Digital D.C. Motor Speed Control Using Hall Effect Phenomenon

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ABSTRACT: Various technique can be used to control of a dc motor , such as using the phase locked-loop principles, digital input, or anolog inputs. If desired, the speed of the motor may also be monitored with LED or LED displays.The project digital DC motor speed controller illustrates the use of digital inputs to control the speed of a DC motor. To process the digital inputs, a D/A converter will be used, while a combination of a speed sensor (Hall Effect) and F/V converter will be used to sense and convert the speed frequency into an appropriate voltage.

Keywords: Introduction of project; concept of hall effect; internal architecture of speed sensor; block diagram; working principle; equations and table, conclusion; acknowledgement and references .

1) INTRODUCTION

The project digital DC motor speed controller to control the speed of motor by using the digital inputs. That digital input is provided to digital to analog converter (D/A). Since the output of the D/A converter is directly proportional to binary equivalents of its digital inputs. The output voltage of D/A converter will be maximum positive when all the inputs logic are 1.This means that when all inputs are logic 1 the motor will run at a maximum speed. Now here we will used the hall effect switch (speed sensor) ,that will also generate the analog voltage or hall voltage (V_H). In fact , the key to the operation of the circuit is that the differential amplifier maintains a specific difference between two input voltages so that motor speed is constant at the selected digital input setting.

2) CONCEPT OF HALL EFFECT

When a beam of charged particles passes through a magnetic field, forces act on the particles and the beam is deflected from its straight line path. The beam of charged particles refers to the electrons flowing through a conductor. When a current carrying conductor is placed in a magnetic field perpendicular to the path of the electrons, the electrons are deflected from its straight line path. Therefore, one side of the conductor becomes negative portion and the other side becomes positive one. The transverse voltage is measured and is known as Hall Voltage.

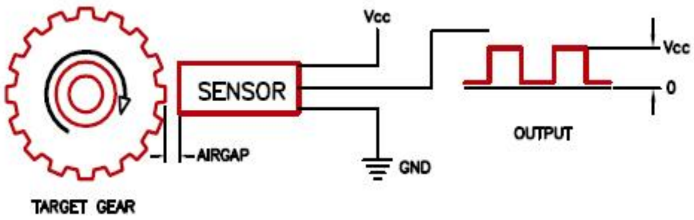

Figure -1 Sensor Generating pulse signal

II (a) INTERNAL ARCHITECTURE OF SPEED SENSOR

The internal architecture of speed sensor will be explained below as shown in figure 2.

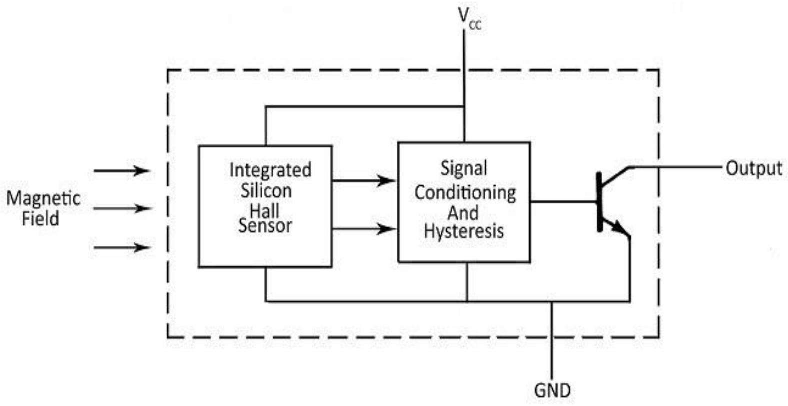

Figure 2(a) TL170 bipolar hall-effect switch equivalent circuit

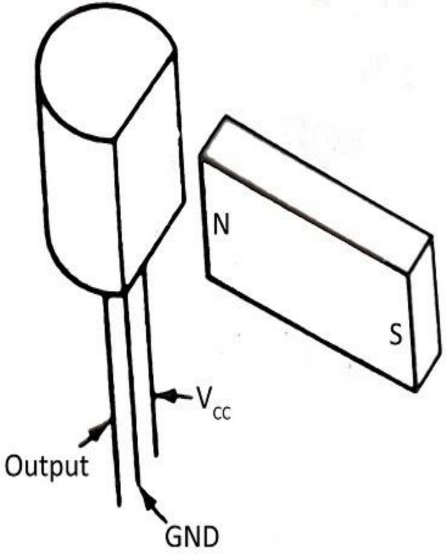

Figure 2(b) On-State arrengement

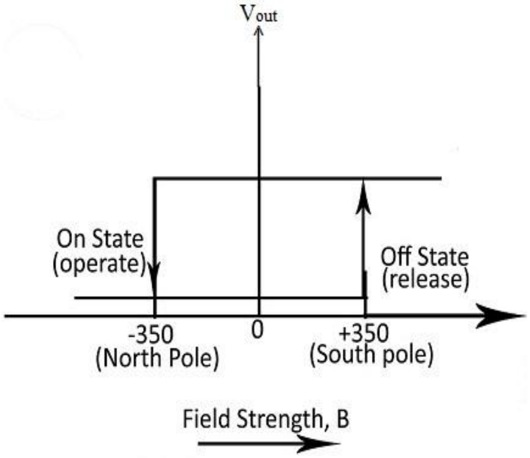

Figure 2(c) Electrical Switching characteristic

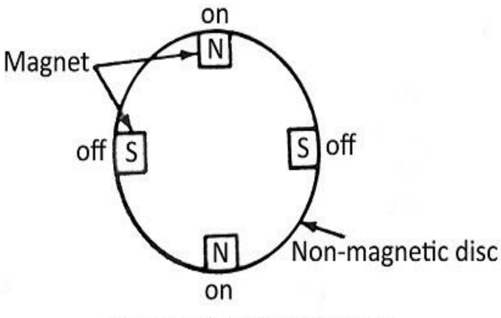

Figure 2(d) Practical setup

Figure-2 TL170 bipolar Hall-Effect switch

Figure (2) shows the equivalent circuit, operating arrangement, and an electrical switching characteristic with hysteresis of Texas Instruments TL170 bipolar Hall-effect switch. The TL170 is a three-terminal plastic package that consists of a silicon sensor, signal conditioning and hysteresis function, and an open-collector output stage integrated onto a monolithic chip [see figure 2(a)]. The output of the device is compatible with bipolar or MOS logic circuits. Figure 2(b) shows the practical setup for the on state. The sensor is on (output voltage ≤ 0.04 V) when the magnetic field (B_{ON}) associated with the permanent-magnet North Pole is perpendicular to the surface of the sensor and below a certain level, called the operate point or the threshold. On the other hand, the sensor is off when the magnetic field (B_{OFF}) emitted from the south pole of a permanent magnet is perpendicular to the surface of the sensor and above a certain level, called the release point. The TLI70 has a typical operate point of ≤-350 gauss and a release point of ≥350 gauss with a magnetic switching hysteresis ($B_{ON} – B_{OFF}$) of 200 gauss typically. The negative and positive magnetic fields are defined as those fields that are emitted from the north and south poles, respectively, of a permanent magnet. The magnetic switching hysteresis curve of the TLI70 is shown in Figure 2(c). The sensor is designed so that its output stage can withstand up to 20 V in the off state and can sink up to 16 mA in the on state.To operate, the TL170 sensor is positioned so that the plain surface of the sensor faces the permanent magnet. In addition, to obtain two samples per revolution and hence help to control the motor speed more accurately, four permanent magnets are used in Figure 2(d). These magnets are glued to the 4-in. diameter disk with alternately south and north poles up, as shown in Figure 2(d). The disk is then mounted on the motor's shaft. When the motor is running, the TLI70 is turned on due to the magnetic field strength of the North Pole and turned off due to the magnetic field strength of the South Pole. Therefore, because of four permanent magnets the sensor will generate two cycles per revolution. The distance between the magnets and the sensor, however, depends on the strength of the magnets. For the TL170 used in Figure (2), a magnetic field strength magnitude of ≥350 gauss is necessary. When the motor is running, the distance between the disk and sensor can be adjusted so that the output of the sensor is a pulse waveform. Remember that the output amplitude of the sensor depends on the supply voltage and is independent of the rpm of the motor.

3) BLOCK DIAGRAM

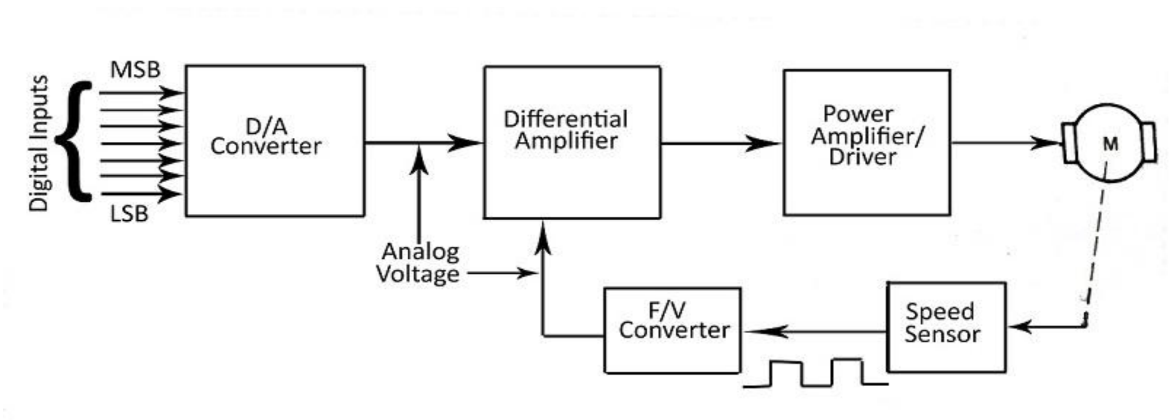

Figure-3 Block Diagram

4) WORKING PRINCIPLE

Figure shows the block diagram of a digitally controller dc motor. The output of the D/A converter is proportional to the binary equivalent of its digital input. The differential amplifier compares the D/A converter output with the output voltage of the F/V converter . The resulting difference voltage is an input to the power amplifier /driver stage. The output of the power amplifier /driver then drives the dc motor. The speed sensor converts the motor's speed in to a pulse waveform,which is in turn converted in to a proportional voltage by the F/V converter since the output of the F/V converter since the output of the F/V converter is processed using a negative feedback formed with the differential amplifier, the motor is kept at aconstant speed corresponding to the setting of the digital inputs. In fact, the key to the operation of the cicuit is that the differential amplifier maintains a specific difference between two input voltages so that motor is constant at the selected digital input setting. Since the output of the D/A converter is directly proportional to the binary equilent of its digital inputs,the output voltage of the D/A converter will be maximum positive when all the input are logic 1. This means that when all inputs are logic 1 the motor will run at a maximum speed. Now suppose that the motor is initially running at a certain speed and digital inputs have just been set to lower the speed. This action will reduce the output voltage of the D/A converter, which in turn reduces the difference between the two input voltages of the differential amplifier, resulting in a reduced drive for the motor. Therefore, the speed of the motor will be lowered until the output of the F/V converter is such that a specific input difference voltage for the differential amplifier, which is required to keep the motor running at a constant speed, is reached. The difference voltage necessary to maintain the constant motor speed is a function of the physical dimensions and electrical characteristics of the motor. These include torque, speed, inertia, and current and voltage ratings of the motor. Thus the constant difference voltage and, in turn, a constant motor speed is maintained through the use of negative feedback. The digital inputs may be calibrated in terms of revolutions per minute (rpm). In addition, the output of the speed sensor may be applied to the frequency meter/indicator to monitor the motor's speed.

5) EQUATIONS AND TABLE

Now let us reconsiderthe circuit of figure (1)&(2). The D/A and F/V converters in this figure should be adjusted initially as follows:

4800 rpm = 4800*(n)**/**60 Hz(1)

Now here 'n' is the number of digital input samples.

Input voltage of a motor (V) = V_o (D/A) – V_o (F/V)
(2)

Where

V_o (D/A) = Output voltage of Digital to Analog Converter

V_o(F/V) = Output voltage of Frequency to Voltage Converter Which is in Analog form

The input voltage of motor is coming from the output voltage of differential amplifier.

The output voltage of differential amplifier is the difference between the two input voltage. Here two analog voltage is formed first is D/A (digital to analog voltage) and second voltage is formed by speed sensor through F/V (frequency to voltage) that voltage is also be the analog voltage.

Serial number	Number of binary inputs (n)	Output of D/A voltage	4800*n/60 Hz	Output of F/V	Input voltage of motor	Motor speed
1	00000001	2.15	80	0.4	Low voltage	1000 rpm
2	00000011	2.30	160	0.8		
3	00000111	2.45	240	1.2		
4	00001111	2.60	320	1.6	Average voltage	2100 rpm
5	00011111	2.75	400	2.0		
6	00111111	3.05	480	2.4		
7	01111111	3.15	560	2.8		
8	11111111	3.50	640	3.2	Maximum voltage	4800 rpm

For example

The motor in Figure (3) initially starts running when the input binary code is $(00000110)_2$. Thereafter, the motor speed increases with the digital input until the motor attains a maximum speed at $(00111111)_2$. After $(00111111)_2$, however, the motor speed does not increase further even though the digital input is increased. In other words, we get 6-bit resolution instead of 8-bit. To obtain 8-bit resolution, an appropriate DAC with better resolution, a motor having favorable electromechanical specifications and a differential amplifier with proper gain must be selected. The principles illustrated in the digital dc motor speed control of Figure-3 are used in the cruise control of automobiles.

When we select the digital sample is $(00000110)_2$ then the value of input sample (n) is 2.

Then using equation (1)

=4800*(2)/60 Hz

=160 Hz

The above frequency will be converted in to appropriate voltage by using the Frequency to Voltage converter (F/V) and that voltage is known as Analog Voltage.

6) CONCLUSION

In this project the hall effect technique is used to control the speed of the motor. According to above figure the output of the speed sensor is in frequency form and that frequency is converted in to appropriates voltage by using F/V converter that voltages is also known as analog voltage. With all the inputs high (logic 1) then that will generate the maximum speed of motor and that speed of motor will gererate maximum magnetic field so that field generate the maximum frequency and correspond voltage also by using speed sensor. That speed sensor is connected by negative feedback. The most advantages of negative feedback is that have no any gain or power loss. The another most advantage is that will recycle the voltage.

7) ACKNOWLEDGEMENT

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