BULLETIN 1101

Magnetic Pickups

For speed and position control

NON-CONTACT · SELF-POWERED · ACCURATE SPEED/FREQUENCY CONVERSION · HIGH RELIABILITY · LOW COST · HIGH ADAPTABILITY IN FORM, PERFORMANCE, AND OPERATING ENVIRONMENT

tsi

TRANSDUCER SYSTEMS, INC.

Broadly applicable sensors...motion, position, speed

Cams, gears, shafts with keyways, slotted computer memory discs, pulleys with notches or cutouts—in operation, all these items rotate, spin, or otherwise move in regular or periodic motion. Their indentations or protrusions often serve as actuators for variable-reluctance magnetic pickups.

In motion, these and other rotating, sliding, or oscillating mechanisms supply the kinetic energy which enables the magnetic pickup to function. In return, the pickup gives a voltage output as each actuator passes it. Information extrapolated from output pulse amplitude, number, and frequency is then used to determine position, or linear or rotational velocities, or other essential motion-related data.

Variable-reluctance pickups provide non-contact sensing. Actuator motion remains free from interference. Being passive components, pickups require no outside power source to produce their electrical pulses. With no moving parts, they give reliable performance over long and maintenance-free service lives. And these components are as versatile as the names they go by; pickups, speed and position sensors, pulse generators, crankshaft position sensors, sync and timing sensors...

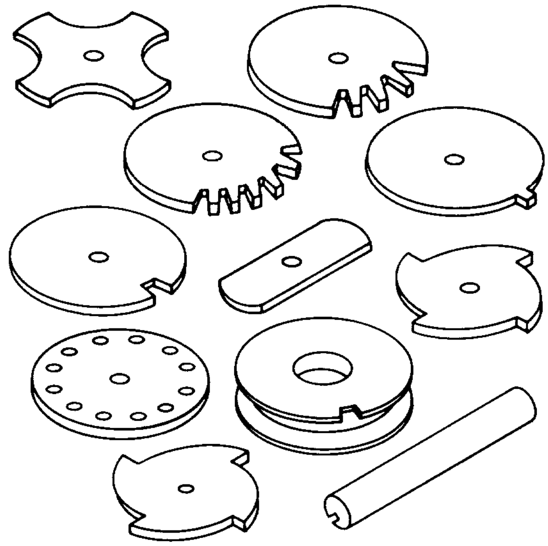


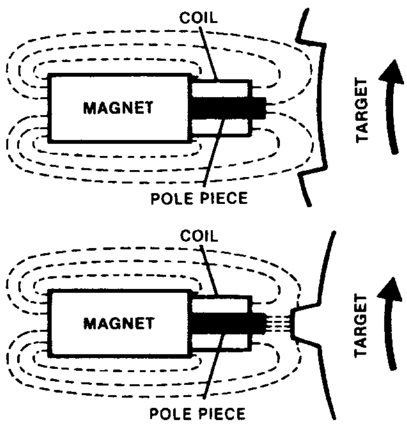
FIGURE 1 Magnetic pickup actuating mechanisms

Variable reluctance—how the pickup works

A permanent magnet inside the sensor projects a magnetic field to the area immediately in front of the sensor pole piece.

high-reluctance magnetic circuit

FIGURE 2



low-reluctance magnetic circuit

Any ferromagnetic (carbon steel, magnetic stainless steel, iron) actuator moving through this area, or suddenly leaving it, alters the reluctance state and produces a voltage output (see figure 2).

Provided the actuator passes through the sensing area with sufficient speed (generally >100 ips), the sensor generates an electrical pulse of useful level, proportional in amplitude to the speed of the actuator, and highly analogous in waveform to actuator shape. Output frequency, resulting from a rapid succession of passing actuators, is a particularly useful value for speed control, with the upper range for distinguishable cycles exceeding 1 MHz.[1]

[1] *Magnetic pickups in jet-turbine applications sense speed beyond 200,000 rpm.*

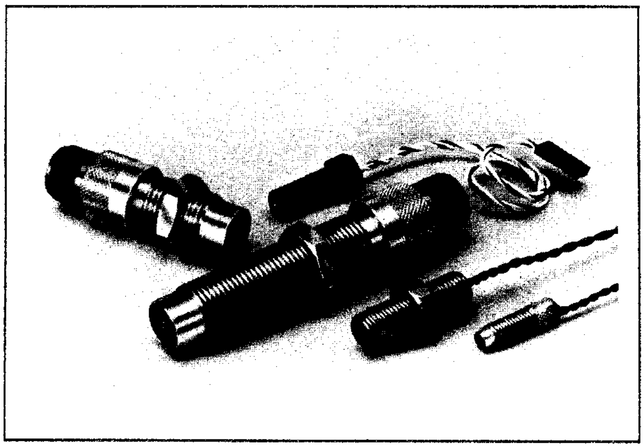
From principle to practice

The point is to match the principle to the application—the optimum performance, within necessity, to the lowest-cost package, ie., performance to specification, no more, no less.

The TSI selection process—totally pliable to your needs

We're experts in the design and manufacture of magnetic pickups. That means you shouldn't need to be. At TSI, we simplify your design concerns, and respond with compatible, high-performance, low-cost sensors.

The discussion herein focuses upon the many magnetic-pickup design variables we control. Pictured samples supply material answers to specific application demands. They also demonstrate the wide range of sensor shapes, sizes, and performance characteristics available from TSI.



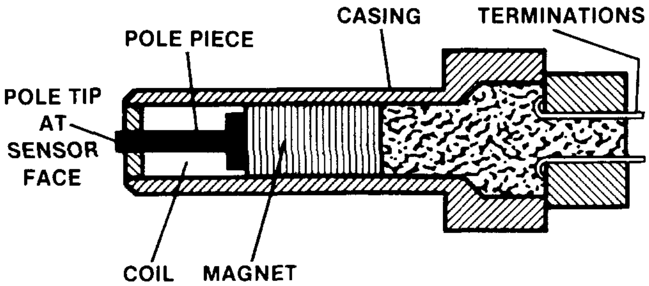


FIGURE 3 The basic magnetic pickup

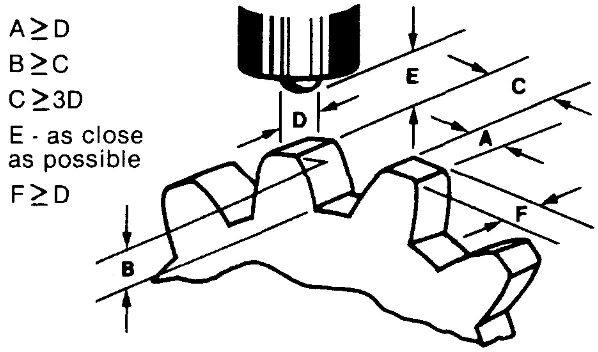


FIGURE 4 Optimum sensor/actuator relationship (example, gear tooth)

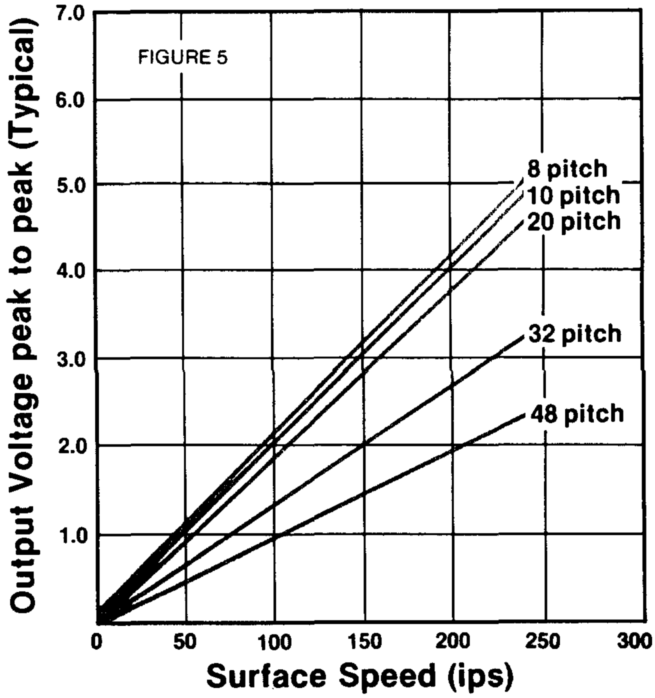
Output decreases as air gap increases

As air-gap distance increases, the actuator's ability to generate a signal in the pickup diminishes. The industry-standard air gap for measuring sensor output, for example, is 0.005″. Typical operational air gaps range from as low as possible to 0.080″.

Within limitations, increased magnetic flux density can compensate for greater air gaps, to a practical maximum of 0.2″, assuming an otherwise optimum actuator/sensor relationship (figure 4), and a minimum actuator surface speed of 100 ips.

Amplitude, speed, time, and zero crossing

Output amplitude and frequency are directly proportional to time rate-of-change of flux and actuator speed. At the output's zero crossover (shown below), the centerline of the pole piece and that of the actuator are precisely aligned. Unless the width of the actuator (Figure 4, "A" above) grossly surpasses the sensor pole piece diameter (Figure 4, "D" above), the zero crossover is a well-defined coordinate, often used as a reference.



Gear pitch and surface speed vs. output voltage

Model VR250-850-ST

0.005″ air gap 100 kΩ load 0.060″ pole-piece diameter

Figure 5 illustrates the effect of target surface speed upon output voltage, in combination with variances in target dimensions. Among the five gear pitches shown, the 8-pitch example yields highest output at all surface speeds, and in relation to the 0.060″-diameter pole piece, most closely approximates the optimum sensor/actuator relationship (figure 4). Note, however, useful output available even from the 48-pitch example.

Target/sensor orientation to output zero crossing

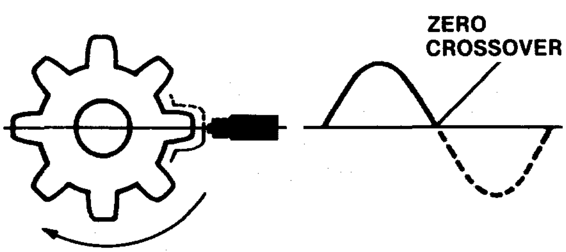
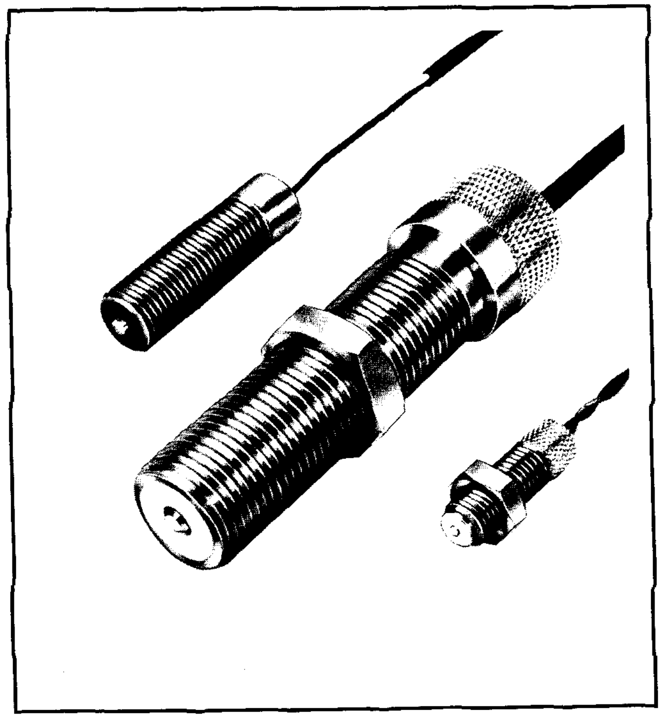


FIGURE 6



Sensor size selection

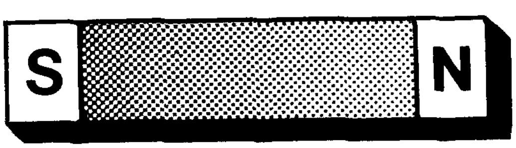
The three TSI magnetic pickups shown differ greatly in size, as do their component parts, for many reasons. Pole-piece, coil, and magnet sizes vary for their own distinct, as well as inter-related, purposes (see below). Sensor size increases generally improve durability. But the predominant factors determining sensor size are *space limitations* and *desired output*. Maximizing output for a specific application is a common design practice. This serves to overcome the electro-magnetic noise that is often present within the sensor environment.

Generally, as sensor size increases, so does output capability. There are, of course, economic constraints.

Magnet size—the flux behind the output

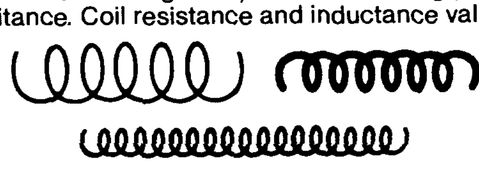
Each of the above pickups contains an Alnico magnet of *similar magnetic density*. *Assuming this constant*, differing magnet sizes generate differing magnetic field strengths. Measured at 0.005″ from the pole tip, and in the presence of a 20-pitch gear tooth, these field strengths are 700 gauss for the smallest (¼″ OD) sensor, 950 gauss for the ⅜″ OD sensor, and 1900 gauss for the ⅝″ OD sensor.

Typical TSI magnetic pickups range *in size from* 0.187″ OD to 1.25″ OD and 0.5″ to 4.5″ in length. This range can accommodate a wide variety of magnet sizes. A choice of magnetic material (Alnico, permanent-magnet ferrite, and rare-earth such as samarium-cobalt) adds another variable to the selection of sensor field strengths. Thus, magnetic flux density at the sensor face is *available in a large range of magnitudes from TSI.*



Output character—from the coil

TSI winds the coils for all its magnetic pickups. With this comes the flexibility to match the impedance of the sensor to that of an application's downstream electronics, *and to maximize output voltage (determined* by number of winding turns) while minimizing parasitic capacitance. Coil resistance and inductance values, within theoretical and practical constraints, can be specified by the user. In rare instances when power, rather than voltage, takes priority, coil-wire diameter can *be increased, thus reducing resistance and enhancing* the power-delivery capability of the sensor. Available sensor resistance values, 50 to 10,000 ohms; available inductance values, 10 to 3000 mH.



Also, the greater the coil size, the more copper exposed to flux, and the higher the sensor output capability.

Pole-piece diameter—the limit to flux flow

As pole-piece diameter increases, so does pole-piece ability to conduct magnetic flux. In the three-pickup photograph above, from the smallest component to the largest, the pole-piece diameters measure 0.060″, 0.093″, and 0.125″ respectively. Within the TSI line, typical pole-piece diameters range from 0.060″ to 0.250″, helping provide outputs in larger sensor models as high as 300 V p-p.

Total magnetic capability at TSI

Sensor magnet, coil, and pole-piece are integral variables calculated into the design of the optimum magnetic sensor for a specific application—areas subject to broad design flexibility at TSI.

Resolution and pole-piece selection, key variables in performance.

The pole piece of the sensor and the shape of its tip play a large role in output and resolving capabilities. Varying power output and resolution requirements call for a complete selection of pole-tip shapes—a complete selection from TSI.

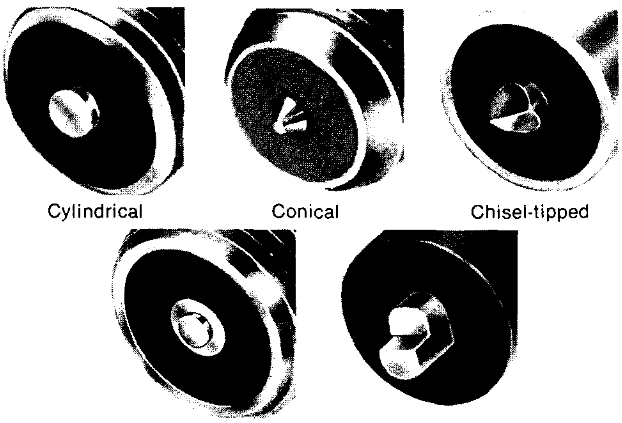
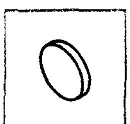
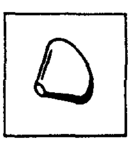


FIGURE 7
Pole-tip shapes



The cylindrical pole piece

is most commonly used in magnetic pickups, and is the most economical, for obvious machining considerations. Of the four standard variations, the cylindrical tip provides the greatest cross-sectional area directly exposed to the actuating surface, and therefore best serves as an absorber and conductor of magnetic flux. As a pure transducer, the sensor generates its highest output with a cylindrical pole piece (see table). The immediate tradeoff is in resolution, also a direct function of exposed pole-tip area.



Conical pole pieces improve

resolution by decreasing pole-tip area. The smaller tip enables the sensor to maintain an optimum actuator/sensor relationship (figure 4) in combination with smaller distances between actuators. Although output capability is diminished, this sacrifice is often superseded by high resolution requirements. Conical pole tips require the most sophisticated machining techniques, and allow the least production tolerances. They place no additional orientation requirements upon installation.

Chisel-tipped pole pieces

resolve to the levels of conical tips without sacrificing output. They do however, require orientation upon installation (figure 8), and presume the actuating surface to be at least as wide as the breadth of the chisel tip. To simplify installation, an orienting score or mark is usually placed on TSI chisel-tipped sensors.

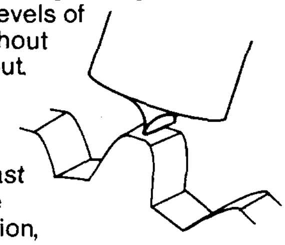
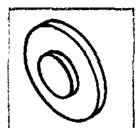
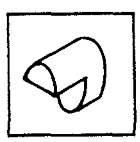


FIGURE 8
Chisel-tipped sensor mounting



The stepped pole piece

combines the resolving capability of a conical tip with the production benefit of a simpler machining process. Stepped tips, rather than conical, are often specified for larger tip diameters, less subject to damage from transport, installation, use, as well as the actual machining process itself. The stepped pole piece delivers high resolution, and is an economical innovation from TSI.



Custom pole pieces, as in the

photograph above, further demonstrate TSI flexibility in producing to application demands. This particular pole piece was developed to permit axial, rather than radial, sensor mounting in relation to an actuating gear. Increased output is attained by exposing two perpendicular, yet equally well-exposed, pole-piece surfaces to the tooth. The application does, however, call for extremely low tolerances on all sensor and actuator axes.

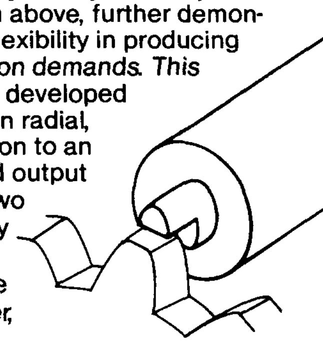


FIGURE 9
Sample custom-tipped sensor mounting

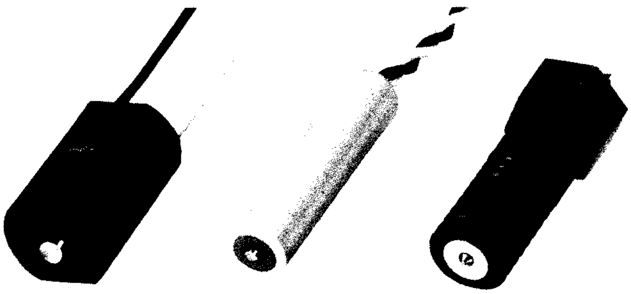
Output and resolution vs. pole-tip shape

type	sample shank diameter	tip x-axis dimension	tip y-axis dimension	resolution	voltage output
cylindrical	0.060″	0.060″	0.060″	to 26-pitch	100%
conical	0.060″	0.010″	0.010″	to 80-pitch	20%
chisel	0.060″	0.010″	0.060″	to 80-pitch	100%
chisel maloriented 90°	0.060″	0.060″	0.010″	to 26-pitch	20%
stepped	(Not available in 0.060″ shank, 0.010″ tip.)				

For tough environments, for kind environments, performance to specification.

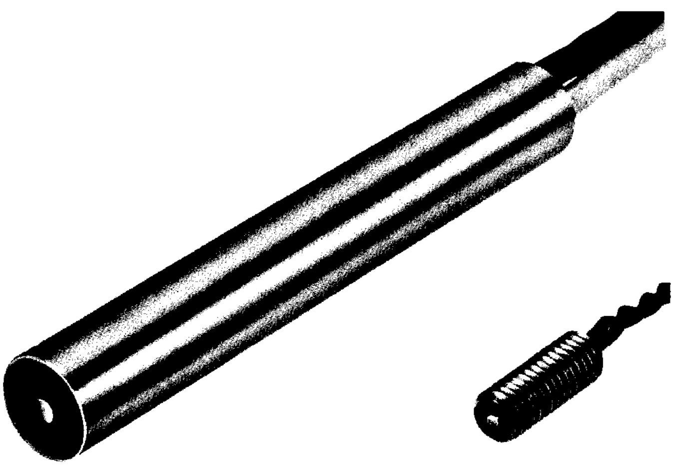
Total immersion, broad temperature extremes, potentially explosive, and electromagnetically noisy environments are all addressed by the TSI line, in addition to those models for normal operating environments. The examples below demonstrate the TSI selection of component packages.

The economy and versatility of plastics



Wide variety of casing shapes and sizes. Delrin, polypropylene, nylon, and glass-filled nylon materials. Factory injection molding. Operating extremes from −40°F to 180°F (−40°C to 82°C). 0.437″ OD to 1.75″ OD. Compatible with all pole-piece, magnet, and termination combinations. UNF threads standard. Several options.

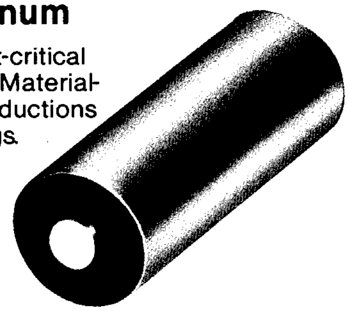
Steel durability, magnetic and non-magnetic stainless-steel shielding.



0.187″ OD to 1.75″ OD. Operating temperature extremes from −100°F to 320°F (−73°C to 150°C). Threaded and non-threaded, UNF and UNJF. Knurled and non-knurled casings. Full factory machining capabilities. All pole-piece, magnet, coil, and termination combinations. Photo also demonstrates TSI miniaturization capability.

Lightweight aluminum

Commonly used in weight-critical applications; aircraft, etc. Material-related machining cost reductions provide production savings. Full design flexibility.

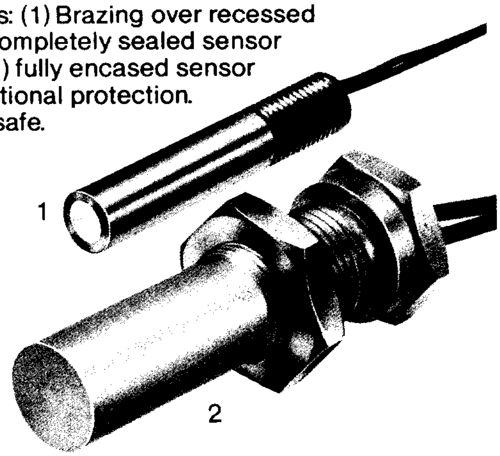


For extreme heat and cold

Special TSI magnetic pickups are available for operation at −148°F (−100°C), 932°F (500°C) and all temperatures in between. Stainless-steel casings. Ceramic bobbins.

Recessed pole tips and hermetic sealing

Two methods: (1) Brazing over recessed pole tip for completely sealed sensor face. Also, (2) fully encased sensor face for additional protection. Intrinsically safe.



Terminal configurations

TSI offers more than 30 standard terminal configurations, using twisted or untwisted cable of various sizes, with or without shielding. Pin connectors, like all configurations, available to specifications. Complete manufacturing flexibility.