AN APPLICATION OF 2-D SILICON HALL DEVICE FOR INDEPENDENT DIRECTIONAL MAGNETIC FIELD MEASUREMENT TECHNIQUE

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Abstract— This research presents an application of two dimensions Hall device for magnetic flux density measurement with independent directional magnetic field measurement technique [1],[2]. This new design two dimensions Hall Device can measure magnetic field from two dimensions which can replace original Hall sensor system that use two commercial Hall devices located perpendicular to each other. The new device is tested and the measurement result has shown capability of the device to measure magnetic field in two dimensions. The output voltage is depending on angle that magnetic flux line interact with Hall device which correspond to sine and cosine functions. Therefore, from this characteristic, it can be proven that the new designed Hall Device can be used for independent directional magnetic field measurement technique and can increase accuracy of measurement system.

Index Terms—Hall Sensor, Two dimensions, independent directional magnetic field measurement technique.

I. INTRODUCTION

Generally, the magnetic flux density measurement by using one Hall sensor may not be able to provide accurate measurement result. In other word, the output voltage from Hall sensor corresponds to sine function which depending on measurement angle between magnetic field and Hall sensor. With this limitation the measurement angle can effect to measurement result accuracy.

Recently, the independent directional magnetic field measurement technique is developed to reduce an angle limitation of Hall sensor. This original technique use two commercial Hall sensors locate perpendicular to each other and use output signal from both Hall sensors that sine and cosine function to analyze and calculate magnetic flux density by trigonometric function which independent to direction of magnetic field. However, the disadvantage of original system is two Hall devices must be located perfectly perpendicular to each other in order to get high accuracy measurement.

Therefore, the purpose of this research is to use 2-D Hall device base on a simple silicon fabrication process technology. The advantage of this 2-D Hall device that can be respond to magnetic field more than one dimension, perpendicular field (B_z) and parallel field (B_x) and also this device is designed to measure magnetic flux density from each magnetic field direction and the output signal response can be analyzed to correspond to perfectly sine and cosine function. Furthermore, two signal of this device are connected to signal conditioner circuit for amplify and adjust sensitivity to be similar to each other which can show similar output response to original Hall sensor but without limitation on angle of measurement.

With this technique, the new designed device can eliminate alignment issue when using regular commercial Hall device. Also this new designed device can measure magnetic flux density with high accuracy measurement result.

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II. DEVICE STRUCTURE

The two dimensions Hall device structure is fabricated with silicon technology process at Thai Microelectronics Center (TMEC). For fabricated 2-D Hall structure processes, Al metal material is growth by using RF-Sputtering technique on the 20-30 Ω.cm p-type silicon wafer is shown the cross-section in Fig.1.

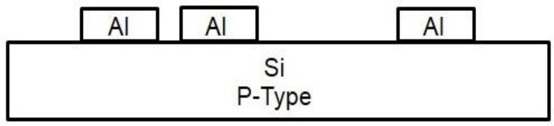

Fig. 1 The cross-section of device

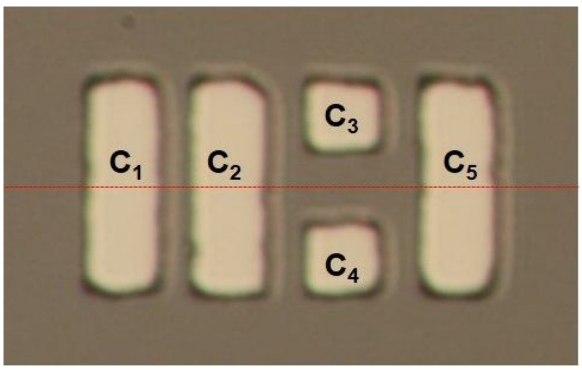

Fig. 2 The five contacts of 2-D Hall device

The Al thin film is etched to get five ohmic contacts, the surface pattern of five ohmic contacts (C_1 to C_5) are shown in Fig. 2. For C_1, C_2 and C_5 use to bias current,

C_3 and C_4 are used to sense Hall voltage deviation for perpendicular field direction and the C_1, C_2 are sensitive contacts of parallel field interact to active area of 600×600 μm^2. Both the two output signals are connected to signal conditioner circuit for amplify voltage signals and adjust the sensitivity response for signal similarity.

III. EXPERIMENTAL

The magnetic field measurement, there are four main part of the system which consist of 2-D Hall device, signal conditioner circuit, analog to digital converter and computation part. The measurement system diagram are shown in Fig.3.

In the first step of experiment, The signal sensitivity of perpendicular field and parallel field response were tested on 2-D Hall Device. Both magnetic field directions interact with active area that shows in Fig.4 with bias current direction of device. The fix bias current is 1 mA applied to c_1, c_2 and c_3 through two resistors that connect to c_1, c_2. The perpendicular field of 2-D Hall device response is measured across c_3 to c_4 sensitive contacts and the parallel field response is measured across c_1 to c_2.The magnetic field is applied to 2-D Hall device by using electromagnet which varied magnetic flux density from 0-3,000 Gauss. Hall voltage data of both magnetic field response are collected and evaluated to analysis sensitivity of this device.

In the second step of experiment, Hall device is rotated 0-180 degree by 10 degree/step in constant magnetic flux density as 3,000 Gauss. Fig.5 is showing magnetic properties testing method to characterize magnetic response of 2-D Hall device. The purpose of this experiment is demonstration the output response of two signals depend on an angle that correspond as sine and cosine function.

For analog voltage of 2-D Hall device are converted to digital signals by ADC and transmitted to computer and analyzed constant Hall voltage. The constant Hall voltage are calculated by (1) [2] using Lab-VIEW programming.

$$k_1 \sin^2\theta + k_2 \cos^2\theta = 1 \qquad (1)$$

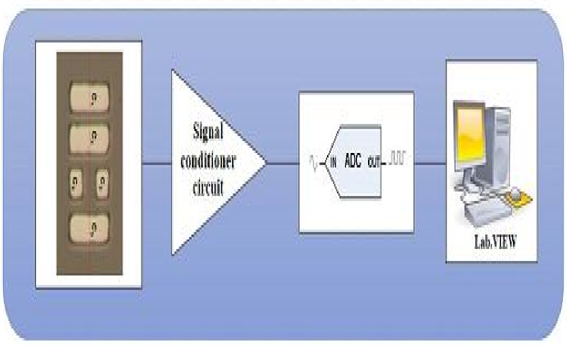

Fig. 3 Diagram of magnetic field measurement system.

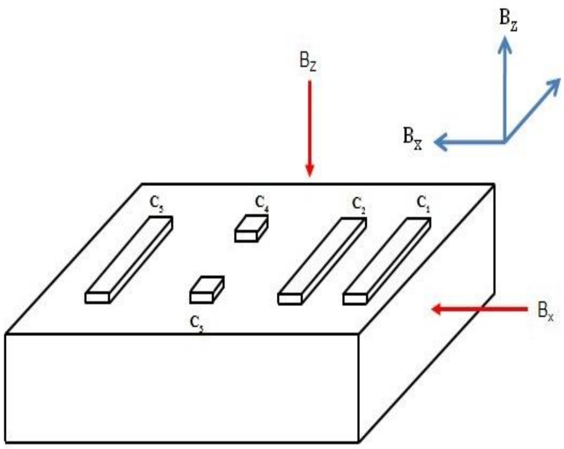

Fig. 4 Sensitivity on two dimensions magnetic field testing

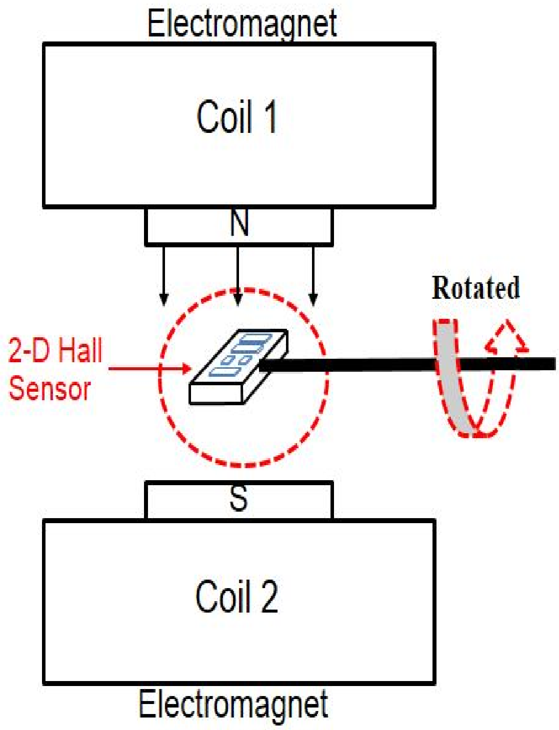

Fig. 5 Apparatus of magnetic properties testing

IV. RESULT AND DISCUSSION

In the independent directional magnetic field measurement system, the similar sensitivity response from both directions of magnetic field (B_z and B_x) is required. Therefore to achieve this requirement, the experiment is designed by connecting the signal conditioner circuit to 2-D Hall device sensor in order to amplify and adjust the output Hall voltage signal. The magnetic flux density is varied from 0 - 3,000 Gauss and the voltage signal response is then measured. The comparison of magnetic field from both directions measured by 2-D Hall Device is shown in Fig.6. The sensitivity response for perpendicular field (B_z) is 0.00140 mV/G and for parallel field (B_x) is 0.00138 mV/G which is similar to each other with only 1.4% different.

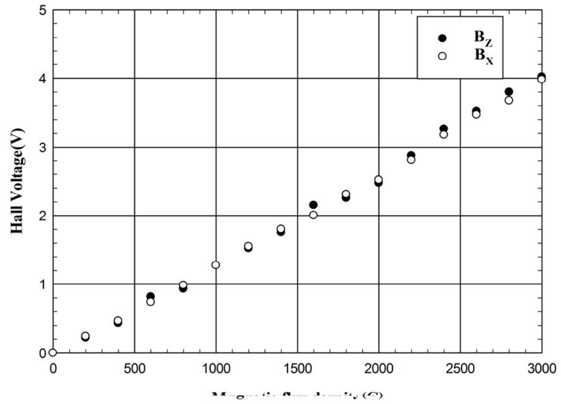

Fig. 6 Sensitivity of 2-D Hall device with amplifier circuit

In order to confirm phase different between each magnetic field, the experiment is designed by apply 3,000 Gauss constant magnetic field and rotate 2-D Hall device every 10 degree from 0 – 180 degree and measure output voltage. The voltage output result Fig.7 has shown 90 degree phase different between perpendicular field and parallel field which can be determined as sine and cosine function. As measurement result, it is proven that the designed device is efficient for independent directional magnetic field measurement system.

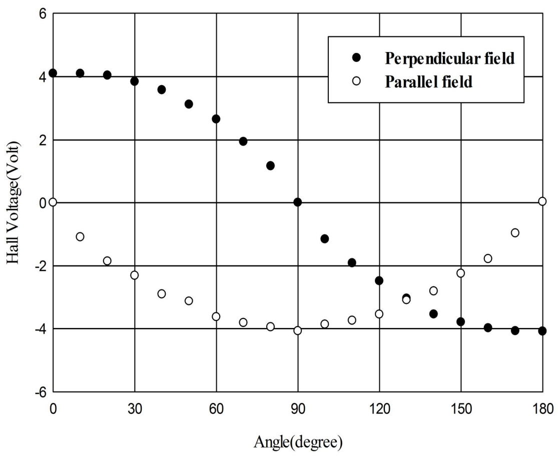

Fig. 7 2-D Hall device response depend on an angle

The final experiment is designed in order to measure the independent directional magnetic field by rotate the 2-D Hall Device from 0 – 180 degree under constant 3,000 Gauss magnetic flux density and measure voltage output of each rotation angle for both directions of magnetic field. The output result is then analyzed and calculated constant Hall voltage by (1) using LabVIEW programming. The result as shown in Fig.8 shows similar constant Hall voltage output for each measurement angle. The average constant Hall voltage is 4.30846 volt.

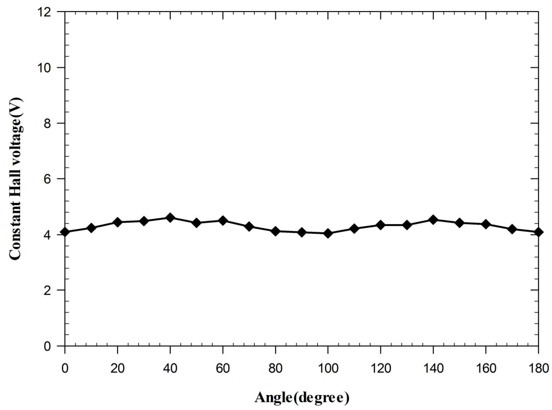

Fig. 8 The Independent Directional Magnetic field Measurement Technique at flux density as 3,000 Gauss

CONCLUSION

The 2-D Hall Device has capability to measure two dimensions both perpendicular and parallel magnetic field with only five ohmic contacts. Also this device has simple Hall Effect structure design with less process for fabrication which can reduce cost for design and fabrication of the device. The experiment results are proven that the new designed of 2-D Hall Device is efficiently measure variation of magnetic field in 2 directions. The result of experiment corresponds sine and cosine function that show the perfectly perpendicular to each other of two dimensional response of this device and very well aligned with principle of independent directional magnetic field measurement technique.

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