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READING OF MOVEMENT PARAMENTS OF A CONTINUOUS RIGID PENDULUM USING EFFECT SENSOR HALL

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INTRODUCTION

Currently, there are several sensor devices developed and already used in different types of electronic devices. One of them is the Hall effect sensor (HAMSDEN, Edward Hall) which, by detecting the presence of a magnetic field in its proximity, raises a level of electrical voltage at its output.

This device can be used to make that, when detecting the presence of a certain direction of a magnetic field by a magnet (GRIFFITHS, David J.) it triggers a magnetic field in the opposite direction to the same through a coil, consequently causing between them a repulsion and with that, causing a rigid pendulum to move continuously. Due to the physical interaction between the pendulum movement (HALLIDAY, David; RESNICK, Robert.) and electronics originated and detected by the sensor, the reading of its operating parameters can be carried out in an effective way. This work aimed to show the description of the operation, reading the frequency and parameters of the supply voltage and current supplied to the coil for movement of a continuous rigid pendulum for analysis and data collection using effect sensor Hall which later used for further analysis and conclusions.

METHODOLOGY

To obtain the functionality, as well as its corresponding readings of the rigid pendulum movement, it was initially studied, analyzed and elaborated in several parts:

- Study and analysis of Hall effect sensors;
- Solenoid drive circuit;
- Study, analysis and construction of the solenoid;
- Construction of the rigid pendulum and
- Reading measurements of pendulum movement.

STUDY AND ANALYSIS OF HALL EFFECT SENSORS

Hall effect sensors detect the presence of a magnetic field in their vicinity and send an electrical signal at their output. They are made of semiconductor materials that, with the force generated by the presence of a magnetic field, deviates the path of the path of electric charges provided by the application of an external electric current (RAMSDEN, Edward.). The accumulation of these electrical charges on the side faces provides a potential difference that can be detected as shown in Figure 1.

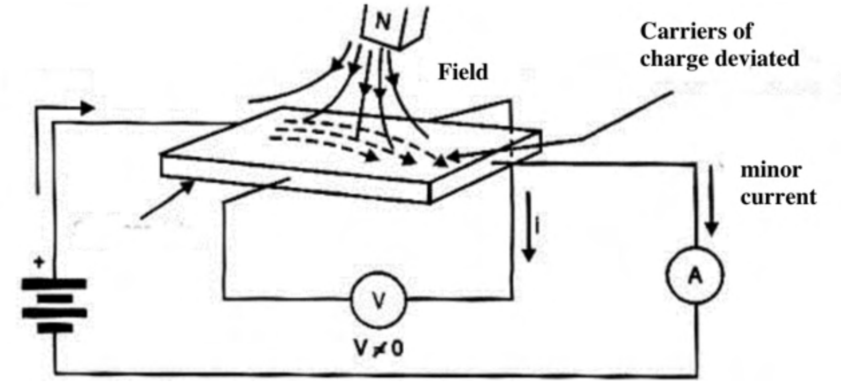

Figure 1- Magnetic field detection principle by Hall effect sensor

Source: <http://www.newtoncbraga.com.br/index.php/como-funciona/6640-como- funcionam-os-sensores-de-efeito-hall-art1050>

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There are basically four types of sensors: Monopolar, which operates in the presence of a positive magnetic field, ceasing when this field disappears; Bipolar, which detects and remains in operation in the presence of a south pole magnetic field and only ceases when it detects a north pole magnetic field; Omnipolar, which detects and remains in operation either in the presence of a south or north pole magnetic field and only ceases when it detects a magnetic field in the opposite direction; Hall effect latch, which has its input activated in the presence of a magnet and keeps activated until it feels the presence of a magnetic field again. The Omnipolar sensor was used in this work due to the simplicity in its elaboration and assembly, not requiring, in the assembly of the pendulum, to observe if the magnet fixed at the end of the pendulum is positioned in front of the coil with the pole facing north or south.

SOLENOID DRIVE CIRCUIT

The solenoid drive circuit is used to magnetize a solenoid every time it detects the presence of a magnetic field through a Hall effect sensor. The magnetic field generated in the solenoid must have the same polarity as the magnet, that is, if the magnet has north polarity, the magnetic field generated must also be and vice versa so that it produces a force of repulsion between the two, so that, whenever the magnet passes in front of the solenoid, a force appears that accelerates the pendulum movement (RAMSDEN, Edward.). In addition, this circuit must introduce a delay time between the moment of sensitization of the magnetic field and the activation of the solenoid so that the pendulum can continue its trajectory, but with a force introduced by the presence of the magnetic field originated by the solenoid.

As it was shown in the electrical diagram of Figure 2, the solenoid circuit is basically a device that provides a current gain through the TIP41C transistor with a time delay caused by resistor R3 and capacitor C1. The Hall effect sensor, indicated as U1 in the figure, emits a high level signal at its output 3 every time it detects the presence of a magnetic field and remains so and only

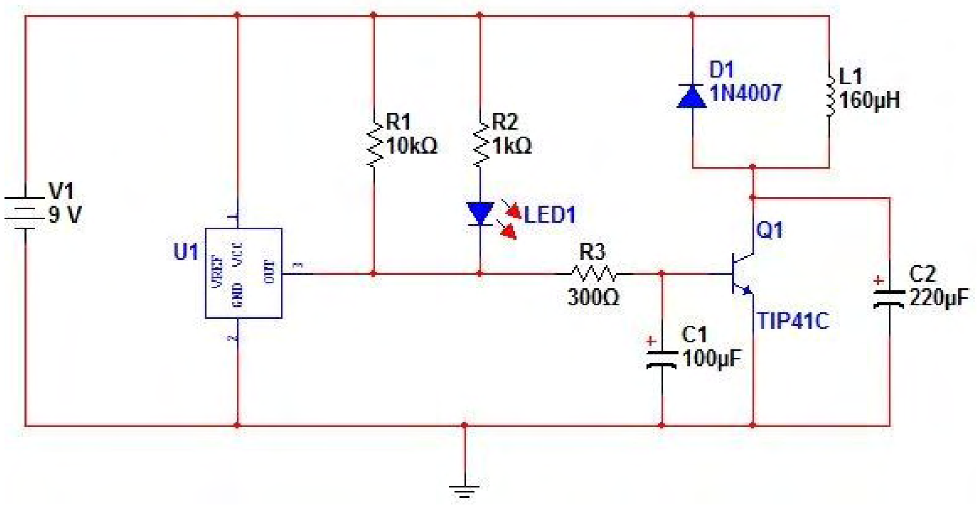

Figure 2 - Solenoid drive circuit.

Source: Prepared by the author himself.

returns to the low level when it senses the presence of a new magnetic field. opposite direction, which is caused by the solenoid. LED1 serves to indicate this magnetic field detected by the sensor. Diode D1 prevents the electric current caused by the interruption of the energy stored in the solenoid indicated as L1 from flowing into the transistor collector, which could cause damage to it. Also, capacitor C2 has the function of keeping the voltage on the transistor collector very stable, which facilitates its visualization on the oscilloscope. The picture in Figure 3 shows this circuit mounted on a printed circuit board and the Hall effect sensor attached to the solenoid that causes the magnet to repulse.

STUDY, ANALYSIS AND CONSTRUCTION OF THE SOLENOID

As shown in Figure 3, the solenoid is made up of 140 turns of 28 AWG enameled wire wound around a hollow plastic cylinder support 4 mm2 in diameter by 10 mm in length, making an inductance of 160 μH. This one solenoid produces a magnetic field and is capable of repelling and pushing the magnet causing a force capable of accelerating the pendulum's movement.

CONSTRUCTION OF THE RIGID PENDULUM

The rigid pendulum was mounted on a wooden support. Its rigid aluminum wire rod is 125 mm long, hanging from a nail that allows it to rotate freely with minimal friction. The photo in Figure 4 shows the construction detail of this pendulum. It can also be seen that there is a transparent plastic protractor that allows to show the degree of inclination of the pendulum when it is in motion.

RESULTS AND DISCUSSIONS

READING MEASUREMENTS OF PENDULUM MOVEMENT

In order to read the pendulum movement, a previous theoretical study of the movement of a rigid pendulum was carried out.

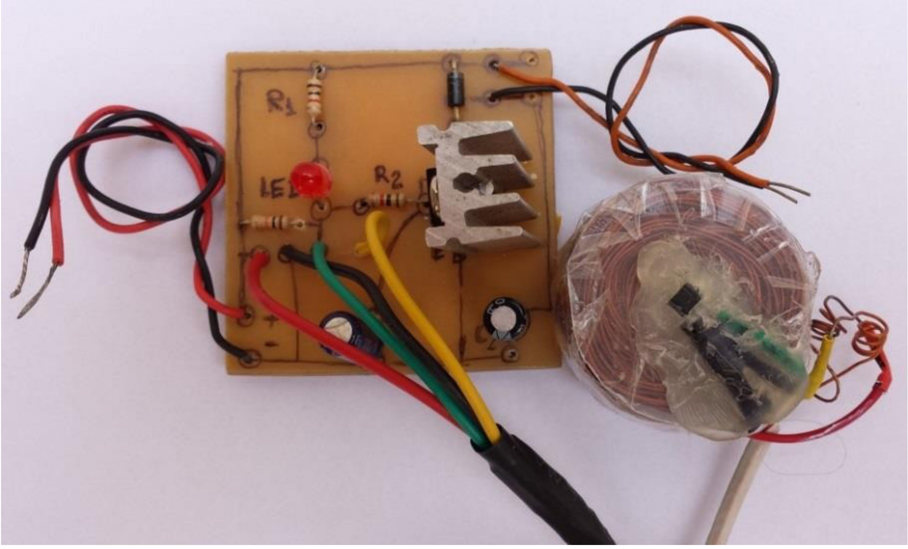

Figure 3 – Photo of the solenoid drive circuit and the Hall effect sensor attached to the solenoid.

Source: Prepared by the author himself.

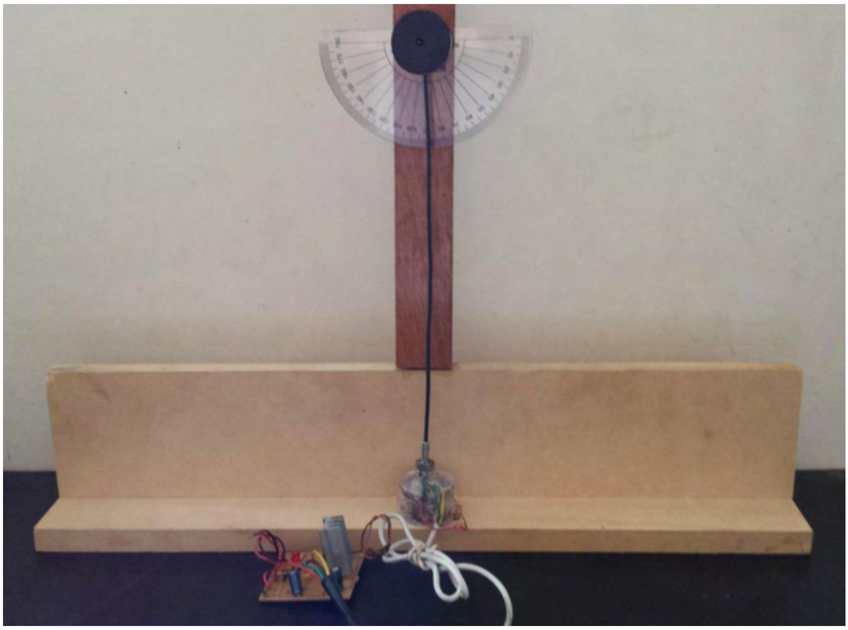

Figure 4 – Photo of the rigid pendulum hanging from a nail.

Source: Prepared by the author himself.

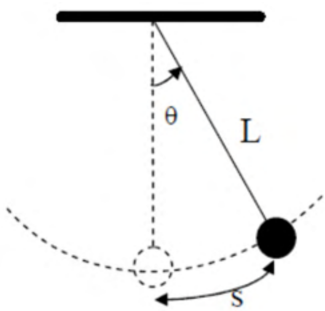

Figure 5a- Schematic of a pendulum simple

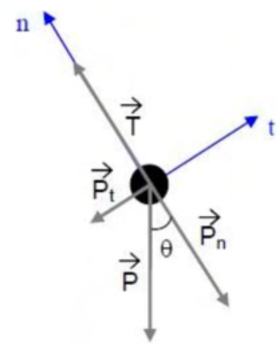

Figure 5b- Forces applied to a body suspended

Source: Pendulum - Laboratory Guide - Paper No. 3 - ISEC.

Originally this study is based on a simple pendulum with small amplitude oscillations.

A simple pendulum consists of a body of mass m, suspended by a rigid string of negligible mass and length L, which describes an oscillatory motion in the vertical plane as shown in Figure 5a. Two forces act on the body: the weight P, with the vertical direction, and the tension T exerted by the string, with the direction of the string, as shown in figure 5b (LUNAZZI, José J. Pendulo).

The period T0 of the simple harmonic motion described by the pendulum is given per:

$$T_0 = \frac{2\pi}{\omega} = 2\sqrt{\frac{L}{g}} \quad (1)$$

Where:

T_0: Angular motion period

L: Pendulum length

g: Gravity acceleration

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Once the frequency f_0 is the inverse of the period:

$$f_0 = \frac{1}{T_0} \quad (2)$$

The frequency f0 of the movement is given by:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{g}{L}} \quad (3)$$

The value of acceleration due to gravity g can be calculated using the expression:

$$g = 9.78032 - 0.1967 \times 10^{-5} h \quad (4)$$

Where h is the height above sea level where the pendulum is located to carry out the measurement tests. Considering that the place where the measurements were made is 390 m then:

$$g = 9.78032 - 0.1967 \times 10^{-5} \times 390 = 9.77955 \text{ m/s}^2 \quad (5)$$

MEASURED FREQUENCY OF THE PENDULUM

The pendulum has length L = 0.24 m. Therefore, the theoretical frequency must be f0T = 1.0159Hz. In the experimental procedure, the frequency obtained was f0P = 1.0125 Hz. An experimental error of 0.33% which can be considered reading as quite accurate.

MEASUREMENTS OF THE ANGLE Θ AS A FUNCTION OF THE VARIATION OF THE POWER SUPPLY VOLTAGE OF THE PENDULUM CIRCUIT (V_F) AND CURRENT IN BOBONA (I_B)

The variation of the angle θ as a function of the power supply voltage is due to the energy generated in the form of a magnetic field that drives the pendulum movement, causing an accelerated movement, thus having a continuous intermittent movement. The greater the value of this source voltage, the greater the impulse given to the pendulum. Consequently, the greater the current applied to coil IB, the greater the angle θ.

Measurements were made of angle θ in degrees as a function of the voltage variation of the power supply and current in the IB coil. The results obtained are in Table 1 and its graph in Figures 6 and 7.

It can be seen that both graphs are similar as the source voltage is increased, which will proportionally increase the current applied to the coil.

Through the interpolation by the SciDavis software, the voltage equations V = f(θ) e I = f(θ):

$$V_f = 0.153\theta^2 + 0.964\theta + 3.659 \quad [V] \quad (6)$$

$$I_f = 3.659\theta^2 + 0.120\theta + 0.023 \quad [mA] \quad (7)$$

These results are important because they allow us to analyze the behavior of several other movements under similar conditions.

FINAL CONSIDERATIONS

This work showed the possibility of making a rigid pendulum of intermittent oscillations using an electronic circuit with a Hall effect sensor that can be used for the study and analysis of its physical behavior, calculation of the height of a certain place in relation to the sea level through measurement of the frequency of oscillation and in demonstrations of scientific events.

In the results of the measurements presented, it was possible to verify, as expected, that the oscillation frequency does not depend on the variation of the angle caused by the voltage variation of the power supply. This variation is solely conditioned to the acceleration of gravity and the length of the pendulum rod.

measure nº	V_F (V)	I_B (mA)	Angle θ (°)
1	1	8	5
2	2	16	6
3	3	24	8
4	4	32	10
5	5	40	12
6	6	48	15
7	7	56	18
8	8	64	21
9	9	72	25
10	10	80	29
11	11	88	33
12	12	96	37

Table 1: angle measurements θ (°) as a function of the variation of the supply voltage (VF) and current in the coil (IB).

Source: Prepared by the author himself.

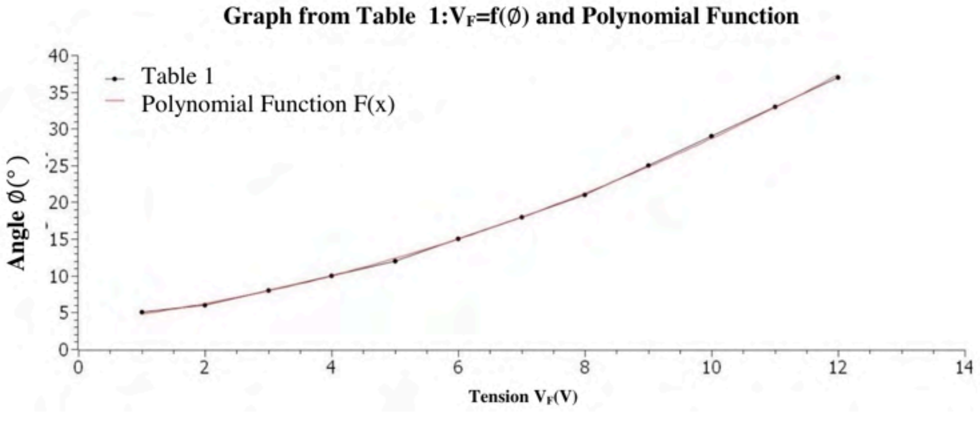

Figure 6 – Graph of angle variation as a function of supply voltage variation and also of its corresponding polynomial function.

Source: Prepared by the author himself.

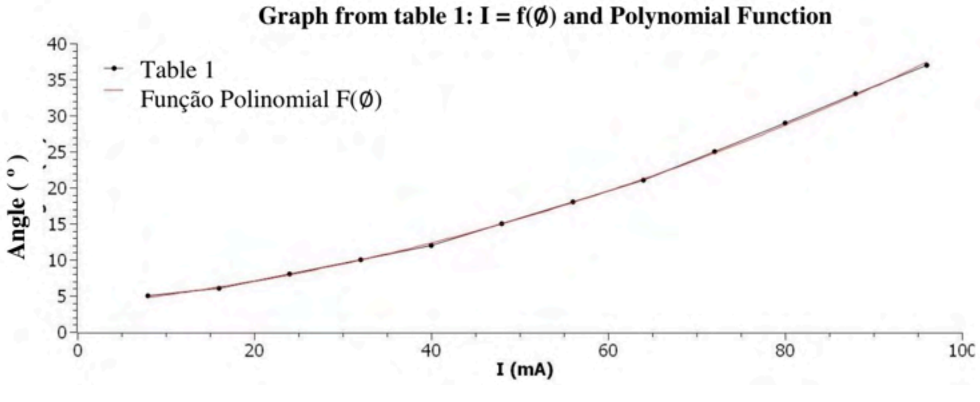

Figure 7 – Graph of the variation of the angle as a function of the variation of the current applied to the coil and also of its corresponding polynomial function.

Source: Prepared by the author himself.

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