Chapter 7

Application Examples

Introduction

This chapter presents a variety of customer applications as well as a variety of concept illustrations. These applications represent some of the most popular and effective ways of utilizing Hall effect sensing devices. However, the use of these products is far from being limited to these illustrations. In many cases, variations of the concept, may be used in other applications as well.

The following is a partial list of applications/products where MICRO SWITCH Hall effect sensors have been successfully applied.

Digital output sensor applications

- RPM/speed detectors (motor control)
- Timing measurement (photographic equipment)
- Ignition timing
- Position sensors (as low as .002” detection)
- Pulse counters (printers, motor drives)
- Valve position sensors
- Joy stick applications
- Door interlocks
- Current sensing (motor control systems)
- Fan/damper detection
- Brushless DC motors
- Tachometer pick-up
- Flow meters (replaces reed switches)
- Relays (replaces elect/mech contacts)
- X/Y & indexing tables
- Proximity detectors
- Security (magnetic card or key entry)
- Banking machines (automatic tellers)
- Telecommunications (on/off hook detector)
- Pressure sensors
- Limit switches
- Lens position sensors
- Paper sensors
- Test equipment
- Shaft position sensors
- Vending machines
- Embossing machines

Linear output sensor applications

- Current sensing
  - Disk drives
  - Variable frequency drives
  - Motor control protection/indicators
  - Power supply protection/sensing
- Position sensing
  - Pressure diaphragms
  - Flow meters
  - Damper controls
  - Brushless DC motors
  - Wiperless/contactless potentiometers
- Encoded switches
  - Rotary encoders
- Voltage regulators
- Ferrous metal detectors (biased Hall)
- Vibration sensors
- Magnetic toner density detection
- Tachometers

Chapter 7 Application Example directory

Flow rate sensor

Figure 7-1 illustrates a concept that uses a digital output bipolar sensor and magnets mounted to an impeller to measure flow rate for a water softener. In this design, the softener can be made to automatically recharge on demand, instead of on a timed basis. Demand is determined by measuring the amount of water that has passed through the softener. When a certain level is reached, the recharge cycle begins.

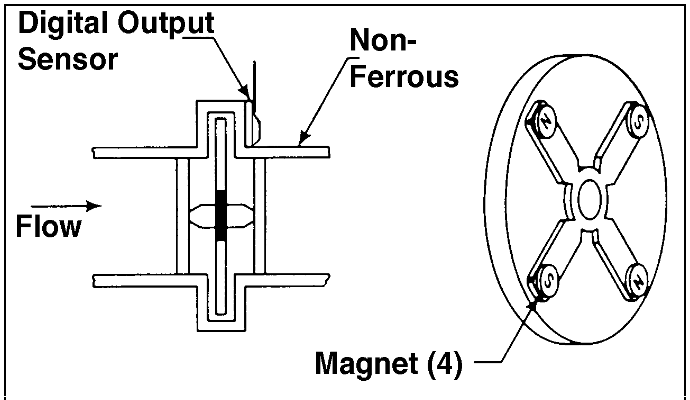

Figure 7-1 Flow rate sensor

There are various methods for designing Hall effect flow meters, but the general principle is the same: each actuation of the sensor, by a magnet or by shunting the magnetic field, corresponds to a measured quantity of water. In the example shown, the magnetic field is produced by magnets mounted on the impeller blade. The impeller blade is turned by the water flow. The sensor produces two outputs per revolution.

Besides the immediate savings derived by the proper usage of the salt, this approach provides more reliability, and longer life and the assurance of a continuing supply of softened water.

Sequencing Sensors

Sequencing and/or duration of a number of operations can be achieved by different kinds of mechanical configurations, as illustrated by Figure 7-2. In the first example, Figure 7-2A, a number of ferrous disks or cams are clamped to a common shaft. The disks are rotated in the gaps of Hall effect vane sensor. A disk rotating in tandem with its mate is used to create a binary code which can establish a sequence of operations. Programs can be altered by replacing the disks with others having a different cam ratio.

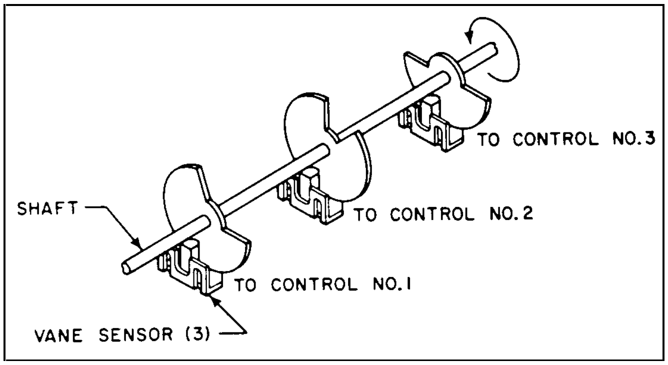

Figure 7-2A Cam-operated vane sensors

Operation is stated in terms of the position of the disk located in the gap with respect to the center line of the sensor. In the absence of the disk (a cut-out), flux from the magnet reaches the digital output sensor and the output is ON. When the disk material is in the gap, flux is shunted from the transducer and the output changes state.

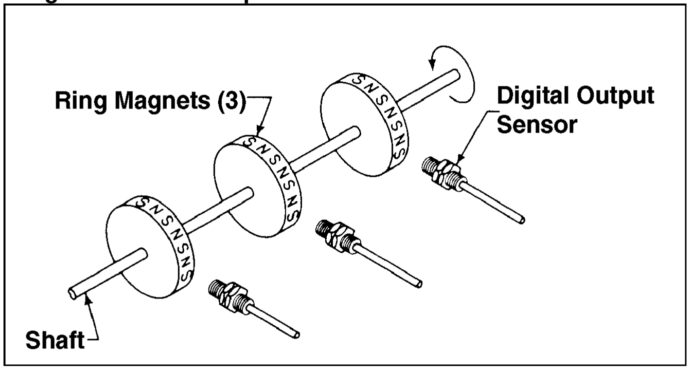

Figure 7-2B Ring magnet operated sensors

Another approach to establishing a series of events is illustrated by Figure 7-2B. Ring magnets are mounted on a rotating shaft. The outputs from the bipolar sensors can be varied by increasing or decreasing the number of pole-pairs on the ring magnets.

There are numerous configurations that could accomplish the sequencing/duration task. The possibilities are endless.

Proximity sensors

Figure 7-3 illustrates two concepts for developing a proximity sensor that can be used for accurate positioning. In the first example, Figure 7-3A, four digital output unipolar sensors are threaded into an aluminum housing and actuated individually by four magnetic actuators.

In use, event signals are generated by the sensors which represent distances measured from a reference surface. These signals define the acceptable dimensional limits between which the item under test must generate electrical pulses. In a known application, each of the sensors has accumulated at least 8 million operate/release cycles per month and is still operating, without replacement or maintenance.

In the second example, Figure 7-3B, four digital output bipolar sensors are actuated by one magnet mounted on a rod. Applications using this concept can achieve linear positioning accuracy of .002”. Sensing various lens locations for photo-processing equipment is an ideal application for this concept. It could also be used to sense the precise location of a moving table for a 35mm slide mounter.

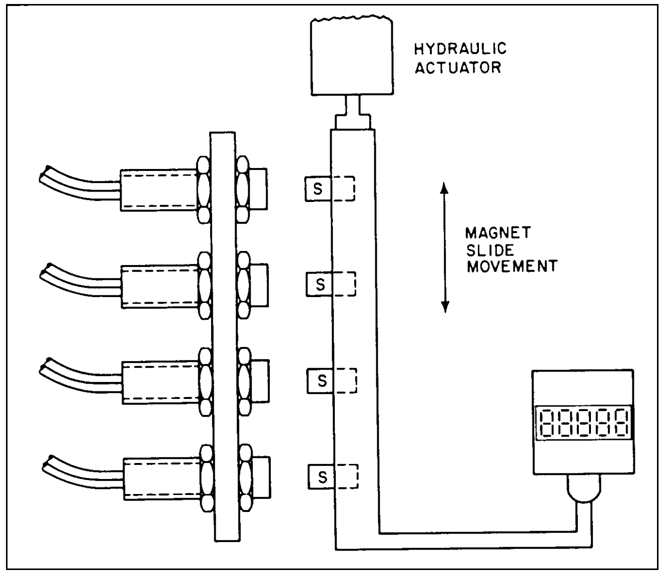

Figure 7-3A Proximity sensors

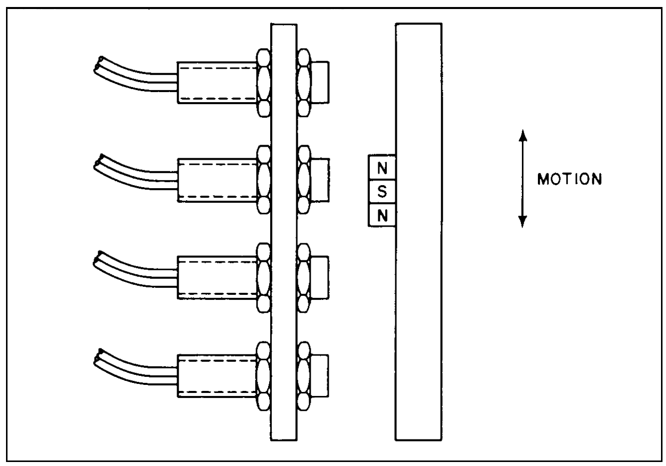

Figure 7-3B Proximity sensors

Office machine sensors

Office machines are being designed that operate more reliably than ever before. Copiers, fax machines, computer printers - anything in the office with moving parts.

Figure 7-4 illustrates a concept using a mechanically operated Hall effect switch to detect paper flow. Advantages of this approach include: no contacts to become gummy or corroded; very low force operation; extremely long life and direct interface with logic circuitry.

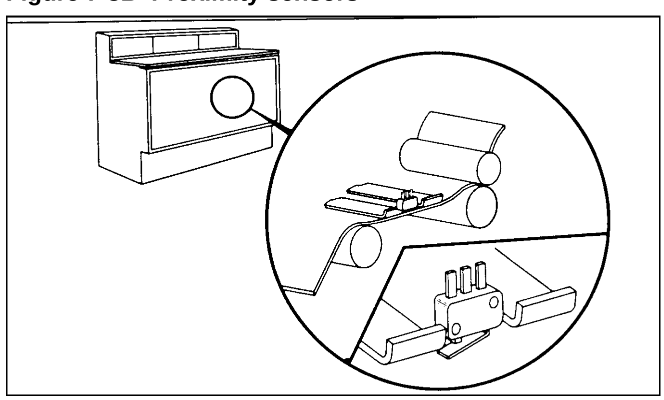

Figure 7-4 Paper detection sensor

Linear output sensor concepts

Linear output Hall effect sensors can provide mechanical and electrical designers with significant position and current sensing capabilities. These sensors combine a Hall effect integrated circuit chip with the state-of-the-art thick film technology. Linear output sensors can be used in a wide variety of sensor applications. Position sensing of cams, shafts, floats and levers, temperature sensing, current sensing, and circuit fault detection are just a few of the many possible applications.

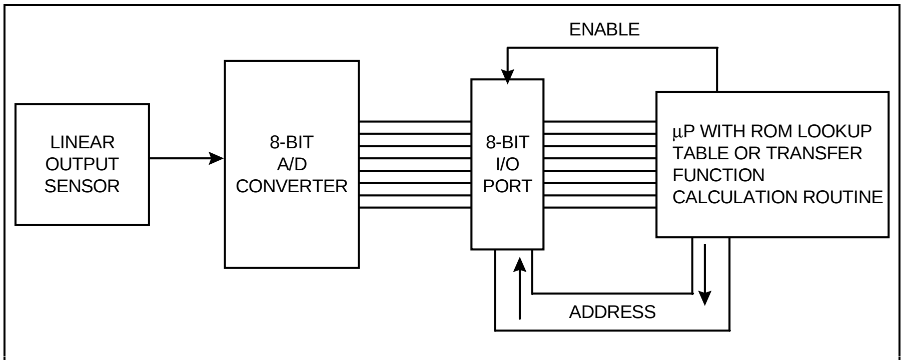

Figure 7-5 Microprocessor linearization

The output voltage of a linear sensor as a function of magnetic field (from a permanent magnet or an electromagnet) is linear, while the output voltage as a function of distance may be quite non-linear. Several methods of converting the voltage output of a linear sensor to one which compensates for the non-linearity of the magnetics as a function of distance are possible. One method of obtaining a linear relationship between distance and gauss is shown in Figure 7-5. This involves converting the analog output to digital form. The digital data is fed to a microprocessor which linearizes the output through a ROM look-up table, or transfer function computation techniques.

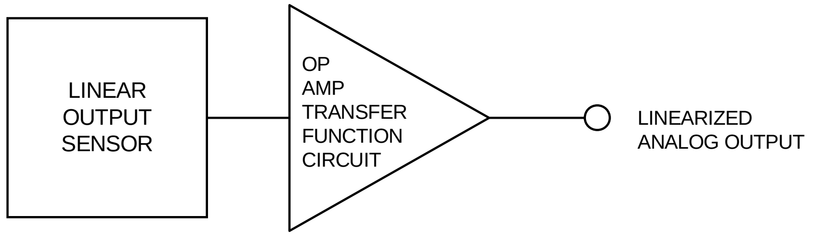

Figure 7-6 Analog linearization

Figure 7-6 diagrams a second method which involves implementing an analog circuit which has the necessary transfer function, to linearize the sensor's output.

Adjustable current sensor

Figure 7-7 illustrates a concept approach for an adjustable trip point current sensor used in welding equipment. In this example a toroid core and linear output sensor are combined with a remotely located voltage comparator to produce a precision digital output. The sensor's operate point could be made to vary by less than 20 gauss over the entire temperature range. Thus, a very accurate current sensor with high repeatability over a wide temperature range can be achieved without designing a complex magnetic system.

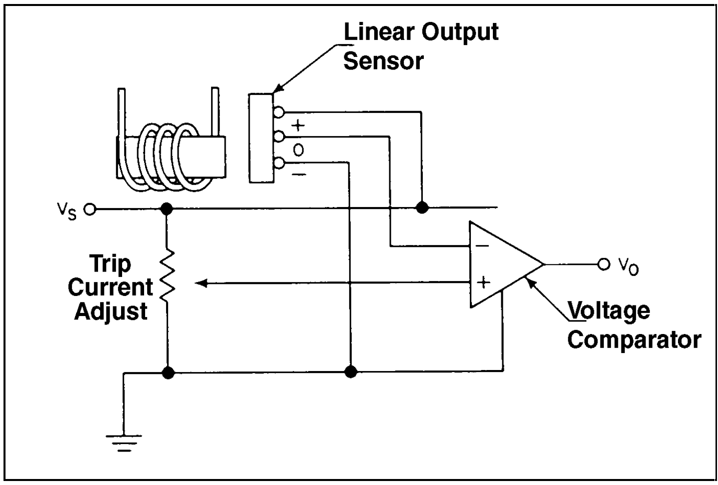

Figure 7-7 Adjustable current sensor

Linear feedback sensor

Linear output sensors have many possible applications where monitoring and linear feedback is needed for analog control systems. A typical application is in a mechanical system where position is controlled by an input voltage, or current sensing in a regulated current power supply. This concept is illustrated in Figure 7-8, where the position of the magnet carrier is automatically adjusted to correspond to the potentiometer setting.

Automated heating, ventilating, and air conditioning (HVAC), and process control are areas where sensors using the principles shown in Figure 7-8 can be used. By mounting a magnet in a valve actuator or damper, exact position can be determined.

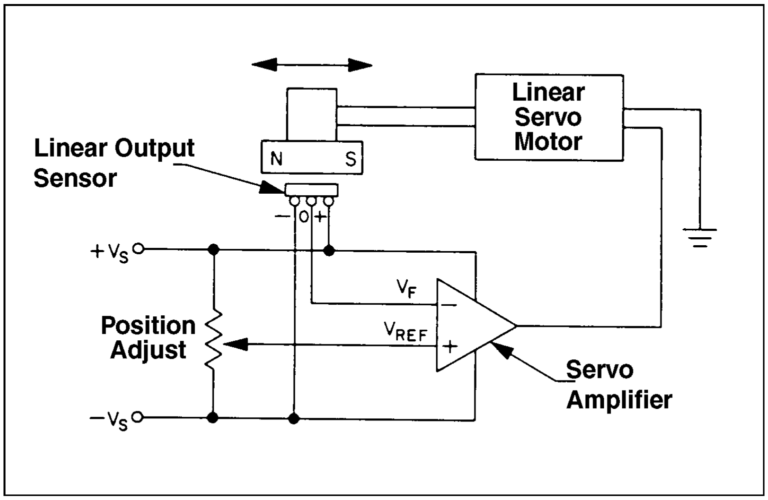

Figure 7-8 Linear feedback sensor for analog control systems

Multiple position sensor

Figure 7-9 illustrates how several positions or current levels can be sensed by using several voltage comparators with a linear output sensor. This allows convenient indexing of a mechanical device or current detection of several levels, such as normal current, slight overload, and short circuit. The position sensor shown in Figure 7-9 has three digital outputs, each indicating a different position of the magnet. A sensor of this type could be used in robot control to initiate a move fast, slow down, and stop command.

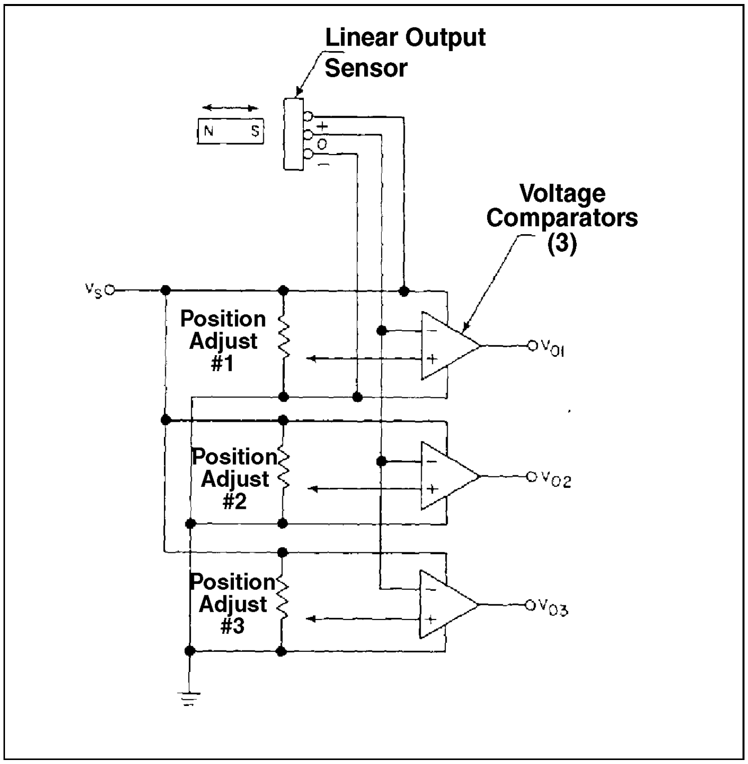

Figure 7-9 Multiple position sensor

Microprocessor controlled sensor

Figure 7-10 illustrates a concept that combines a digital-to-analog converter and a voltage comparator with a linear output sensor to produce a programmable digital output sensor. A distinct advantage of this approach is that the sensor does not require constant monitoring by the microprocessor. Using data latches in the D/A converter, the microprocessor presets the value where an operation is to take place, then continues with other processing until the sensor/voltage comparator combination signals the microprocessor through the interrupt mode.

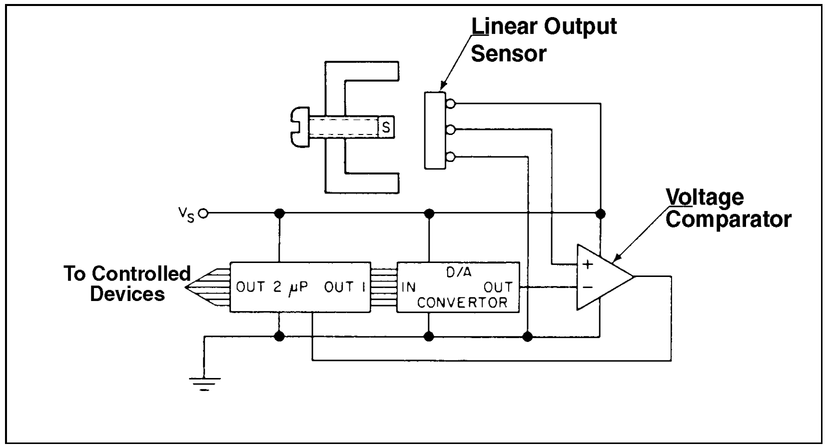

Figure 7-10 Microprocessor controlled sensor

Sensors using this principle can be used in motor current monitoring. The monitor checks for overload, undercurrent, and phase failure, all under microprocessor control. The microprocessor allows programming of desired operate current levels and time delays. This approach allows operation over a wide dynamic range of currents without changing components such as heater elements, shunts, or current transformers.

Anti-skid sensor

Figure 7-11 shows a possible solution for controlling the braking force of a wheel so that it doesn't lock-up. A biased Hall effect sensor is used. The sensor is positioned to sense an internal tooth gear. The gear could be the disk brake hub.

The reaction time of the braking system will determine the frequency of the signal as a function of wheel revolution.

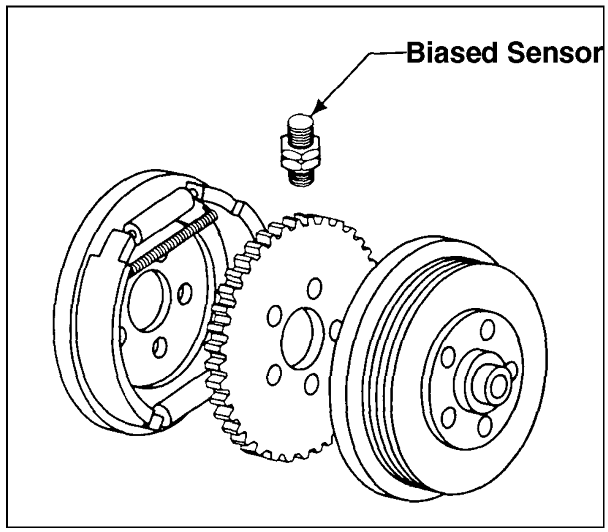

Figure 7-11 Anti-skid sensor

Door interlock and ignition sensor

Figure 7-12 illustrates a concept approach that uses a digital output bipolar sensor to provide a signal that energizes the inside courtesy lights to provide an extra measure of safety.

A sensor is positioned so that a magnet rotates by it when the key is turned in the door lock. Ice, water and other problems associated with adverse environmental conditions are eliminated. This approach could also serve as an electrical interlock for the ignition system.

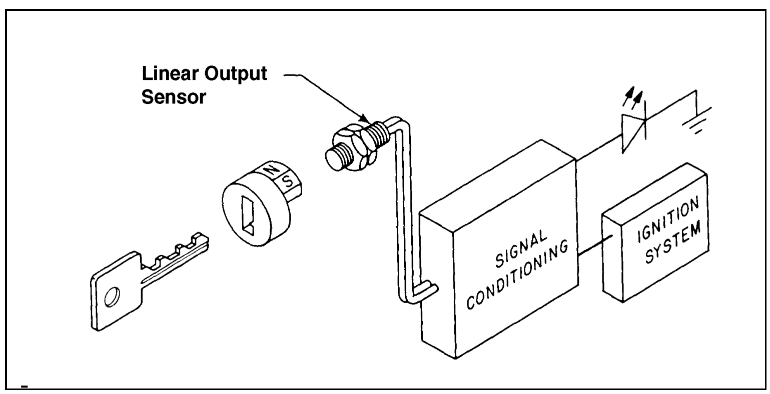

Figure 7-12 Door interlock sensor

Transmission mounted speed sensor

Figure 7-13 illustrates a simple concept approach for designing a transmission speed sensor. A digital output bipolar sensor is actuated by sensing the magnetic field created by a rotating ring magnet driven by the speedometer output shaft. The frequency of the output signal is proportional to speed. Advantages of this approach are: the output signal is not affected by changes in speed, fast response, long life and high system reliability.

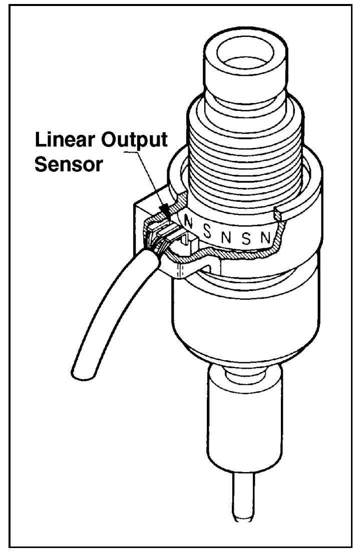

Figure 7-13 Speed sensor

Crankshaft position or speed sensor

A temperature compensated -40°C to +150°C (-40°F to 302°F) vane operated sensor is mounted in the damper hub lip, as illustrated in Figure 7-14. The frequency of the output signal will be proportional to the speed of the crankshaft, even down to zero speed. Since the magnetic field is being interrupted, vibration, eccentricity and end play tolerance have little effect on the output signal. Notches in the lip can be used as timing marks to indicate the position of the crankshaft. Direct interfacing of the sensor to the on-board microprocessor adds additional reliability to the system.

Distributor mounted ignition sensor

Figure 7-15 illustrated how the points in the distributor can be replaced by a vane operated sensor. A cup-shaped vane, with as many teeth as there are engine cylinders passes through a digital output vane sensor. The resultant logic level pulses trigger ignition system firing without the use of points. The major advantages of this approach are low speed operation (output signal not affected by changes in speed), fast response, simplified system design and high system reliability. Automotive ignition systems are one of the toughest applications with a temperature range of -40°C to 150°C and 4.5 to 24 VDC voltage range.

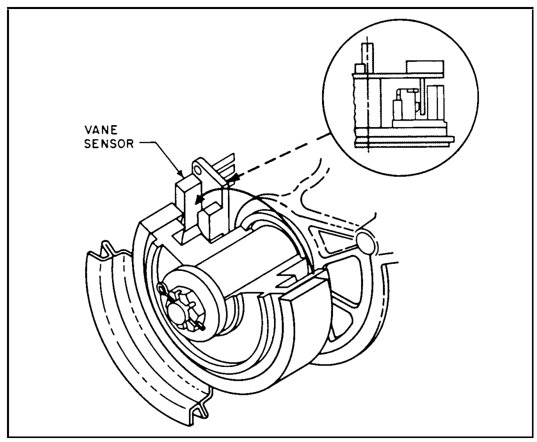

Figure 7-14 Speed sensor

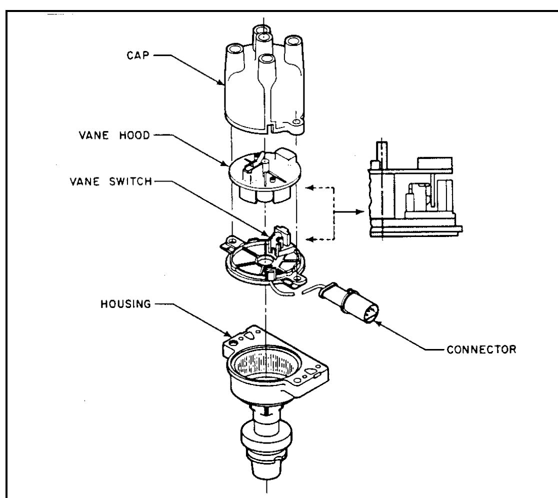

Figure 7-15 Ignition system sensor

Level/tilt measurement sensor

A digital output unipolar sensor can be installed in the base of a machine with a magnet mounted in a pendulum fashion as illustrated in Figure 7-16. As long as the magnet remains directly over the sensor, the machine is level. A change in state of the output as the magnet swings away from the sensor is indication that the machine is not level. A linear output sensor/magnet combination could also be installed in such a manner as to indicate degree of tilt.

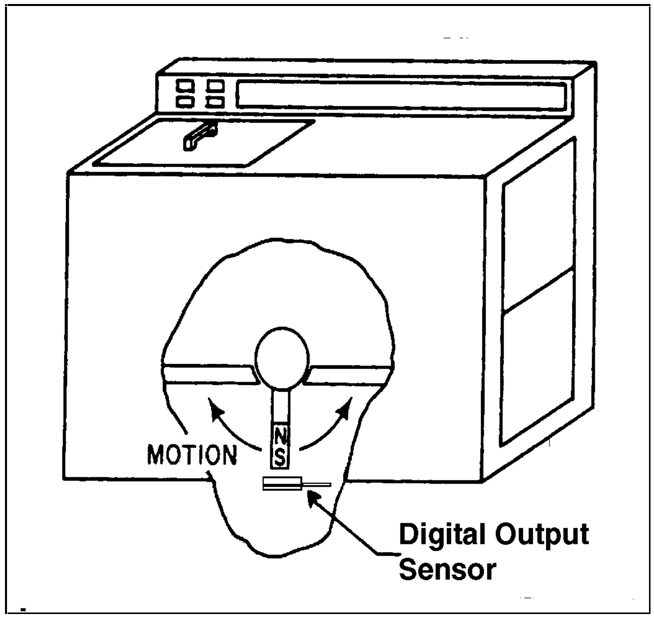

Figure 7-16 Level/tilt sensor

Brushless DC motor sensors

Brushless DC motors differ from conventional DC motors in that they employ electronic (rather than mechanical) commutation of the windings. Figure 7-17 illustrates how this electronic commutation can be performed by three digital output bipolar sensors. Permanent magnet materials mounted on the rotor shaft operate the sensors. The sensors sense the angular position of the shaft and feed this information to a logic circuit. The logic circuit encodes this information and controls switches in a drive circuit. Appropriate windings, as determined by the rotor position, are magnetic field generated by the windings rotates in relation to the shaft position. This reacts with the field of the rotor’s permanent magnets and develops the required torque.

Since no slip rings or brushes are used for commutation; friction, power loss through carbon build-up and electrical noise are eliminated. Also, electronic commutation offers greater flexibility, with respect to direct interface with digital commands.

The long maintenance-free life offered by brushless motors makes them suitable for applications such as; portable medical equipment (kidney dialysis pumps, blood processing equipment, heart pumps), ventilation blowers for aircraft and marine submersible applications.

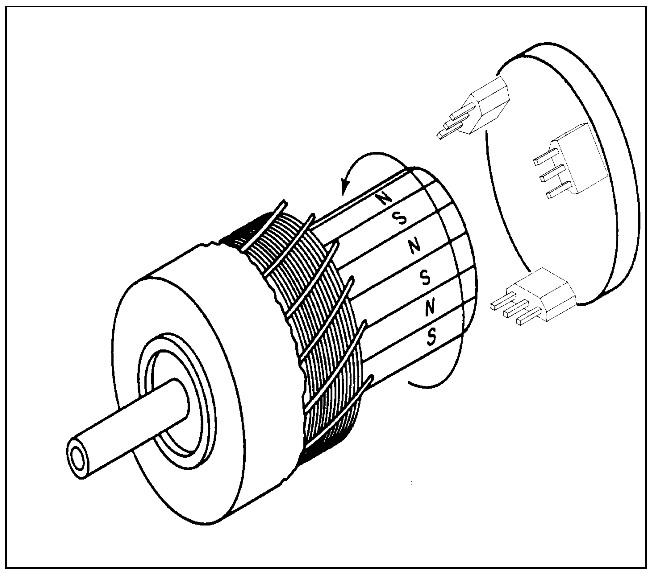

Figure 7-17 Brushless DC motor sensors

RPM sensors

The RPM sensor is one of the most common applications for a Hall effect sensor. The magnetic flux required to operate the sensor may be furnished by individual magnets mounted on the shaft or hub or by a ring magnet. Figure 7-18 illustrates some basic concepts for designing RPM sensors.

Most of the RPM sensor functions listed below can be accomplished using either a digital or linear output sensor. The choice depends on the application's output requirements.

- Speed control
- Control of motor timing
- Zero speed detection
- Tape rotation
- Under or overspeed detection
- Disk speed detection
- Automobile or tractor transmission controller
- Fan movement
- Shaft rotation counter
- Bottle counting
- Radical position indication
- Drilling machines
- Linear or rotary positioning
- Camera shutter position
- Rotary position sensing
- Flow-rate meter
- Tachometer pick-ups

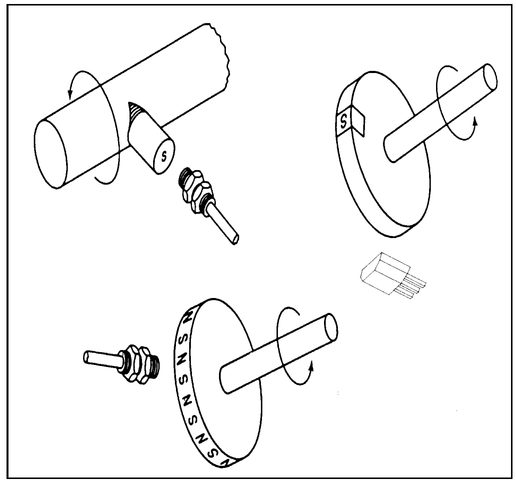

Figure 7-18 Basic RPM sensors

Remote conveyor sensing

Figure 7-19 illustrates a simple solution for keeping tabs on a remote conveyor operation. A digital output unipolar sensor is mounted to the frame of the conveyor. A magnet mounted on the tail pulley revolves past the sensor to produce one output per revolution. This output can be used to provide an intermittent visual or audible signal at a remote location to assure that all is well. Any shutdown of the conveyor will interfere with the normal signal and alert operators of trouble. With no physical contact, levers or linkages, the sensor can be installed and forgotten.

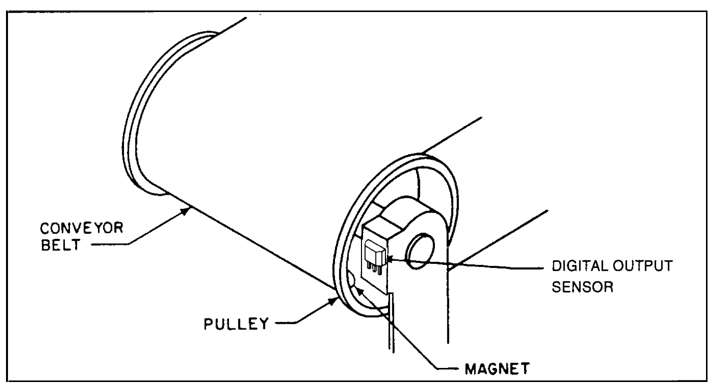

Figure 7-19 Remote conveyor sensing

Remote reading sensor

A digital output bipolar sensor actuated by a rotating ring magnet or interrupting the flux field in a vane sensor can initiate almost any action. Figure 7-20 illustrates two concept approaches for a remote reading sensor.

Self service gas stations have created a demand for pumps with remote reading capabilities. Every ON/OFF operation of the sensor could correspond to .1 gallon. Another approach could use a vane switch interrupted by an impeller blade. Once again each operation of the sensor could correspond to a measured amount.

The mechanical mechanism in a utility meter can be replaced with a ring magnet and bipolar sensor to provide a pulse output. These pulses are counted electronically to determine power usage. The reading is stored in a transponder and data fed to a master computer by telephone lines. Working through the telephone company, this system can extract meter readings, analyze usage and control high-energy-using appliances (such as air conditioners) by shutting them off during peak usage periods.

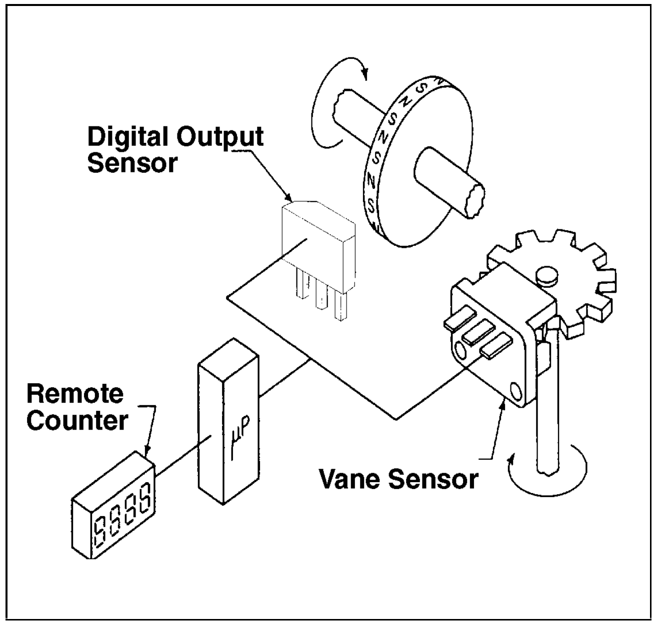

Figure 7-20 Remote reading sensor

The small size, exceptional long life, logic compatibility and non-contacting operation of the sensor are ideal for applications of this type.

Current sensors

Linear output Hall effect sensors can be used to sense currents ranging from 250 milliamperes to thousands of amperes. The isolated (no passive connection required) analog voltage produced by the sensor can be modified by adding amplifiers or comparators to achieve digital outputs, level shifting, temperature compensation, gain changes or other desired parameters. Linear sensors offer both high frequency response (AC) and DC measurements. When a linear sensor is positioned near a current carrying conductor, the output voltage developed is proportional to the magnitude of the field surrounding the conductor. Since the field magnitude at a particular point is proportional to the current level.

The simplest current sensor configuration consists of a linear output sensor mounted near a conductor as illustrated in Figure 7-21. This type of configuration is usually used to measure relatively large current surges around high voltage lines or equipment found in electrical power plants.

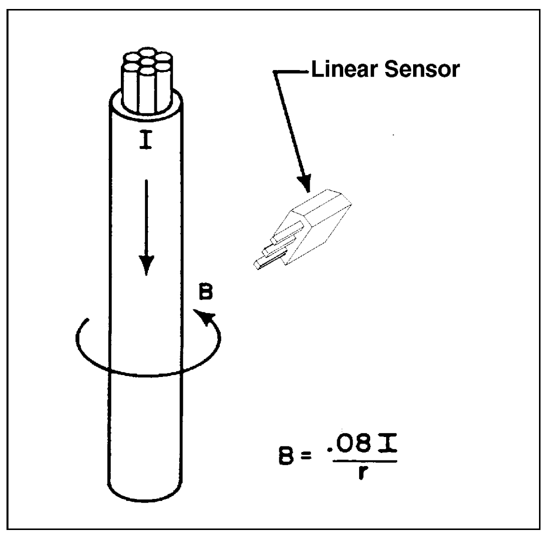

Figure 7-21 Simple current sensor

The sensitivity of the simple current sensing system shown in Figure 7-21 can be increased by adding a flux concentrator (refer to chapter 3) to the sensor. With the addition of a flux concentrator, these sensors can be used to check over or under speed, overload (current surges), undercurrent and phase failure for large motors or generators.

Figure 7-22 illustrates an even more sensitive current sensor system. This approach consists of a torroid core with a linear sensor positioned in the gap. The core encloses the sensor and acts as an additional flux concentrator. These sensors are able to measure currents from 250 milliamperes to approximately 1000 amperes.

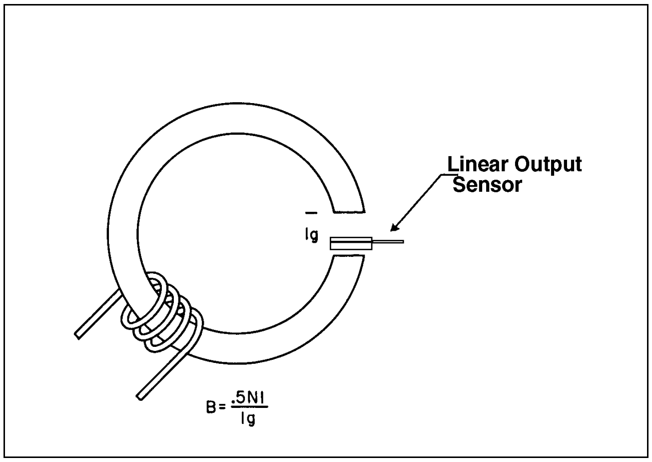

Figure 7-22 Low level current sensor

Selecting the core material for the toroid requires some care. For example, cold rolled steel has high remanence. The magnetic induction remains after removal of the applied magnetomotive force, therefore, this would be a poor choice. Ferrite materials, silicon steels, or permally are logical choices because of high permeability and low remanence. Your final choice must be based on actual testing in the application. Values of residual induction given by the materials suppliers are usually for a closed magnetic loop. Current sensors requires large air gaps, therefore, application characteristics should be measured. The residual induction values given by suppliers do, however, provide relative indications for material comparison.

Coil position on the toroid core is not critical. The wire used should be capable of carrying the maximum current continuously. The maximum wire gage provides minimum voltage drop. Count the number of turns as the number in the center of the core.

Current sensors using toroids are useful in systems which require a broad dynamic range, no series resistance and a linear measure of current. An additional benefit is that the sensor can provide isolation from two dissimiliar power supplies as might be found in such applications as motor controls with current feedback.

Flow rate sensor

Figure 7-23 illustrates a concept design for a flow meter using a biased linear output sensor. As the flow rate through the chamber increases, a spring loaded paddle turns a threaded shaft. As the shaft turns, it raises a magnetic assembly that actuates the sensor. When flow rate decreases, the coil spring causes the assembly to lower thus reducing the output voltage of the sensor.

The magnetics and screw assembly are designed to provide a linear relationship between the measured quantity, flow rate, and the output voltage of the sensor.

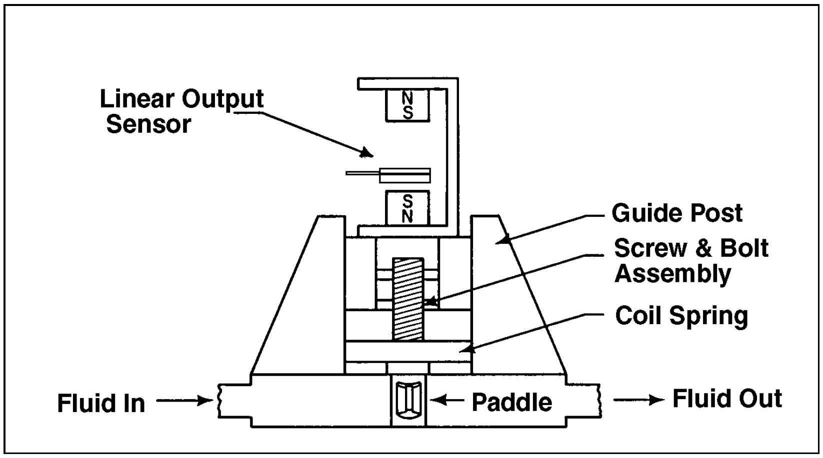

Figure 7-23 Flow rate sensor

If only critical flow is important, the magnetics can be modified to use the bipolar slide-by mode. Using bipolar slide-by, a high resolution measure of flow rate can be achieved at a critical level.

Piston detection sensor

Figure 7-24 illustrates two possible solutions for detecting position of the piston in a high-pressure non-ferrous cylinder. In the first example, Figure 7-24A, plastic form ring magnets are implanted in the grooves of the piston. Three linear output sensors are mounted on the outside of the cylinder to detect top and bottom stroke and indicate mid position for the analog control system. An advantage of this approach is; since the magnets need no external power, they can be sealed inside the cylinder.

In the second approach, Figure 7-24B, the piston is made of ferrous material (cylinder non-ferrous). Once again three linear output sensors are mounted on the outside of the cylinder. In this case bias magnets are used to "fine tune" the characteristics of the magnetic system. In operation, whenever the ferrous piston passes by the sensing face of the sensor, it acts like a flux concentrator to increase the field detected.

Advantages of both approaches include; small size of sensors, no external power for the magnets, temperature range of -40°C to +150°C (-40°F to +302°F) and the ability to operate in contaminated environments.

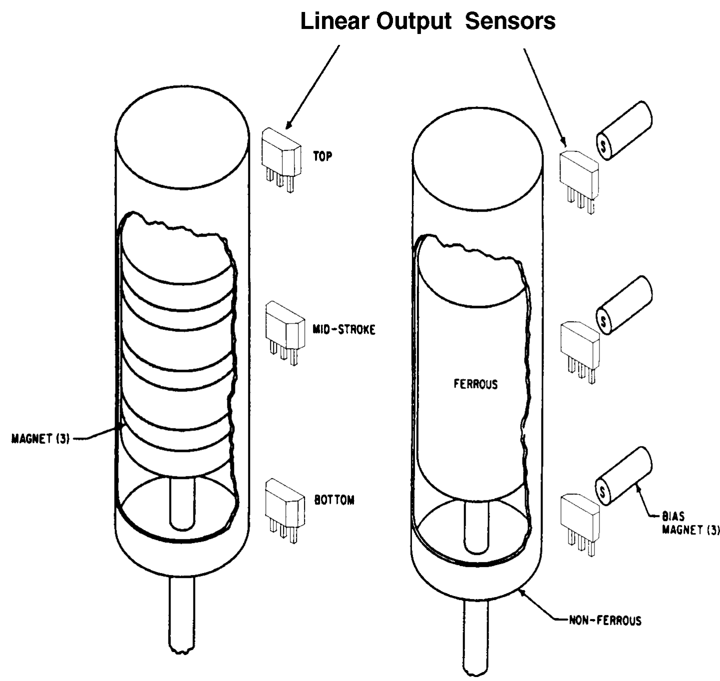

Figure 7-24 Piston detector sensors

Temperature or pressure sensor

The properties of a linear output sensor allow quantities other than position and current to be sensed. When a linear sensor is combined with appropriate magnetics, it can be used to measure temperature or pressure. Figure 7-25 illustrates this concept.

In pressure sensing, a magnetic assembly is attached to a bellows assembly. As the bellows expands and contracts, the magnetic assembly is moved. If the sensor is placed in close proximity to the assembly, an output voltage proportional to pressure input can be achieved.

Temperature measurement works similarly to pressure, except that a gas with a known thermal expansion characteristic is sealed inside the bellows assembly. As the chamber is heated, the gas expands causing a voltage from the sensor that is proportional to the temperature.

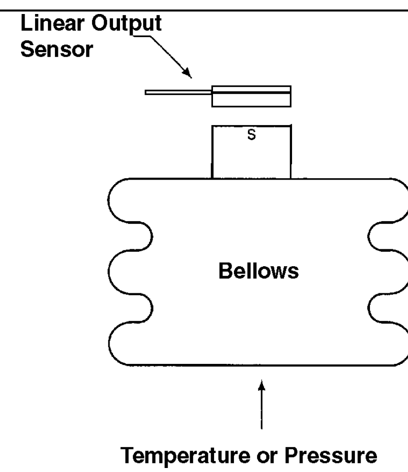

Figure 7-25 Temperature or pressure sensor

Magnetic card reader

A door interlock security system can be designed using a linear output sensor, magnetic card and a microprocessor linearization circuit as illustrated in Figure 7-26. In this example the card slides-by the sensor producing an output. This analog signal is converted to digital, to provide a crisp signal to operate the relay. When the relay's solenoid pulls-in, the door can be opened.

For systems that require additional security measures, a series of magnet can be molded into the card. A constant speed motor-driven tray slides this multi-coded card past the sensor or an array of linear output sensors, generating a series of pulses. These pulses are addressed to a decoding unit that outputs a signal when the correct frequency is present. Or it could generate a multi bit encoded function, that allows entry to selected units.

Computer systems and banking terminals are ideal applications for this concept.

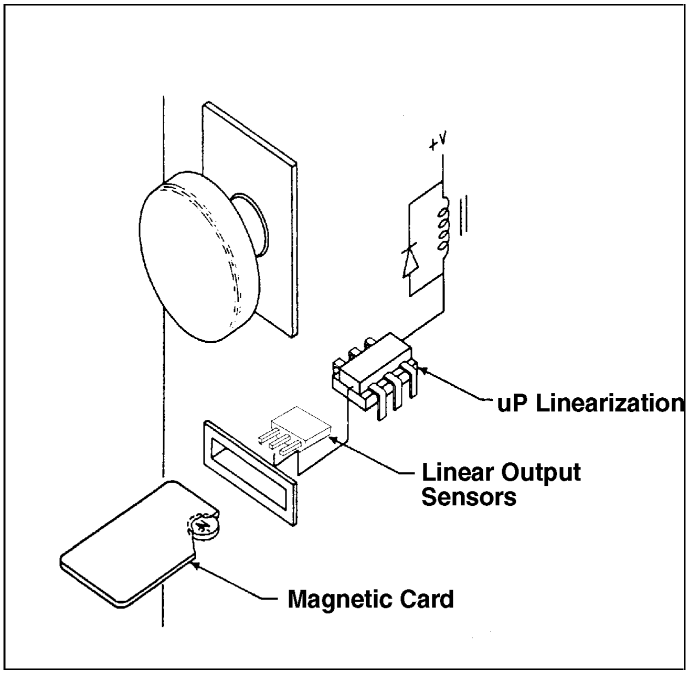

Figure 7-26 Magnetic card reader

Throttle angle sensor

Figure 7-27 illustrates a concept that uses a linear output sensor to provide a signal proportional to the angular position of the throttle butterfly valve. The arm of the throttle is contoured to provide the desired non-linear characteristics. The magnet is mounted on the choke lever.

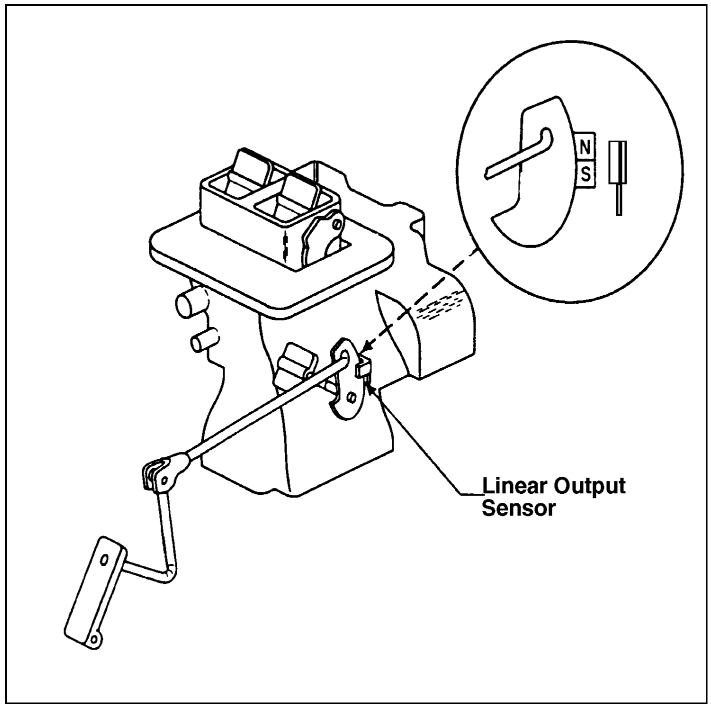

Figure 7-27 Throttle angle sensor

Automotive sensors

Figure 7-29 suggests many concepts where Hall effect sensors can be applied as monitoring, positioning or safety feedback devices for the automotive market. Both digital and linear output sensors are used in such applications as: flow meters, current sensors, position sensors, interlocks, pressure sensors, RPM sensors, etc.

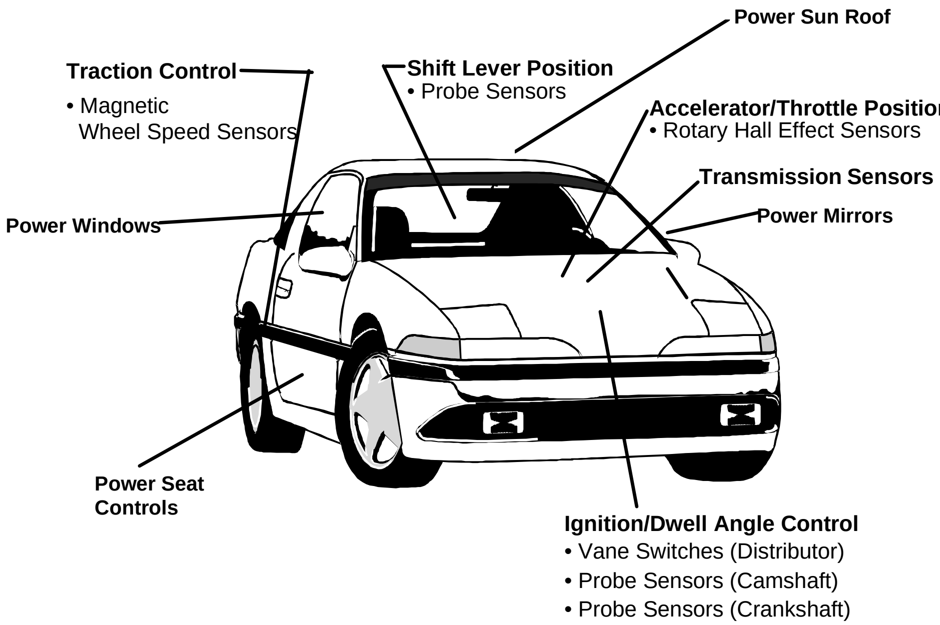

Figure 7-29 Automotive sensor concepts