Design and implementation of Infrared Laser Object Vibration Sensor circuit

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Abstract

In this work, an electronic device which is able to receive a vibration modulated laser signals had been designed, and these vibrations will be converted through the device to hearable sound with high quality.

The transmitter represented by infrared laser diode of 808 nm and the receiver is a complicated detector which consists of phototransistor to detect the reflected laser beam from the window, an integrated circuit of LM358 to pre-amplify the electronic signal. First order filter is to eliminate noises and unwanted signals, TDA2002 integrated circuit is to amplify signal to nearly ten times from the incident signal to the TDA2002, speaker to hear the voice.

The vibrations are made by the source –which can be living or non-living source- will causing a resonant frequency with the window. So, the incident lR laser beam will have this frequency and through reflection from the window the reflected laser beam will have vibrations, these vibrations will be incident on the photo-transistor and the receiver will work to output the sound.

Experimental results proved that this device is able to function properly through 20 meter with good sound quality, this was because of the use of (1 W) laser diode of 808nm.

Key words: Infrared Laser , Sensor circuit

تصميم وتنفيذ ليزر الأشعة تحت الحمراء في دائرة متحسس الأهتزاز

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الخلاصة

في هذا المشروع قد تم تصميم جهاز الكتروني قادر على استلام اشارات ليزريه مضمنه بالاهتزازات و تحويل هذه الاهتزازت الى صوت مسموع و ذو جودة عالية.

وذلك ببناء دائره المستقبل. حيث تم في هذه الدائره استخدام ترانسزتور ضوئي لتحويل الاشارات الليزريه المضمنه الى اشارات الكترونيه وكذلك استخدام دائره ال LM358 المتكامله التي تعد مرحله ما قبل تضخيم الاشاره وهي مرحله تحسين الاشاره و تهيئتها للتضخيم العالي من قبل دائره ال TDA2002 المتكاملة و قد تم بناء مرشحين من النوع الاول مكونه من مقاومه و متسعه لتنقيه الاشاره من الضوضاء و كذلك مقاوم خانقه لتحسين التنقية.

ان الاهتزازات الناشئه عن مصدر صوتي معين تجعل المكان المتواجد فيه المصدر يهتز معها رنينيا اي بنفس التردد هذا هو المبدأ الاساسي لعمل الجهاز و كذلك مبدأ الانعكاس عن السطوح الشفافه– قليله الامتصاص للاشعه.

عندما يسقط شعاع الليزر غير المرئي على نافذه بعيده فانه سينعكس وفقا لمبدأ الانعكاس و سيكون الشعاع المنعكس مضمن بموجه صوتيه ناشئه عن الاهتزازات الحاصله في هذه النافذه عندها سيقوم المستلم باستقبال هذه الاشاره بعد عمليه الترصيف الدقيق للاشعه , وسيقوم الترانسزتور الضوئي بتحويل الاشاره الضوئيه الى اشاره الكترونيه تدخل للدائره و تتم عليها عمليات الترشيح و التنقية والتضخيم لتظهر النتيجه كصوت مسموع.

اثبتت النتائج العمليه ان الجهاز باستطاعته ان يعمل لمدى 20 متر بأستخدام ليزر ذو قدرة 1 واط وطول موجي 828 نانومتر.

الكلمات المفتاحية: اشارات ليزريه مضمنه ، مبدأ الانعكاس، عمليات الترشيح و التنقية والتضخيم

1. INTRODUCTION

The Infrared laser vibration sensor is a surveillance device that uses a laser beam to detect sound vibration in a distant object.

The object is typically inside a room where a conversation is taking place, and can be anything that can vibrate in response to the pressure waves created by noises present in the room.

The object has been preferably a smooth surface. The laser beam is directed into the room through a window, reflects off the object and returns to a receiver that converts the beam to an audio signal.

The beam may also be bounced off the window itself. The minute differences in the distance traveled by the light as it is reflected from the vibrating object which are detected interferometrically. The interferometer converts the variations to intensity variations, and the electronics are used to convert these variations to signals that can be converted back to sound.

Rippled glass can be used as a defense, as it provides a poor surface for a laser vibration sensor, minimum laser power which is called threshold power that have to be measured [1,2].

The basic theory of a laser vibration sensor is the reflection ability of laser light when it tricks a certain window, the reflected beam angle (θ_r) is equal to incidence beam angle (θ_i).This is the basic law of reflection, as shown in figure (1)[3].

Reflection of light is either specular (mirror-like) or diffuse (retaining the energy, but losing the image) depending on the nature of the interface [4].

In addition, if the interface is between a dielectric and a conductor, the phase of the reflected wave is retained; otherwise if the interface is between two dielectrics, the phase may be retained or inverted, depending on the indices of refraction [5].

A mirror provides the most common model for secular light reflection, and typically consists of a glass sheet with a metallic coating where the reflection actually occurs. Reflection is enhanced in metals by suppression of wave propagation beyond their skin depths. Reflection also occurs at the surface of transparent media, such as water or glass [6].

2. EXPERIMENTAL WORK

2.1 The sensor design

The sensor is completely an electronic circuit, and is designed accurately to function as receiver of the reflected laser beam to be amplified, filtered and amplified again to reach the speaker, and figure (2) shows schematics of the operation.

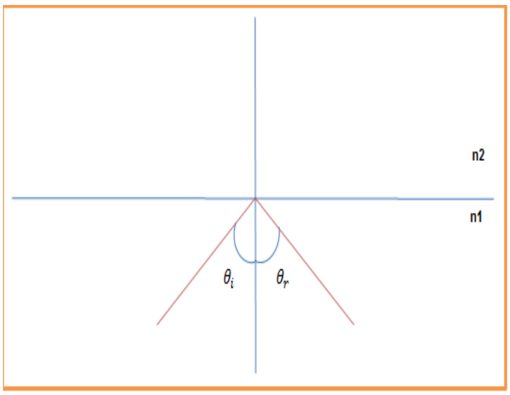


Figure (1): schematic diagram of light reflection

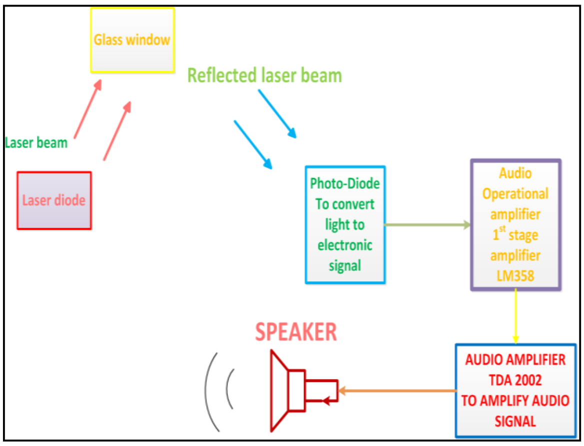


Figure (2): schematic diagram of the laser vibration sensor

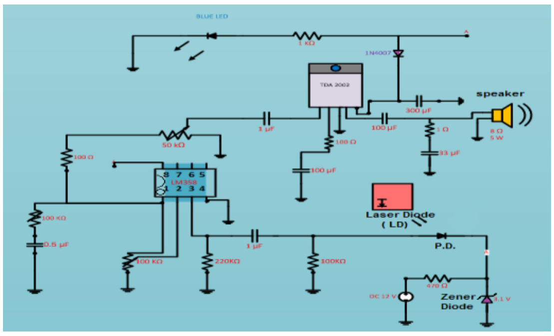
The laser is an incident to the glass window which then absorbs the vibration of the window.The reflected beam of laser now having the absorbed vibrations of the glass window and this reflected beam will pass through the sensor phototransistor which will transform this signal to electronic signal and then the signal will be amplified by the well-known integrated circuit for audio amplification which is LM358. After, the signal will be amplified and filtered by 1st order filter of resistor and capacitor then the blocking capacitor will block DC and allows AC signal to pass through the speaker which will give the output as a hearable sound.

2.2 Practical design of the circuit:

As been explained in figure (2), which is the basis for the design and a perfectly successful design was designed as shown in figure (3) :

The structure of the sensor which had been soldered in an electronic board is shown in figure (4).

Figure (3): The structure schematics of



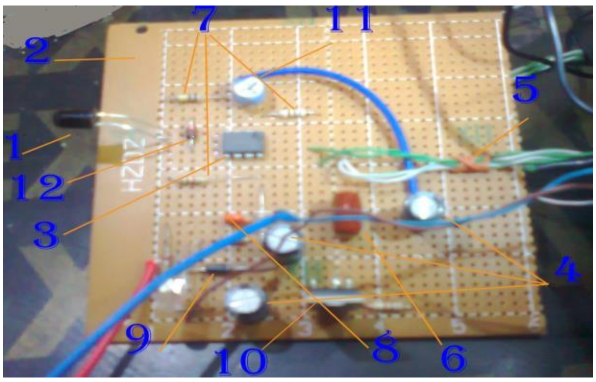


Figure (4) :Internal view at the sensor

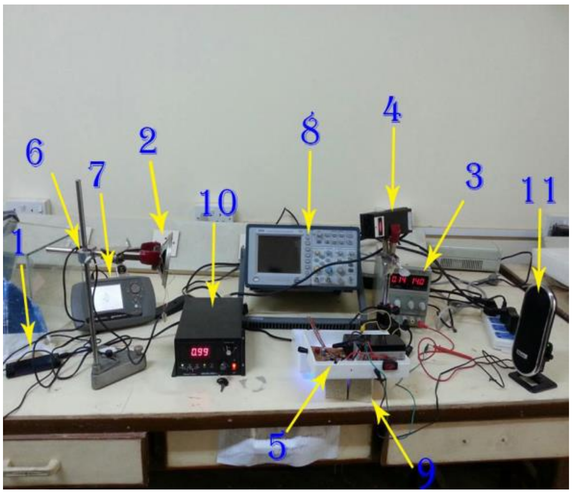
From figure (4):

1. Phototransistor: for receiving light signal
2. Integrated board : to build the circuit in it
3. LM358 IC: to amplify the signal
4. Capacitors
5. Wires to be connected to the variable resistor that controls sound volume.
6. Non polarity capacitor
7. Resistors
8. Non polarity capacitor
9. Diode: for safety purpose
10. TDA2002 IC: for amplification of the signal
11. Variable resistor
12. Zener diode

2.3 Final setup

The final setup of the project is shown in figure (5), then the device is worked successfully.

Alignment is the key procedure for good sound output, therefore mounting holders and bricks have been used to get excellent alignment.



Figure(5): The final set- up.

Detail description of the setup:

1. The mobile here is used as sound source and is connected through headphone connector wire to a speaker.

2. The speaker is chosen for its high vibrating capability and a round mirror is pasted on the center of the speaker to let the speaker be a reflector surface for the incoming laser beam.

3. The power supply is set to 14 V to supply the sensor with enough voltage to operate.

4. The laser diode of 808 nm wavelength with power of 1W was used to transfer the sound from the vibrating speaker to the sensor by means of reflection.

5. The sensor was connected with speaker to hear the output sound.

6. Mounting holders were used for alignment purposes.

7. The power meter was used to measure laser power for many locations.

8. The Oscilloscope was used to view the output as sound wave.

9. The sensor was put on small bricks for alignment purpose.

10. The laser power supply.

11. Output speaker that displays sound.

3. Experimental results

3.1 Results at speaker terminals:

The speaker output voltage with time when the device is turned ON, but there is no vibration made is shown in figure (6).

Figure (6) :Speaker output (no voice)

The output voltage with time when the device is turned ON, and there is a vibration made (medium knock sound), as shown in figure (7)

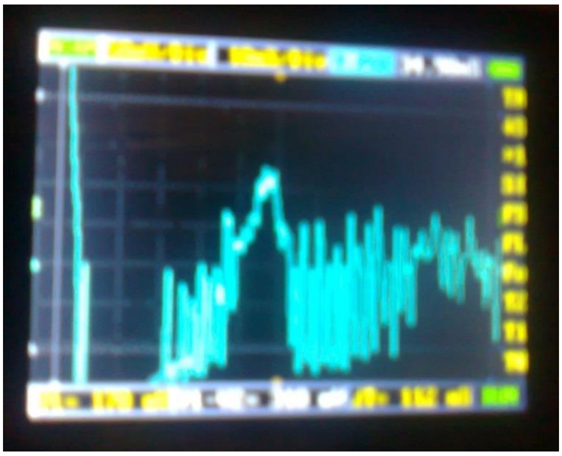


Figure (7): Speaker output (with vibration made)

The difference between the result of figure (6) and figure (7) is that the figure (6) has only one peak which represents the voltage signal which is near 9 volts, but when vibration is made near the device – which is knock in the figure (7), the sound the has been heared from the device's speaker is as shown in figure (7) which represent the knock, that off course indicate the successful operation of the device.

3.2 Results at phototransistor terminals:

The output voltage with time when there is no vibration made is shown in figure(8).

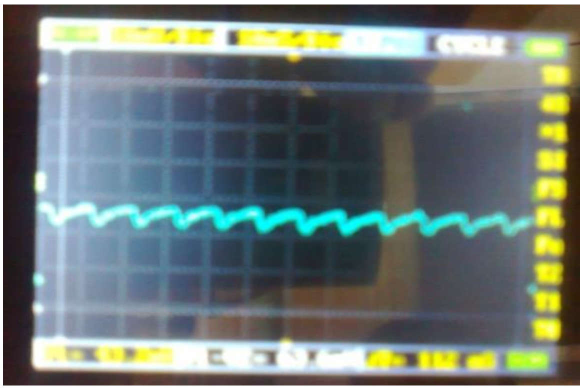


Figure (8): Photo-transistor with no vibration

The output voltage with time when vibration us made, is shown in figure (9).

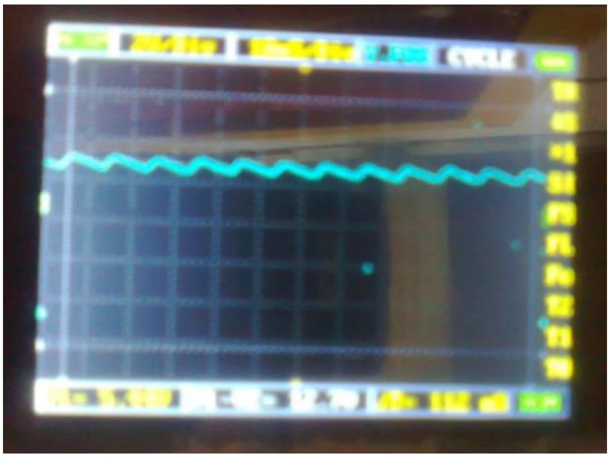


Figure (9): Photo-transistor with vibration

Figure (8) shows voltage at certain peak, but figure (9) shows the voltage at different peak , this indicate the succession of the phototransistor to receive different signal levels.

3.3 Maximum allowable distance.

A MATLAB program has been designed and executed to evaluate perfect values of the absorption coefficient and the allowable distance that the device works in it perfectly.

After calculation of the sound absorption coeffienct, a curve was plotted to show the maximum allowable distance, the result is shown in figure (10).

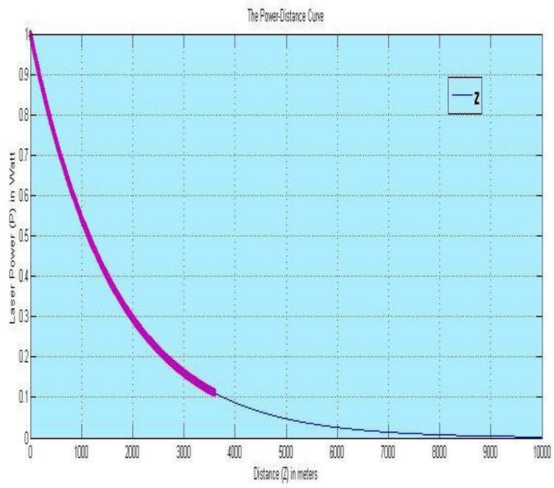


Figure (10) : The power – distance curve using MATLAB

The bold curve represents the allowable distances to hear a good sound, the critical power of the laser power is 0.11 watt which is at a distance of nearly 3500 meter or 3.5 kilometer, while the unbolded curve represents a non-recognized sound due to noises and laser beam attenuation.

3.4 Laser diode power and current relation

The curve is defining the relation between laser power and laser current, as shown in figure (11), the results was drawn using MATLAB program. The importance of this curve is that the experimenters can't select a certain value of laser power instead they will have to select a current value.

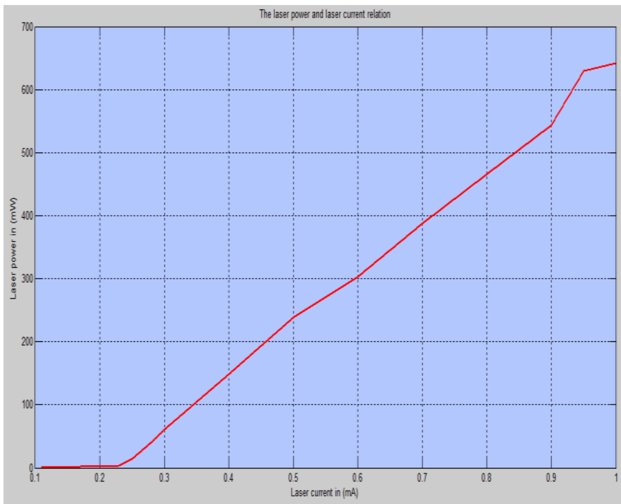


Figure (11). Relation between laser power and laser current

The figure shows proportional relation between laser current and laser power until the current reach a value of about 0.9 mA the power will change proportionally but with different increment.

Conclusion

1- The laser power is an important parameter that affects sound quality.
2-The laser diode of any visible wavelength will not work with the device that has been designed only near infrared wavelengths from 700-1100 nm can work but the laser diode of 808 nm is the best for the operation.
3- The incident laser beam should be perpendicular to the window to achieve minimum vibration losses.
4- Whenever the angle of deviation is large the sound will have more noise.

5. this device is able to function properly through 20 meter with good sound quality

Reference

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