FUNCTIONALITY TEST FOR MAGNETIC ANGULAR POSITIONING INTEGRATED CIRCUIT

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Key words: angle measuring, integrated hall sensors, magnetic sensors, HALL sensor array, integrated coils, semiconductors, microelectronics, silicon wafers, magnetic fields, ASIC, Application Specific Integrated Circuits, functionality test, testing devices, wafer probers, automatic testing

Abstract: A description of the low cost, fully automated on silicon wafer testing procedure of the magnetic angular positioning integrated sensor is presented. The problem to be solved is, how to implement repetitive and rotating magnetic field around the silicon wafer. This must be done while testing integrated circuits on the wafer prober. Such magnetic field is needed for proper measurements of the integrated hall sensor array functionality.

Testiranje integriranega magnetnega senzorja za merjenje kota

Ključne besede: merjenje kotov, HALL senzorji integrirani, senzorji magnetni, polje HALL senzorjev, tuljave integrirane, polprevodniki, mikroelektronika, rezine silicijeve, polja magnetna, ASIC vezja integrirana za aplikacije specifične, preskušanje funkcionalnosti, naprave preskusne, naprave preskusne za rezine silicijeve, preskušanje avtomatsko

Izvleček: Predstavljen je način avtomatskega testiranja silicijevih rezin z integriranim magnetnim senzorjem za merjenje kota. Potrebno je bilo rešiti problem, kako zagotoviti ponavljajoče in vrteče se magnetno polje okoli silicijeve rezine med testiranjem na testni napravi. Takšno magnetno polje je namreč potrebno za meritev integriranega polja Hall-ovih senzorjev.

Introduction

Positioning systems are very common devices in modern machinery. There is strong demand for inexpensive, accurate magnetic angular positioning device - monolithic CMOS circuit. Such devices can be used for example in automotive industry for reliable throttle position sensor or drive by wire implementations. Cost of such sensors can be further reduced by fast, on silicon wafer functionality testing. This enables us to skip expensive die bonding, wiring and packaging of bad dices.

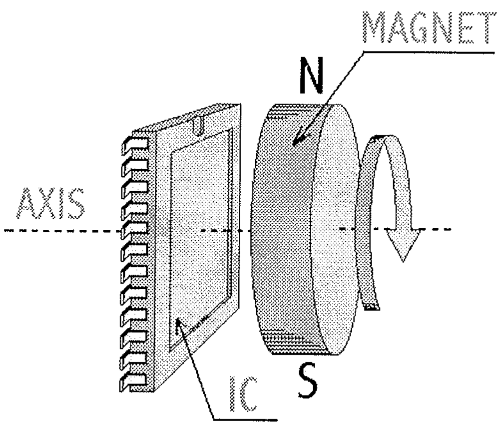

Figure 1. *Rotating magnet above the chip*

Description of the magnetic angular positioning integrated circuit

The magnetic angular positioning circuit determines the absolute angular position of the magnet rotating above the chip. Such magnet produces a rotational magnetic field as shown in figure 1. This can be done with an array of Hall magnetic sensors, positioned around the circle with the same center as the axis of the rotating magnet. Outputs of these sensors are connected to two adders, whose output defines signals S (1) and C (2). The signals S and C are orthogonal and have function of sinα and cosα, where α is actual angle of the magnet rotation. Such array of Hall magnetic sensors is shown on figure 2.

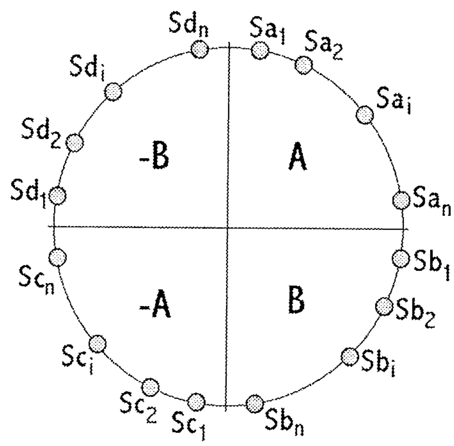

Figure 2. *Structure of the sensors*

$$S = \sum_{i=1}^{n} Sa_i + \sum_{i=1}^{n} Sb_i - \sum_{i=1}^{n} Sc_i - \sum_{i=1}^{n} Sd_i \qquad (1)$$

$$C = -\sum_{i=1}^{n} Sa_i + \sum_{i=1}^{n} Sb_i + \sum_{i=1}^{n} Sc_i - \sum_{i=1}^{n} Sd_i \qquad (2)$$

As we mentioned before, the problem to be solved is, how to test the chip without implementing the mechanical environment as shown on figure 1. Such environment is almost impossible to realize on the silicon wafer test level.

Implementation of the functionality test

Instead of building a special mechanism for fixing and rotating the magnet above the chip, it is possible to generate magnetic field with on-chip integrated coils as shown on figure 3. Here we can see a layout of the magnetic Hall sensor in the middle of the coil with six turns. For that purpose two metal layers are used.

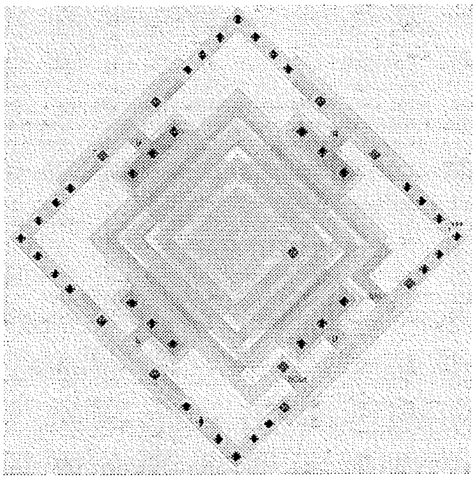

Figure 3. *Layout of the integrated coil*

Figure 4 demonstrates the structure of all sensors with coil. All coil turns are in the same direction. We can also see, how the coils are connected together. N coils have one input and one output terminal.

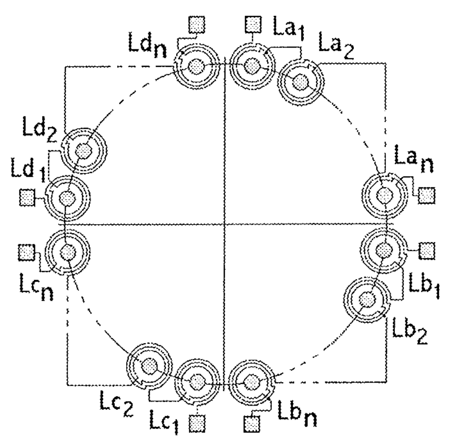

Figure 4. *Structure of the integrated coils*

As we can see on figure 4, it is also possible to reverse the sign of magnetic field by reversing the coil terminals. When applying the same current I_A through the sensor coils La_i and through reversed coils Lc_i the signal **S** corresponds to $+2nI_A$, due to the current I_A and when applying the same current I_B through the coils Lb_i and through reversed coils Ld_i, the signal **C** corresponds to $+2nI_B$, due to the current I_B.

However, according to (1) and (2) the contribution of current I_B to signal **S** is $+2nI_B$ and the contribution of current I_A to signal **C** is $-2nI_A$. Therefore we have:

$$S = 2nI_A + 2nI_B \qquad (3)$$

$$C = 2nI_B - 2nI_A \qquad (4)$$

This is shown on figure 2. If we use current **A** equal to $I_A = I_A \sin \omega t$ and current **B** equal to $I_B = I_B \cos \omega t$ signals **S** and **C** become orthogonal functions with the amplitude:

$$\sqrt[2]{(2nI_A)^2 + (2nI_B)^2} \qquad (5)$$

This shows, that properly controlled, on chip integrated coils can actually replace the rotating magnet while testing the functionality of the sensors on the magnetic angular positioning integrated circuit.

In our test environment we have wafer prober, semiconductor parametric test system HP-4062B with switching matrix, multifunction card DAQ-1200 with analog output capability from National Instruments and two personal computers. One of them is equipped with HP-IB (Hewlett Packard Interface Bus) card. This card is used to control wafer prober and Hewlett-Packard test system. Figure 5 represents our test configuration.

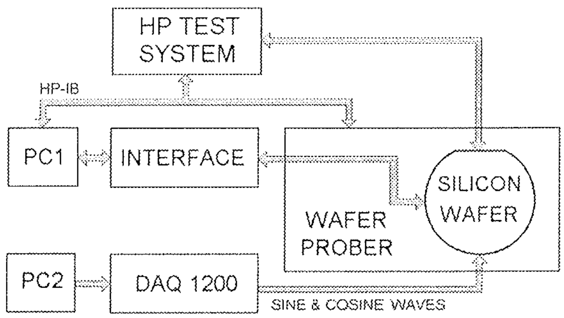

Figure 5. *Test environment*

Conclusion

By adopting and properly controlling on chip integrated coils, we transformed mechanical rotation α into measurable harmonic function $j\omega$ of selected integrated coil currents. The equivalence between actual signal from the rotating magnet and the signal generated from the properly controlled integrated coils has been also determined.

Figure 6 presents the photograph of the integrated circuit for angular positioning. On this picture we can see, how magnetic sensors with amplifiers are distributed on the circle within the chip surface.

Diagram on figure 7 presents an example of measuring results compared with reference angular positioning device. We can easily determine that the absolute error is about ±1bit. Since measured chip has nine bits for absolute angular positioning, it is capable to determine 512 different angular positions. In this case absolute error of ±1bit means actual error of ±0.7 angular degree.

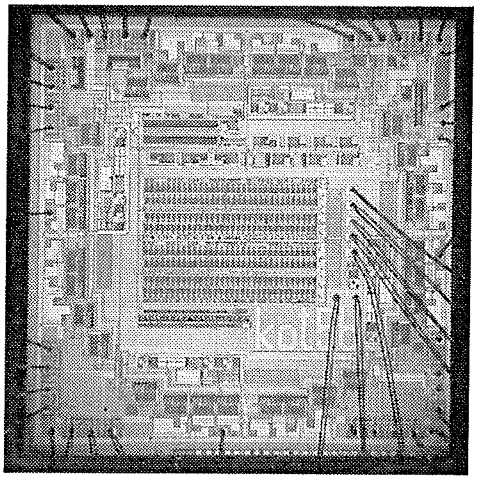

Figure 6. *Integrated circuit for magnetic angular positioning*

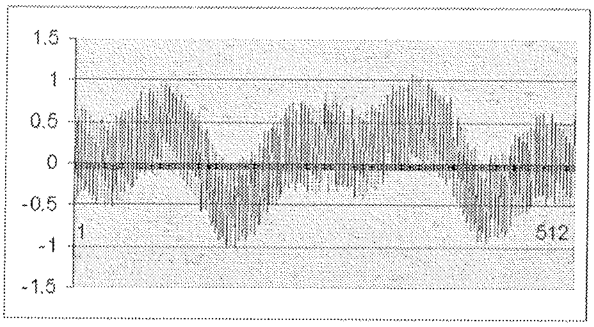

Figure 7. *Diagram for absolute error while rotating 360 degrees.*

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Prispelo (Arrived): 26.10.01 *Sprejeto (Accepted): 10.12.01*