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REAL-TIME AUDIO TRANSMISSION SYSTEM BASED ON VISIBLE LIGHT COMMUNICATION

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Abstract

A simple prototype of an optical wireless audio system by using laser diode as a source for the transmitter has been proposed. In this project, we designed and implemented a wireless optical transmitter and receiver system that established an audio communication at some distances with weak signal via visible light communication. The wavelength that used for this project is 635 nm which is visible wavelength range. Based on the experimental results, the visible light communication system can work successfully within in distance up to 30 meters. This project is successfully improved the transmission distance and signal coverage area effectively with low cost of hardware, high communication speed and almost no limit to bandwidth.

Keywords: Optical wireless communication, free space optical, laser, audio transmission

Introduction

The Optical wireless communication (OWC) also known as Free Space optical (FSO) system is a system that modulates visible or infrared (IR) beams through the atmosphere to propagate any data signals in a system that transfer a signal via visible light usually the wavelength is 380 nm to 740 nm through free space. In other words, it uses light to propagate the signal or to transmit the data in free space, FSO system uses light as the optical source such as a light emitting diode (LED) or laser diodes (LD) to transmit a data instead of enclosing the data stream in a glass fiber but it transmits the modulated light beam through the air. Hence, OWC is gaining reception in an increasing to the number of sectors of science and industry, owing to it is a very unique combination of the features such as extremely high bandwidth, rapid deployment time, license and tariff-free bandwidth allocation, low power consumption, weight and size.

The system using visible light technology has become a significant advantage over a radio frequency (RF). Therefore, optical wireless visible light knowledge seems to be perfect for managing wireless communication in

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the future. Furthermore, visible light transmission does not interfere with the existing RF system and does not controlled by the Federal communication commission (FCC) regulations. In addition, this project can build some privacy for sending and receiving data as visible light does not penetrate the wall, thus providing a level of privacy in the area.

Moreover, the newest publications have attracted considerable interest in using wireless optical communication links in aircraft and space vehicles. Using on-board wireless optical communication has great potential for size, weight, power, cost and EMI reduction. Therefore, this project will provide the initial drive to transmit voice and music by the light source and propagate through free space to be received with improving the distance up to 30 meters. Furthermore, this project also undertakes as a solution for problems about limited distance for transmitting the audio signal and reduces the noise.

Figure 1 shows the basic diagram of the optical wireless audio system or free space optical system (FSO) where the system is called line of sight (LOS) simplex communication system. The light from transmitter must be transmitted in straight lines without any divergence or scattering. It is divided into two main parts consisting of a transmitter circuit and a receiver circuit.

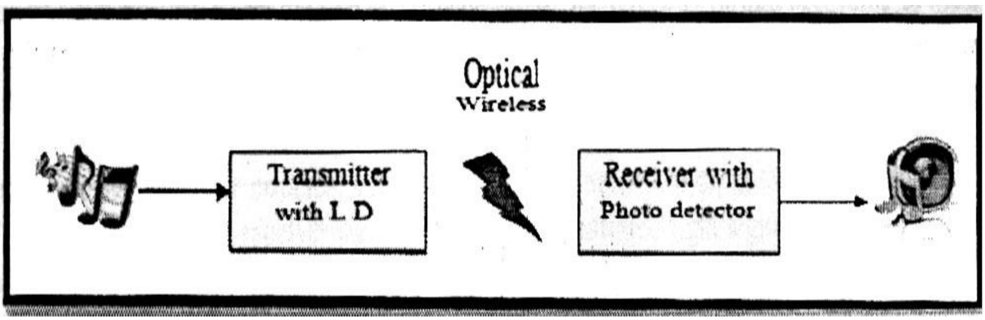


Figure1 : Basic Diagram of the Optical Wireless Audio System

System Operation

The system consists of a transmitter which is fed from the audio signal source and a receiver which picks up the modulated laser signal from transmitter.

There are two basic types of modulation that can be applied to this application, AM (amplitude modulation) and FM (frequency modulation). An AM system has the advantage of being extremely simple, but it has a major drawback in that any non-linearity in the system produces distortion on the audio output signal. In practice quite significant levels of distortion would almost certainly result, and it is better to use an FM system where non-linearity in the laser diode, laser diode driver, and photo detector do not affect the audio output quality. The block diagram for audio transmission is shown in Figure 2.

The receiver must convert the variation in frequency back into an audio signal using some form of frequency to voltage converter. The photo detector is connected in a potential divider circuit which is in turn connected across a voltage source. The varying light level is thus converted to varying resistance through the detector element, and to a varying voltage by the potential divider circuit. The equipment uses a simple FM set up and the block diagram for the audio receiving is shown in Figure 3.

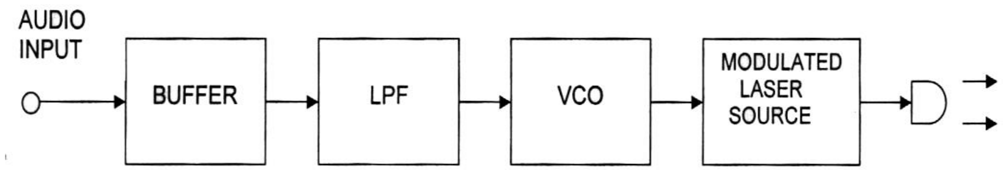


Figure 2 : Block Diagram for Audio Transmission System

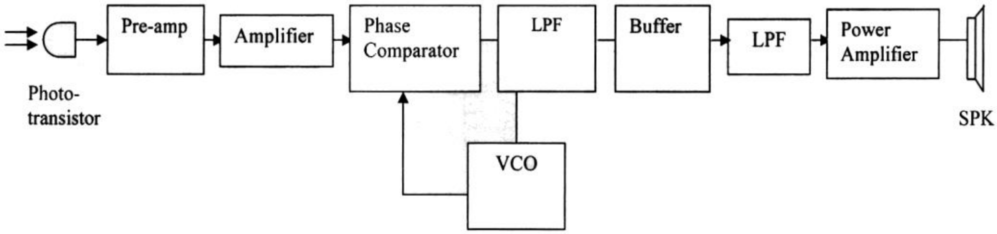


Figure 3 : Block Diagram for Audio Receiving System

Circuit Design

3.1 Transmitter Circuit

Figure 4 shows the circuit diagram of the transmitter circuit for audio signal. This circuit is slightly more simple of the two devices, and really consists of little more than a VCO (Voltage Controlled Oscillator). The output frequency of VCO is dependent on the control voltage, and this voltage is modulated by the audio input signal. An FM system is not distortion less though, to obtain a good quality audio output, the VCO and the frequency to voltage converter at the receiver must have good linearity.

The transmission circuit is more than just a VCO, and one of the additional stage is a buffer stage at the output which provides a reasonably high drive current to the laser diode. The circuit is designed around IC 3 which is a CMOS 4046 BE phase-locked loop, but in this circuit only the VCO section of the device is utilized. C_6, R_6 and VR 1 are the timing components, and VRI is adjusted to match the center frequency of the transmitter VCO to that of the PLL decoder in the receiver circuit.

The output of the VCO is fed to the anode of semiconductor laser diode via resister R_7 and coupling capacitor C_7. When the power is applied to the laser diode via resister R_8, the generated laser beam output is about 635 nm and current flow into the laser diode is about 50mA. ICI is the input buffer stage and it will give enough high input impedance. The low pass filter is based on IC 2 which also operates as a unity voltage gain buffer stage. The filter gives the system a band width of about 15 kHz. This is marginally less than the full audio range, but is sufficient to provide a very respectable audio quality (Comparable to FM radio).

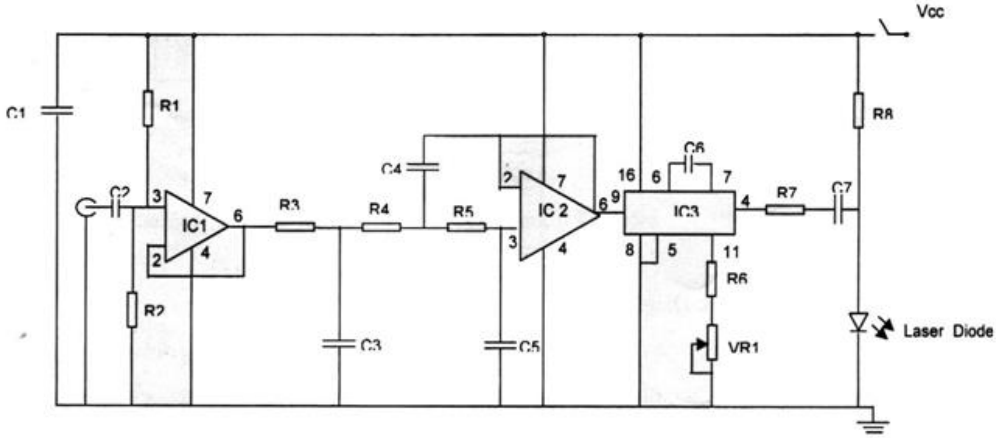


Figure 4: The Complete Circuit Diagram of the Transmitter Circuit for Audio Signal

3.2 Function of Phase-Locked Loop

A phase locked loop provides the frequency to voltage conversion. The phase comparator, low pass filter and VCO make up the phase locked loop. The relative phase and frequency of the input signal and the VCO are checked by the phase comparator, which provides a series of output pulses. These pulses are integrated by the low pass filter to produce a reasonably smooth control voltage for the VCO. If the VCO is at a lower frequency than the input signal or even if it is just slightly lagging the input signal in phase, the output from the low pass filter goes to a high voltage and boosts the operating frequency of the VCO. Similarly, if the VCO is at a higher frequency than the input frequency, or leading it in phase, the output of the low pass filter goes to a low voltage. This reduces the VCO's operating frequency.

There is a negative feedback action here which results in the VCO locking on to the same frequency as the input signal, and also keeping in phase with it. This assumes that the input frequency is within the locking range of the circuit.

3.3 Receiver Circuit

The circuit diagram of the receiver circuit for audio signal appears in Figure 5. A phototransistor is used as the light detector, and this provides good sensitivity at the high carrier frequency and we use laser light as the carrier frequency. TR 2 is a gain phototransistor, and the collector to emitter resistance of TR 2 is connected with R9 to form a potential divider across the supply lines. The pulses of light cause the collector to emitter resistance of TR 2 to fall slightly, and this generates small negative pulses at the collector of TR 2. The output from the detector circuit is quite low at typically only a few mV RMS or less. A two stage gain amplifier is used to boost and clip the signal to give virtually square wave output to drive the frequency to voltage converter circuit. TR 3 is connected as a high gain common emitter amplifier, and it produces the first stage of amplification. IC 4 is connected as an inverting amplifier with a voltage gain of 20 dB, and this provides the second stage of amplification. The clipped signal at the output of IC 4 is compatible with the input of IC 5, which is another 4046 BE CMOS phase-locked loop. In this case it is used as the phase-locked loop detector. The link across pin 3 and 4 connects the output of the VCO to the input of the phase detectors (only the one of which is used here). R_{19} and C_{12} form the low pass filter between the phase comparator's output and the control input of the VCO while C_{12} and R_{17} are the VCO's timing components. R_{18} is the load resistor for the built-in-source follower buffer stage of IC 5, so demodulated audio can be taken from pin 10 of IC5.

IC 6 is used as the basis of the low pass filter at the output of the unit, and this is essentially the same as the filter at the input of the transmitter. The output from IC 6 is fed to the input of IC 7, which is an audio power amplifier. This provides an excessive output signal for most headphones, and resister R_{24} is therefore used to attenuate the output signal. The circuit will handle signal voltage of up to about 1V RMS or so with distortion of under 1%. The current consumption of the audio receiving circuit is about 12mA.

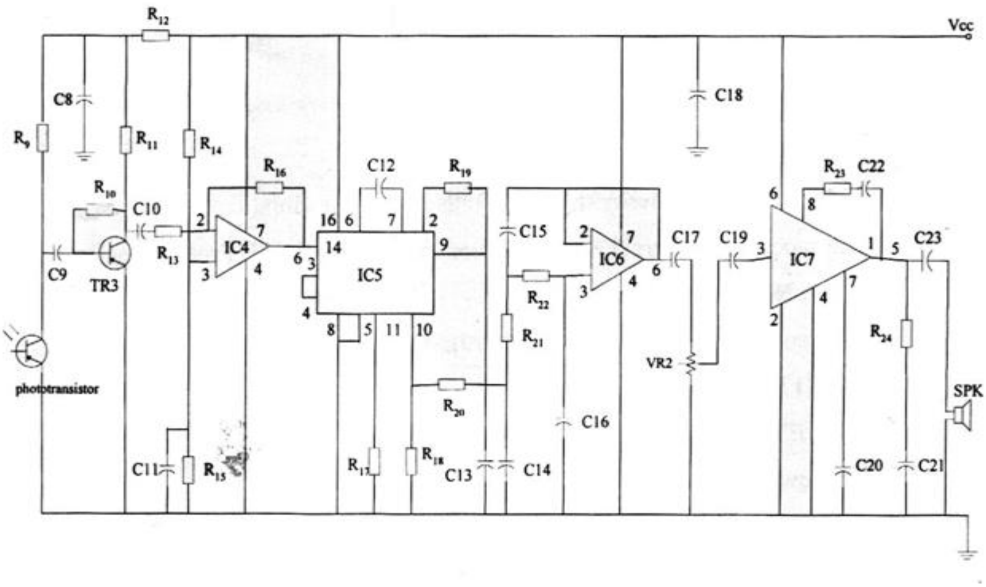
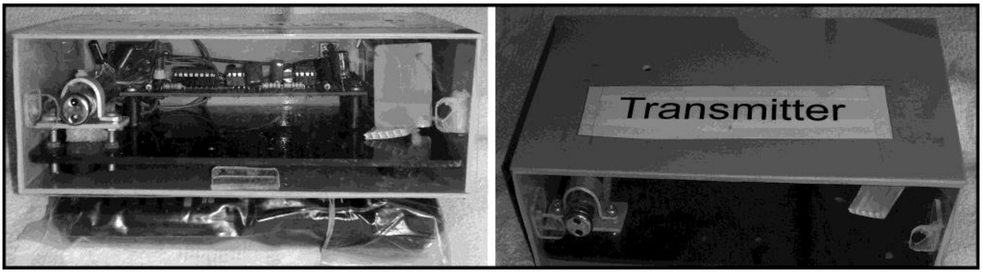


Figure 5: The Complete Circuit Diagram of the Receiver Circuit for Audio Signal

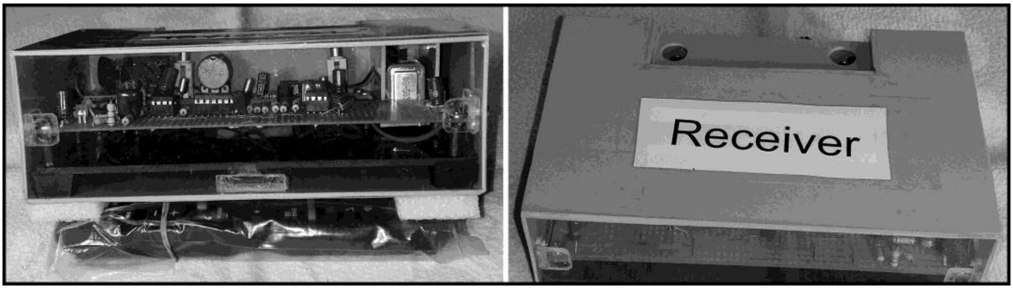
Result and Discussion

Figure 6 shows the complete prototype of optical wireless audio system. Both transmitter and receiver work by using battery (9V). Transmitter uses semiconductor laser as a data carrier. Transmitter uses frequency modulation to produce a series of audio signal encoding. Then, the receiver will receive the signal light, demodulate and enforce signals that can be sent by voice amplifier where the music can be heard. One can observed that the recent circuit setting can give a good or satisfactory results with a fairly high input level of around 250 mV to 1V RMS.

This project can operate up to 30m distance. If one can align the transmitted laser beam to reach the light sensor (phototransistor) of receiving circuit, so it can be used as a remote device for several purpose. The operating range is mainly depended on the laser output power.



(a) Transmitter Circuit



(b) Receiver Circuit

Figure 6 : The Constructed Prototype of Transmitter and Receiver Circuits

Conclusion

A method for transmitting and receiving of audio signal within a specified distance interval was presented. We recommend to improve the efficiency of optical wireless transmission by using laser diodes (LD) as the light source, because the LD can hit the laser over long distance with low noise. Therefore, this system is a good system and has high potential of commercialization that can be used in various applications such as wireless communication in the museum, airplane, intercom, TV sound system, closed circuit cameras and remote control devices.

If stereo operation is required, the most simple way of achieving this is to use a separate transmitter and receiver circuit for each channel. Furthermore, this project will proceed to transmit audio and video simultaneously with low noise in the future.

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