PROJECT REPORT

LASER AUDIO TRANSMISSION

Course No : EEE 310
Course Name : Communication System I Lab

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Introduction

Wireless audio transmission has become an integral part of modern communication systems. There are various techniques available to transmit audio wirelessly. Laser audio transmission is one of the basic transmission methods. By implementing this we get an in-depth understanding of laser transmission, including its working principles, advantages, disadvantages, and potential applications.

At first, we discussed the theoretical background of laser audio transmission, including the principles of modulation and demodulation of electromagnetic waves. The important concepts that we leaned through this project are the working principles of Class D amplifiers, which are commonly used in wireless audio transmission systems, and uses of pulse-width modulation, amplitude modulation, filtering, and amplification etc.

We also discussed some potential applications of laser audio transmission, including its use in audio communication systems for hazardous environments, security, underwater communication systems, and wireless audio transmission in home theaters and music systems.

Overall, this project aims to provide a comprehensive overview of laser audio transmission and its potential applications.

Objective

- To transmit audio signal wirelessly through laser ray in short distance.
- To get a practical understanding of amplitude modulation.
- To understand how wireless transmission works.

Theoretical Background

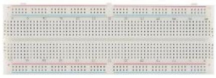
Laser audio transmission is a technique for transmitting audio signals using modulated laser light. The process involves modulating the amplitude of a laser beam with the audio signal to produce a modulated light signal. This modulated light signal can then be transmitted through the air or other transparent medium, such as glass or plastic, to a receiver where it is detected and demodulated to extract the original audio signal.

The theoretical background of laser audio transmission is based on the principles of modulation and demodulation of electromagnetic waves. In this case, the electromagnetic waves are in the form of laser light, which is a coherent and monochromatic form of light. The intensity of the laser light is multiplied with input audio signal in order to generate modulated signal, which will carry the message signal in envelop of the high frequency carrier or laser signal.

At the receiver, the modulated light signal is detected by photodetector in solar panel, which converts the optical signal back into an electrical signal. The electrical signal is then demodulated to extract the original audio signal. The demodulation process is typically achieved by envelop detection using an amplifier that can reconstruct the audio signal and send it to a loudspeaker so that we can hear the signal.

Components Used

Parts	Specification	Picture
Solar Panel	▪ Polycrystalline silicon ▪ Max work voltage:5V ▪ Max work current: 200ma ▪ Dimension: 90mm×90mmx3mm	
Laser Diode	▪ Output Power: Min 2.5mW, Typical 3.0mW, Max 5.0mW ▪ Working current: Min 10mA, Typical 20mA, Max 25mA ▪ Working voltage: Min 2.3VDC, Typical 4.5VDC, Max 8.0VDC ▪ Wavelength: 650nm	
Speaker	▪ 8 Ω ▪ Maximum Power: 2 W ▪ Dimension: 1.5 x 0.79 x 0.22 inch	
PAM8403-GF1002 Stereo Audio Amplifier Module	▪ Type: Class-D ▪ Model: PAM8403-GF1002 ▪ Dimensions: 29.5 x 20.2 x 15mm ▪ Operating Voltage: 2.5 V to 5.5 V ▪ Output Channel: 2x ▪ Output Power: 3 W + 3 W (at 4 Ω) ▪ High Amplification Efficiency: 85%	
Potentiometer	▪ 10k Potentiometer	

LM386N	▪ Low Voltage Audio Power Amplifier ▪ Wide Supply Voltage Range: 4 V–12 V or 5 V–18 V ▪ Low Quiescent Current Drain: 4 mA ▪ Voltage Gains from 20 to 200	
Audio Jack	▪ 3 pole jacks. ▪ Audio Plug size: 3.5 mm	
Breadboard	▪ 830 Point ▪ Used to build the audio amplifier circuit	
Jumper Wire	▪ Male To Male Jumper Wire	
Power Adapter	▪ Input: 100V - 240V AC, 50Hz/60Hz ▪ Output: 5V 3A	

Circuit Diagram

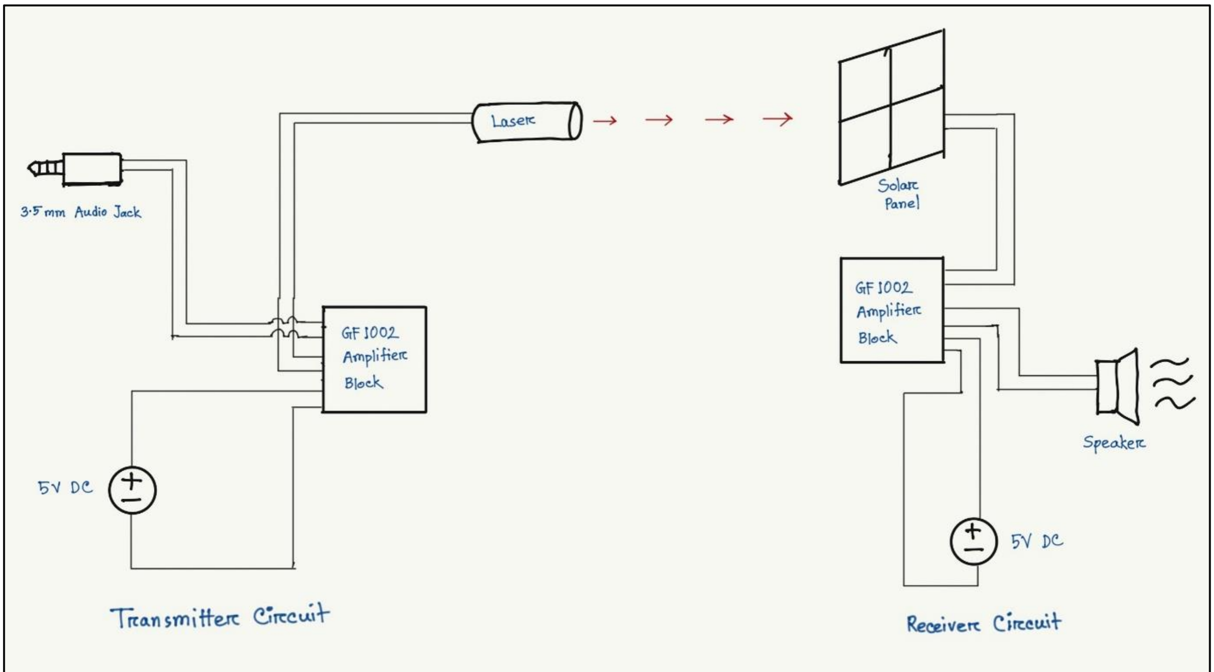


Figure: Circuit diagram of the designed circuit

Working Principle

Laser transmission is a wireless transmission system. First, the analog audio signal is taken as input through a 3.5 mm audio jack. Then, the signal is amplified using a GA1002 amplifier. The amplified signal is then sent to a laser diode, which produces an intensity-varying laser beam. The intensity of the laser beam varies with the amplitude of the audio signal, so amplitude modulation is used here. We know that an amplitude-modulated signal can be detected non-coherently by envelope detection. The laser light falls on a solar panel, which produces an alternating voltage. The generated voltage varies with the message signal amplitude, so if we amplify this, we can reconstruct the message audio signal. The amplifier output is then sent to a speaker, and we can hear the sound.

The main amplifier block used in both modulator and demodulator is PAM8403-GF1002. The detail of this block is given below:

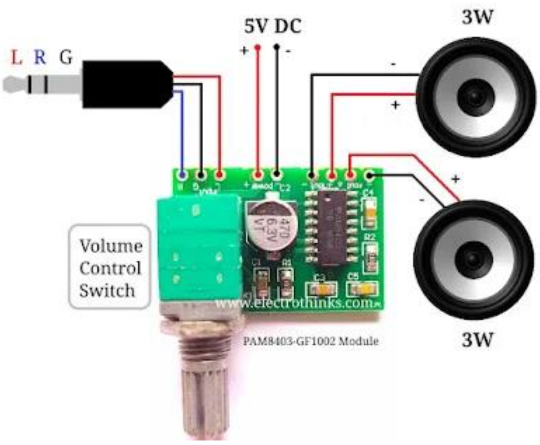


Figure: Connection diagram of a PAM8403-GF1002 module

The circuit diagram of this module is given below:

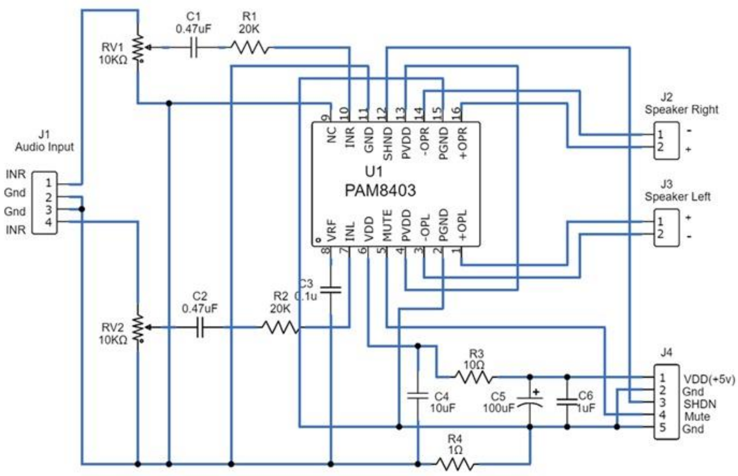


Figure: Circuit diagram of a PAM8403-GF1002 module

The PAM8403-GF1002 module mainly consists of the IC PAM8403. It is a 3W, class-D audio amplifier. It offers low THD+N (Total Harmonic Distortion Plus Noise), allowing it to achieve high-quality sound reproduction. It is based on filterless architecture which allows the device to drive the speaker directly.

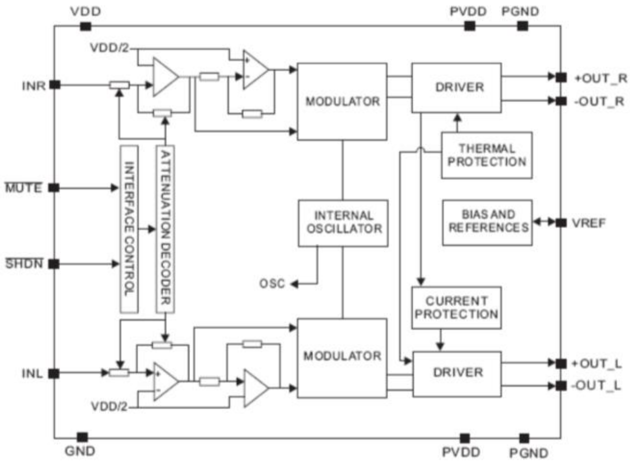


Figure: Functional Block diagram of PAM8403

Class-D amplifiers work by generating a train of rectangular pulses of fixed amplitude but varying width and separation, representing the amplitude variations of the analog audio input signal. This class of amplifier operates by switching the output stage transistors between fully ON and fully OFF states. The output stage transistors are used as switches to generate a high-frequency pulse-width modulated (PWM) signal that is filtered to produce the final audio output signal. The working principles of Class D amplifier can be explained as follows:

Pulse-width modulation: The input audio signal is first converted into a PWM signal with a fixed frequency using voltage comparator circuit. The PWM signal has a fixed amplitude and frequency but the duty cycle, or the proportion of time the signal is ON versus OFF, varies with the input audio signal. The higher the input signal, the longer the ON time of the PWM signal.

Output stage: The PWM signal is then applied to the output stage, which consists of a pair of transistors that act as switches. These transistors are either fully ON or fully OFF, and the duty cycle of the PWM signal determines the percentage of time each transistor is ON. When one transistor is ON, the other is OFF, and vice versa.

Filter: The output of the switching stage is a high-frequency PWM signal that needs to be filtered to remove the high-frequency components and recover the original audio waveform. A low-pass filter is used for this purpose, which removes the high-frequency components and passes only the low-frequency audio signal to the load.

The advantage of Class D amplifier is its high efficiency, which results in less power dissipation and less heat generation compared to other types of amplifiers. As the transistors operate only in on-off regions, its efficiency is better than other types of amplifiers (Theoretically up to 100%). However, Class D amplifier also has some disadvantages such as higher distortion at high frequencies, limited bandwidth and susceptibility to electromagnetic interference.

We used this amplifier block in both transmitter and receiver circuit. But, in receiver circuit we also used LM386N based post amplifier to increase the sound level at output. If we use a second amplifier, the output signal becomes loud, but more distorted. So, we omitted the post amplifier in the final design.

Transmitter Circuit

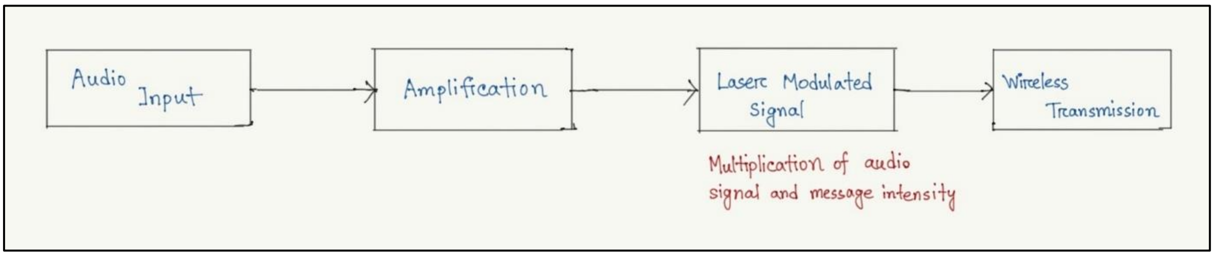


Figure: Transmitter Circuit Block Diagram

Receiver Circuit

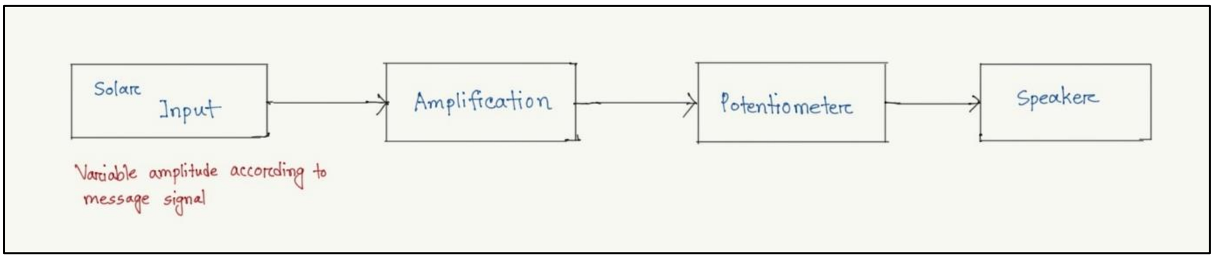


Figure: Receiver Circuit Block Diagram

Amplifier Circuit using LM386 :

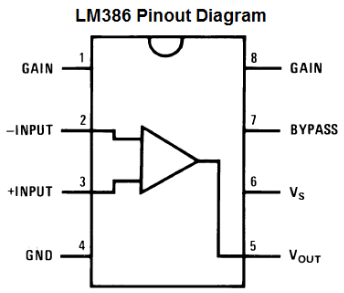


Figure: LM386 Pinout Diagram

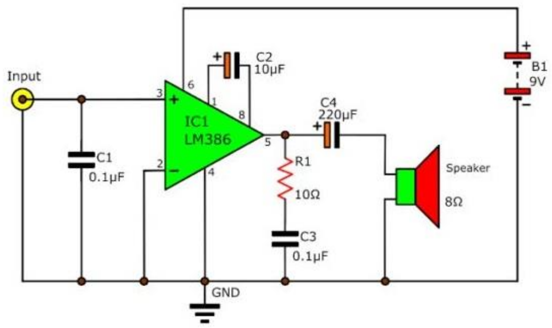


Figure: LM386 Amplifier Circuit

The LM386 is a power amplifier designed for use in low voltage applications. It is a class AB power amplifier. If we use this circuit in our output stage, the signal gets amplified, and noise also becomes high. One possible reason could be the device gets saturated and the higher amplitude gets cropped. Adding more amplifiers adds analog interference. At the final design, we omitted this part because of better noise performance.

Problem Faced

- We first used LM386 to amplify the audio input signal in the transmitter. But unfortunately, this was not creating satisfactory output. So, we used prebuilt preamplifier and post amplifier.
- We used a 0.5W audio speaker. In this attempt the sound was heard but there was a bit noise mixed with the output. One approach to solve this was to increase the power but that will need external cooling system to counter the extra heat produced.
- We used a small solar panel whereas the performance could have been improved if we used bigger solar panel.
- We did not get satisfactory result due to smaller laser diode.

Using the LM386 circuit, noise, smaller laser diode, smaller solar panel etc.

Advantages

1. Safety: The laser light used in this project can not be accessed without being directly in front of it. Thus it can not be hacked from far away.

2. Speed: Laser light travels at the speed of light. So, data transmission is very fast in this case.

3. Easy to use: The project was very easy to make. Thus data transmission in this way would be very easy.

4. Cheap: Main equipment of laser audio transmission is a laser diode which not much high in price. It only requires two amplifiers. Those are very cheap too. So the entire setup would be cheap.

Limitations

- Laser communication system needs line of sight. This system cannot work if there is any obstructions between the transmitter and receiver.
- Noise performance of laser communication wasn't satisfactory.
- We only used analog modulation for the audio transmission system which has lower noise performance.

High noise, not enough loud, only analog modulation

Future Developments

We can increase the overall performance of our project by using digital modulation techniques. If we converted the audio signal to digital signal and transmitted it instead, the receiver could have detected the message more accurately. By incorporating digital modulation techniques like PCM, PDM we can increase the overall noise performance of the system.

Can be add digital modulation techniques, like PCM, PDM etc.

Applications

1. Signal transmission: Firstly, secured audio transmission is possible by means of laser light.

2. Security: If continuous receiving of signal is hampered by any moving object it can be used to monitor unwanted activity in the region.

3. Vehicle speed measurement: If a vehicle passes through the laser light its speed can be measure by using the following formula,

$$v = s/t$$

where, v = velocity of the vehicle
s = car length
t = time length when the solar panel did not receive any signal

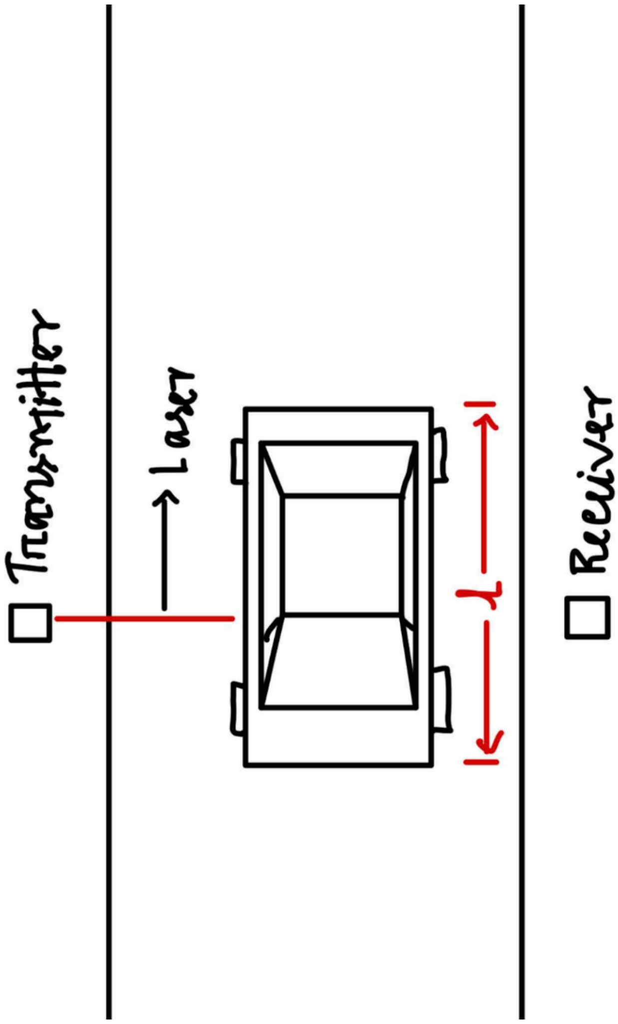


Fig: Measurement of speed of vehicle using laser audio transmission

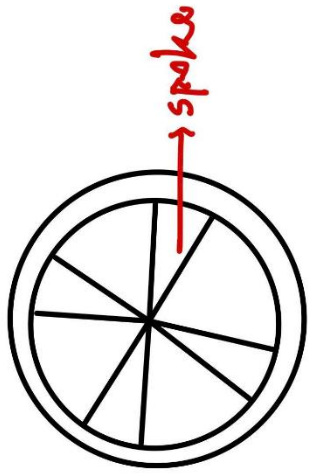
Another Method for measuring speed: We have to fit a laser transmitter and receiver in both sides of a car wheel rim. If in T seconds the laser light gets cut by the rotating rim spokes, the velocity can be calculated by the following formula,

$$v = r\,w$$

where $w = (n/s)/T$

n = number of times the receiver doesnt receive any signal

s = number of spokes



Conclusion

When electrons within a crystal are simulated by the photons in a flash lamp, light gets amplified, photons bounce off the mirrored ends and some photons escape in the form of a laser beam. This laser beam can be used in various multidisciplinary fields. One of them is optical communication. In communication systems, laser diodes have brought fast, secure, reliable, and cheap data transmission. Though it has tradeoffs like the laser diode requiring high energy. Overall, it is an efficient transmission method. Various problems were faced while completing this project. As sound signal is of high frequency and has many frequency bands, not up to the mark connections in a bread board introduces a lot of noise. Thus, prebuilt amplifiers were used. A big chunk of the energy emitted by the laser was getting wasted in the environment. This could have been avoided by covering the laser path with a shed. As a lot of high frequency noise was introduced in the system, a low pass filter could have been used to remove noise from the system. In future, all the troubles still being faced can be solved in the above-mentioned ways and a fine-tuned version of this project can be presented.