National Aeronautics and Space Administration

Sensor Technology

Single Coil Absolute Position Sensor (SCAPS) with Inductive Gap Sensor (GapSyn) and Add-On Technologies

A novel position sensor with gap sensing capabilities and a suite of three associated technologies that can be incorporated into the lead technology to enhance sensing and other functions





This technology suite, developed by NASA's Marshall Space Flight Center, includes a Single Coil Absolute Position Sensor (SCAPS) with Inductive Gap Sensor (GapSyn) and three associated technologies that can be incorporated into the primary technology to perform additional sensor functions and serve as a short-range antenna and close proximity transmitter and receiver. Applications for these technologies span a broad range of industries and they can be combined to perform a variety of functions.

Benefits

- **Robust:** Relies on printed circuit board (PCB) technology, which is well-established and highly reliable
- **Economical:** Uses components that have a low manufacturing cost
- **Effective:** Incorporates a limit switch, which provides advantages over other commercially available sensors
- **Flexible:** Includes primary technology that has unique functionality and can be augmented to perform a variety of functions

technologyopportunity

Single Coil Absolute Position Sensor (SCAPS) with Inductive Gap Sensor (GapSyn)

The Technology

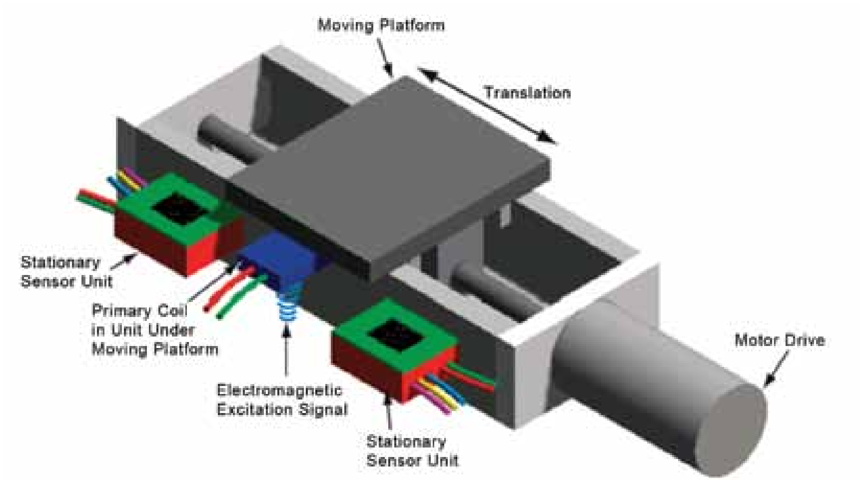
This technology (MFS-32224-1) combines NASA's GapSyn innovation (MFS-32218-1) with existing NASA SCAPS technology (MFS-32213-1), creating a novel position sensor with gap sensing capabilities. This innovative combination significantly improves the SCAPS technology and produces a sensor with the ability to self-calibrate and operate in a wireless or true non-contact configuration. Depending on the application, this sensor technology can provide absolute position in various forms and can be easily integrated into user designs.

How it Works

The SCAPS technology is a small, non-contact, absolute position sensor that can be used as a linear position sensor, x-y position sensor, limit switch, and/or gap sensor, either independently or in combination. In SCAPS, which is used where there is relative motion between two components or structures, an excitation coil is mounted on one component, and it induces a signal in a sensor coil that is mounted on another component. The magnitude and phase of the sensed signal unambiguously define a precise position.

GapSyn is a unique inductive gap sensor that measures the absolute magnitude of the gap between two members that move relative to one another. A signal is induced in a planar "sensor synchronizer" coil, parallel and close to the emitter coil. The strength of this signal is directly proportional to the gap between these two coils.

One purpose of this innovation is to provide the excitation signal phasing information to the sensor side of the SCAPS technology. This allows the two components to not be directly wired together and allows for wireless operation of the SCAPS sensor technology. A second purpose of this innovation is to provide the sensor electronics a means by which sensor calibration can be independently achieved. In-situ calibration allows the sensor to be self-calibrated initially and then be re-calibrated autonomously at any time.



Several other discrete inventions developed by NASA innovators comprise this technology, including:

An Absolute Limit Switch (MFS-32192-1) takes advantage of the value of the induced voltage and uses a predetermined value of the sensed signal to determine an absolute limit switching point, such as to stop a movable carriage.

A ferromagnetic metal backing layer (MFS-32219-1) provides a flux return path, thus enhancing the signal-to-noise ratio and signal linearity, as well as increasing the usable range of the position sensor. The metal backing is ideally "mu-metal," a nickel-iron alloy that has a very high magnetic permeability. Depending on the application, a thin, lightweight mu-metal foil may be appropriate, which would add little mass or volume.

A miniature housing (MFS-32000-1) with a sealable cover contains a small circuit board with electronics and a communications interface.

Why it is Better

Integration of the GapSyn coil into the SCAPS technology allows the sensor unit to be completely separate from the excitation unit. It allows for wireless operation of the sensor coil, produces a constant voltage, and can be packaged in the same location as the SCAPS sensor. The device can be easily integrated into various applications because it can be designed to be self-calibrating; the basic sensor utilizes only two active and inexpensive components; and the sensor can be attached by an adhesive or can be inside or underneath the outer skin of a component. The sensor technology can be physically scaled up or down in size and can be designed with redundant coils without adding additional volume. Tested prototypes have achieved accuracies of four microns, and greater accuracies are possible with other sensor configurations. The emitter can use excitation frequencies ranging from several kilohertz to the megahertz region. The sensor is extremely reliable and repeatable and exhibits data correlations greater than 0.99999.

The SCAPS technology with GapSyn can be combined with three other NASA technologies to create additional applications and benefits (see below).

Patents

NASA’s Marshall Space Flight Center has received patent protection for this technology: U.S. Patent Nos. 7,116,098, 7,081,730, and 7,134,885.

Benefits

- **Precise:** Provides absolute position and provides improved precision when compared with conventional position sensing techniques
- **Low-cost:** Uses inexpensive components
- **Reliable and self-calibrating:** Exhibits data correlations of 0.99999 or better
- **Non-contact:** Allows coils to be completely sealed against the environment
- **Simple:** Uses only two active components
- **Scalable:** Adjusts to meet application requirements
- **Flexible:** Integrates easily into several applications and supports other NASA technology

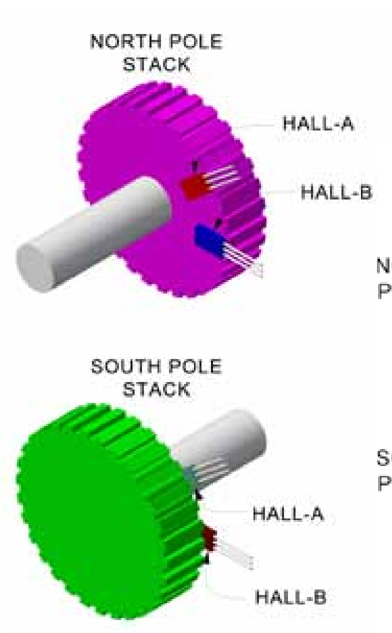
Applications

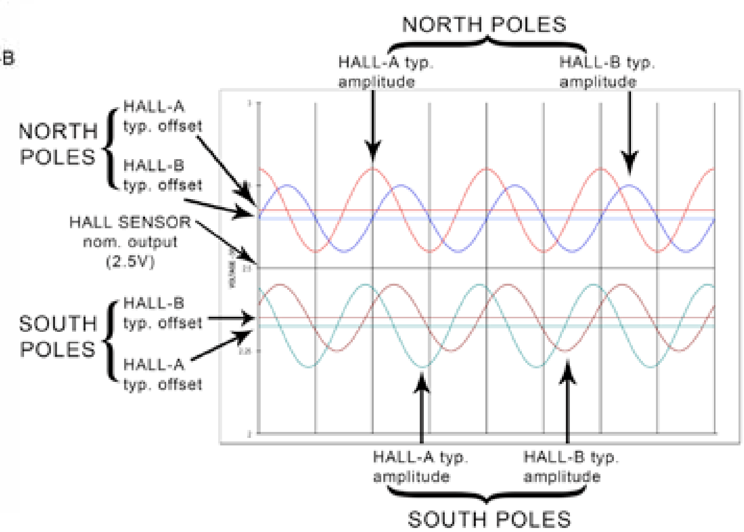
- CNC, water jet, and laser milling machines
- Pick and place machines for semiconductor manufacturing and automated biotech operations
- Inkjet and raster printers
- Home and office scanners
- Profilometers
- Industrial robots in which raster, head, and substrate are in close proximity
- Rotary and linear positioning of automotive engine components
- Robot-assisted surgery, biotech micro array, and assay procedures


Inexpensive, Rate Insensitive, Linear, Load Compensating System for Hybrid Stepper Motors

The Technology

NASA innovators have developed a system for sensing the position of a rotor in a hybrid stepper motor (MFS-32402-1). This technology is a rate-insensitive (operates at any speed, including zero rate), linear feedback sensor system that can be used for controlling two-phase and multi-phase stepper motors. The sensor system can supply positional information on an incremental basis, or the data can be interpolated to further increase the accuracy. This stepper motor application exploits the basic SCAPS technology to measure angular displacement in a hybrid stepper motor, allowing closed loop control.





How it Works

For a two-phase stepper motor, this technology uses a pair of Hall sensors to generate electrical signals with waveforms that are in phase with the back electromagnetic force of the stepper motor's two phases but are 90 degrees out of phase with one another as the stepper motor rotors turn. This yields rate-insensitive position signals for a hybrid-type rotor. This technology can be expanded for multi-phase stepper motors. It can also provide incremental position outputs or the sine and cosine waves can be interpolated to increase the accuracy of the encoder outputs.

Why it is Better

The novelty of this innovation is that the described positioning of simple Hall sensors provides rate-insensitive position signals for a hybrid-type stepper motor rotor. The position signals can be used in a stepper motor control system. The system can provide incremental position signals or the sine/cosine waves can be interpolated to provide more accurate encoder outputs.

Patents

NASA's Marshall Space Flight Center has applied for patent protection for this technology.

Benefits

- **Inexpensive:** Uses simple, low-cost components
- **Rate-insensitive:** Works over a wide range of rotational speeds, including zero rotational speed
- **Accurate:** Provides highly precise control of two-phase or multi-phase hybrid stepper motors
- **Fast:** Facilitates excellent response to start and stop commands

Applications

- Document processors
- Printers
- Plotters and scanners
- Facsimile machines
- Hard disk drives
- Needle valves
- Medical equipment
- Automotive equipment

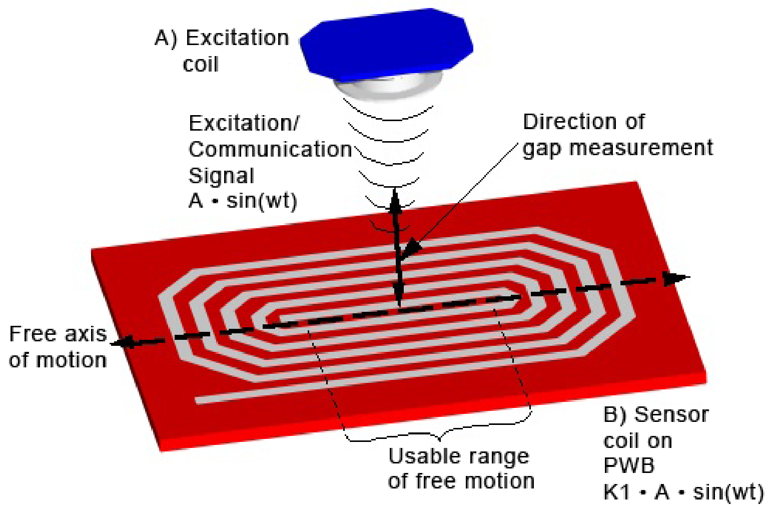
Short Range Antenna/Close Proximity Transmitter and Receiver

The Technology
This technology (MFS-32228-1) is an inexpensive and effective method of exchanging information over a short distance between two devices when each is equipped with a coil. This short-range, non-contact data communication method is ideally suited for use in conjunction with NASA's GapSyn technology.

How it Works
The transmitting and receiving coils of the GapSyn device are essentially antennas that can both transmit and receive positional information between two devices that share the same sensor. Once the devices are determined to be sufficiently close to one another using the GapSyn method, the excitation coil can be energized with a frequency-modulated signal that can then transmit information to the sensor coil. The gap sensor measures the absolute magnitude of the gap between two members that move relative to one another. A signal is induced in a planar "sensor synchronizer" coil, parallel and close to the emitter coil. The strength of this signal is directly proportional to the gap between these two coils.

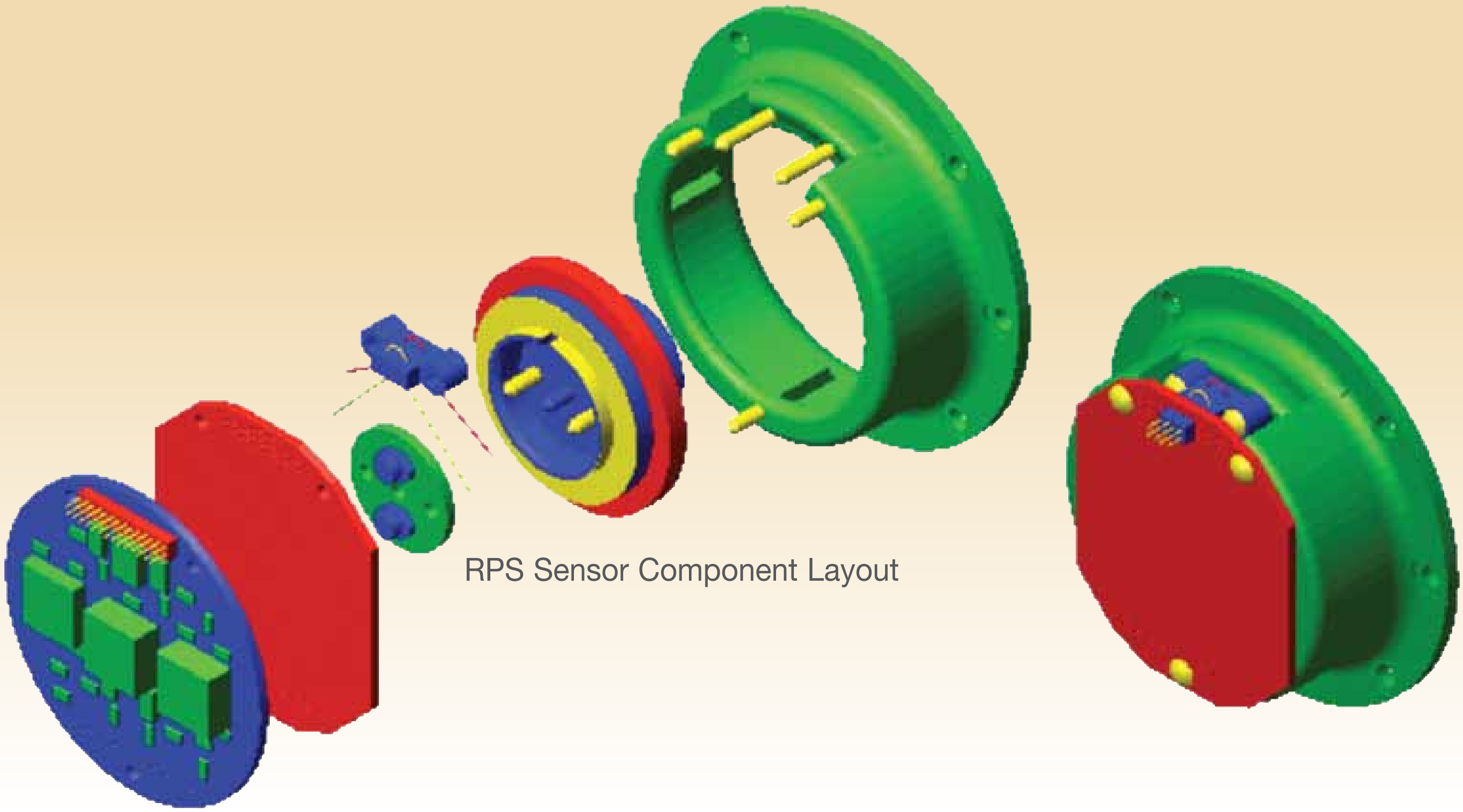
Why it is Better
This invention makes significant improvements to the GapSyn technology by enabling it to measure the gap between two devices and also transmit and receive data between two devices using the same sensor. There are no known devices with the multi-functional capability of this invention, and this device will help meet the need for such technology in precision positioning devices and other applications.

Patents
NASA's Marshall Space Flight Center has applied for patent protection for this technology.



Benefits
- **Inexpensive:** Applies easily to GapSyn technology
- **Efficient:** Combines two functions in a single device
- **Unique:** Is the only device that provides this combined capability

Applications
- Milling machines
- Pick and place machines
- Printers and scanners
- Industrial robots
- Automotive equipment
- Medical devices
- Aerospace technology



RPS Sensor Component Layout

Integrated Signal Conditioning Electronics and Printed Wiring Board (PWB) Rotary Position Sensor

The Technology

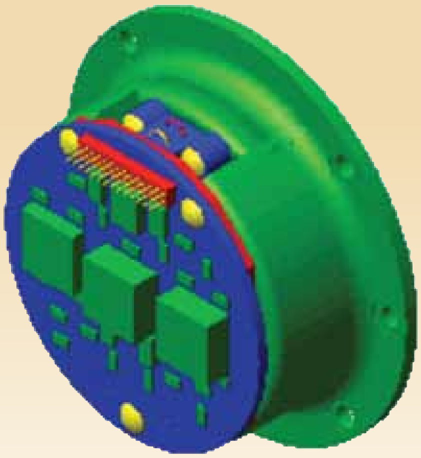
NASA innovators have developed an Integrated Signal Conditioning Electronics and Printed Wiring Board (PWB) Rotary Position Sensor (MFS-31238-1) for sensing rotary speed or rotary position. This compact device—which extends the basic SCAPS technology from linear displacement measurement to angular displacement measurement—is made up of a speed or position sensor as well as all of the electronic circuitry necessary for its operation and required signal processing, all enclosed in a single housing with a shaft for coupling to an external rotary machine. The housing and most of the other mechanical hardware can be common to a variety of different sensor designs. Hence, the technology can be configured to generate any of a variety of outputs by changing the interior sensor assembly.

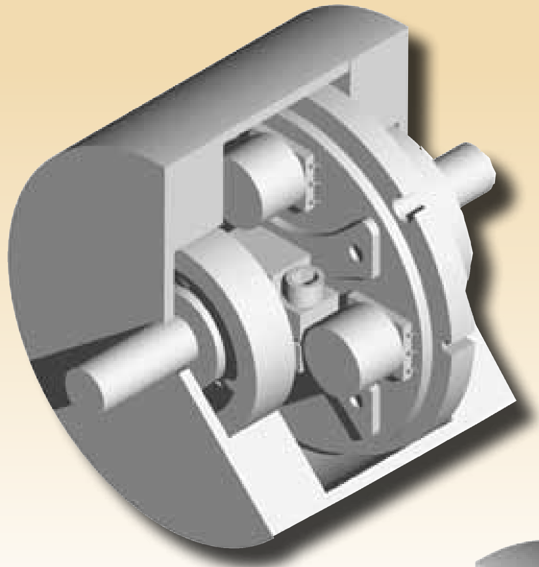
How it Works

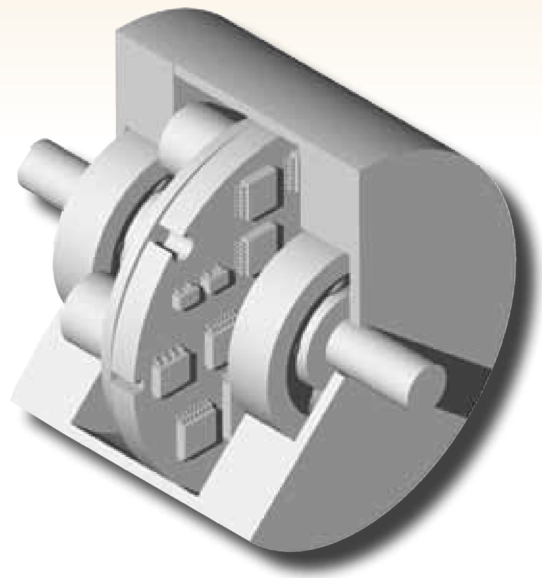
The internal sensor assembly includes excitatory and readout-integrated circuits mounted on printed circuit boards. The excitation coil induces a signal in a sensing coil that is read by integrated circuitry. The induced signal represents the rotary position or speed of the sensing coil relative to the excitation coil. A sheet of high-magnetic-permeability metal ("mu metal") is placed between the winding board and the electronic-circuit board to prevent spurious coupling of excitatory signals from the transducer windings to the readout circuits. When the shaft of the device is mechanically connected to that of the rotary machine and it is supplied with power, it generates an output signal that indicates the rotary position or speed without the need for additional external signal processing.

Why it is Better

The incorporation of all of the necessary excitatory and readout circuitry into the housing in a compact arrangement is the major difference between this technology and prior rotation-sensor units. This technology could be used in a variety of shaft-driven machines for precisely controlling and monitoring rotation speed and rotary position. The technology has several advantages over other rotary position sensors including resolvers, encoders, Hall effect sensors,







and potentiometers. It offers absolute position—as opposed to incremental position—and the manufacturing costs of this unit are small compared to a resolver and absolute encoder.

Patents

NASA's Marshall Space Flight Center has received patent protection for this technology (U.S. Patent No. 6,313,624) and has applied for foreign patent protection.

Benefits

- **Self-contained:** Includes all components within a single housing and requires no external electronics
- **Economical:** Uses simple, low-cost components and is easy to manufacture
- **Compact and lightweight:** Has small components and housing
- **Precise:** Provides accurate and reliable measurements, particularly when compared to other devices offering a linear mode

Applications

- Automotive engines, drive trains, wheels, and steering
- Downhole tubulars for drilling and servicing operations in oil fields
- Turbomachinery and tools
- Precision equipment, such as printers, cameras, needle valves

Licensing and Partnering Opportunities

This suite of technologies is being made available as part of NASA's Innovative Partnerships Program (IPP), which seeks to transfer technology into and out of NASA to benefit the space program and U.S. industry. NASA invites companies to consider licensing this suite of technologies (see table below), individually or as a group, for commercial applications.

Single Coil Absolute Position Sensor (SCAPS) with Inductive Gap Sensor (GapSyn) [MFS-32224-1]
MFS-31218-1
MFS-31529-1
MFS-32000-1
MFS-32192-1
MFS-32213-1
MFS-32218-1
MFS-32219-1
MFS-32318-1
Integrated Signal Conditioning Electronics and Printed Wiring Board (PWB) Rotary Position Sensor
MFS-31238-1
Inexpensive, Rate Insensitive, Linear, Load Compensating System for Hybrid Stepper Motors
MFS-32402-1
Short Range Antenna/Close Proximity Transmitter and Receiver
MFS-32228-1

For More Information

If you would like more information about these technologies, please contact:

Sammy A. Nabors
Manager, Technology Commercialization and Licensing
NASA's Marshall Space Flight Center
256-544-5226
sammy.nabors@nasa.gov

Karen Hiser
Senior Consultant
Fuentek, LLC
919-249-0327
nasa.msfc@fuentek.com

www.nasasolutions.com

National Aeronautics and Space Administration

George C. Marshall Space Flight Center
Huntsville, AL 35812
www.nasa.gov/marshall

www.nasa.gov

NP-2010-02-34-MSFC
7.18.10

Fuentek is a contractor to NASA's Innovative Partnerships Program, providing support for the access and transfer of technology.