Development of a simple RPM measurement system

Akash Kumar[1], Anindya Debnath[1], Antar Banik[1], Kabirul Islam Mondal[1], Partha Pratim Biswas[1], Rik Bhattacharyya[1], T K Maiti[2]

(1. *Department of Applied Electronics & Instrumentation Engineering, Netaji Subhash Engineering College, Kolkata 700152, West Bengal*; 2. *Department of Instrumentation Engineering, Central Institute of Technology Kokrajhar, Assam 783370, India*)

Abstract: The design and development of a timer based revolution per minute (RPM) measurement system were described in this paper. The rotating shaft of a dc motor was used to measure the RPM and timer integrated circuit(IC) 555 was used in astable mode. The frequency of timer output waveform measured by a digital storage oscilloscope (DSO) is almost linearly proportional to the RPM of rotating shaft, and the RPM also linearly varies with the change of the external input voltage level. Hence the linear relationship between the frequency of timer output waveform and the RPM can be obtained. The main advantages of this developed system are linear input-output relationship, small size, easy to carry and cost effective.

Key words: IC 555; astable multivibrator; RPM measurement

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0 Introduction

In different electrical, electronic and processing industries like power plants, oil industries and petrochemical industries, revolution per minute (RPM) measurement is very important. Different RPM measurement techniques, such as optical technique based RPM measurement and tachometer based RPM measurement, are widely used with their merits and demerits[1-7]. Here a RPM measurement system is developed for a rotating dc motor shaft using a timer based astable multivibrator associated with two opto-light dependent resistors (opto-LDRs). In this system, the timer output frequency and RPM of the rotating dc motor shaft have a linear relationship and the measurement is very simple and low cost.

In this paper, a timer integrated circuit (IC) 555 based RPM measurement system was proposed, which provides linar input-output relationship, and is small in size, easily portable and cost effective. The system not only can be used as voltage-frequency converter in various signal conditioning circuits, but also has the similar idea to that of fan speed control.

1 Theory

Fig. 1 shows the timer IC 555 circuit with two opto-LDRs which is the combination of one light emitting diode (LED) and one LDR. In this circuit, timer is working in astable mode. According to the working principle of timer[8-9], the capacitor charging time (T_C) and discharging time (T_D) can be written as

$$T_C = 0.693(R_{LDRA} + R_{LDRB})C_S, \tag{1}$$

$$T_D = 0.693 R_{LRDB} C_S, \tag{2}$$

where R_{LDRA} and R_{LDRB} are the resistances of LDRA and LDRB respectively; C_S is the capacitance of external capacitor.

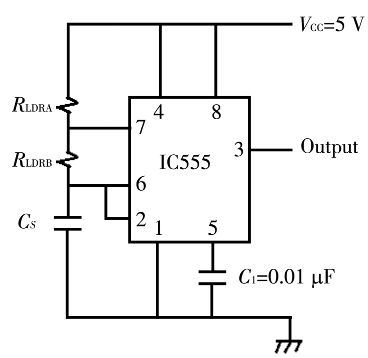

Fig. 1 IC 555 based astable multivibrator circuit with two LDRs

The time period of the timer output (T) is given by

$$T = T_C + T_D = 0.693 \times 3 R_{LDRA} C_S, \tag{3}$$

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Corresponding author: T K Maiti (tkmaiti89@gmail.com)

and the frequency of the timer output waveform (f) is

$$f=\frac{1}{T}=\frac{0.481}{R_{\mathrm{LDRA}}C_{\mathrm{S}}}. \tag{4}$$

Now the current (I) passing through the LEDs is given by

$$I=\frac{V_i-2V_{\mathrm{LED}}}{R}, \tag{5}$$

where V_i is the input voltage; $R=220\ \Omega$ is the current controlling resistance; V_{LED} is the voltage drop across the LED or threshold voltage, and the value of this threshold voltage is around 1.28 V.

The light intensity (Lux) generated by LED is proportional to the current passing through this diode, i.e.

$$Lux=K_1 I, \tag{6}$$

where K_1 is the proportionality constant.

The resistance of LDR (R_{LDR}) is related with the incident light intensity as

$$R_{\mathrm{LDR}}=\frac{K_2}{Lux}, \tag{7}$$

where K_2 is a proportionality constant. Maximum resistance $R_{\mathrm{LDR}}=4.5$ kΩ at 10 lux and maximum resistance $R_{\mathrm{LDR}}=0.7$ kΩ at 100 lux.

By substitution of the Eqs. (5)−(7), Eq. (4) can be rewritten as

$$f=AV_i+B, \tag{8}$$

where A and B are constants and depend on the values of K_1, K_2, R (220 Ω) and C_{S} (470 pF).

Based on the working principle of dc motor[10], it is known that the RPM of the rotating dc motor shaft linearly depends on the current passing through the armature and this current once again depends on the supplied dc voltage to the motor. Therefore, the relationship between the RPM of a rotating dc motor and the supplied dc voltage can be written as

$$RPM=CV_i+D, \tag{9}$$

where C and D are constants and depend on the values of torque, torque constant, external applied voltage (E_{ext}) and rotor coil resistance.

By substitution of the Eq. (8), Eq. (9) can be rewritten as

$$RPM=af+b, \tag{10}$$

where a and b are constants and depend on the values of A, B, C and D.

Therefore, Eq. (10) shows that the RPM of a rotating dc motor is linearly proportional to the frequency of timer output waveform.

2 Design procedure and experimental setup

Eq. (10) can be applied to design the RPM measurement system using the IC 555 based astable multivibrator circuit. Fig. 2 shows IC 555 based astable multivibrator circuit with opto-LDRs[11]. Two dc motors that are identical in all respects are used to fulfill our requirements. Here a dc supply of 12 V is used to excite a dc motor (M_1) and this motor is directly coupled with another dc motor (M_2). R_{Control} is used to control the current through the armature of motor M_1. Due to direct coupling between the two motors (M_1 & M_2), the voltage V_i generated by motor M_2 is used as the supply dc voltage for the two opto-LDRs, which are associated with the timer based astable multivibrator.

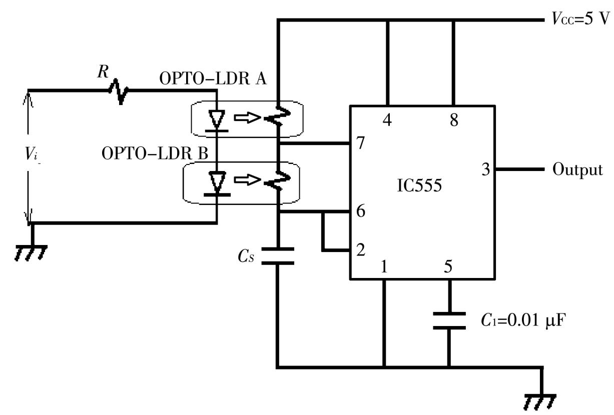

Fig. 2 IC555 based astable multivibrator circuit with opto-LDRs

Fig. 3 shows the experimental setup for measuring the RPM of a rotating dc motor shaft. According to the operation of IC 555 based astable multivibrator, with the armature current of dc motor (M_1) changes, RPM of the coupled motors will be changed and a dc voltage (V_i) will be generated at the output of dc motor (M_2). This generated dc voltage is used as the supply dc voltage for the opto-LDRs, i.e. this generated dc voltage controls the resistances of LDRs, which in turns helps to change the frequency of the timer output waveform. We measured the RPM of dc motor (M_1/M_2) using a non-contact type digital tachometer (made by Mextech; model No. DT2234C) and the timer output frequency using digital storage oscilloscope (DSO). Therefore, by measuring the timer output frequency, RPM of a rotating dc motor can be measured.

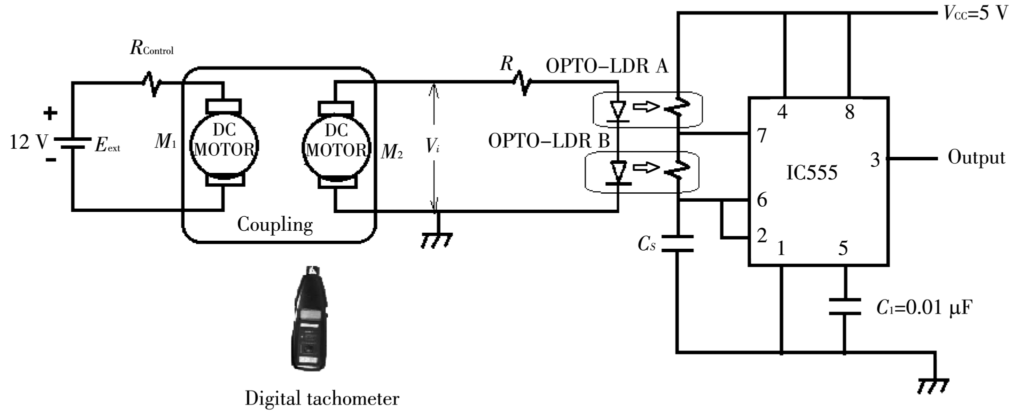

Fig. 3 Experimental setup

3 Results and discussions

The experimental setup of Fig. 3 has been used for the actual experiment and the different collected as well as calculated data are shown in Table 1. Based on the data from Table 1, we plotted the variation between the dc supply volatage (E_{ext}) and the actual RPM of a rotating dc motor (M_1) which is directly coupled with another dc motor (M_2), as shown in Fig. 4. Here we varied the dc supply voltage to vary the rotational speed of the dc motor, and it is observed that the system works effectively in supply voltage of 10—12 V. Fig. 5 graphically shows the variation between the actual RPM measured by a digital tachometer and the timer output frequency (f) measured by a DSO. This measured frequency is multiplied by the key factor of pulse sensed per revolution (PPR) with the value of 60 to obtain the calculated RPM of dc motor (M_1). Fig. 5 indicates that the relationship between RPM and timer output frequency is almost linear.

Table 1 Different collected and calculated data

No.	DC supply voltage E_{ext} (V)	Actual RPM of motor M_1	Generated output voltage by motor M_2 (V)	Timer output frequency f (Hz)	Calculated RPM of dc motor M_1 [$=60f$]	Measurement error in RPM (%)
1	12.00	3 500	6.66	58.00	3 480	− 0.57
2	11.50	3 330	6.32	55.38	3 323	−0.21
3	11.00	3 175	5.99	52.50	3 150	−0.78
4	10.50	3 030	5.71	49.54	2 972	−1.91
5	10.00	2 845	5.30	45.50	2 730	−4.04
6	9.50	2 710	5.05	42.48	2 549	−5.94
7	9.00	2 555	4.74	39.50	2 370	−7.24

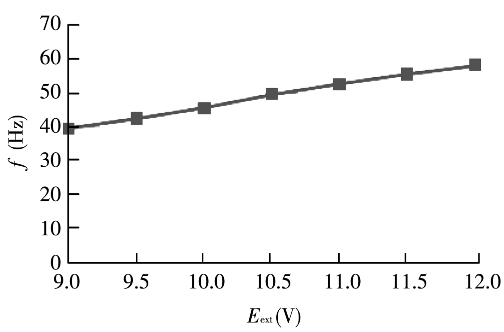

Fig. 4 Dc supply voltage and timer output frequency

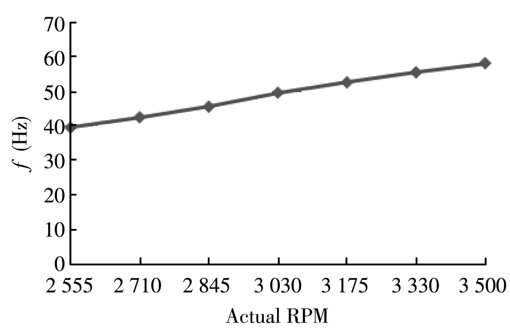

Fig. 5 Actual RPM of a rotating dc motor (M_1) vs. timer output frequency

It is clear from Fig. 6 that the percentage error reduces in the higher RPM measurements.

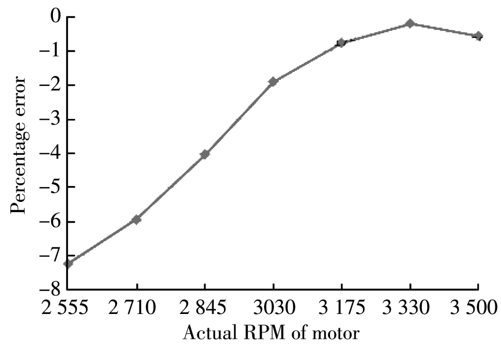

Fig. 6 Relationship between actual RPM of a rotating dc motor and calculated percentage errors in RPM measurements

4 Conclusion

This paper described a RPM measurement system of a rotating dc motor. This system is very simple, low cost and provides a linear input-output relationship which is an important requirement for a measurement system. Besides, this system can be interfaced easily with microprocessor/microcontroller and personal computer without an analog-to-digital converter (ADC) for further processing. Because of the simplicity of this system, this measurement system can be used for RPM measurement of dc motors in different industrial applications. This type of developed project is very attractive and may motivate the scholars or engineers to utilize their knowledge for design, development, implementation and testing in a single project.

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简易转速测量系统设计

Akash Kumar[1], Anindya Debnath[1], Antar Banik[1], Kabirul Islam Mondal[1], Partha Pratim Biswas[1], Rik Bhattacharyya[1], T K Maiti[2]

(1. Netaji Subhash 工程学院 应用电子与仪器工程系，加尔各答 700152，西孟加拉；
2. 科克拉贾尔中央理工学院 仪器工程系，阿萨姆 783370，印度)

摘 要： 介绍了一种基于定时器的转速测量系统的设计与开发。使用直流电动机的转轴来测量其转速，定时器 IC 555 用于不稳定模式。使用数字存储示波器(DSO)测量的定时器输出波形的频率几乎与转轴的转速成线性比例，而这个转速又与外部输入电压水平的变化成线性关系，由此得到了定时器输出波形频率与转速之间的线性关系。该系统的主要优点是线性输入-输出，体积小，便于携带且成本低。

关键词： 定时器 IC 555；非稳多谐振荡器；转速测量

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