

PNI White Paper

Magneto-Inductive Technology Overview

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This white paper examines how magneto-inductive (MI) sensing works and then discusses some inherent advantages of MI sensing.

HOW MAGNETO-INDUCTIVE SENSING WORKS

A picture of PNI's MS2100 2-axis magneto-inductive (MI) sensor, incorporating two PNI MI sensors and PNI's control ASIC, is shown in Figure 1. PNI's MI sensors typically are used in an L/R oscillation circuit, with a basic circuit shown in Figure 2.

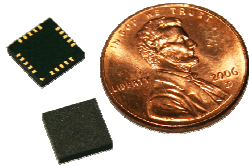


Figure 1: PNI's MS2100 2-Axis MI Sensor

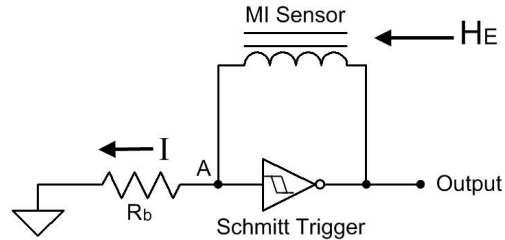


Figure 2: Basic MI Sensing Circuit

H_E represents the external magnetic field parallel to the coil. The total magnetic field the sensor experiences, H , is a function of the external magnetic field and the magnetic field established by the current running through the circuit, I . This can be expressed as:

$$H = k_0 I + H_E$$

where k_0 is a constant that depends on certain physical parameters of the sensor.

For the circuit shown, assuming a "0" value (0V or some value less than the trigger value) on the input to the Schmitt trigger, A , the Output value will be inverted to a logical "1" at some voltage V_S . This gradually will drive the voltage up across the MI sensor until the voltage at A reaches the trigger threshold for the Schmitt Trigger, V_H . At this point, the Schmitt Trigger will see the voltage at A as a logical "1", and the output will become a logical "0". This will drive the voltage down across the MI sensor, setting up an oscillation as depicted below in Figure 3. Note that the current, I , essentially mimics the voltage waveform at A .

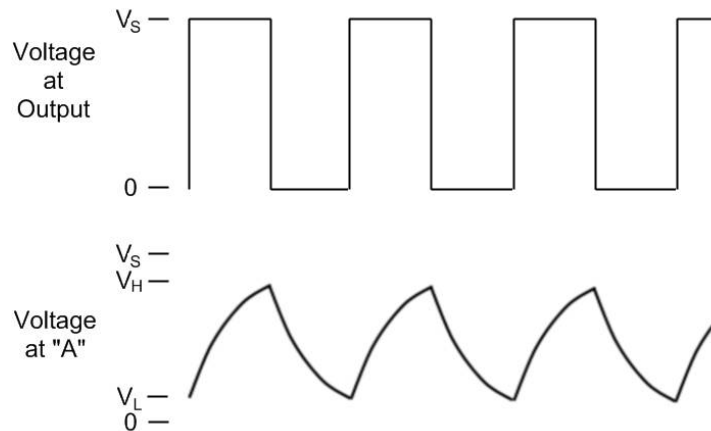


Figure 3: Waveforms for Basic Oscillator Circuit

PNI's MI sensors incorporate a solenoidal-geometry coil wrapped around a high-permeability magnetic core. The inductance of a highly permeable material will vary with the applied

magnetic field. Consequently, the sensor's inductance, μ , is a function of the magnetic field, H , as depicted in Figure 4.

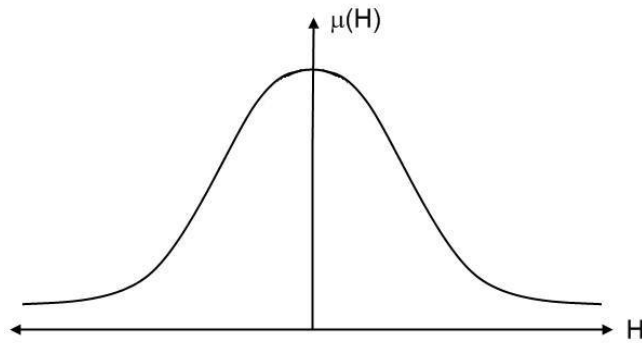


Figure 4: Inductance (μ) of Highly Permeable Material vs Magnetic Field (H)

For the circuit depicted in Figure 1, the bias resistance, R_B , and drive voltage on the Schmitt Trigger, V_S , are selected such that the sensor's magnetic field is in the non-linear regime of the permeability curve. Figure 5 depicts the voltage output when the circuit is driven with either a positive or negative bias, but with no applied external magnetic field. Note that the period of oscillation is the same whether the circuit is positively or negatively biased.

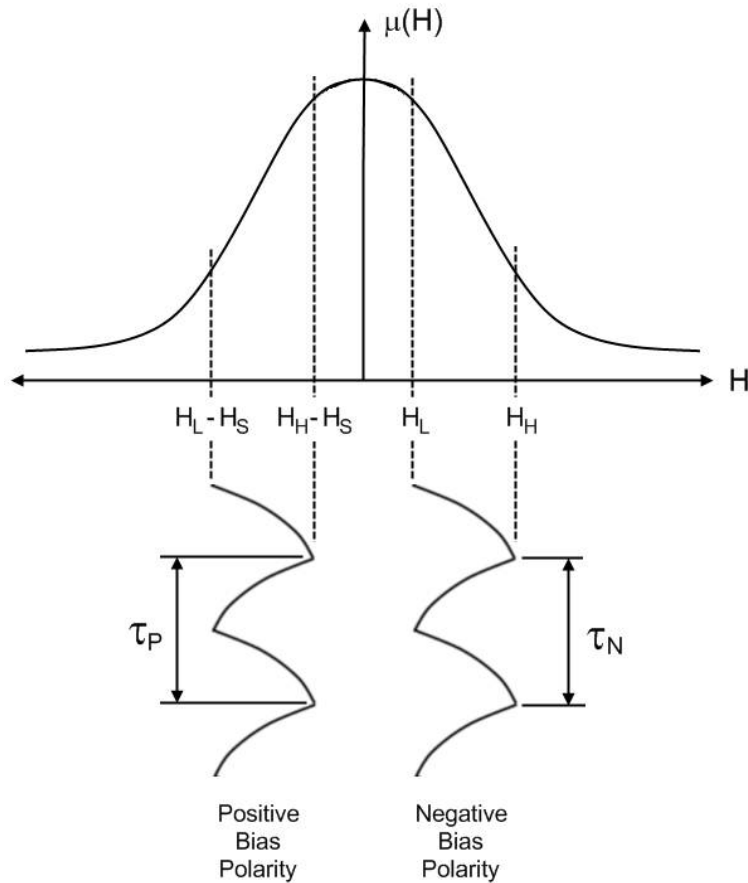


Figure 5: Sensor Circuit Operation with No Applied External Field

When an external magnetic field is applied, H_E (such as Earth's magnetic field), this causes both the positively and negatively biased curves to shift in the same direction. As depicted in Figure 6, this shift causes the inductance to increase when the circuit is positively biased and to decrease

when negatively biased. This, in turn, causes the period between cycles, τ , to increase for the positively biased circuit and decrease for the negatively biased circuit.

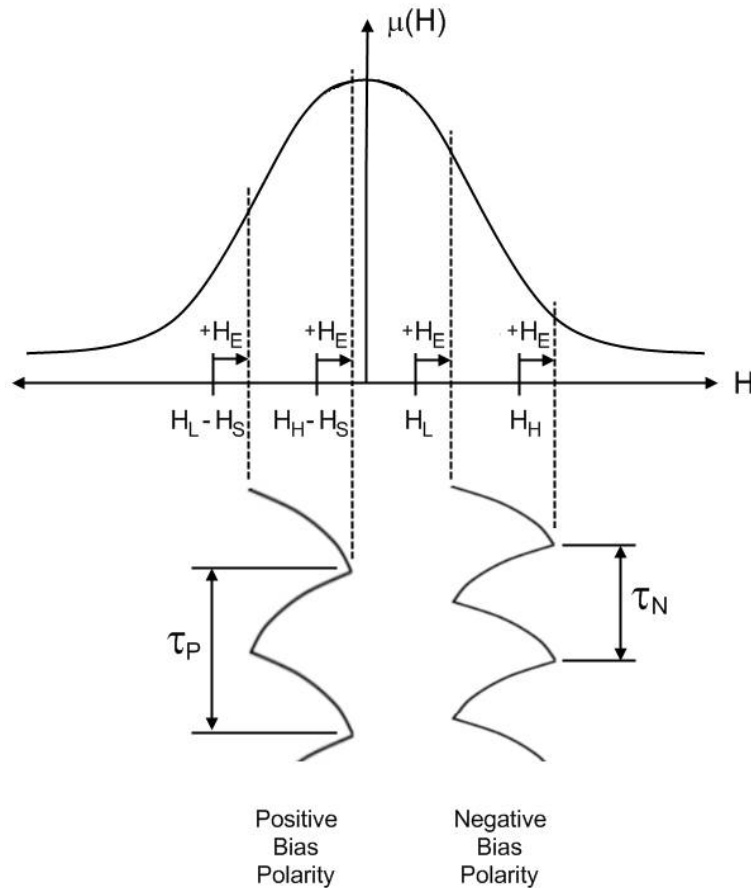


Figure 6: Sensor Circuit Operation with Applied External Field

By measuring the time to complete a fixed number of oscillations (periods) that occur in the forward and reverse polarity directions and taking the difference between these two values, it is possible to derive the strength of the external magnetic field. This represents the underlying principle to PNI's magneto-inductive sensing technology.

DISCUSSION

Magneto-inductive sensing has some particularly useful attributes that set it apart from other magnetic sensing technologies. Specifically:

- The output is inherently digital. The output from PNI's ASIC is a clearly defined number, and this number is directly related to the applied magnetic field. Most other technologies provide an analog output which require additional component hardware, such as amplifiers and analog-to-digital converters.
- Very high resolution, on the order of 10 nT, can be obtained with the basic circuit. In comparison, competing technologies either cannot achieve this level of resolution due to inherent noise floors, or it can be comparatively expensive due to the need for costly external components.
- Low power consumption. Power consumption with MI technology is inversely proportional to the sample rate, such that at an 8 Hz sample rate power consumption is

typically 1.5 mW, while at a 300 Hz sample rate it is typically 7.5 mW. In comparison, magneto-resistive (MR) sensors generally consume around 15 mW to 30 mW, making MI technology 2x to 20x more power efficient, depending on the implementation.

- No need to set/reset MI sensors. Competitive technologies, such as MR, often require sending a high current pulse through the sensor in order to reset the magnetic domains within the core material. This pulse mandates the ability to generate a large peak power, on the order of several watts, and this power spike can cause problems with other components within a users system. Such a set/reset signal is not required with MI sensors.
- Output is inherently stable over temperature. The reverse/forward biasing nature of PNI's MI circuit athermalizes the output since changes in the bias resistance or inductance due to temperature are experienced in both the forward and revers directions, and are thus cancelled.
- No hysteresis. PNI's MI sensor design and the forward/reverse biasing nature of the MI circuit result in virtually no hysteresis. Since hysteresis directly affects the accuracy of measurement, PNI's MI sensors can be used for applications that require high accuracy.

For a more detailed discussion of magneto-inductive technology, see Slawomir Tumanski's article "[Induction coil sensors – a review](#)" in *Measurement Science and Technology*, **18** (2007) *R31-R46*.

For information on all of PNI's discrete sensing components and compassing modules, go to www.pnicorp.com.