OPTICAL COUNTER USING AN OPTICAL COMMUNICATION SYSTEM

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1. INTRODUCTION

There is no doubt that the world is undergoing a major telecommunication revolution due to using the optical communication field which is one of the newest and most important fields nowadays. That is why this device which uses the advantages of the optical components was actually mounnted as printed circuit boards. The idea of this device based on converting the desired variation to electrical pulses that are transferred using an optical transmitter through an optical fiber cable then they are detected by an optical receiver. Further, these pulses will be inserted to the data processing in order to monitor this signal by counting the number of these pulses, hearing the sound of the pulses and visualizing these pulses using a LED. This paper is divided into two parts. First part explains the device and how it works. Second part explains how it can be used as:

- Heart rate monitor
- Tachometer (RPM counter for motors)
- Money Counter
- Device used in quality control in textiles

2. THE DEVICE COMPONENTS AND OPERATION

This device consists of four components:

- Optical transmitter
- Optical fiber cable
- Optical receiver
- Data processing

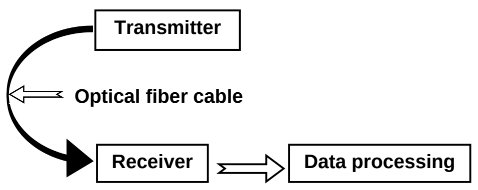

Fig. 1 Block diagram for the whole system.

2.1 The Optical Transmitter

It's the responsible part of converting the variations to electrical pulses and amplifies these pulses before converting them to their equivalent light signals. It consists of a photosensor, an operational amplifier and an optical source (LED).

2.1.1 The photosensor

It's the most important component in the device that converts the variations to their equivalent electrical pulses. That can be done by putting a reflective surface above of the vibrating object. The reflective surface vibration causes modulation for the signal (this effect is known by a Doppler effect). The photosensor consists of a light source (LED) and a photodetector (phototransistor). To understand its operation let us assume that it is desired to count the RPM for some motor. First, stick a reflective surface upon the surface of the motor cylinder (vibrating object) and justify this reflector to rotate in front of the photosensor. While the LED is emitting its optical signals, the reflector cuts the path of the optical signal and reflects it back to the phototransistor. During the next revolution the reflector reflects the light back to the phototransistor again. So, the phototransistor will detect one optical signal each one revolution. By this way, each revolution is converted to an electrical pulse thus; a train of pulses that corresponds to the number of revolutions is obtained.

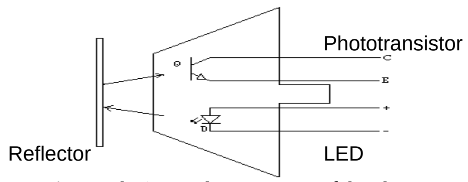

Fig. 2 The internal components of the photosensor.

2.1.2 The operational amplifier

It amplifies the electrical signal produced by the photosensor by 250X using only one stage from the four stages of 324 IC.

2.1.3 The optical source (LED)

LED is a semiconductor PN-junction device that emits light by spontaneous emission. It converts the amplified electrical signal to its equivalent optical one which can be transmitted through an optical fiber cable. The following schematic diagram shows the structure of the transmitter.

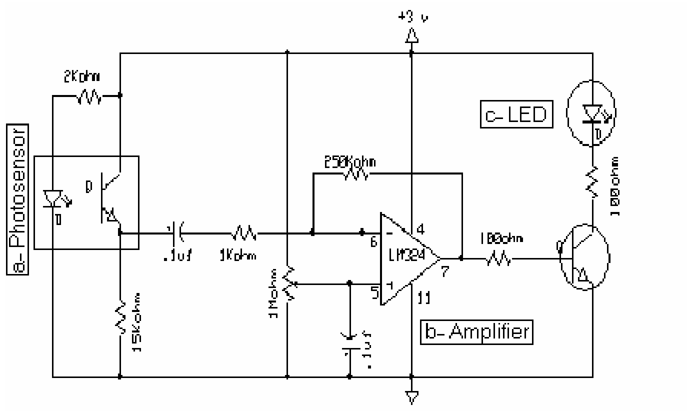

Fig. 3 The schematic diagram of the transmitter.

2.2 The Optical Fiber Cable

The equivalent optical signal is transmitted through an optical fiber channel which is a dielectric waveguide that operates at optical frequencies. It consists of core, cladding and a buffer and it may be fabricated from glass or plastic (Glass is preferred because it has lower attenuation). Despite of the fiber cable expenditure, it is important to be used in some applications due to its advantages:

i. Immunity from electromagnetic interference.
ii. It can be used in combustible environment.
iii. Security from monitoring.
iv. Low loss. (Cable Attenuation = 0.31dB/km).
v. Large bandwidth (i.e. multiplexing capabilities).
vi. Small size and light weight

TABLE I
THE CHARACTERISTICS OF THE USED OPTICAL FIBER CABLE

Characteristic	Symbol	Value
Peak emission wavelength	λ	660 nm
Effective diameter	D	1 mm
Numerical Aperture	NA	0.5
Rise Time	t_r	80 ns
Fall Time	t_f	40 ns

2.3 The Optical Receiver

The receiver detects the optical signal which has traveled through the fiber cable. It converts this signal to the equivalent electrical one. The simple structure of the receiver makes its fabrication very easy because it consists of a phototransistor and an amplifier. Figure 4 shows the structure and the schematic diagram for the receiver.

2.3.1 The phototransistor

The phototransistor is a kind of optical detectors. As light irradiates the base of the phototransistor, electron hole pairs are formed and these pairs constitute a flow of base current. The intensity of the current flow is directly related to the brightness of the incident light.

2.3.2 The operational amplifier

It amplifies this electrical signal 100X using only one stage from the four stages of 324 IC.

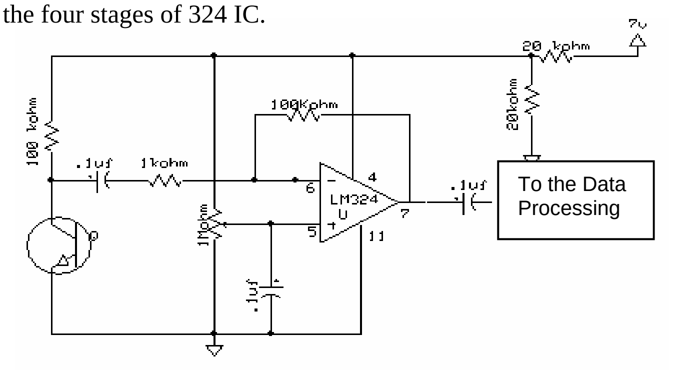

Fig. 4 *The schematic diagram of the receiver.*

2.4 The Data Processing

Now, it is required to notice the pulses after they have been sent using the optical communication system by hearing the sound of the pulses, visualizing them by a LED and counting the number of these pulses. The data processing is the responsible part for preparing the pulses and counting them. It has a very simple structure comparing with the other circuits which make the same operation. Some simple modifications can be done for this circuit according to the desired application. Figure 5 shows the block diagram for the whole circuit of the data processing.

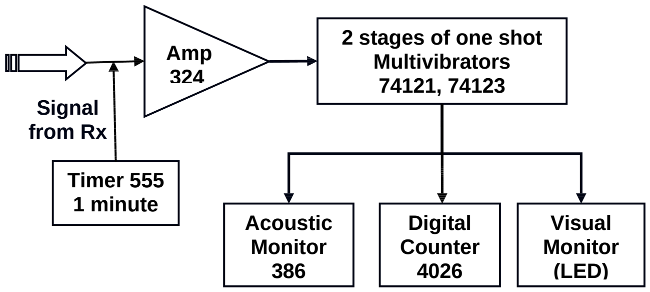

Fig. 5 *Block diagram for the data processing.*

The data processing consists of the following parts:

- The timer
- The operational amplifier
- 2 stages of monostable multivibrators
- The acoustic monitor
- The Digital Counter

2.4.1 The timer

Its operation is to stop the counting operation after 1 minute. The IC **555** is used in order to build a monostable timer circuit which is designed to operate for 1 minute by supplying it with the main power supply. The other components of the data processing except the digital counter are fed from the timer output. It's too easy to adjust the timer to operate for 1 min. by connecting:

- resistor (R_1) between pin# 7 and the power supply
- capacitor (C_1) between pin# 2 and the ground.

according to the relation

$$T = 1.1 \times R_1 C_1 \quad (1)$$

Let R_1 = **545** Kohm & C_1 = **100** µf

Therefore; the timer output will supply the other components of the data processing - except the digital counter - for T = 1 min. before turning them off.

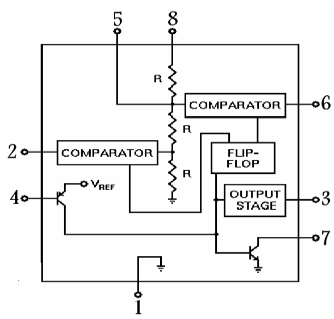

Fig. 6 *The functional block diagram of the 555 timer IC. Connect resistor R_1= 545Kohm capacitor C_1 = 100µf The other components except the digital counter are fed from pin# 3.*

2.4.2 The operational amplifier

Some applications don't require the optical communication system and use the data processing only by connecting it directly to the photosensor. In this case; the weak electrical pulses that are produced by the photosensor need to be amplified by using 2 stages from the operational amplifier 324 which produce an amplification of 1000X. The rest two stages may be used in some applications.

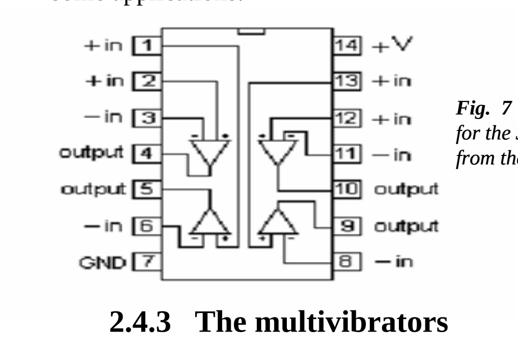

Fig. 7 The internal structure for the 324 IC. only 2 stages from these 4 stages are used.

2.4.3 The multivibrators

The multivibrators are used to produce a square-wave output as they have the property of regeneration. There are 2 types of multivibrators astable type and monostable type. The astable multivibrator produces a continuous output that consists of a train of square pulses so, it acts as an oscillator. The monostable multivibrator generates a single square pulse depending upon the received input-trigger pulse. the monostable type is used in this circuit in order to increase the time width of the pulses.

2.4.3.1 First stage 74121

The one shot monostable multivibrator 74121 IC has three trigger inputs: A_1, A_2, and B. Depending on the circuit design, any or all of these three pins may be connected to the input trigger signal. The "A" inputs are active low and the "B" input is active high. The input logic circuit reads if A_1 OR A_2 goes low AND B goes high, the one-shot will fire its pulse.
The operational amplifier output is connected to the input "B" so, when a trigger input "B" activates the device, the Q output will go HIGH. The following diagram illustrates this operation.

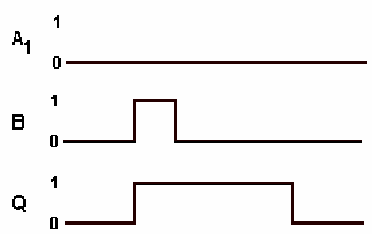

Fig. 8 The timing diagram for the input triggers and output square wave of 74121one shot monostable multivibrator.

The pulse duration is determined by an external resistor (R_2) and capacitor (C_2) connected to pins R_{EXT}, and R_{EXT}/C_{EXT} consequently. The internal structure of the 74121 IC is shown in figure 9. If the value of capacitor connected to C_{EXT} is greater than 1µf, the pulse width (tw) is obtained by the equation:

$$tw = 0.7 \times R_2C_2 \quad (2)$$

So, to obtain pulse duration = **4** msec
Let R_2= **5** Kohm & C_2= **1**µf

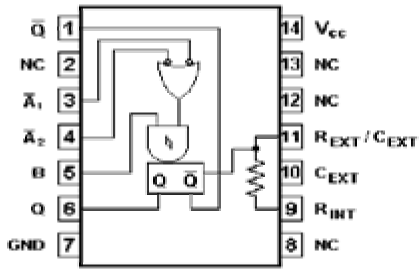

Fig. 8 The internal structure of the 74121 IC

2.4.3.2 Second stage 74123

The difference between the 74123 IC and 74121 IC is that 74123 can be used for high speed applications as the money counter or the tachometer. 74121 is sufficient for low speed applications such as the heart rate monitor where the device counts low speed pulses. It works as 74121 but its pulse width can be controlled using the relation:

$$tw = 0.45 \times R_3C_3 \quad (3)$$

Where

C_3: The capacitor connected between pin# 7 and pin# 6.
R_3: The resistor connected between pin# 7 and the timer output.

So, to obtain pulse duration tw = **14** msec
Let R_3= **5** Kohm & C_3= **6**µf

2.4.4 The audio amplifier

By adding this circuit, an amplified speaker can be used to monitor the signal by hearing it. The circuit amplifies the input signal by 20X. A gain of 200X can be obtained by connecting a 10µf capacitor between pins 1 and 8.

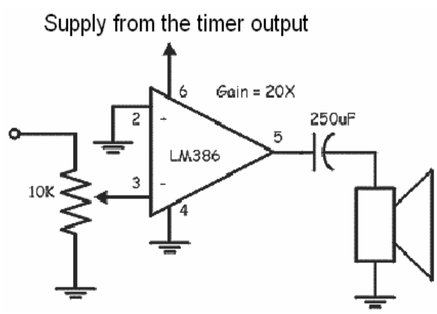

Fig. 9 The schematic diagram of the audio amplifier circuit.

2.4.4 The digital counter

The pulses are ready now to be counted after they get out from 74123. Most of the counter circuits use two IC's (such as 7448 and 7490) which are TTL ICs for counting and driving the seven segment LED display. Here, a fast speed two decades counter is built with an amazing digital integrated circuit [the **4026** CMOS IC]. This IC has the functions of counting and at the same time is a direct driver by itself to common cathode seven segment displays. The advantages of using this IC comparing with the different pulse counter circuits are:

- Reducing 50% of the size.
- The other circuits require more troublesome wiring.
- Low power consumption (2 CMOS ICs instead of 4 TTL ICs).

During building the counter circuit, start with the first stage; the unit's decade. Once this decade have been mounted according to the shown schematic in figure 10, put it to work and be sure that all the numbers from 0 to 9 appear complete one by one of the IC. After being sure that the first decade works properly, continue with the construction of the second one which is an exact copy of the first stage except that pin# 1 of this second decade is connected to pin# 5 of the first decade (the carry out pin) without the 1000 ohm resistor.

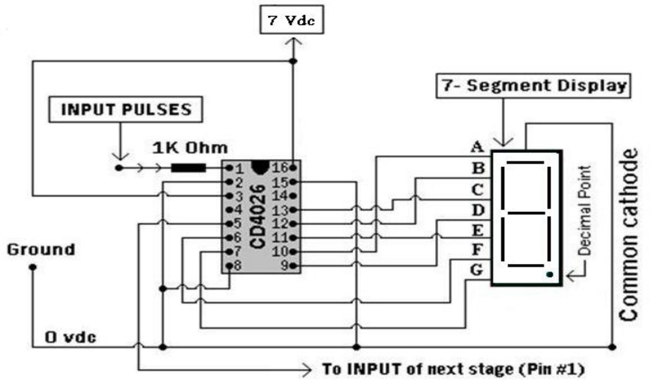

Fig. 10 The schematic diagram for the counter circuit.

The supply of the counter circuit is the main power supply in order not to turn the seven segment displays off after 1 minute.

The following figure shows the total schematic diagram for the data processing. Note that, the signal can directly enter the data processing using the photosensor instead of the receiver.

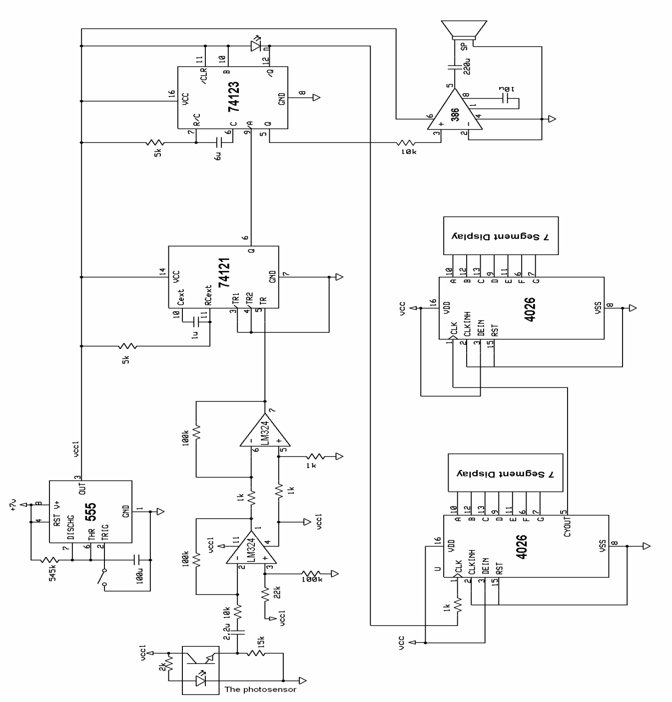

Fig. 11 The schematic diagram for the data processing.

3. Applications

The following applications were already implemented in the laboratory. It is clear now that this device can count the variations that occur in front of the photosensor. This part shows a brief explanation to how this property can be used.

3.1 Heart Rate Monitor

Using the photosensor, the pulses of the heart can be converted to an electrical signal. The LED of the photosensor emits optical signal which go towards the reflective surface where is on the left hand artery of the patient; this mirror reflects the optical signal again to the phototransistor. Mirror vibration causes modulation for the received light signal. The modulated light gets out as an electrical signal. It may be significant to use the optical communication system in case of many patients.

3.2 Tachometer

This application was illustrated while explaining the operation of the photosensor. [Revise part 2.1.1]

3.3 Money Counter

In this application; the reflective surface will be the edge of the currency paper. The total amplification due to the transmitter, the receiver and the data processing equals 2.5×10^{7}. So, it is not strange that this device can sense the reflection occurred by the edges of the papers. It is required to add another part to this device in order to rotate the money packets in front of the photsensor. In the other hand, it is not necessary to use the optical communication system in such application thus; the data processing is connected directly to the photosensor, but the useless stages of 324 IC are used to get the required gain.

3.4 Quality Control in Textiles

One way to control the quality of the weaves is to monitor the uniformity of separations between threads in order to be sure of the thread spacing regularity during weaving. That can be done by monitoring the velocity uniformity of the sewing machine needle by taking the needle surface as the reflective surface and connect the electrical output of the transmitter to a digital oscilloscope. Note that; the transmitter is used only without using any other part of the device. The following diagram illustrates this application. The horizontal axis represents the time spacing in nanoseconds between each needle penetration that have been obtained using this device and the vertical axis represents the penetration force obtained using another device.

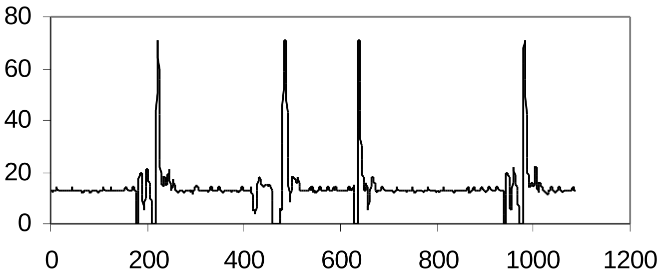

Fig. 12 The timing diagram versus Penetration force.