PWM output (PB0) proportional to the potentiometer setting. The MOSFET (Q1) drives the motor with the PWM output, and a Schottky diode (D1) protects against inductive surges.

RPM Readout

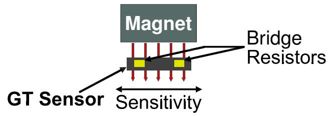
The microcontroller (U3) measures the time between gear teeth and calculates the motor RPM. The microcontroller generates a PWM output (PB1) proportional to the calculated speed to drive the meter (U1). A voltage divider (R1, R3) scales the output for the 200 mV meter range (0.01 mV/RPM).

Power Supplies

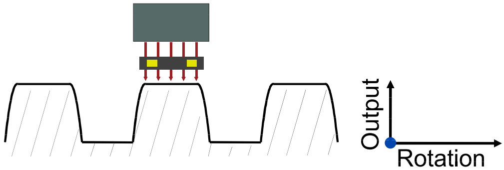
The motor and sensor are powered directly by the battery. A five-volt regulator (U2) powers the microcontroller and meter. A nine-volt battery is used for convenience, but the sensor power supply can be as high as 30 volts, and the The regulator and comparator in this demonstration are rated at 36 volts. The DC002-10E regulator is also rated to 170°C, complementing the sensor's high operating temperature range (150°C).

Magnetic Operation

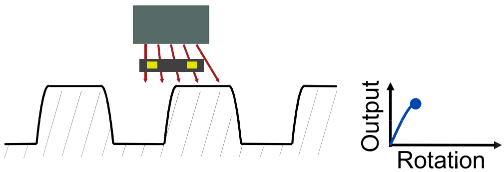
As shown at right, the sensor includes two spaced sensor elements. A bias magnet provides magnetic field.



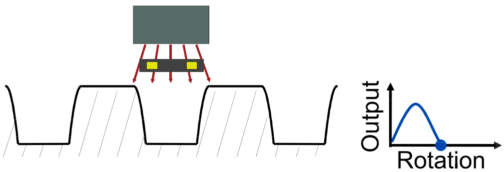
The sensor elements form a Wheatstone bridge, which is balanced for zero output when centered over a gear tooth.



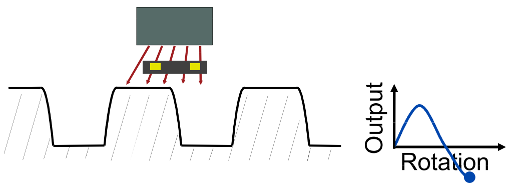
As the gear turns, the magnetic flux lines are deflected into the direction of sensitivity by passing steel gear teeth. This unbalances the sensor, generating a differential output.



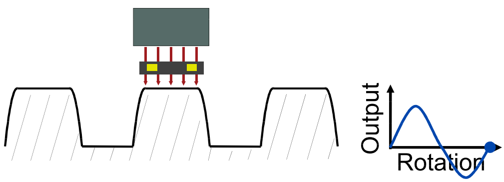
The sensor output returns to zero when centered over a gap.



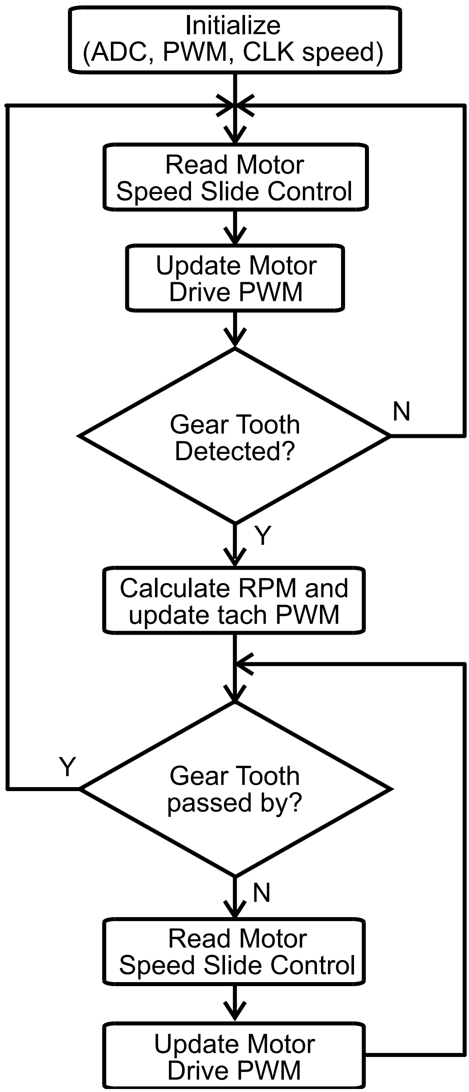
The sensor output reverses polarity as the tooth passes the sensor.



The sensor output is sinusoidal, with one cycle per tooth.



Demonstrator Flowchart



Demonstrator Software

```
#include <avr/power.h>
// defines for setting and clearing register bits
#ifndef cbi
#define cbi(sfr, bit) (_SFR_BYTE(sfr) &= ~_BV(bit))
#endif
#ifndef sbi
#define sbi(sfr, bit) (_SFR_BYTE(sfr) |= _BV(bit))
#endif
int motorPWM = 0; //potentiometer motor speed control input
unsigned long currentTime = 0; //Timer of most recent zero-crossing
unsigned long oldTime = 0; //Timer of previous zero-crossing
unsigned long period = 0; //Time between revolutions
int RPM = 0; //Scaled RPM for tach PWM output;
void setup()
{
   //set system CLK to 16 MHz
   if (F_CPU == 16000000)
      clock_prescale_set(clock_div_1);
   //set pin data directions
   sbi(DDRB,DDB0);
   sbi(DDRB,DDB1);
   cbi(DDRB,DDB2);
   cbi(DDRB,DDB4);
   //initialize ADC to PB4
   sbi(ADCSRA,ADEN);
   sbi(ADMUX,MUX1);
   // set the ADC prescalar to 16
   cbi(ADCSRA,ADPS2) ;
   sbi(ADCSRA,ADPS1) ;
   cbi(ADCSRA,ADPS0) ;
   //set output compare mode to inverting PWM (allows for 0% duty cycle)
   sbi(TCCR0A,COM0A1);
   sbi(TCCR0A,COM0B1);
   sbi(TCCR0A,COM0A0);
   sbi(TCCR0A,COM0B0);
   //turn on fast PWM mode
   sbi(TCCR0A,WGM01);
   sbi(TCCR0A,WGM00);
   //set Timer/Counter0 prescalar
   sbi(TCCR0B,CS01);
   sbi(TCCR0B,CS00);
   //initialize PWM outputs to 0 (255 = 0 for inverting PWM)
   OCR0A = 255;
   OCR0B = 255;
}
void loop()
{
   sbi(ADCSRA,ADSC); //start ADC conversion to read motor speed
   while(!(ADCSRA & 1<<ADIF)); //wait until conversion is complete
   motorPWM=ADCL|(ADCH<<8); //store the result
   OCR0A=255-motorPWM/4; //update the motor drive PWM output on PB0
   if(PINB & 0x08) // calculate RPM if a gear tooth is detected
   {
      currentTime = micros(); //note Timer/Counter0 needs to be 64 for micros() to be correct
      period = currentTime-oldTime;
      oldTime = currentTime;
      RPM=60000000/period*255/20000/56; //RPM=60E6/period; 255=PWM FS; 20000 RPM=meter FS
      if (RPM < 1||RPM > 255) //avoid overflow
         RPM = 0;
      OCR0B = 255-RPM; //update the tach PWM output on PB1
      while(PINB & 0x08) //wait until the gear tooth passes by to restart the loop
      {
         sbi(ADCSRA,ADSC); //start ADC conversion to read motor speed
         while(!(ADCSRA & 1<<ADIF)); //wait until ADC conversion is complete
         motorPWM=ADCL|(ADCH<<8); //store the result
         OCR0A=255-motorPWM/4; //update the motor drive PWM output on PB0
      }
   }
}
```

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