Application Bulletin AB-13

Magnetic Immunity and Susceptibility

GMR Basics

NVE's IsoLoop products are based on the Giant Magneto-resistive (GMR) effect. The GMR effect is observed in thin film layered structures that consist of at least two magnetic layers, separated by a thin nonmagnetic conductive layer (Figure 1). Resistance of such structures is low if the magnetic layers are magnetized in the same direction (parallel), and high if the layers are magnetized in the opposite direction (antiparallel). The difference in resistance between parallel and antiparallel magnetic states is usually between 4% and 10% of the total resistance of the material. The thin film GMR "stack" of metals is only a few hundred Angstroms thick, with some layers as thin as only a few atoms thick.

In simple terms the GMR effect can be explained as follows. The origin of electrical resistivity of conducting materials is the existence of scattering centers for conduction electrons. The higher the density of scattering centers, the higher the electrical resistivity of the material. Electrons traveling through a GMR structure carry spin orientation determined by the last visited magnetic layer.

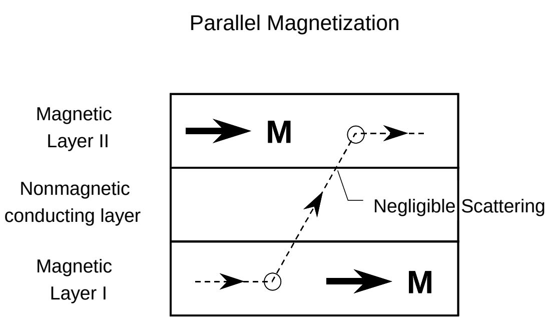


Fig 1a. Low Resistance

When the adjacent magnetic layers are magnetized in the same direction (Figure 1a), the conduction electron arriving from magnetic layer *I* has a high probability of entering layer *II* with negligible scattering because its spin orientation matches the layer magnetization (the majority of electron spins in the layer).

On the other hand, when the layers are magnetized in the opposite direction (Figure 1b), the majority of spin-oriented electrons suffer strong scattering at the interface because they do not match the layer magnetization.

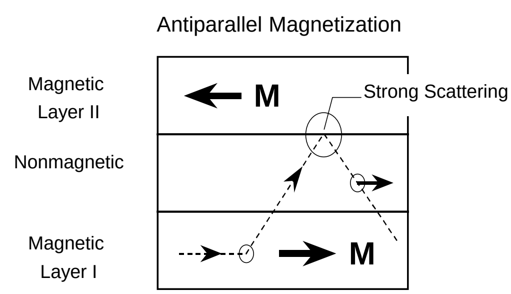


Fig 1b. High Resistance

In this way, the resistance of the GMR structure is low when the layers are magnetized in parallel fashion and high when they are magnetized antiparallel. NVE's isolator products employ 4 GMR resistors in a balanced bridge configuration to translate that difference in resistance to a digital signal proportional to magnetic field strength and direction.

Magnetic Immunity and Susceptibility

In order to understand the concepts of magnetic immunity and susceptibility as related to a GMR isolator, it is important to understand the underlying magnetic structure involved. NVE uses a GMR device known as a *Spin Valve* in its isolator products. In its simplest form, a spin valve is composed of

two magnetic layers, the *pinned layer* and the *free layer*, separated by a nonmagnetic conduction layer. The pinned layer is *Exchange Coupled* (Exchange Coupling is the name given to the quantum mechanical effect where atoms of two magnetic or non-magnetic layers share electrons with parallel spins) to an underlying antiferromagnet. The purpose of exchange coupling the pinned layer to the antiferromagnet is to establish its magnetization in a fixed direction (ie to bias the pinned layer). The free (unbiased) layer changes its direction of magnetization after the application of a relatively low magnetic field (<2 mT). Since the pinned layer is biased, a relatively large magnetic field (>40 mT) is required to change the direction of its magnetization.
The structure of a typical spin-valve is shown in figure 2a.

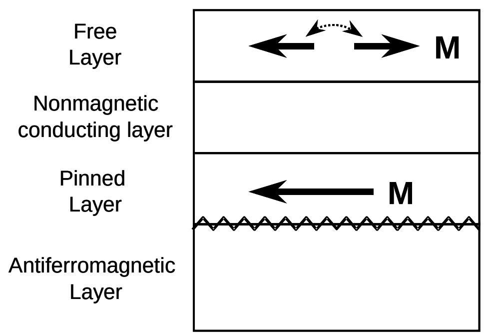


Fig 2a. Simple Spin Valve

Figure 2b shows the transfer function of a typical GMR spin-valve sensor.

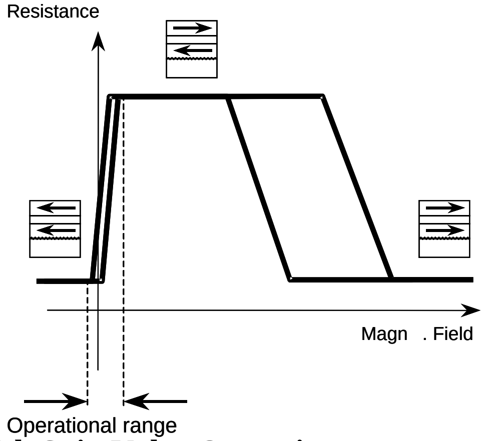


Fig 2.b Spin Valve Operation

In zero magnetic field the layers are magnetized parallel, therefore the resistance of the spin-valve is low. When the magnetic field is increased slightly, the free layer changes the direction of magnetization and the layers are then magnetized anti-parallel. The resistance of the spin valve in this state is increased. Further increasing the magnetic field leads, with significant hysteresis, to the change of direction of magnetization in the pinned layer, which results in resistance decrease. In the IsoLoop, only the low field part of the whole ***R(H)*** (resistance vs. magnetic field) characteristic is used.
Figure 3 shows an IL7xx series isolator in block format. The coil and coil driver circuit generate a magnetic field in response to an incoming digital signal. The GMR bridge in turn creates a differential output voltage that is sensed by the comparator and translated back to the digital domain.

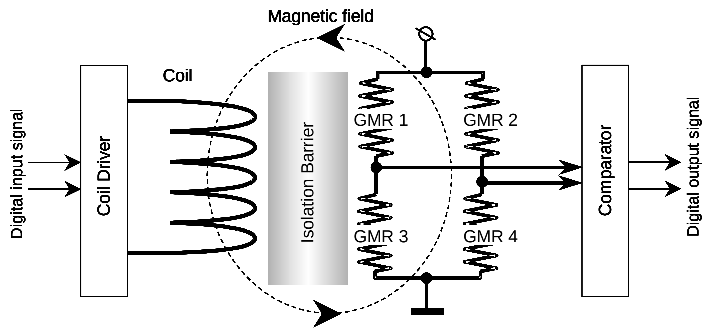


Fig. 3 Simplified IL7xx Isolator

A logic low-to-high-to-low transition at the input of the device in Figure 3 results in the bridge response shown in Figure 4.

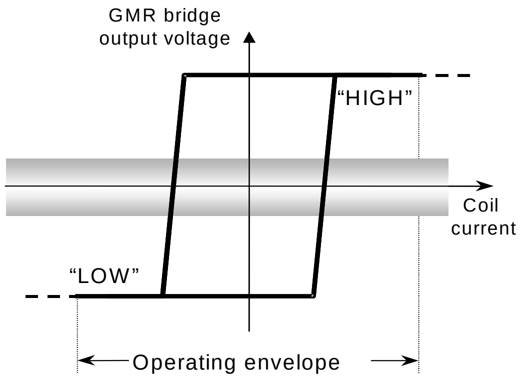


Fig. 4 IL7xx Bridge Response

The shaded area in Figure 4 represents the comparator threshold voltages. Note that when coil current is zero (magnetic field is zero), there are two stable states for this device, representing low and high logic states.

Magnetic Immunity

There are two design elements of the bridge that are aimed specifically at increasing the immunity the isolator shows in the presence of an external magnetic field: differential signaling and direct shielding. A magnetic shield is plated over the entire bridge area as shown in Figure 5.

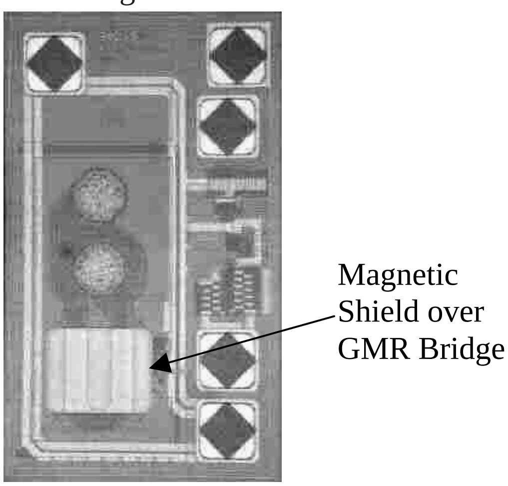


Fig.5 Actual Isolator chip

The shield boosts the signal generated by the coil since the signal's magnetic field cannot "escape" vertically. It also shields the bridge from unwanted magnetic signals that may be present in the operating environment. The differential signaling technique means that the device only responds to differential magnetic fields. The limit of both of these techniques is the saturation level of the materials. Once the shield is saturated magnetically, it becomes transparent to external fields, and no attenuation of external signals will occur. If the shield is saturated, the GMR resistors can then also become saturated and the bridge will no longer provide the +/-5% response expected for an input logic change. At saturation, all four resistors in the bridge will have the same resistance, so no signal change will take place at the bridge output.

Magnetic Susceptibility

Both of the magnetic field saturation effects described are designed to take place well outside the normal operating curve of the device. The limits of susceptibility for most industrial, commercial, telecom, residential and medical applications are governed by the European Electromagnetic Compliance specifications EN50081, EN50082 and EN600001. IsoLoop products offer three times the level of immunity to perturbations required by these specifications in the worst-case field orientation for the isolator. If the user is able to orient the device for maximum immunity, that figure jumps to at least seven times the compliance specifications.

The list below details the specifications and methods used to evaluate the IsoLoop's magnetic immunity and susceptibility performance.

EN50081-1 Residential, Commercial & Light Industrial
Methods EN55022, EN55014

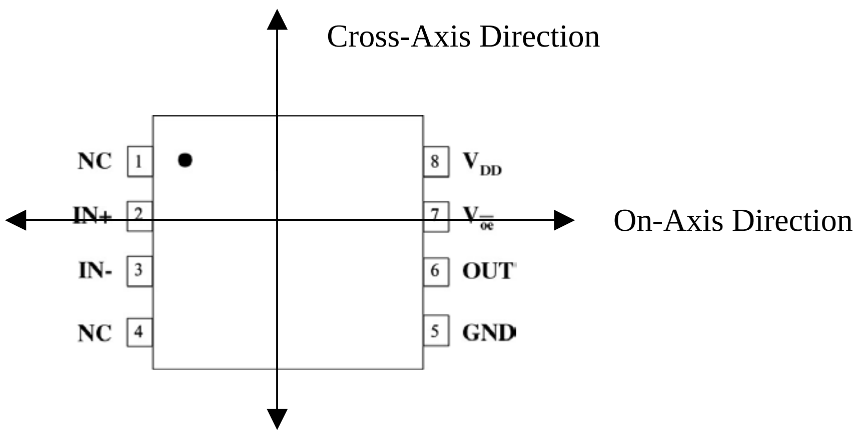
EN50082-2 Industrial Environment
Methods EN61000-4-8 (*Power Frequency Magnetic Field Immunity*), EN61000-4-9 (*Pulsed Magnetic Field*), EN61000-4-10 (*Damped Oscillatory Magnetic Field*)

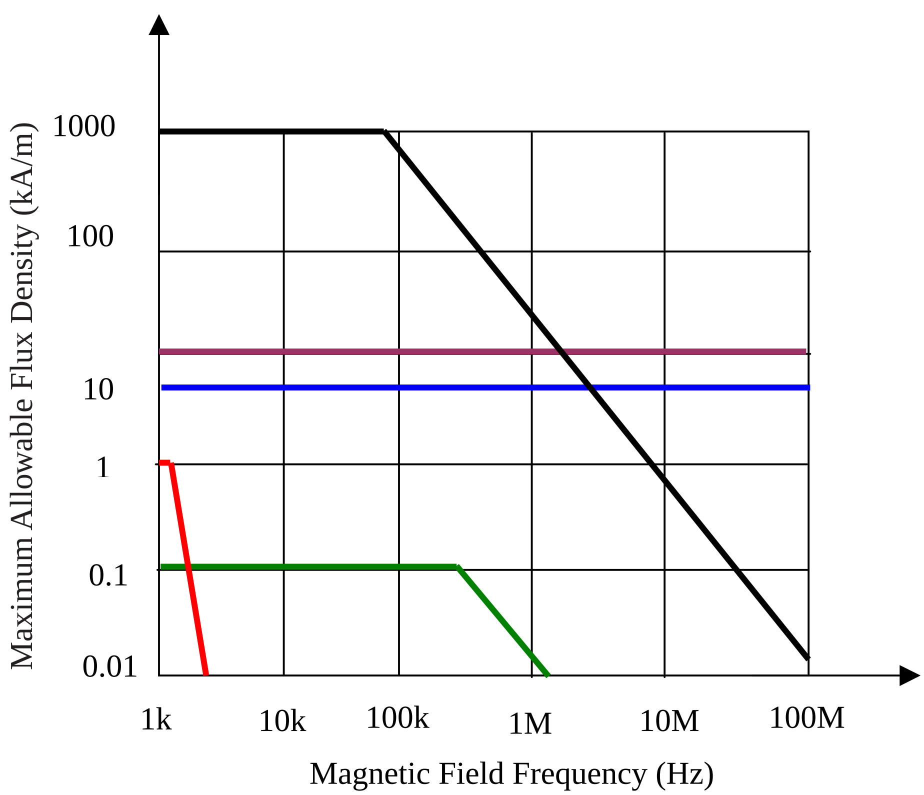
It is worth noting that the IsoLoop family is most susceptible to dc magnetic fields. Device performance actually improves when the frequency of an applied ac field is increased. That's in stark contrast to transformer-coupled isolators whose performance drops off dramatically as the frequency of the external field approaches 100kHz.

Table 1 illustrates IsoLoop performance against the relevant EN specifications. Chart 1 shows the relative linearity of the IsoLoop isolator's immunity with frequency of applied field and compares it with transformer-coupled isolators.

Specification Name	Spec Limit (A/m)	IsoLoop Specification (A/m)	
		Cross-Axis	On-Axis
EN50081-1, Methods EN55022, EN55014	100	7,000	2800
EN50082-2, Method EN61000-4-8 (*Power Frequency Magnetic Field Immunity*)	1000	7,000	2800
EN50082-2, Method EN61000-4-9 (*Pulsed Magnetic Field*)	1000	10,000	4000
EN50082-2, Method EN61000-4-10 (*Damped Oscillatory Magnetic Field*)	100	10,000	4000

Table 1





Key

See Table 1 for color codes

Transformer Coupled Isolators