

## Magnetoresistance Effect

In simple terms, the magnetoresistance is the relationship that exists between the regular resistance on a material and the change of it on a magnetic field applied. It was discovered by L. Kelvin on the XIX century.

When an external magnetic field is applied over a desirable high  $\mu$  material (carrier mobility) that is experiencing an electrical current, a Lorentz force is created and consequently interacts with the charge carriers. When this happens, and the electric field is properly oriented an effect of “increased resistance” appears.

Performing the math, one can have an electric charge with a velocity of the charges depending of the electric field intensity on which the charge is submerged (Eq. A):

$$v = \mu E$$

If added to this we have a magnetic flux of density  $B$ , then the following equation (Eq. B) is satisfied:

$$v = \mu(E + v \times B)$$

Then, replacing the same  $v$  within we have (Eq. C):

$$v = \mu \left( \frac{E + \mu E \times B}{1 + (\mu B)^2} \right)$$

As  $E$  and  $B$  are vectors, if their inner product is 0, this is  $E \times B = 0$  then the velocity can be simplified into (Eq. D):

$$v = \mu E \left( \frac{1}{1 + (\mu B)^2} \right)$$

By comparing Eq. A with Eq. D, one can simply understand that the former is larger, as D's fraction can only have 1 as a max value when  $\lim_{B \rightarrow 0} \frac{1}{1 + (\mu B)^2}$

On the other case, D can be smaller always that  $B$  is not at 90 degrees from  $E$ , which translates on a slower movement and smaller current as consequence.

With the above explanation on mind, the magnetoresistance clearly depends on the magnetic field direction

One massive application of the magnetoresistance is the Giant Magnetoresistance, commonly known as GMR. This is largely used in read heads of the magnetic disks for computer information storages, that are sensed using magnetic fields. There has been a lot of development on the GMR Sensors, that has resulted on the hard drive disks increased capacities.

The GMR is also applied on biosensors, MEMS and as an alternative to Opto-Isolators. The following image shows a diagram of the physical layout of a GMR.

