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Microcontroller Based High Power LED Stroboscope

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Abstract - The following is a design and implementation- oriented approach for the construction and understanding of working principle of a stroboscope. Here, I present a ground up procedure to design and build this device. A stroboscope is a device that aids in the process of measuring the cyclic speed of a rotating body. The device (in the approach I have opted for) largely consists of three major components viz. microcontroller, MOSFET and high power LED.

In a nutshell, the user sets the frequency (desired rate) of brief pulses, the same is then generated and conditioned by the microcontroller so as to serve the switching purpose. The high power LED is made to shine on the rotating body which is subject to study. The frequency of flashes is varied until the rotating body appears stationary due to strobe-effect. The user has freedom to willingly raise or lower the device's flashing frequency until the match is obtained. Thus, at the instant when the rotating body appears stationary, we conclude that the frequency of flashes is equal to the cyclic frequency of the rotating subject body hence, the cyclic frequency of the rotating subject body is known and displayed on an LCD. A detailed explanation and insight of the same follows.

Keywords - Stroboscope, Strobe-effect, LED (Light Emitting Diode), Microcontroller, MOSFET (Metal Oxide Semiconductor Field Effect Transistor).

I. INTRODUCTION

In the current nomenclature, stroboscope inherits its name from the Greek word 'strobos' meaning *whirling* and the English word 'scope'. Thus, as the name suggests, it is a device used to monitor (measure) the (rate of) whirling motion of physical objects. A stroboscope can be constructed by either mechanical or electronic know-how. The mechanical model of stroboscope is a primitive one and does not involve the use of a light emitting device in any way whereas the same is one of the key building blocks of the electronic model. The electronic model of stroboscope incorporates more sophisticated, controllable and advanced techniques to serve the purpose. This era's stroboscopes are preferably portable and handy thereby making the applications versatile and comfortable respectively. The commercial models of stroboscope today are usually battery operated which makes them portable. The basic and most vital component of this device is the microcontroller employed with the aim of generating a user defined frequency of brief pulses which are responsible for driving the power LED. In this particular approach, the microcontroller employed is Microchip Technology's PIC18F452 which is a 40-pin, 8-bit microcontroller built on Microchips PIC architecture. This is an easy to use, program and a versatile microcontroller which is extensively adequate to conform to all domains of technical necessities of an efficient stroboscope with cutting-edge accuracy. The second component of importance is the MOSFET which is here employed to function as a high-speed switching device to toggle the power LED between ON and OFF states. The MOSFET receives its switching signal from the microcontroller at a user defined rate. A power MOSFET such as IRFZ14 is capable of providing very high switching speeds and at the same time offers low ON-state resistance. The TO-220AB package is widely implemented in the industry due to compact size, high power dissipation capability (50W) and cost-effectiveness when put to implementation in mass production of devices in which it is used. The LED used is of high power (5W) and is generally manufactured in the form of a 3x3 matrix of LEDs. It is commonly available in all electronic stores due to high efficiency despite the fact that its cost is comparatively higher than other lighting devices, for example, Neon-Flash Tubes which require high excitation. However, an LED is by far the perfect lighting device for the purpose of a battery-operated stroboscope due to low consumption of power. One of the most important features of a device from the viewpoint of an end user is how and in what form does the device convey/display its measurements and findings to the user in a manner which is of practical utility. Here, stroboscope has an inbuilt display module (LCD) for displaying the calculated frequency and/or time period of the cyclic frequency in a real time reference. Evidently, the LCD is controlled by the same microcontroller (PIC18F452).

II. PRINCIPLE OF WORKING

When a rotating body is observed under the influence of brief flashes of a bright luminous device, its motion exhibits an apparent fashion. This is a result of what's called the *'Strobe-effect'*. The strobe-effect is a visual illusion in which the cyclic motion of the body can inherit either of the following three visual possibilities depending upon the relation between the actual cyclic frequency of the body and rate of brief and bright flashes shone upon it.

a) Rate of flashing > Cyclic frequency

Inference: Object appears to rotate in a direction opposite to that of the original direction but slower. The understanding of the same can be obtained in depth from the following explanation.

Explanation:

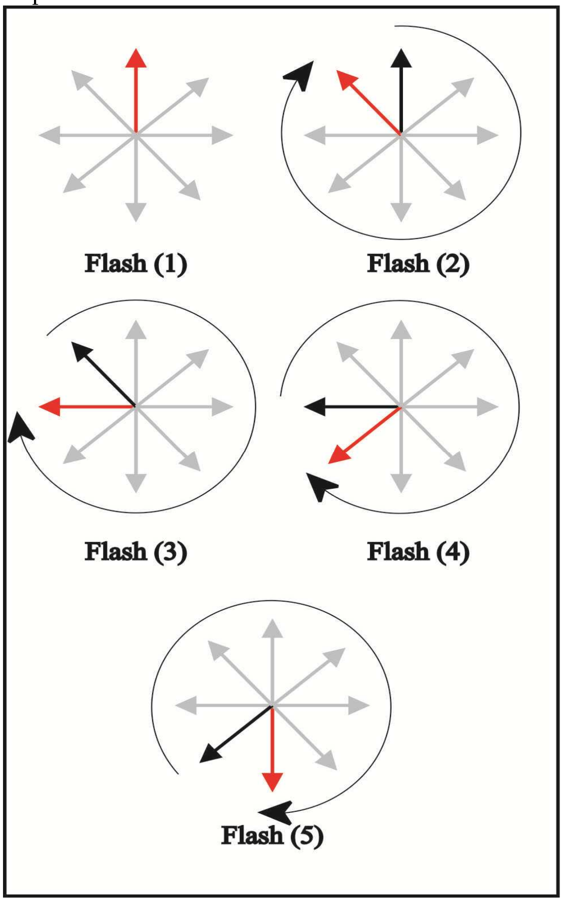

Fig. 1

Key: Red – Position at current flashing instant
Black – Position at previous flashing instant
Grey – Positions at future flashing instants

With reference to above figure (Fig. 1), it is evident that if the time duration between two consecutive flashes of light is less than the time required for the rotating object to complete 1 rotation, then the object appears to rotate in opposite direction. This can be visualized by tracing the current position of the object at each of the five flashes. I.e. by tracing the red arrow.

b) Rate of flashing < Cyclic frequency

Inference: Object appears to rotate in a direction same as that of the original direction but slower.

Explanation:

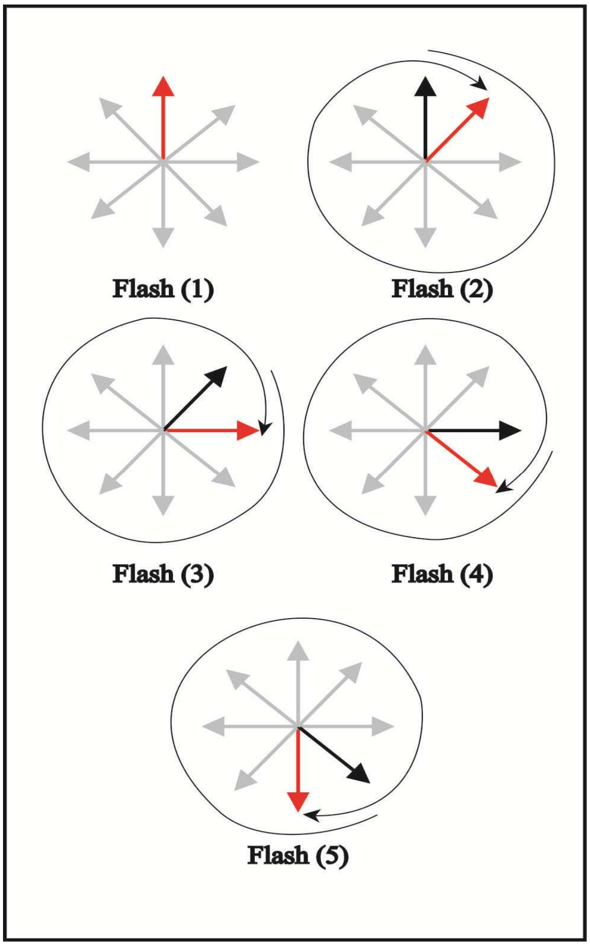

Fig. 2

Key: Red – Position at current flashing instant

Black – Position at previous flashing instant
Grey – Positions at future flashing instants

With reference to above figure (Fig. 2), it is evident that if the time duration between two consecutive flashes of light is greater than the time required for the rotating object to complete 1 rotation, then the object appears to rotate in the actual (real) direction. This can be visualized by tracing the current position of the object at each of the five flashes. I.e. by tracing the red arrow.

c) Rate of flashing = Cyclic frequency
OR
Rate of flashing = n X (Cyclic frequency)
(Where n = Natural number)

Inference: Object appears absolutely stationary.

Explanation:

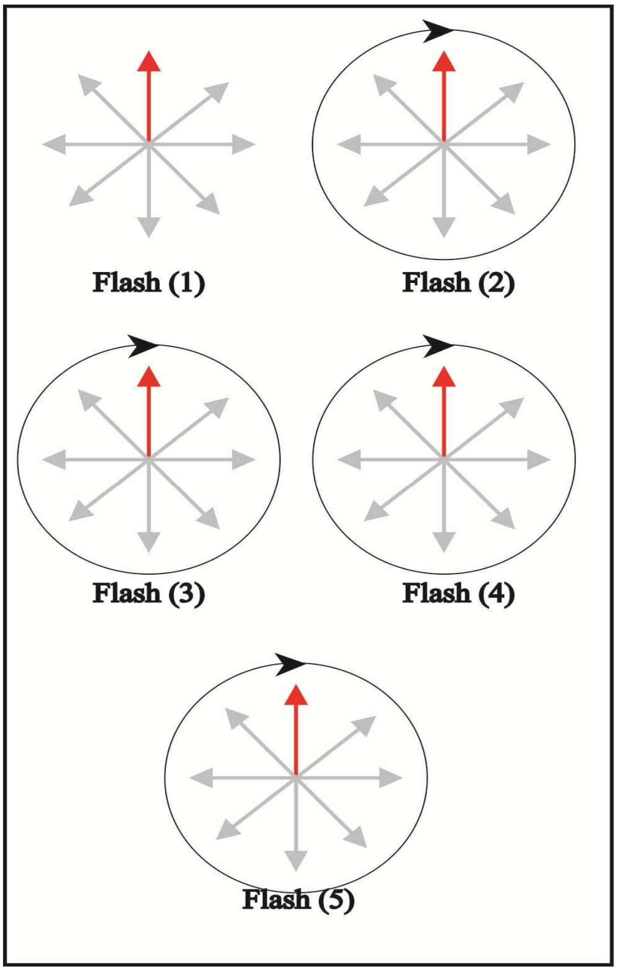

Fig. 3

Key: Red – Position at current flashing instant
Black – Position at previous flashing instant
Grey – Positions at future flashing instants

With reference to above figure (Fig. 3), it is evident that if the time duration between two consecutive flashes of light is exactly equal to the time required for the rotating object to complete 1 rotation or to complete *n* rotations where n is a natural number, then the object appears absolutely stationary. This can be visualized by tracing the current position of the object at each of the five flashes. I.e. by tracing the red arrow.

Note: The current and past positions of at consecutive flashes happen to co-inside.

III. CONSTRUCTION

Let's consider an A.C powered stroboscope which involves the implementation of A.C to D.C converter. However, in a battery powered stroboscope approach, this step may be eliminated. The circuit of a linear dual power supply is as shown in the following figure (Fig. 4).

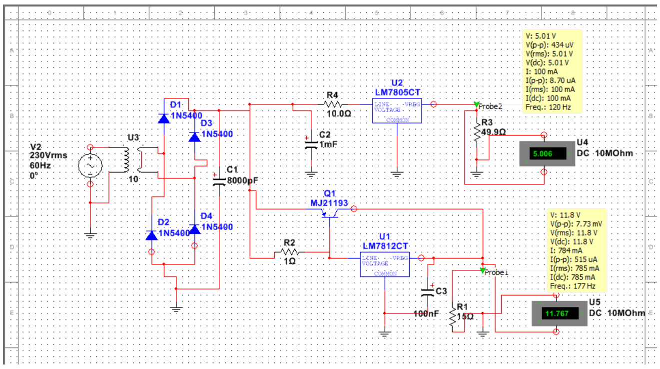

Fig. 4

The input to power supply is 230V – 50Hz A.C whereas the outputs we obtain are 5V - 100mA for microcontroller and LCD module and 12V – 785mA for high power LED. The power supply is to be designed by studying the power requirements from the datasheets of all the active devices used in the circuitry. The power supply can be implemented on a Printed Circuit Board. It must be noted that mounting of the transformer used in the power supply of this device is best done not on the Linear Power Supply (LPS) PCB. Thereby, minimizing the area of the same and hence the cost.

The construction of stroboscope is made extensively simpler and compact without compromising with the efficiency with the Printed Circuit Boards (PCB). This also adds to the reliability of the device. It is suggested that the power supply module and the main circuitry are printed on

two different boards for easy troubleshooting of either of the circuitries and further development of the device.
The practical circuit implementation can be better understood by referring to the following circuit diagram (Fig. 5) showing all the important pin connections and interfacing of different components as well as display module with the microcontroller.

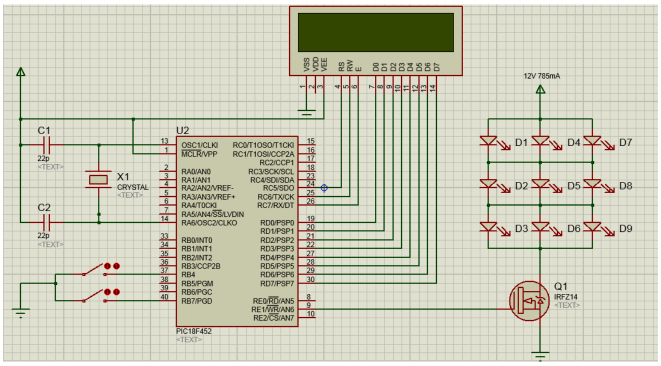

Fig. 5

The LEDs mounted are in a matrix arrangement, reason being, the commercial power LEDs available today are usually manufactured in the form of such matrix combinations of a number of smaller LEDs The advantage of this matrix connection is that even if one or multiple LEDs fail, the remaining LEDs will continue to function without any interference as the disadvantages of failure of series connection of devices are overcome due to the matrix connection and also to considerably scatter the emission of thermal energy by the LEDs. It must be noted that power LEDs dissipate a substantial amount heat over a period of time, therefore one must always make provisions for efficient heat dissipation and distribution mechanisms in the design process so as to protect the device from thermal failure. The same can be done by the introduction of various types of cooling mechanisms. To state a few, which can be ceramic or metal heat sinks and/or cooling fans.

IV. WORKING OF CIRCUITRY

The microcontroller is programmed to output pulses of user defined frequency where the ON time ad OFF times are exactly equal, I.e. a square wave is generated of which the frequency is variable. The LED is wired in such a manner that its anode will have supply voltage and current at all times. But when the microcontroller fed output to the MOSFET is low, the MOSFET turns OFF and the cathode of the LED will be grounded and hence complete the turn-on circuit. But, when the microcontroller output to the MOSFET goes high, the MOSFET turns ON and the LED will be made to fall into OFF mode as the microcontroller output will be now grounded and the LED will no longer have a complete circuit for conduction due to the absence of lower voltage at cathode with respect to anode.
This will repeat for square pulses of all frequencies.

V. .DIRECTIONS FOR USE

Once the device is turned ON, the stroboscope is to be pointed towards the rotating body of interest of which the cyclic frequency is to be measured. After the device boots up, the user may start varying the rate of flashing of the power LED with the aid of two switches (say S1 and S2) on the device. The switches S1 and S2 are preprogrammed to raise or lower the rate of flashing respectively and hence used to vary the flashing rate until the rotating subject body appears stationary due to strobe-effect. At this point the, the user may obtain the cyclic frequency of the object by simply referring to the value displayed on the liquid crystal display.

VI. PRECAUTION

Never point the stroboscope in someone's eye as that may prove hazardous to one's vision due to high-intensity flashes.

VII. ACKNOWLEDGEMENTS

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