SENSOR APPLICATIONS OF PERMALLOY THIN FILMS

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Sensors utilizing permalloy thin films have been developed for measurement of temperature, current, proximity and air flow. These sensors utilize the resistive and magnetoresistive properties of permalloy. Their design, construction and performance will be described and compared to some well-known technologies in each sensing area.

Permalloy is attractive for magnetic sensing because the full scale change in magnetoresistance is developed for fields on the order of 50 gauss or less. The sensitivity facilitates the construction of proximity sensors capable of detecting very small targets, and allows the design of current sensors which utilize simple flux collectors. Another important feature of permalloy (81% Ni, 19% Fe) is that it has no magnetostriction, minimizing concerns regarding stress sensitivity induced by packaging the sensors.

The magnetoresistive properties of permalloy have been known for many years. With the development of permalloy thin film techniques, it is now possible to construct low cost, batch processed sensors using this technology. The magnetoresistive effect $\Delta R/R$ in permalloy is on the order of 2.5% for a 50 gauss field, adequate to construct useful sensors. The magnetoresistive effect in permalloy is shown in figure 1. The resistance is a maximum when the applied field is zero and decreases as the magnetic field is increased. Note that this function is symmetrical about the zero gauss axis. Using the magnetoresistance effect in AC applications, therefore, requires that a bias field be applied to avoid a two-valued output. The magnetoresistive effect is also nonlinear, (approximating a $\cos^2$ function), so that constructing linear sensors poses significant problems.

One approach to constructing a permalloy linear current sensor is through the use of a rebalance scheme. A simple flux collector constructed from a strip of permalloy formed into a circular shape contains multi-turn rebalance coils. The conductor carrying the current to be measured is passed through the flux collector. This sets up an applied field which is sensed by a permalloy bridge. The electrical signal thereby generated is amplified and applied to the rebalance coils. Thus, this sensor operates at a fixed point on the permalloy magnetoresistance function, making its non-linearity inconsequential. Another approach is the use of geometries for the permalloy elements which linearize the characteristic.

Less well known is the fact that permalloy can be used for temperature sensing, providing the same sensitivity as platinum with higher base resistances and at lower cost. The resistance vs. temperature characteristics of permalloy and platinum are compared in figure 2.

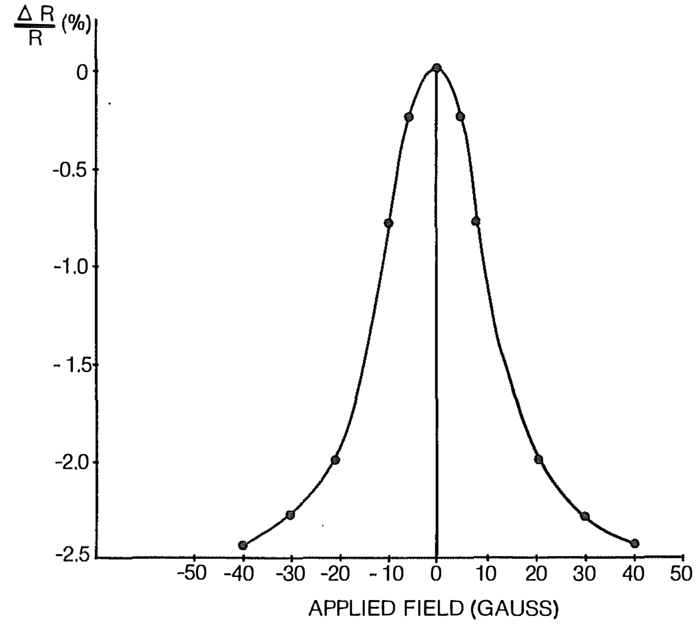

Fig. 1: Magnetoresistance In Permalloy

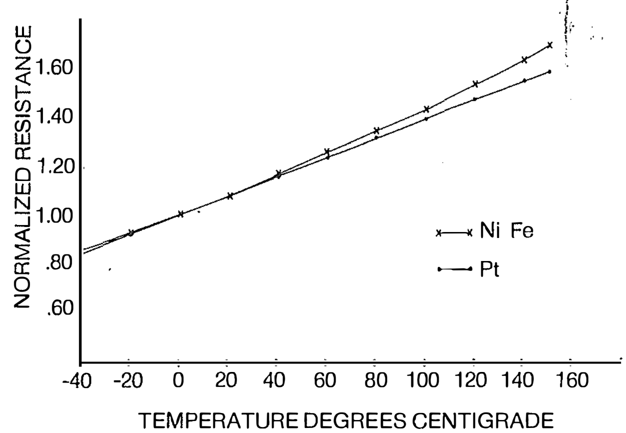

Fig. 2: Resistance vs. Temperature Comparison Of Permalloy & Platinum

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Careful design reduces magnetic sensitivity to negligible levels. Relatively thick films approach the bulk properties of permalloy, yielding consistent TCR characteristics. Laser trim is used to standardize the room temperature resistance to a $\pm 0.15\%$ tolerance, making the devices interchangeable.

By mounting the temperature sensor on a ceramic with a low-value laser-trimmed thick film resistor (used as a heater), a simple air flow sensor results. With constant power applied to the heater, increasing air flow reduces the temperature (and resistance) of the sensor. The temperature of the air flow sensor is given by $T = TH + TA - fV$, where TH is the temperature rise due to the heater resistance, TA is the ambient temperature, f is a non-linear function relating resistance to air velocity, and V is the velocity of the air flow. Another temperature sensor placed in the same air flow allows the effect of ambient temperature (TA) to be removed. The resistance vs. air velocity characteristic of this device is illustrated in figure 3.

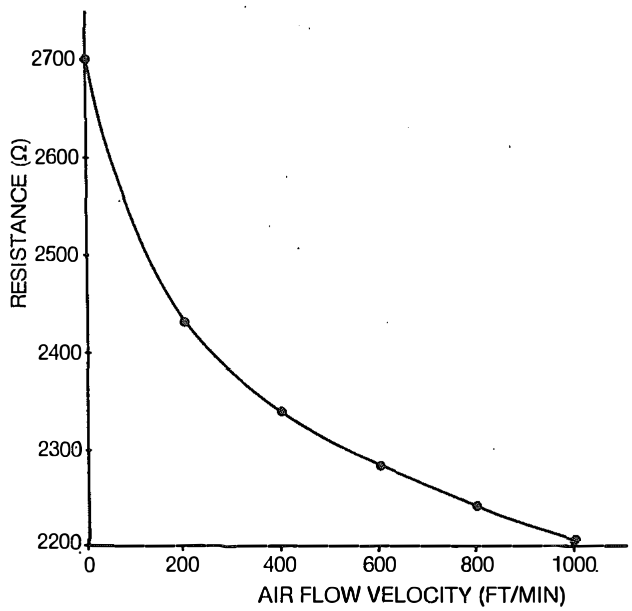

Fig. 3: Resistance vs. Air Velocity Characteristic Of Air Flow Sensor

The common thread in the sensors just described is their utilization of permalloy thin films to achieve improvements in the performance vs. cost spectrum. Finally, bipolar or CMOS signal conditioning electronics may be placed on the same die with the thin film sensor, resulting in fully integrated sensors.