

INPROX Technology

Moving beyond the limits of tomorrow's boundaries.

Aerospace
Automotive
Commercial
Defense
Industrial
Medical



VARIABLE REACTANCE DIGITAL SENSOR TECHNOLOGY

INPROX Technology

Inprox Technology Corporation, the leading advanced digital sensor developer for emerging sensor technologies is being recognized again for its significant contributions to advancing the state of the art of advanced sensor technology. This is **inGen Direct**, a revolutionary variable reactance inductive sensor technology suite which includes a cutting-edge streamlined interface architecture; the Direct Digital Signal Transfer Methodology or DDSTM. Apart these powerful technological advances are capable of significantly enhancing critical sensor application solutions across aerospace, automotive and industrial markets...together they are quite simply re-writing what it means to measure physical changes and how devices communicate those changes.

The next generation of variable reactance inductive and capacitive based direct digital sensor technology has evolved into **inGen Direct**, a platform of advanced capability sensor systems; speed (with inherent zero speed, run-out detection, material deformation and angular measurements), advanced linear position sensing; including CFLD technology (an impressive LVDT-type sensor technology employing 'captive field' design), rotary position and pressure sensing – all developed around the guiding principle of moving beyond the limit of tomorrow's boundaries

Product managers and senior engineering teams are looking towards the market for innovative sensor solutions - ones that significantly advance product offerings; solve critical technical problems; create new possibilities; all while cutting costs... welcome to inGen Direct.



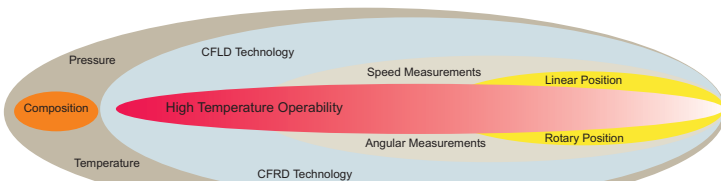
What is Direct Digital?

The Direct Digital circuit is employed with the inGen Direct suite of advanced variable inductive based sensors; linear position, rotary position, advanced speed, pressure and temperature sensors; the output is in the form of a hyper-accurate square wave 'frequency of oscillation' that gets sent directly to a microprocessor—without any signal conditioning.

What is inGen Direct?

inGen Direct is the brand name of the technology suite of sensors - each empowered with cutting edge abilities - such as speed measurement with inherent zero speed, no magnets, -110 C to +650 C operability ranges, angular measurements, run-out detection and even gear teeth (or shaft) profiling - all in one sensor.

inGen Sensor Suite Matrix



A Precision Methodology for Signal Transfer Capabilities



Our valued customers and strategic licensee's understand what these capabilities mean to advancing their product offerings; including sensor technology capabilities that can offer new and innovative temperature rating operability ranges (-110°C to +650°C), higher resolutions predicated on the one step square-wave output (inherent in the **inGen** circuit and the DDSTM); as well as little-to-no measurable hysteresis, no magnets in use...and the list goes on. This is the power to solve complex applications - whether they are integrated directly into aircraft engines or on demanding industrial OE; from household appliances to vital national defense systems – **INPROX Technology** is charting a new course – bringing advanced materials, designs and ideas to the sensor industry as a whole; moving ahead in cooperation and in concert with our partners and customers.

Common Bus Multi-node Ready



INPROX Technology is also leading the way in the aerospace and automotive markets with an innovative control methodology and common bus solution—the Direct Digital Signal Transfer Methodology. The idea of multiplexing control functions in automotive and aerospace systems is not new concept. What is new is the way in which the inGen Direct frequency signal is generated in the first place – measurements flow right from the physical quantity to be measured to frequency with no intermediate steps—**no signal conditioning of any kind**.—and that frequency is in the form of a square wave that is read like a pulse train by a digital microprocessor. Nothing could be simpler. This is multiple distributed sensors all on a common signal bus; simplified and streamlined, offering higher accuracy, lower costs, derivative value interpretations, continuous outputs for 'fault condition by signal' and even the ability for multiple sensors to share the same electronics (each sensor element having a different output frequency range). This is what this revolution is all about.

Direct Digital Methodology

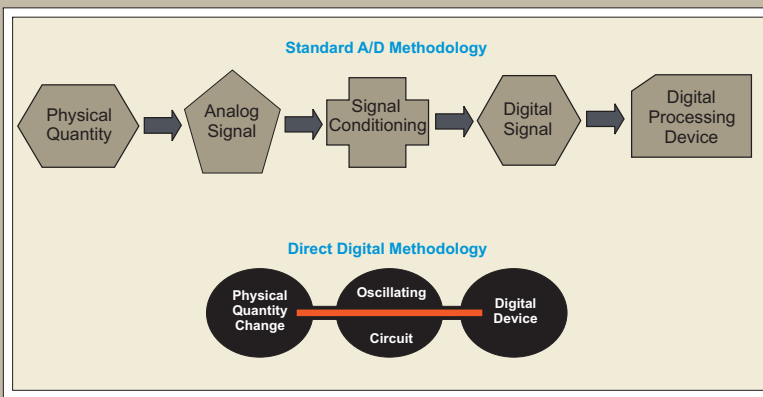
Direct Digital is a revolutionary one step signal transfer methodology, a time based continuous square wave output requiring no signal conditioning of any kind. This is the elegant and technologically streamlined one step method designed to fit a broad range of critical systems requirements. INPROX Technology has developed a revolutionary methodology that does not use a data word; the frequency of oscillation (from a specialty tuned oscillator) is fed directly to a microprocessor in the form of a natural square wave. This digital data signal communicated in raw form offers a hyper accurate, error free, high resolution bit train that can be exploited for a host of critical data points. In addition, real time self diagnostics as part of this continuous output format can be used to monitor systems for varied fault conditions.

The **inGen Direct** sensor technology platform is a true breakthrough in next generation performance digital sensor capabilities, circuit design and signal transfer methodology.

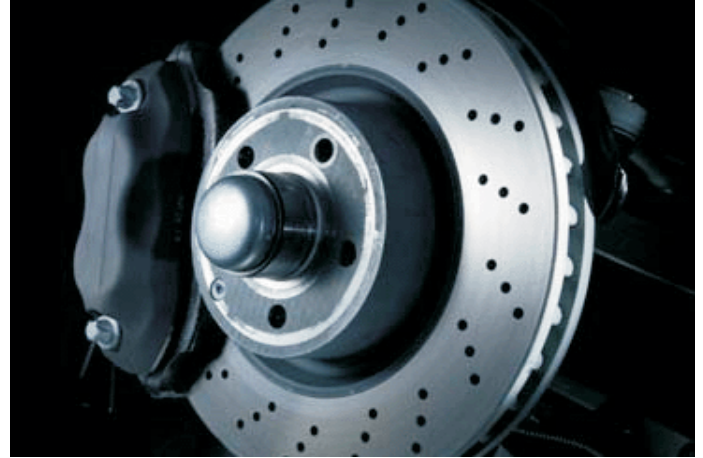
The direct digital method is designed to provide uniformity of a common digital language within complex distributed systems operating on different inputs - current, voltage, sine wave - now systems can utilize data without conditioning.



The **Direct Digital** circuit converts non-electric physical quantities such as speed, linear and rotary position into a corresponding frequency of oscillation signal – a natural square wave that is easily processed by FADEC's, ECU's EEC's and decentralized controls. Compared to analog sensors, a **Direct Digital** signal offers higher resolution, better dynamic response, higher stability and more immunity to interference; is easier for transmission and processing; easier for multiple channel signals, and lower in cost.



A Leap Forward in Digital Signal Transfer



In general, sensors convert a physical quantity to be measured into an electrical signal, which is then processed to be used for various purposes. Traditionally, a complete sensing system is made of the following processes or steps:

Step 1 - This represents the underlying physics that governs the working principal of sensor. For example; a thermistor relates the temperature change to the change of resistor value of the sensor. A Linear Variable Differential Transformer (LVDT) relates displacement to the change of induced voltage of coils. Several important characteristics of a sensing system such as sensitivity, accuracy, resolution, dynamic response, and others, are determined by the working principles of this step.

Step 2 - The raw output of the electrical signal from Step 1 is rarely "benign" in that it needs some forms of processing or modification before it can be used. Some analog signal outputs are too small, say, in microamperes, which need to be amplified. Some signal output is highly nonlinear in relation to a measured physical quantity; and this signal may need to be linearized. Some signal may be too noisy that needs to be filtered. Some signal output may be in alternative current (AC) that needs to be rectified into a DC signal. Still some signals may be in a particular range that is not convenient to process; which in turn needs to be scaled. There are still more signal processing techniques such as normalizing modulation (ex) that can be involved in this step that are generally known as 'Signal Conditioning'. It is important to bear in mind that the signal conditioning step not only changes the sensor output, but also has a cost impact, introduces error, and time delays (through filtering); effecting significantly the overall sensor system's performance.

Step 3 - In many sensing systems, the analog signal still needs to be converted again, back into a usable digital signal; which again compounds errors, time delays and costs.

Direct Digital offers a revolutionary one step approach; by taking a critical analog quantity to be measured; such as position, speed, temperature or pressure-converting that physical change into a frequency in the form of a square wave. From there it is a simple matter to count the edges of the square waves and in turn get a very high accuracy measurement - now the speed of the processor finally determines the accuracy- a new methodology for the microprocessor age.

A New Paradigm in Speed



Direct Digital Measurements

Advanced Speed Measurement Sensor Technology

INPROX Technology's variable inductive and capacitive digital sensor technology for advanced speed measurements is changing the fundamental assumptions which have dominated the discussion centered on finding innovative and practical solutions in a wide array of market segments. This is the new paradigm of speed sensor technology; a dynamic measurement system functioning in tandem with a revolutionary digital signal transfer methodology -- a fundamental set of advancements over Hall, VR and optical sensing devices.

inGen Direct sensor technology is advancing the state of the art, offering attributes that provide a powerful new set of technical resources for customers and partners alike—a digital sensor technology that is capable of significantly expanding automotive, aerospace and industrial speed measurement applications through performance enhancement, and a compelling communication methodology—the [Direct Digital Signal Transfer Methodology](#).

Direct Digital Methodology

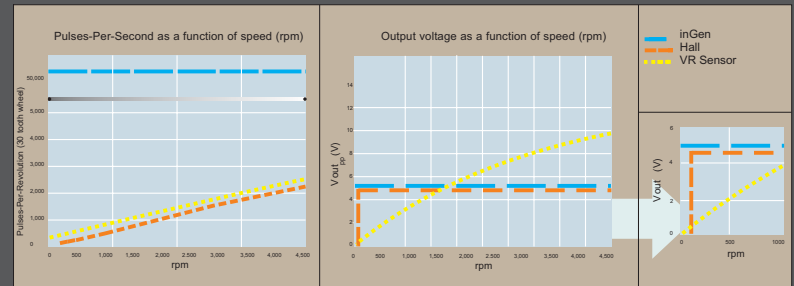


The [Direct Digital](#) circuit design and signal transfer methodology is a time based, continuous square wave output capable of communicating with any ECU and [requiring no signal conditioning](#) of any kind —the elegant and technological breakthrough - a one step design to fit critical engineering requirements. [Direct Digital](#) does not use a data word; the frequency of oscillation (from a specialty tuned oscillator) is fed directly to any microprocessor in the form of a natural square wave . This digital data bit train in raw form offers a hyper accurate, error free, high resolution bit train that can be exploited for a host of critical data points. In addition, real time self diagnostics as part of this continuous output format can be used to monitor systems for varied fault conditions—and zero speed indications.

Advanced speed sensing has been a focus of our senior design team from its inception. By solving some of the fundamental challenges involving speed measurement - we have set the bar very high indeed. It is going to be a long time before it gets re-set again. Is that a good feeling? – [No, that is inGen Direct.](#)

A rising tide lifts all boats...

In a significant developmental leap forward the [inGen Direct](#) sensor technology suite removes all magnets from the speed sensing equation, opening up new target and target viability options to allow recognition for the first time on both ferrous and non-ferrous targets; including aluminum and metal coated plastic parts as precision targets. Our R&D teams realized early on in the technological development process that one could virtually eliminate hysteresis in speed sensing by opening up the technology to these varied and flexible target materials--on aluminum targets hysteresis of $<2.5 \times 10^{-4}\%$ at 50 m/sec target speed are common.



Number of teeth: 36
 Wheel diameter: 130mm
 Resolution: 0.05 degree
 Hysteresis: <0.00025%
 10X Resolution
 10X Dynamic Response

tested at 50 meters/sec wheel speed- 7300 rpm

For this next generation of proprietary variable inductive sensors - *magnets are unnecessary in the execution of the core sensing function; instead inGen Direct technology operates free and clear of this complicated and potentially long term problematic setup.*



Signal refresh rates can be tailored to the requirements of the system. In motor speed applications for example where a motor might rotate at a speed of 12,000 RPM (which is considered to be high speed)--motor speed is $12,000/60 = 200$ Hertz--If the target is a one lobe cam (ex.) the signal refresh of 144 kHz will give an output signal every 0.5 degrees of rotational motion. This innovative circuit and sensor methodology has very little delay in response times, thus higher dynamic response bandwidth is achieved.

Leading sensor and control R&D groups have not found all of their basic speed sensor needs met in the market by existing Variable Reluctance (VR), Hall-effect and optical technology based speed sensors; especially those that are required to operate in difficult or extreme application environments. The variable reactance inductive technology that [INPROX Technology](#) has pioneered, coupled with advances in our direct digital circuit design and communications methodology are currently enabling a broad re-assessment of what is possible in terms of sensor attributes and performance.

The Elegance of One Step

Technological Development

Standard variable reluctance technology sensors require a change in flux that induces a voltage change in the sensor coil. Without significant target motion there is no change in flux and therefore no induced voltage. That's why standard VR does not work effectively at measuring zero speed. Hall-effect sensors sense the strength of a magnetic field perpendicular to the direction of current flow through a semiconductor. The magnetic field induces Hall voltage across the semiconductor. The Hall effect does not need motion to work. A change in the strength of the magnetic field will cause a change in the Hall voltage. However, the Hall voltage differential is small, so in practice to get accurate zero speed measurements two Hall sensors are employed in a quadrature arrangement.

With both VR and Hall sensors the output of the sensor element is a voltage that changes between presence or absence of the target tooth. So the voltage is "A" with a tooth present and "B" with tooth absent. If a particular system employs a 36 tooth wheel and the wheel speed is 1800 rpm (30 revolutions per second) then the output frequency would be $30 \times 36 = 1.08 \text{ kHz}$. (1800 rpm is a standard for induction electric motors.) This can be converted into a square wave for data processing. The period of the signal is 926 microseconds. Lets compare this performance data to [inGen Direct...](#)



Smart speed sensing with [inGen Direct](#) places new and existing applications in the fast lane with regards to dynamic response and the power of a continuous raw data bit -train – all without the parking break of signal conditioning slowing you down.

With [inGen Direct](#) the sensor output frequency is not related to wheel speed or the number of teeth on a gear. It might be (example) 115kHz with a tooth present and 105 kHz with a tooth absent. Regardless of target speed the mean frequency of the output will be 110 kHz. The period of the signal is 9 microseconds, or 100 times faster. Since, VR fundamentally operates by sensing changes in a magnetic field (as does Hall-effect) counting gear teeth (ex.) as they pass by the face of the magnet causing the flux passing through the magnet, and consequently the VR sensor's coil, to vary. However, VR has been recognized as one of the only options that had been available for higher temperatures – given the necessity of solving applications expeditiously – VR has been the choice over Hall-effect sometimes the only choice for these environments – up til now.

Like all other speed technologies, when a target feature (such as a gear tooth) is moved close to the sensor, the flux is at a maximum. When the target is further away, the flux drops off. As the target moves, this results in a time-varying flux that induces a proportional voltage in the coil. Subsequent electronics are then used to massage this signal to get a usable digital waveform that can be in turn utilized by an ECU, counted and timed. In this manner VR sensors will count only the edges of the gear tooth—that is all.

One of the things we set out to do with this technology – was to produce a speed sensor platform that was as accurate as optical based sensors; with a one-upped ruggedness over standard Hall and VR technologies and cost comparative with the most competitive lower cost sensor technologies.

A Precision Methodology Crossed with Next Gen Technology



With the impressive high resolution capabilities of the [inGen](#) digital sensor technology platform – not only are the gear teeth or shaft movements monitored and counted directly – by removing the magnet and sensing off the target itself – the fundamental physical quantity changes (position/speed) provide a crystal clear multi layered digital output to read and in turn provide systems with highly accurate data, as well as high bandwidth data without the costly, time consuming and error producing "massage" of different signal conditioning schemes. Instead of counting the teeth or other features– we can know precisely, through a pre-selected or standard frequency range, volumes more about the target and system in question; teeth profile, run-out (shaft or bearing), acceleration, deceleration, angular position, zero speed – all without measurable hysteresis. If we know that the valley of the gear tooth is referenced as 100kHz and the peak is 115kHz; we have thousands of hertz to provide scale. That is the elegance of this design and a critical attribute that runs throughout the platforms adaptations; including advanced speed measurement. The amount of critical data – communicated through this groundbreaking architecture of a direct ECU timing window to frequency interface is an order of magnitude greater.

“..teeth profile, run-out (shaft or bearing), acceleration, deceleration, angular position, zero speed—all without measurable hysteresis.”

In terms of difficult and extreme application environments – the [inGen Direct](#) sensor is charting an impressive new course in low and high temperature range operability; in noise immunity and in linearity—it also helps that this innovative design does not have a precision reference to ground. In addition, by harnessing the inherent power of this high resolution advanced square wave output methodology, the quality of the [Direct Digital](#) format signal is focused and relevant; interference, which affects more of the amplitude of a signal, has little impact on the quality of the [inGen](#) output.

Our sensor technology designers have engineered in -110°C to +450°C operational ranges; advancing the parameters of even the most robust VR sensors without the need for temperature sensitive magnets, signal conditioning; increasing dynamic response time and providing zero speed indications. Add those powerful capabilities to the direct digital methodology and we find a complete and compelling total solutions package.



High Temperature Operability

Direct Digital - One Step Interface

Achievements in high temperature environment capable variable reactance inductive sensor technology; which **INPROX Technology** is pioneering, are providing practical solutions for critical applications requiring linear, rotary and speed measurements for aerospace, automotive and industrial customers.

—“..customers can now expect..sensor operability ranges from -110°C to +650°C (-160°F to +1200°F) with micron capable resolution and (a) linearity of 0.1%”

Our digital sensor design team led by **G. Brandt Taylor** and **Steven Beard** developed a new standard in sensor temperature limits and operations for our portfolio of innovative direct digital sensors. These sensors had been designed with aerospace customers in mind; our time and efforts going towards perfecting this aspect of digital sensor performance. And today these are the same advancements that are now being used to help construct the next generation of turbine engine controls, sensors for household ovens and thousands of other sensor systems.

Magnetic technologies including Hall-effect, VR, AMR, GMR and inductive based LVDT coils have particular temperature limits - we set out to re-define the upper and lower operability ranges for position and speed measurement sensors. We engineered our revolutionary circuit and sensor design to break new ground enabling a new generation of application solutions performance viability

Our engineers began this latest advance in high temperature variable inductive in order to advance the state of the art in sensor technology. In the end we changed the very nature of what our partners can expect in terms of critical sensing options and operability; these high temperature capabilities are now just another part of our digital direct sensor technology portfolio.

A New Level of Performance

Now, each of our customers and partners; those from the aerospace and automotive markets, to the industrial markets and beyond can expect cost competitive sensor operability ranges from -110°C to +650°C; with micron capable resolution and linearity as low as 0.1%.

The **Direct Digital** circuit design and digital signal transfer methodology is creating new opportunities in the area of microprocessor interface - including advancements for FADEC and automotive ECU systems. **INPROX Technology** has revolutionized signal methodology with a time based continuous square wave output requiring no signal conditioning of any kind –the elegant one step design innovation to solve critical engineering requirements. Real time self diagnostics as part of this continuous output format can be used to monitor systems for varied fault conditions producing the next set of system solutions today.

The **Direct Digital** format is re-writing the very nature of of system control and communication.



The next generation of variable reactance inductive digital direct sensor technology has evolved into **inGen Direct** - a revolutionary platform of advanced capability sensor technologies; speed (with inherent zero speed, run-out detection, material deformation and angular measurements), smart presence sensors, linear position, rotary position and pressure sensors - all developed around the guiding principle of moving beyond the limit of tomorrow's boundaries.

Our valued customers and strategic licensee's understand what these capabilities, including innovative temperature ratings, mean to solving their difficult applications - whether they are integrated directly into aircraft engines or into industrial OE machinery; from household appliances to vital national defense systems - **INPROX Technology** is charting a new course - bringing advanced materials, designs and ideas to the sensor industry as a whole; moving ahead in cooperation and in concert with our partners and customers.

A SIGNIFICANT BREAKTHROUGH IN VARIABLE REACTANCE SENSOR TECHNOLOGY

One Step Design

inGen Direct - Direct Digital - A Market Survey

The sensors and controls market is changing - rapidly - and that rate of change is only going to accelerate. New technological developments, coupled with an evolving and highly competitive global business environment make change an imperative for us all.

We read in newspapers and see on television a myriad of sensor technologies being woven into the very fabric of the clothes we wear - we know that the future is going to be billions of sensor data streams; questions of distance, of time, temperature, velocity; even pressure. Everywhere.

INPROX Technology, understands how to fundamentally advance your product offering. That's why we've developed **inGen Direct**- this is sensor technology that facilitates growth. Robust temperature performance capabilities are just a part of what these digital sensors can offer. Developments and advances in the material sciences, in manufacturing processes; even advances in the sophistication of microprocessors have come together to form a performance nexus - a combination of abilities.

The Direct Digital format has the ability to take industrial motors, diesel engines, turbine engines and electric motors into the "smart" technology age.



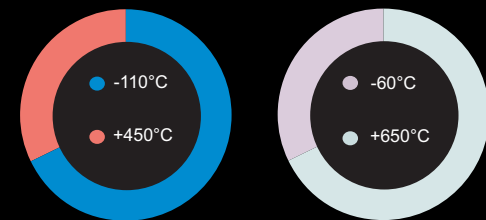
"These are not just specifications on a page, these are the attributes that level playing fields; these are attributes that can change an industry."

The **Direct Digital** circuit which provides an error free 'frequency of oscillation' output is poised to re-write the common language of control architecture; with an innovative signal transfer methodology; the **Direct Digital Signal Transfer Methodology**. A direct interface between sensor and microprocessor - without the need for analog-to-digital conversion or signal conditioning of any kind. That's the revolution.



A New Level of Performance

Some of the advantages that the **inGen Direct** suite of advanced sensor technologies includes: improved adaptability to digital control equipment; improvements in system reliability; reduced sensitivity to electrical noise and temperature drift; as well as common-mode variations on the ground bus. Benefits such as; higher resolution, better dynamic response and greater linearity; durability, longer mean time before failure, lower hysteresis, higher stability, lower costs, more immunity to interference, an easier process of transmission and extended capabilities for multiplexed signals - all come as part of the package.



Higher Temperature Operability

Direct Digital sensors will be the champions of this application environment. So we'd like to invite you to evaluate **inGen Direct** for yourself; let our sales engineers and business development professionals present some of the remarkable abilities this revolutionary sensor technology can offer to advance your product offering.

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