

## Development of OPTO-LDR coupled timer based voltage to frequency converter

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**Abstract:** This paper describes the development of a timer based voltage to frequency converter (VFC). Timer LM555 is used in astable multivibrator mode with two OPTO-LDRs (light dependent resistors) in the circuitry. The frequency of timer output waveform which is measured using a digital storage oscillator (DSO) is almost linearly proportional to the applied input voltage. Hence we obtain a linear relationship between the frequency of timer output waveform and the input voltage. Because of its quasi-digital output, the main advantages of this developed converter are linear input-output relationship, small size, easy portability and high cost performance. In addition, the timer output waveform can be directly interfaced with personal computer or microprocessor/microcontroller for further processing of the input voltage signal without intervening any analog-to-digital converter (ADC).

**Key words:** timer LM555; astable multivibrator; light emitting diode (LED); light dependent resistor (LDR); voltage to frequency converter (VFC); digital storage oscillator (DSO)

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## 0 Introduction

Sometimes it becomes very important requirements in different electrical, instrumentation, electronics and process industries like power plants, oil industries and petrochemical industries to transmit different output signals of sensors (voltage or current signals) for the industrial automation purposes. To do this we widely use voltage to current converter (VCC), voltage to frequency converter (VFC), etc. Therefore, sensor output signal is to be converted in a suitable form so as to process it very straightforwardly and reliably. Different types of VCC techniques for both grounded and floating loads as well as VFCs<sup>[1-7]</sup> are widely used for this purpose. Since sensor signal transmission through VFC technique is

more reliable than VCC technique, here we have developed a VFC using a timer (LM555) based astable multivibrator associated with two OPTO-LDRs (light dependent resistors)<sup>[8]</sup> for sensor signal transmission remotely in the industrial environment. The timer output frequency and the applied input voltage relationship is linear. This measurement system is also very simple, low cost, and small in size.

## 1 Theory

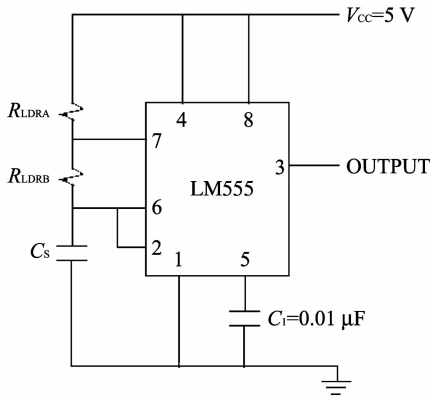
Fig. 1 shows the timer IC LM555 circuit with two OPTO-LDRs which are the combination of one light emitting diode (LED) and one LDR. In this circuit, the timer is working in astable multivibrator mode. OPTO-LDR is nothing but a combination of LED and a LDR. As per the working principle of timer<sup>[9-10]</sup>,

the capacitor charging time ( $T_C$ ) and discharging time ( $T_D$ ) can be written as

$$T_C = 0.693(R_{LORA} + R_{LORB})C_S, \quad (1)$$

$$T_D = 0.693R_{LORB}C_S, \quad (2)$$

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



**Fig. 1 LM555 based astable multivibrator circuit with two LDRs**

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

$$T = T_C + T_D = 0.693 \times 3 \times R_{LORA} \times C_S, \quad (3)$$

and the frequency ( $f$ ) of the timer output waveform is got as

$$f = \frac{1}{T} = \frac{0.481}{R_{LORA} \times C_S}. \quad (4)$$

Now the current ( $I$ ) passes through LEDs is given by

$$I = \frac{V_I - 2V_{LED}}{R}, \quad (5)$$

where  $V_I$  is the applied input voltage,  $V_{LED}$  is the voltage drop across the LED and  $R$  is the current limiting resistance.

The light intensity ( $Lux$ ) generated by LED is proportional to the current passing through this diode as

$$Lux = K_1 I, \quad (6)$$

where  $K_1$  is the proportionality constant and  $Lux$  is the luminous of light.

The resistance of LDR is related with the incident

light intensity as

$$R_{LDR} = \frac{K_2}{Lux}, \quad (7)$$

where  $K_2$  is a constant and  $R_{LDR}$  is the resistance of LDR.

On substitution of Eqs. (5)–(7), we can rewrite Eq. (4) simply as

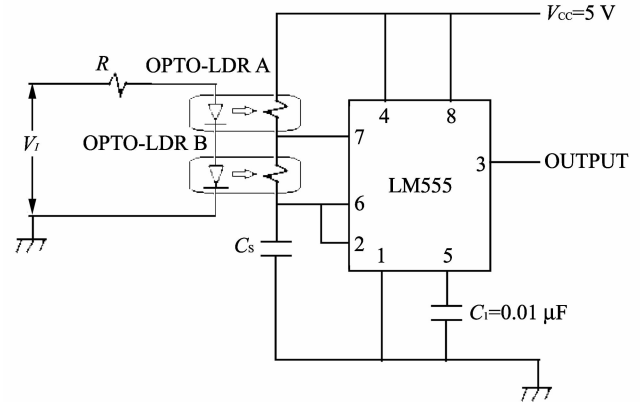
$$f = AV_I + B, \quad (8)$$

where  $A$  and  $B$  are constants.

Therefore, Eq. (8) shows that  $f$  is linearly proportional to  $V_I$ .

## 2 Design procedure and experimental set-up

Eq. (8) can be utilized to design VFC timer LM555 based astable multivibrator circuit. Fig. 2 shows timer LM555 based astable multivibrator circuit with two OPTO-LDRs.



**Fig. 2 LM555 based astable multivibrator circuit with OPTO-LDRs**

This circuit is implemented and it can be used as the experimental set-up.  $V_I$  is applied in the input circuit containing the current limiting resistor ( $R$ ), and LEDs.  $R$  is used to control the current through the LED. Since the LEDs are used as the light sources for two LDRs which are associated with the timer based astable multivibrator and the current of these LEDs depends on the applied  $V_I$ , the timer output frequency obviously depends on the applied  $V_I$  which is used as the supply dc voltage for the two OPTO-LDRs.

As per the operation of LM555 based astable mul-

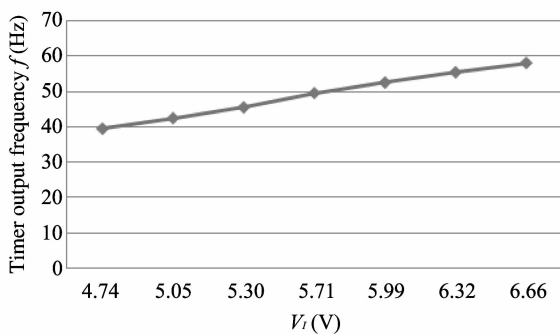
tivibrator, due to change in  $V_I$  the current through the LEDs will be changed and the light intensity generated by LEDs will also be changed. Due to this change in light intensity which is directly incident on the LDRs which in turns change the resistors of  $R_{LDRA}$  and  $R_{LDRB}$  and hence as a result the timer output frequency will also be changed. We have measured the timer output frequency using a digital storage oscilloscope (DSO). Therefore, by measuring the frequency of timer output, the input voltage can be determined, i. e. voltage to frequency converter can be developed.

### 3 Results and discussions

Fig. 2 is used as the experimental set-up for the actual experimental purposes and the different measured data are shown in Table 1. Based on the data from Table 1, we have plotted the graph between the applied  $V_I$  and the measured  $f$ . The graphical representation has been shown in Fig. 3 and it is found that the timer frequency-input voltage relationship is almost linear.

**Table 1** Measured data for applied  $V_I$  and timer  $f$

	1	2	3	4	5	6	7
Input voltage $V_I$	4.74	5.05	5.30	5.71	5.99	6.32	6.66
Timer output frequency $f$ (Hz)	39.50	42.48	45.50	49.54	52.50	55.38	58.00



**Fig. 3** Graphical representation of timer output frequency  $f$  and input voltage  $V_I$

### 4 Conclusion

This article describes a timer based VFC and this converter is very simple, low cost and also provides a linear input-output relationship which is a very essential prerequisite for a measurement system. Another advantage of this developed system is that because of its quasi-digital output, it can be interfaced easily with microprocessor/microcontroller and personal computer without intervening with an ADC for further processing purposes.

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# 基于光敏耦合定时器的压频转换器的实现

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**摘要:** 研制了基于定时器的压频转换器, 电路主要由工作于非稳态多谐振荡器模式下的定时器 LM555 和两个光敏电阻构成。由于数字存储振荡器测得的定时器输出波频率与所施加的输入电压基本呈线性比例关系, 所研制的转换器为类数字输出, 因此具有线性输入/输出关系、体积小、易携带和高性价比等优点。此外, 定时器输出波可以直接与 PC 机、微处理器或微控制器相连, 不需要模/数转换器就能完成对输入电压信号的进一步处理。

**关键词:** LM555 定时器; 非稳态多谐振荡器; 发光二极管; 光敏电阻; 压频转换器; 数字存储振荡器

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