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Magneto-sensor circuit efficiency incremented by Fourier-transformation

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ABSTRACT

In this paper detection by recognized intelligent algorithm for different magnetic films with the aid of a cost-effective and simple high efficient circuit are realized. Well-known, magnetic films generate oscillating frequencies when they stay a part of an LC- oscillatory circuit. These frequencies can be further analyzed to gather information about their magnetic properties. For the first time in this work we apply the signal analysis in frequency domain to create the Fourier frequency spectra which was used to detect the sample properties and their recognition. In this paper we have summarized both the simulation and experimental results.

1. Introduction

Magnetic sensors have many applications depending on their construction, e.g. compass for tactical unmanned aerial vehicles, geophysical exploration, non-destructive testing – bridges, health care non-invasive medical evaluation, and data storage (magnetic RAM and hard disk drive heads), plastic cards, etc. Therefore, significant efforts have been made to increase the sensitivity of magnetic sensor system [1–5] based on LC-resonators. The major challenges are high sensitivity and reliability of the magneto sensor device and circuitry. However, from the functional perspective, these magnetic sensors are capable of detection only. In some cases the detector system includes both the sensor and the analyzer. But these sensors are sensitive only to high magnetic field and have cumbersome large feature size. In this work a novel concept to create the device has been used to obtain the information about magnetic permeability. Experimental device has simplicity, functionality and ability to recognize resonance frequency spectra, which can be unique for some alloys and films. Knowledge about the resonant frequencies can give information about magnetic permeability μ and its dispersion $\mu(\omega)$ [6]. In general the permeability is a tensor $\mu_{ik}(\omega)\partial^2\psi/\partial x_i \partial x_k = 0$, where the ψ is the potential of magnetic field $H' = -grad(\psi)$, H' is the variable part of the magnetic field $H = H_0 + H'$ [7]. The developed algorithm can be used as additional analyzer for hidden elements and security label (money, plastic cards, etc., [8]) or also can be used as electronic lock, where data of unique shapes and magnitudes of $\mu(\omega)$ would play such roles. The anomalous $\mu(\omega)$ can be realized using deposition of magnetic and non-magnetic materials and fabricated by sputtering technique [9,10]. Here we introduce the simulation with different values of inductance only to show the algorithm in work and detect the magnetic samples. Also we experimentally checked our algorithm for real Fe_2O_3 samples with different thicknesses.

2. Circuit description

The "working core" of the designed circuit consists of two oscillatory circuits where inductance values L1 and L2 are the part of first (etalon) and second (test-one) resonators (L2 can be changed under test sample influence). Other part of the circuit consists of the three NOR elements (see Fig. 1) which gives the differences of the generated oscillating frequencies of the signals. Magnetic film acts as a magnetic shunt for the read heads (sensors). Due to a specific magnetic reluctivity of these films, it will affect the inductances and consequently on the frequency of

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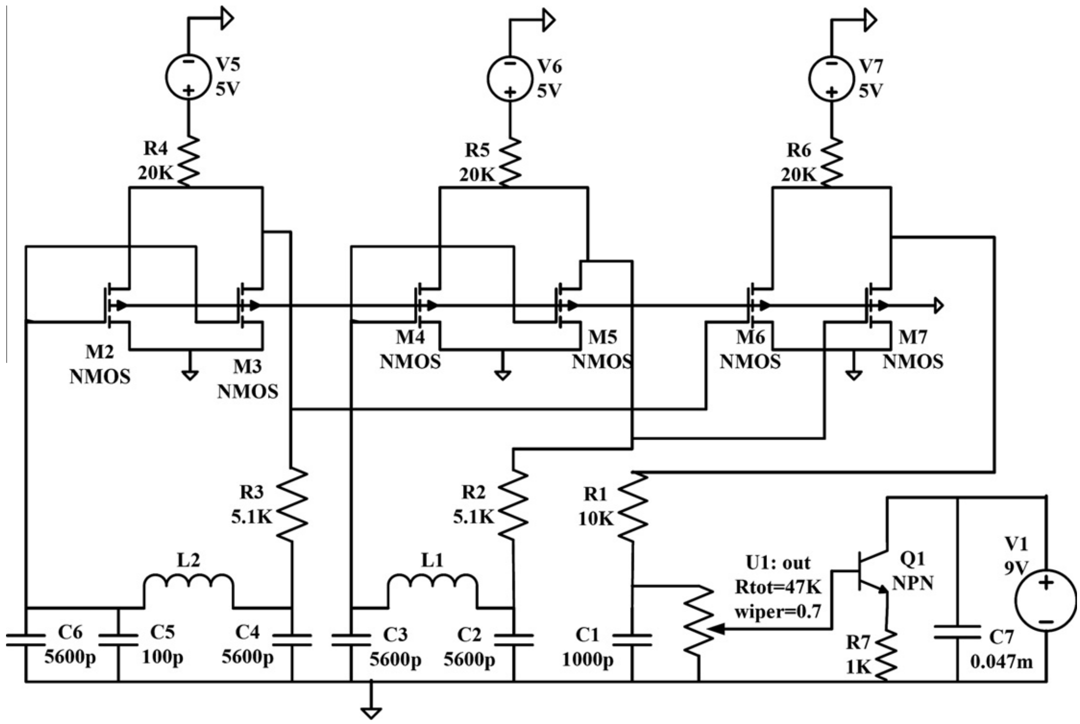

Fig. 1. Schematic of the proposed circuit.

the oscillatory circuit. The principal schedule of the integrated system is as follows: there are three main modules: (1) magnetic read heads and forming signal circuit, (2) Fourier transform circuit, (3) programmable analyzing and comparing procedure module. The working frequency of the experimental device is 0.1 MHz which allows to recognize 10 μm thick films. During the 0.25 s the signal can be recorded as well as time is enough to generate the Fourier transform and analyze it. Analyzing algorithm was written in MATLAB where amplitudes of frequencies look like spectrum with each one with its own intensity (see Section 4).

In Fig. 1 the forming signal circuit of the proposed integrated magnetic sensor is presented. The output of each oscillator circuit is being fed to the NOR logic and the generated two different oscillating signals are again used as input to another NOR element to create the desired frequency difference of the signals. The final output is taken from the emitter of the BJT. The analyzed output of this point is shown in Fig. 2 for a single value of L1 and L2. The final output signal from the emitter of Q1 (in Fig. 1) is being input to a computer by a USB soundcard. This signal is then analyzed by FT technique and saved for analyzing and recognizing algorithm.

3. Simulation, experimental results and discussion

In Fig. 2 we have shown the Fast Fourier transformation (FFT) spectra for two different values of L2 (8.0 mH and 8.5 mH). These values of L1 and L2 represent (simulate) different magnetic samples. It is shown that for L2 = 8.0 mH the first peak is found at 8 KHz and for L2 = 8.5 mH the peak

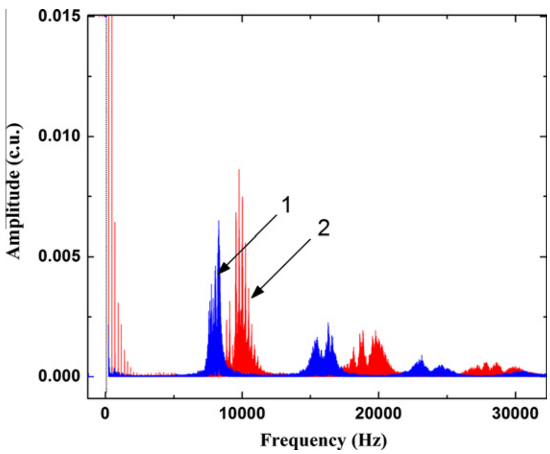

Fig. 2. Fast Fourier transform of the signals with (1) L1 = 8 mH and L2 = 8 mH and (2) L1 = 8 mH and L2 = 8.5 mH.

is shifted to 10 KHz. This shifting of Fourier spectra can be used to identify the material, its thickness, or location mark if this technique is adapted for precision positioning system. Also the positions of peaks in Fourier spectrum confirm that the generated signal can be audible.

Even with decreased inductances (L1 = 1 mH and L2 = 1 mH) the FT spectrum looks similar and this leads to increased sensitivity and allow detecting very thin films. If to change now the L1 = 1 mH to L1 = 1.5 mH with fixed L2 = 1 mH one can measure the sensitivity (of the first peak shifting) and it is 132.4 KHz/mH while sensitivity of the