The Effect Injection Width and Temperature-Offset Compensation of Magnetotransistor

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Abstract

This paper presents effect of injection width on Magnetotransistor. Emitter area was confined by LOCOS and the injection window size was varied from 4, 5 to 10 microns. With bias current of 3 mA the window size 4 micron gives best sensitivity at 10mV/T. Measurement linearity is 0.1 \% full scale. Voltage gain of 10 was used for minimizing temperature coefficient to be around 7.9 mV/\degree C measured from 25 to 125 \degree C. Temperature coefficient divided by sensitivity gives us a relative temperature sensitivity of 7.9 \% T/\degree C. Second magnetic sensor device has been used for temperature compensation. The second device was configured as magnetic field immune then it was used as a temperature offset voltage reference. The added module reduces overall temperature sensitivity down to 0.3 \% T/\degree C.

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1. Introduction

Magnetotransistor based on CMOS production technology are joyfully benefits from its low power consumption, small dimension, design flexibility and compatible with integrated circuits assemble. Considering low power device a few effect parameters need to be concerned such as area of injection terminal and carrier mobility. In the design case emitter area or current path have to be reduced and
redesigned for minimizing majority carriers and maximizing deflection current amplitude to yield higher output voltage for better sensitivity. Typically silicon based semiconductor devices are suffering from a large temperature coefficient which can cause operation off-set drift problem. High temperature coefficient comes from many reasons involving insimmetrical design, generation and recombination in substrate bulk, misalignment of photolithography processes and non-uniform of etching process. Temperature compensation and calibration is recommended at operating temperature if one expect accuracy from this type of sensing devices.

This paper presents low power magnetotransistor sensing both vertical and lateral magnetic field vectors based on Hall effect principle. Detail studies on the relationship between emitter width and power consumption have been done and the thermal offset drift compensation method has been accomplished by the dual magnetotransistor compensation technique. These methods increase the device performance, accuracy and reduce cost on offset calibration.

2. Structure and Operation principle

Figure 1(a) shows structure of the magnetotransistor consisted of emitter, base and collector. Both emitter and collector are p type semiconductor where base and substrate are n type semiconductor. LOCOS was fabricated as a strip around the emitter where it was lefted open as the current path. The dimension of the opened window is refered as the emitter width, $W_E$, which is varied from 4, 5 to 10 microns. The base width and the collector width refered from their contact sizes are 10 microns and the distance between the base and the collector is 20 microns.

Mechanism of the magnetotransistor is based on deflection current between two current paths, such as emitter-base and emitter-collector or other combinations (B-E and B-C or C-E and C-B), which are on influence of magnetic induction vector. The magnitude of the deflection current depended on magnetic flux intensity similar to the principal of Hall Effect. Emitter current is a combination of base and collector currents ($I_B$ and $I_C$) as shown in equation 1 and it can be derived in form of current density as shown in eq.2 [2-3].

$$I_E = I_B + I_C \quad (1)$$
$$I_E = J_{nx} W_E d \quad (2)$$

Where $J_{nx}$ is the current density, $W_E$ is the emitter width and $d$ is the junction depth.

The difference between the base current and the collector current, $\Delta I_{CB}$, as a result of magnetic induction, $B_Z$, can cause the carrier deviates in y axis with $\theta_{B(y)}$ angle compared to its original path. The relation of $\Delta I_{CB}$ can be written as equation 3 and \tan $\theta_{B(y)} = \mu B_Z$ [2-3].

$$\Delta I_{CB(y)} = J_{nx} d \Delta W_E \quad (3)$$
3. Result and Discussion

3.1. The effect injection width

Figure 2 shows a relation between output voltage and magnetic induction flux along with the emitter width variation. The magnetic induction was varied from 0 to 0.4 mT. The slopes represent sensitivities compared three conditions of emitter width (4, 5 and 10 microns). As can be seen from the figure smaller size of the emitter width helps improving sensitivity of the device. At emitter width of 4 microns, the sensitivity increase by 3% compared with the condition of 10 microns width. This results confirm benefit of LOCOS which also reduces leakage current around the emitter to gain more energy efficiency and increases the sensitivity of the device.

\[ y = 0.0079x + 2.2645 \]
\[ R^2 = 0.998 \]

![Figure 2](image_url)

Fig. 2 The relation between magnetic field density and output voltage at emitter width

3.2. The Temperature-offset compensation

Magnetotransistor is a bipolar transistor with two p-n junctions as basic fundamental. The p-n junction plays an important role on temperature dependence of the device derived as a built-in voltage \( V_{bi} \) at the junction. The temperature also affects carrier mobility so the output signal offset as shown in Eq.4.

\[ V_{offset} = V_{\mu(T)} + V_{bi} \]  \[ (4) \]

The Graph shown relationship between temperature and output voltage of the sensing device at zero magnetic induction is presented in figure 3(a). Temperature was ramp up from room temperature to 125 ºC which give the device’s temperature coefficient of 7.9mV/ ºC. Figure 3(b) shows forward I-V characteristic curves of the both diodes (B-C and B-E) at temperature of 40, 70 and 100 ºC which are temperature dependence as same as in reverse bias regime.

![Figure 3](image_url)

Fig. 3 (a) Temperature coefficient of magnetotransistor and (b) Forward bias IV curves of the p-n junctions with temperature
This high temperature coefficient need to be compensated to improve the device’s measuring accuracy. Therefore the double magnetotransistor configuration has been used to solve this problem by using another magnetotransistor with canceling its ability of sensing magnetic field out but still keep its temperature response behaviour. The diagram in figure 4(a) shows this configuration combining the magnetotransistor configed as measurent mode(MT2) with the temperature mode(MT1). The experimental results in figure 4(b) also confirm this method. The graph show two plots of magnetotransistor in measurement mode vs temperature mode and compensated output signal at zero magnetic field applied. The compensated signal shows a good result with only 1.1% deviation from zero magnetic field off-set voltage over the temperature range of 25-125 °C.

Fig. 4 (a) Dual magnetotransistor configuration and (b) Output signal of temperature compensated terminal and output signal

Conclusion

The experimental results inform that reduction emitter width of the magnetotransistor help improving the device sensitivity about 3% from 10 to 4 microns width. The dual magnetotransistor configuration technique reduces temperature coefficient from its original value of 7.9 mV/ºC to 0.3 mV/ºC over the temperature range of 25-125 °C accounted for 1.1% deviated from zero magnetic field off-set voltage.

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References