DESIGN AND CONSTRUCTION OF AN INFRARED WIRELESS HEADPHONE

BY

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Dedication

This project is dedicated to the God of His Dwelling Place, My General (Mr. Bode Badaki), The Prayering units and the entire members of the Yisa's Family.

Declaration

I, Yisa Jonathan Ndagi, declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna

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Abstract

There are various means in our world today by which audio output could be heard. This project details the design and operation of a transmitter and receiver for a wireless infrared headphone system. This is channeled towards achieving the objective of enjoying sounds from audio output devices with minimal disturbance, enjoying high level of privacy and low interference from other signal. All aspects of the design are discussed, these includes;

- Theory of operation
- circuit design
- component selection
- Final enclosure design and schematic picture.

Acknowledgement

I choose to acknowledge the All Knowing, Sufficient and my Source Jehehovah Suddenly who has made this a reality. I say thank you. My sincere gratitude my respected supervisor, Associate prof. Y.A Adediran for his awesome advice and guidance during ECE 527 lectures and beyond. Also my father and H.O.D Engr. M.D Abdullahi thank you sir.

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Chapter one

Introduction

1.1 General introduction:

As next generation electronic information system evolve, it is critical that all people have access to the information available via these systems. Infrared technology, a form of wireless communication which is increasingly present in mainstream application, holds great potential for enabling people with a variety of disabilities to access a growing list of information resources. This already is commonly used in remote control of environmental control system, telecommunication service and personal computer system.

Wireless communication, as the term applies, allows information to be exchanged between two devices without the use of a wire or cable. A wireless keyboard sends information to the computer without the use of a keyboard cable; a cellular telephone sends information to another telephone without the use of a telephone cable. Changing television channels, opening and closing of garage doors, and transferring a file from one computer to another can all be accomplished using wireless technology. In all such cases, information is being transmitted and received using electromagnetic energy, also referred to as electromagnetic radiation.

The invention of wireless (Radio) system of communication has, in a broader sense, led to the reduction of the world to a global village. So if anything is wonderful and its inventor worth thanking, it should be wireless communication invented by Italian scientist. Guglielmo Marconi, the father of wireless communication. (1890). [1, 2]

1.2 Aim and objectives

The main aim of this project is to design and construct an infrared wireless headphone with the following objectives in mind:

- To demonstrate audio transmission using infrared (IR) technology.
- To enjoy sound from audio output devices with minimal disturbance.
- To enjoy high level of privacy and low interference from other signal.

This is targeted towards indoor use, in as much as it can be used for outdoor purposes, with restriction to reception distance. (10-20metres).

1.3 Methodology

The circuit description of Infrared Wireless Headphone can be divided into two (2) parts: The Infrared (IR) Transmitter and Receiver.

The Transmitter:

The IR transmitter employs a simple digital modulation scheme (pulse position modulation) in which a high frequency (40 kHz) carrier is modified by the sinusoidal audio waveform. The 40kHz signal is generated by a free-running astable oscillator and its pulse position is varied in consonance with audio voltage applied to modulation input. The oscillator drives a high power IR emitter LED at 40 kHz to propagate the pulsed audio information through space.

The Receiver:

The receiver module consists of two (2) main circuits;

1. A small signal pre-amplifier stage to raise the micro-volt signal generated by an excited IR photodiode,
2. A567-based PLL centered around 40 kHz that recovers the modulating signal from the PWM transmitter input. The small signal amplifier provides again high enough to amplify the detected IR radiation, raising it above the noise level; created by ambient natural light. This output feeds the PLL where it is compared with a 40 kHz reference oscillator frequency. The PLL tries to 'lock' on to the modulated input waveform applied to its phase comparator, but due to the ΔF deviation occasioned by the modulated, analog voltage which is exactly the ΔF components is produced at the output of the VCO. This analog voltage is the original audio modulating signal. This signal is amplified in a low-power amplifier to drive the pan of the headphone.

1.4 Scope of Study

The scope of this project covers and entails the following areas;

1. The aims and objective of the project.
2. Circuit description of both Transmitter and Receiver
3. Theoretical background of The Infrared and The Headphone.
4. Other types of Headphone technology.
5. Merits and Demerits of the project.
6. Design and Implementation of the project.
7. Test, Result, Problem encountered and Remedies.

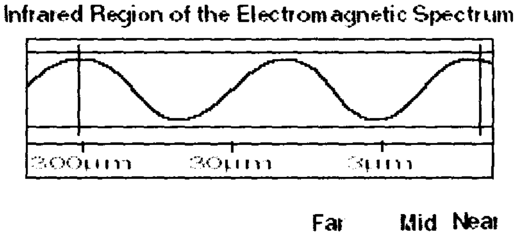
CHAPTER TWO

Literature Review

2.1 Theoretical background of The Infrared:

Infrared (IR) radiation is electromagnetic radiation of a wavelength longer than that of visible light, but shorter than that of radio waves. The name means "below red" (from the Latin infra, "below"), red being the color of visible light with the longest wavelength. Infrared radiation has wavelengths between about 750 nm and 1 mm, spanning five magnitudes. Infrared light lies between the visible and microwave portions of the electromagnetic spectrum. Infrared light has a range of wavelengths, just like visible light has wavelengths that range from red light to violet. "Near infrared" light is closest in wavelength to visible light and "far infrared" is closer to the microwave region of the electromagnetic spectrum. The longer, far infrared wavelengths are about the size of a pin head and the shorter, near infrared ones are the size of cells, or are microscopic. [3]

Far infrared waves are thermal. In other words, we experience this type of infrared radiation every day in the form of heat! The heat that we feel from sunlight, a fire, a radiator or a warm sidewalk is infrared. Infrared light is even used to heat food sometimes - special lamps that emit thermal infrared waves are often used in fast food restaurants and can be used in medical appliances utilized in hospitals such as those used to flex the patients' muscle in the physiotherapy unit. Shorter, near infrared waves are not hot at all - in fact you cannot even feel them. They are used to operate the television set, CD players and even computers once they are properly interfaced. Since the primary source of infrared radiation is heat or thermal radiation, any object which has a temperature radiates in the infrared. Even objects that we think of as being very cold, such as an ice cube, emit infrared. When an object is not quite hot enough to radiate visible light, it will emit most of its energy in the infrared. For example, hot charcoal may not give off light but it does emit infrared radiation which we feel as heat. The warmer the object, the more infrared radiation it emits. Humans, at normal body temperature, radiate most strongly in the infrared at a wavelength of about 10 microns. (A micron is the term commonly used in astronomy for a micrometer or one millionth of a meter.) Many things besides people and animals emit infrared light - the Earth, the Sun, and far away things like stars and galaxies do also. Infrared light, particularly near infrared light can be reflected. [4].



2.2 The Electromagnetic Spectrum:

In 1800.Sir Williams Herschel discover infrared radiation. Then he referred to it as “invisible ray”, “radiant heat”, or “dark heat”. He found that the heating effect increased as he moved a thermometer toward the red from the blue end of the Electromagnetic spectrum. [3]

Electromagnetic waves are those that do not require a material medium for their propagation. They arise from the Electric (E) and Magnetic (M) fields. The combination of the Electric field and Magnetic field wave is called an Electromagnetic (E-M) wave. E-M waves include Gamma rays, X-rays, ultraviolet rays, visible rays, infrared rays, Micro-waves and Radio waves. The whole range of the Electromagnetic waves is known as the Electromagnetic spectrum.

The Electromagnetic spectrum classifies E-m energy according to the frequency or wave length. As shown fig 1.1, the Electromagnetic spectrum ranges from energy wave having extremely low frequency (ELF) to energy waves having much higher frequency, such as X-rays.

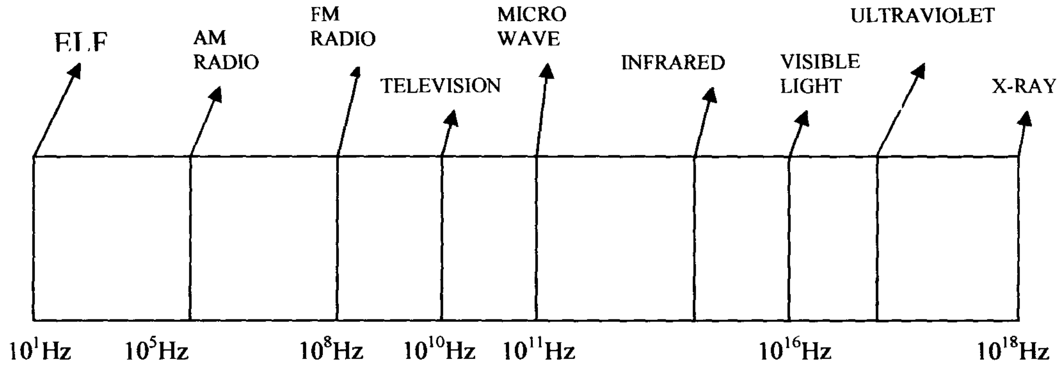


Fig.2.1 The Electromagnetic Spectrum

The frequencies range from 10 hertz (circle per second) to 10^{18} hertz. Some familiar allocated bands are labeled on the spectrum. Approximate locations are as follows.

10 Hertz: Extremely Low Frequency or ELF

10^5 Hz: AM radio

10^8 Hz: FM radio

10^{10} Hz: Television

10^{11} Hz: Microwave

10^{16} Hz: Infrared (frequency range is below the visible light spectrum)

10^{16} Hz: Visible light

10^{16} Hz: Ultraviolet (frequency range is above the visible light spectrum)

10^{16} Hz: X-rays

A typical E-M wave is depicted in figure 2.2 where the vertical axis represents the amplitude or the strength of the wave and the horizontal axis represent the time.

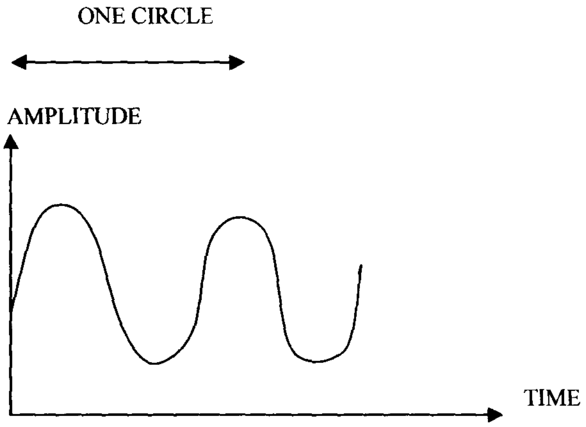


Fig 2.2 The Electromagnetic Wave

In relation to E-M energy, frequency which is expressed in hertz is number of circles a wave completes in one second and is directly related to the amount of information that can be transmitted on the wave. [3]

2.3 Theoretical Background of the Headphone:

Headphones (also known as earphones, ear buds, stereo phones, or headsets) are a pair of tiny loudspeakers, or less commonly a single speaker, with a way of holding them close to a user's ears and a means of connecting them to a stereophonic or monophonic, or binaural audio-frequency signal source such as an audio amplifier, radio, etc. In the context of telecommunication, the term headset is used to describe a combination of headphone and microphone used for two-way communication, for example with a telephone.

Since the introduction of the Walkman and later MP3 players headphones have become a very popular way of listening to stereo, especially among the younger generation. This is despite the fact that headphones are not really suitable for stereo, which is a system designed specifically for loudspeaker reproduction and relying primarily on loudness differences between channels for special effect.

The telephone earpiece in the figure below was common around the turn of the 20th century. Sensitive headphones were the only way to listen to audio signals before amplifiers were developed. Very sensitive headphones such as this were commonly used for early radio work. (1919)

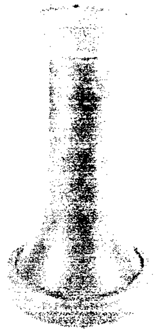


Fig2.3 Telephone earpiece

Headphones can be used both with fixed equipment such as CD or DVD players, home theater, personal computers and with portable devices (e.g. digital audio player/mp3 player, mobile phone, etc.). Some cordless headphones do not need to be connected via a wire, receiving a radio or infrared signal encoded using a radio or infrared transmission link, like FM, Bluetooth or Wi-Fi. These are actually made of powered receiver systems of which the headphone is only a component.

Headphones are widely used for listening to audio sources for recreation. [5]

2.4 Other Types of the Headphone Technology:

Headphones are categorized first by their type of transducer (earspeaker) technology and then by the style of wear. Selecting headphones is an individual process. One size does not fit all. The best headphone choice may depend on the shape and size of one's ears, when and where they will be used, and of course sound quality.

- **Dynamic** headphones are the most common and are available in every form from lightweight foldable to heavy-duty studio monitors. Also called **moving coil** types, they have transducers that are basically miniature loudspeakers, with diaphragms connected to a central voice coil that moves within a magnetic field generated by permanent magnets. This type can be very efficient and is easily powered from a standard headphone jack on a receiver or other component. Dynamic headphones are also very dependable and are the most common type of headphone in recording studios and the field than other types.[6,7]

- **Electrostatic** headphones have thin and lightweight diaphragms that vibrate inside in an electrostatic field. They can reproduce music with great detail and low distortion, because the response time is very fast. A separate high-voltage DC power supply ("energizer") polarizes the diaphragm, which is suspended between two metal plates called stators. The polarizing (or bias) voltage supply is most often AC-based, but there are battery-powered energizers.
- **Electret** headphones (also called **fixed electrostatic**) have permanently polarized diaphragms (or are backed by a polarizing material that emits an electrostatic field), so a biasing power supply is not necessary. However, they must still be driven with the same high-voltage audio signals from a high-voltage amplifier or a step-up transformer connected to a power amplifier. Electret headphones have many of the same sonic characteristics of electrostatics (fast, detailed sound), but the electret elements may be prone to depolarization as they age, at which point they must be replaced.
- **Wireless** and **cordless** headphones operate without a cord. A transmitter (base) plugs into the sound source (the stereo), and the headphones (usually dynamic-type) have a built-in receiver and amplifier. "Wireless" sometimes refers to infrared-based systems (infrared is used in television remote controls) and "cordless" to radio frequency (RF) transmission systems. Infrared systems have a range of 10M or so from the base unit and must be in "line of sight" of the base for clear reception. [6]

2.5 Advantages and Disadvantages IR Wireless Headphone:

Advantages

- Longer range since pulsed IR emission is used.
- Lesser susceptibility to interference because of the modulation employed.
- Higher linearity is obtainable unlike when amplitude modulation is employed.
- Lower circuitry cost in IR as compared to RF.

Disadvantages

- Line of sight: Transmitters and Receivers may be almost directly aligned in IR while in RF, no line of sight is required.
- IR transmission is blocked by common materials like people, walls etc while RF transmission can penetrate most solids and pass through walls
- IR transmission has a shorter range and it is more sensitive to environmental conditions.
- It is subject to background hiss

Chapter Three

Design and Implementation

This section provides details as to the design of the transmitter and receiver portions of the headphones. Several design decisions are common to both the transmitter and receiver. First, both parts operate off the same supply voltage, namely 9V. The primary reason for this is the voltage sensitivity of the CD2025 — the carrier and lock frequencies are dependent on the supply voltage. It is highly desirable to synchronize the transmitter and receiver carrier and lock frequencies for best operation. This is achieved by using identical component values and supply voltages on both the transmitter and receiver PLLs.

Admittedly; however, the supply voltage choice was somewhat arbitrary. In order to operate off a 9V battery (a desirable, portable, high voltage power source), the supply voltage could be at most 7V, due to the 2V drop intrinsic to the LM7805 voltage regulator. Note that a voltage regulator was used so that the supply voltage would not drift with battery aging. To allow for some battery aging, a voltage lower than 7V was preferable. Furthermore, the C2025 datasheet component selection figures were conveniently tailored for 5, 10, and 15V supplies. Hence, a 9V supply was used.

Using a single 9V supply presented some difficulties for the operational amplifiers (opamps). Virtual grounds were created around 2.5V using voltage dividers in these cases to mitigate railing problems.

Second, 0.1μF decoupling capacitors have been added across all integrated circuit power and ground terminals to reduce switching noise. An exception is the 10μF decoupling capacitor near the transmitter diodes, extraordinarily large due to the relatively large current drawn by the diodes. [8]

3.1 PWM Infrared Transmitter:

The transmitter is input a single channel audio signal. This signal is scaled and used to modulate a carrier frequency, encoding the audio signal. The modulated carrier then drives the flicker of infrared LEDs. The design of is detailed below.

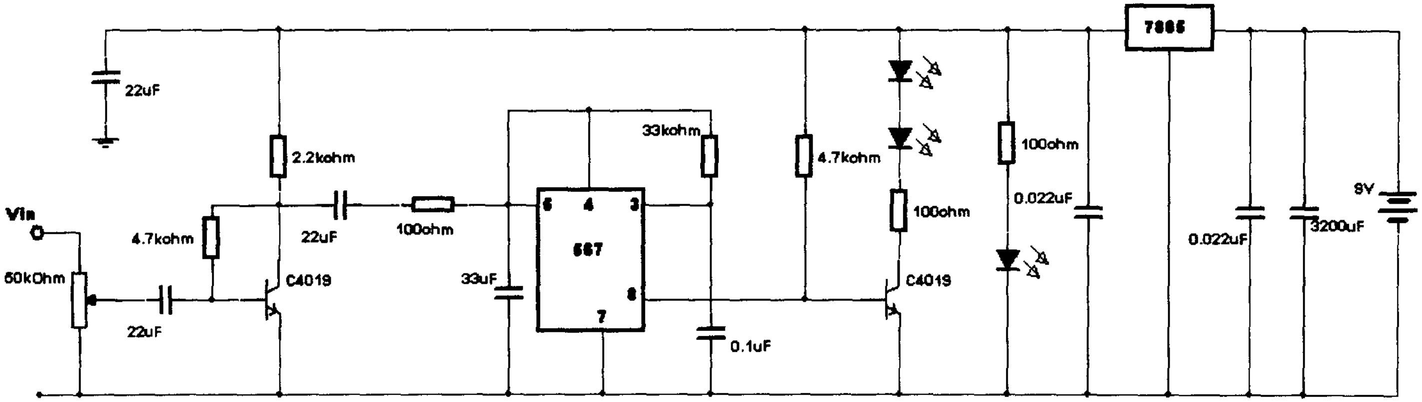


Fig.3.1 Circuit Diagram of the PWM Infrared Transmitter

Input Amplifier:

The purpose of the input amplifier for incoming audio is two-fold. First, the amplifier functions as a buffer with high input impedance and low output impedance so as to not load the source. Second, the amplifier provides a non-inverting gain of 3. The industry standard RCA 1-Vpp source audio signal does not adequately cover the VCO control voltage range. Scaling the source signal up three fold provides for greater FM resolution of the source audio signal. The Burr Brown OPA134 operation amplifier was chosen due to its low noise characteristics and suitability for audio applications. Resistive Johnson noise dominates for input loads greater than 2k. Therefore the DC bias loads, comprised of R1, R2 and R3, R4, and the negative feedback load, comprised of R5 and R6, were kept below this threshold. The gain of this amplifier can be expressed as

$$G = 1 + \frac{R6}{R5} = 1 + \frac{2k\Omega}{1k\Omega} = 3$$

The C2 capacitor serves as a DC block to prevent the virtual ground DC bias from affecting the signal source. The C2 and R1 || R2 also create a high pass filter on the audio signal with a -3dB corner frequency of

$$f_{-3dB} = \frac{1}{2\pi(R1||R2)C2} = 10Hz$$

Sufficient to pass bass components of the source signal.

VCO:

Critical for low distortion of the input audio signal in FM modulation is a highly linear voltage controlled oscillator (VCO). For the transmitter the CD2025BCN VCO was used, with a minimum linearity of 1%. The linearity of this VCO is of course only guaranteed throughout some range — as the control voltage approaches the rails, the frequency can be expected to change non-linearly.

Of secondary, though lesser concern, is the output frequency range of the VCO. For best resolution, a high Δ (input voltage) / Δ (output frequency) ratio is desired. However, linearity likely decreases as this ratio increases. Furthermore, the bandwidth of the output frequency likely also increases, since transitions over a greater frequency range in constant time result in greater Fourier coefficient for higher frequency terms.

Given the linearity requirement, yet incorporating the trade-offs, the VCO output frequency range was chosen to be 25% of the carrier frequency, slightly lower than the 30% deviation lock range of the phase-locked loop (PLL) section of the CD4046, to allow tolerance for error.

Therefore, with a carrier frequency f0 = 200kHz, fmin = 175kHz and fmax = 225kHz. Based on the CD4046 datasheet, suitable component values to design such a VCO resulted in C1 = 100pF, R8 = 150k, and R7 = 71.6k. Note that R7 is a linear combination of 68k and 3.6k standard value resistors. Although precise component values provide for a system more closely matched to the specification, the tolerances can

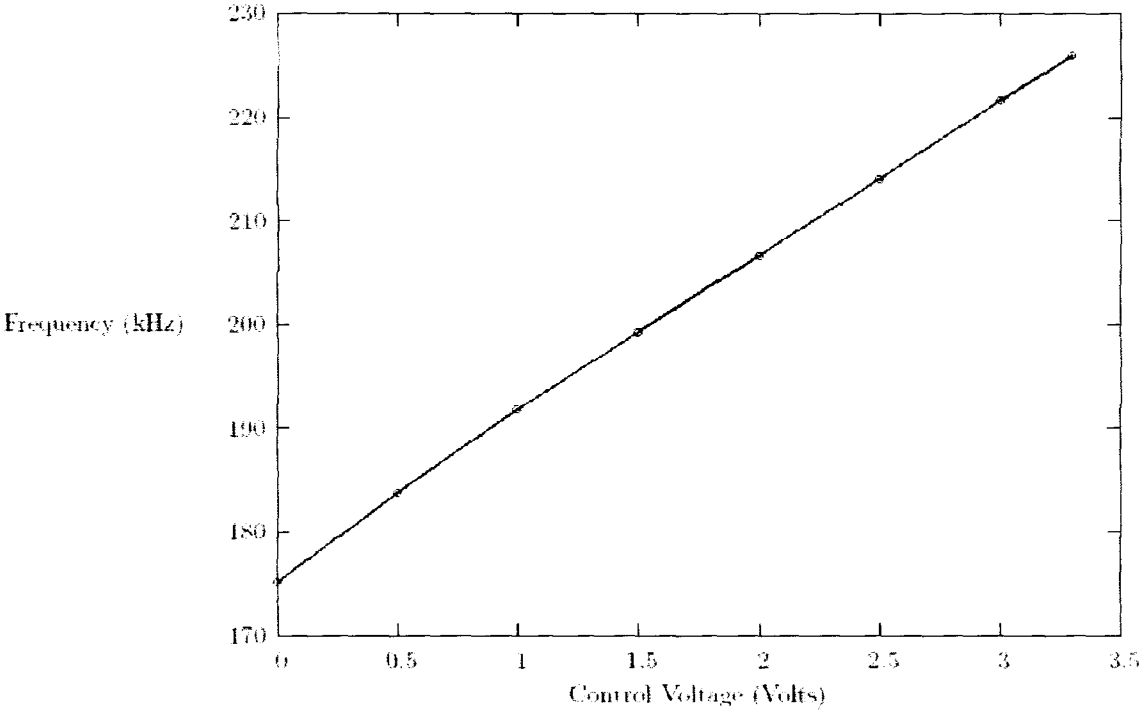


Fig 3.1 Measured Linearity of the Transmitter VCO (Vcc = 9V)

be expected to be randomly distributed over the four components. Furthermore, any deviation will not significantly shift the VCO frequency such that the receiver PLL cannot perform. Therefore, the standard tolerances of 20% for the capacitor and 5% for the resistors are suitable. The measured VCO linearity is provided in Figure 4. The measurements were taken with a supply voltage of 9V. However, for a control voltage of more than 3.3V, the output railed against the positive rail and became immeasurable. Note that the linearity is good in the 180 to 220kHz region, the modulation range the transmitter uses. One interesting aspect of the design is that VCO produces a square wave. This has several detrimental effects. First, the required minimum carrier frequency needs to be higher. The chosen carrier frequency for this project is 200kHz, an order of magnitude greater than the maximum audio component. Second, Gibbs oscillations are more likely to induce noise into the signal path. However, nearly all PLLs have VCOs that exhibit excellent linearity. The alternative, a sine wave VCO from discrete components, would likely induct more noise. [10]

Driver Amplifier:

The purpose of the driver amplifier, as the name implies, is to drive the infrared LEDs with the appropriate amount of current. The amplifier consists of two transistors, Q1 and Q2. Q2 is a LM358 bipolar PNP power transistor that sources current to the LEDs. Q1 is a LM358 bipolar NPN switching transistor that serves as a buffer for the VCO output. The transmitter uses two Siemens LD271 LEDs transmitting in the infrared spectrum at λ = 950nm.

These LEDs were chosen primarily due to their on-hand availability, but the 1μs switching time, low 40pF capacitance, and respectable 30 degree field of view were also taken into account.

Efficiency:

In the forward conductance region, each LED exhibited a measured voltage drop of Vd = 1.3V. Voltage not dropped across the LEDs drops across Q2. Furthermore, the intensity of the light emitted by the LEDs is directly proportion to the current through the LEDs. Assuming higher LED intensity gives the transmitted signal more range, the highest allowable LED drive current is desired, 130mA in the case of the LD271. However, this current also passes through Q2, causing power dissipation. The efficiency η of the transmitter can therefore be characterized as the power dissipated by the LEDs per total power dissipated:

$$\eta = \frac{P_{LEDs}}{P_{Q2} + P_{LEDs}} = \frac{N_{LEDs} I_{drive} V_d}{I_{drive} V_{cc}} = \frac{N_{LEDs} V_d}{V_{cc}} = \frac{N_{LEDs}(1.3V)}{5V} = (0.26)(N_{LEDs}) \leq 1$$

Accordingly, the most efficient transmitter design would utilize three LEDs, with η = 0.78. However, with more LEDs, the load capacitance increases, causing signal attenuation and distortion of the VCO square wave. At the bench, two LEDs produced the best results, yielding η= 0.52 and dissipating 310mW of heat in Q2. [10]

Current Sourcing:

To provide the LEDs with 130mA of drive current, and assuming an hfe of 110 (mean datasheet value for IC = 150mA, VCE = 2V), the base current required is 1.2mA. R10 sets this base current:

$$I_b = \frac{V_{cc} - (N_{LEDs} V_d + 0.7V)}{R_{10}} = \frac{5V - (2 \cdot 1.3V + 0.7V)}{R_{10}} = \frac{1.7}{R_{10}}$$

This yields R10 = 1.4k. Due to the inaccuracy of hfe, R10 = 1k should work as well. In fact, with a 50% duty cycle, the maximum LED drive current is twice as high, namely 260mA, therefore a lower R10 value is acceptable.

Buffer Stage:

At the bench, the need for a buffer stage was realized. The VCO output could not sink the Q2 base current. Therefore, an NPN emitter was added. The NPN transistor, unlike the PNP, sinks base current from the VCO. The emitter resistor sets this base current. The only requirement on R9 is that it be large enough to create a high impedance input on the NPN base so as not to load the VCO output, but small enough so as not to affect the base current sunk from the PNP transistor. In this case 1k was chosen, which reduces the LED drive current by half. For more drive current, R10 could be decreased or removed altogether. One aspect of this design worth noting is that the VCO output is inverted by the PNP transistor, meaning the LEDs are being driven during the negative pulse of the VCO (see Figure 3.2). For FM modulated audio, this should not have a noticeable effect, but to remedy this fact, the current to voltage converter on the receiver was implemented in an inverting manner.

Unexpected Result:

As seen in Figure 3.2, the signal driving the LEDs does not seem to decay rapidly enough during the off time. Anticipating problems, I attempted to fix this using a pull-down resistor, so as to turn the LEDs off more rapidly for a better optical square wave. However, I discovered that the pull-down resistor that gave the best performance, approximately 10, was pulling current away from the LEDs, causing less drive current,less intensity, and hence less range.

Observing the output on the receiver dismissed my worries. I discovered that below the knee in the decay in Figure 5, the LEDs are not conducting and not emitting light.

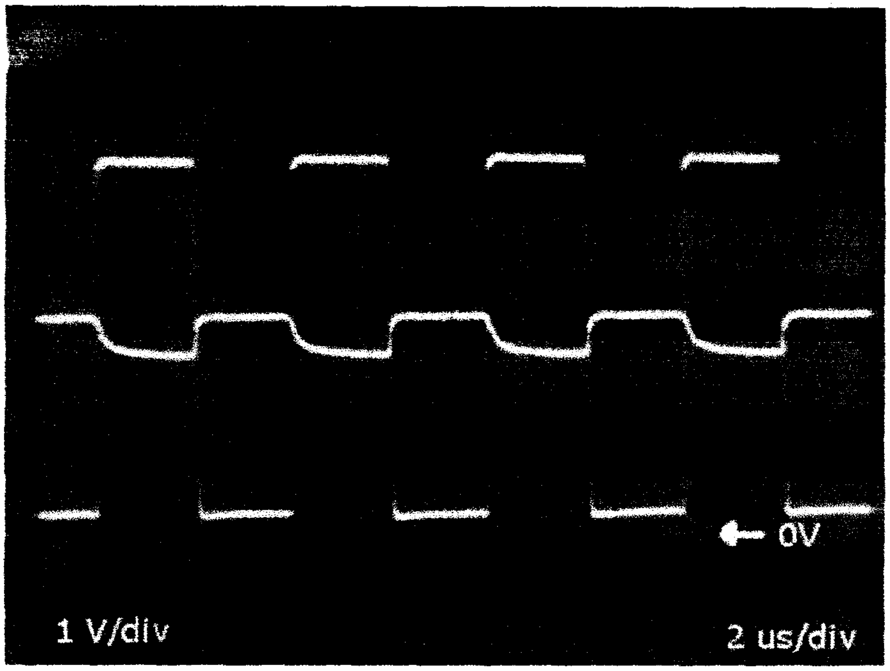


Fig 3.2 Oscilloscope capture of the VCO square wave output (pin 4 of U2) and LED driving signal (emitter of Q2).

3.2 PWM Infrared Receiver:

The receiver detects the faint flicker of infrared light and converts the photoelectric effect current to an amplified voltage signal. This signal is then input to a phase-locked loop that demodulates the single channel of audio. The demodulated signal is buffered through an audio amplifier and output as the headphone driving signal. The design detailed below.

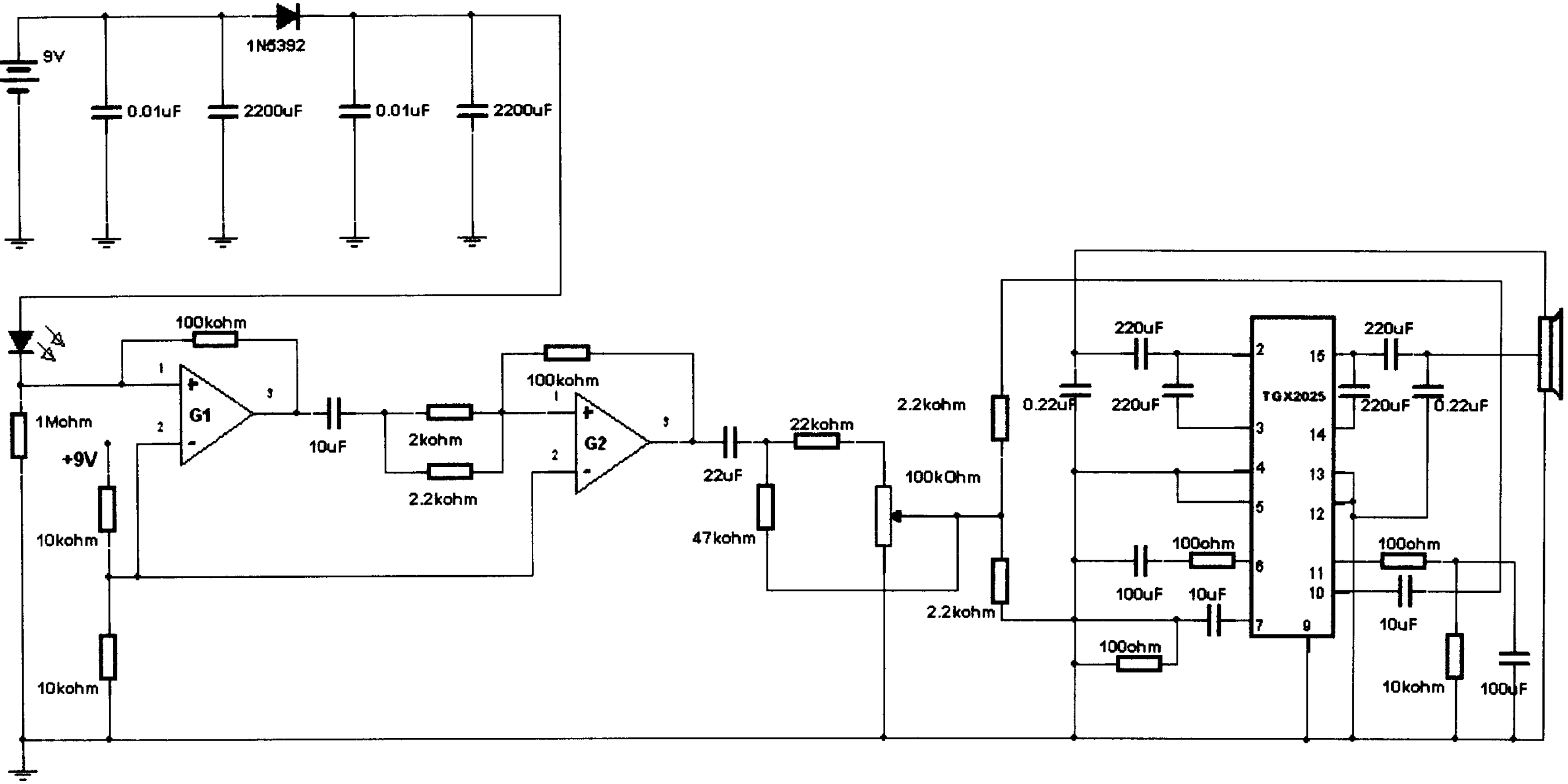


Fig.3.2 Circuit Diagram of the PWM Infrared Receiver

Transconductance Amplifier:

The purpose of this first stage amplifier is to convert the photodiode current into a meaningful voltage signal. To accomplish this, I used an opamp in an inverting configuration. Current generated by the photodiode is counteracted by the opamp generating a voltage such that the current through R22 is equal to the photodiode current. To minimize the amount of noise in the system, I chose R22 to be the largest possible value such that the gain is below the gain-bandwidth curve. Increasing R22 two fold, doubles the gain; however, this only increases the thermal noise by a factor of $\sqrt{2}$. Therefore, to maximize the signal to noise ratio, the first stage should maximize gain. At the bench, 470k for R22 worked best — 100k did not yield enough gain while 1M produced oscillations.

To further maximize gain, I desired an opamp with a high gain-bandwidth product at my carrier frequency, high input impedance, and low input capacitance. The high input impedance requirement led me to choose a JFET opamp. Furthermore, to minimize offset voltage (to prevent railing at high gain) I opted for the added cost of a BiFET opamp. A low input capacitance was critical. High input capacitance would severely attenuate the gain at the carrier frequency. In fact, a good figure of merit is the gain-bandwidth product divided by the input capacitance. [8]

This analysis led me to choose the Analog Devices AD823. This opamp has a 16MHz unity gain-bandwidth product and 1.8pF input capacitance, with 30dB of open-loop gain at the carrier frequency.

The photodiodes that I chose were the PDB-C139F produced by Photonic Devices. The primary reason that I chose this detector was the large supply readily available in the stockroom. This photodiode has a response time of 50nS, a junction capacitance of 18pF at 10V reverse bias, and an optical filter for λ = 950nm. To maximize the detected signal at the carrier, the junction capacitance needed to be minimized with a reverse bias on the detector diodes, D4 and D5. However, a reverse bias causes an undesirable dark current that induces shot noise into the detected signal. To counteract this dark current, I added two identical photodiodes, D8 and D9.

Due to the single supply design of the receiver, the non-inverting input required appropriate biasing. I used two 1M resistors, R20 and R21 to create a voltage divider. The large resistor values minimized shot noise and interference with the dark current. However this choice increased thermal noise. To attenuate this noise prior to the amplifier, I added C17. The -3dB bandwidth of this first order filter is

$$f_{-3\mathrm{dB}} = \frac{1}{2\pi(R_{21}\|R_{22})C_{17}} = 15\mathrm{Hz}$$

low enough to filter out any noteworthy noise without making C17 too large. Note that this is the non-inverting input, not the signal input, so the detected signal is not affected by this filter.

Non-Inverting Amplifier:

In order to increase gain and maximize SNR, I added a second non-inverting gain stage that was readily available in the AD823 dual opamp package. Originally, I intended to implement this stage as an automatic gain control. However, the AD823 rail saturation recovery time is 250ns, adequately small so as not to cause significant distortion of the 200kHzcarrier signal. The offset voltage from the first stage produces a considerable DC bias that, if input to the second stage, produces a flat-line against one of the rails. Therefore, I added C16 to act as a DC bias. To re-bias the signal on the non-inverting input, I added a voltage divider consisting of R26 and R27. However, C16 and R26kR27 also act as a high-pass filter. The corner frequency is

$$f_{\text{-3dB}} = \frac{1}{2\pi(R_{26}\|R_{27})C_{16}} = \frac{1}{2\pi(33\text{k}\Omega\|33\text{k}\Omega)(10nF)} = 950\text{Hz}$$

This is far below the carrier frequency of 200kHz, causing no significant attenuation of this signal, as desired. The resistor combination R24 and R25 select 20dB of non-inverting gain. Originally, R24 was connected to a virtual ground created from a voltage divider. However, at the bench I discovered that this was significantly reducing my range. Since the resistors have tolerances, the bias point on the two opamp inputs was different, hence causing the signal to partially rail and in turn decreasing range. I discovered that a capacitor divider worked well, with the opamp setting the appropriate bias to satisfy the three golden rules. [9] This capacitor divider also creates a low-pass filter for the bias point with a -3dB corner frequency of

$$f_{\text{-3dB}} = \frac{1}{2\pi R_{24}(C_{18} + C_{24})} = \frac{1}{2\pi(1\text{k}\Omega)(0.47\mu F + 0.47\mu F)} = 160\text{Hz}$$

This low frequency is sufficient to prevent the bias point from drifting with the carrier signal. The -3dB point could be moved lower by using a larger resistor value or large capacitors, neither of which is desirable due to noise issues and physical size. Note that the feedback input is not affected by this filter since the opamp is merely sampling a voltage divider of the opamp output signal to the relatively stiff virtual ground created by this capacitor divider.

Demodulator:

A PLL identical to the one found in the transmitter, namely the C2025, demodulates the FM signal. The component values for C6, R12, R13, and R30 are identical to the values for the transmitter to select roughly the same lock range, within tolerance of the components.

In order to increase range significantly, C7 is used to take advantage of the self-biasing feature provided by the PLL. The choice of this component was determined at the bench for best performance. A type I phase comparator (XOR gate) is used in this PLL configuration. Originally, I intended to use a type II phase comparator, since this comparator does not produce a triangle wave oscillation. However, at the bench I discovered that this phase comparator greatly distorted my signal and did not have a flat magnitude response, while the type I performed well.

To attenuate the triangle wave and remove non-audio components, the feedback filter consisting of C8 and R15 was implemented. This filter stabilizes the loop and has a corner frequency of

$$f_{-3\mathrm{dB}} = \frac{1}{2\pi R_{15} C_8} = 16\mathrm{kHz}$$

approximately near the edge of the perceptual audio threshold.

The PLL has a source follower on pin 10 that protects the VCO control voltage (i.e. demodulated signal) from loading. This follower requires a 10k resistive load. R14 supplies this load. Another noise control filter, primarily to remove stray VCO noise, also contributes to the load. R16 and C9 create this filter with a corner frequency of

$$f_{\text{-3dB}} = \frac{1}{2\pi R_{16} C_9} = \frac{1}{2\pi(10\text{k}\Omega)(1\text{nF})} = 16\text{kHz}$$

Note that this is only an approximation. For a complete analysis, R14, R16, R17, C9, and C10 should be considered together, for example, with two-port network theory. [10]

Audio Amplifier:

The final stage amplifies the audio signal.

For low distortion of the signal, the receiver uses an opamp. A common opamp suitable for audio amplification is the National LM386. This opamp is particularly useful since it conveniently allows for a bass boost feature through simple transfer function editing. C13 and R19 edit the transfer function such that the higher frequency components are uniformly attenuated while preserving bass frequency components at original levels.

A final low-pass audio filter is created from C12 and R18. The corner frequency for this filter is

$$f_{\text{-3dB}} = \frac{1}{2\pi R_{18} C_{12}} = \frac{1}{2\pi(200)(47\text{nF})} = 17\text{kHz}$$

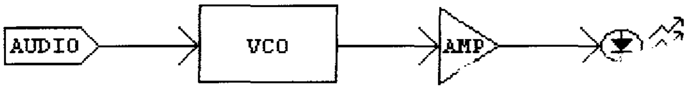
Lastly, C11 removes the DC bias before sending the audio signal to the headphones. The headphone load, typically 32, creates a high-pass filter for the audio signal. The corner frequency of this filter is

$$f_{\text{-3dB}} = \frac{1}{2\pi(32\Omega)C_{11}} = \frac{1}{2\pi(32\Omega)(100\mu\text{F})} = 50\text{Hz}$$

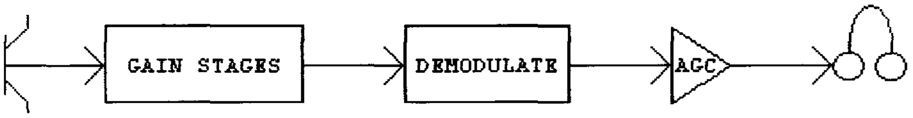
low enough to allow for bass components that are well reproduced by most headphones. To allow lower audio frequencies, C11 would need to be larger since the headphone load cannot be changed. Since many cheap headphones cannot reproduce these very low frequencies well, I opted to limit the physical size of C11 at the cost of a small amount of very low frequency loss.

3.3 Operation:

To provide for the optimal balance of cost, fidelity, complexity, power dissipation, and challenge level, I chose to implement the headphone system using frequency modulation for the transmission of monophonic audio. The instantaneous voltage level of the incoming audio signal is translated to a change in the infrared LED flicker rate. Note that this is fundamentally different from radio FM modulation — the flicker frequency of the infrared light is modulated, not the wavelength of infrared light. On the receiving end, the frequency flicker rate is demodulated to the audio base band signal via a phase- locked loop. The base band audio is amplified and output to the headset. See Figure 3.3 for the block diagram. [10]



Transmitter Block Diagram



Receiver Block Diagram

Fig 3.3 System block diagram

3.4 Power supply:

Since the project is aimed at coming up with a portable, mobile economic and effienciently working headphone, special attention was given to some factors of maintainability with respect to power source. These factors include availability, cost, portability, replacement ability etc. Hence, a 9volt battery was chosen.

Chapter Four

Test, Result AND Discussion

4.1 Construction Procedure and Precaution:

The construction was carried out with utmost. The precaution taking during the soldering were:

- The components were laid on a copper-tracked Vero board and soldered firmly in placed.
- Particular care was taken to orientate polarized component (e.g. capacitors, transistors, diode with respect to potentials.
- A fine guage solder was used to solder the components together with care taken not to bridge the copper tracks lying side by side together.
- After each soldering, the rip of the soldering iron was cleared.

4.2 Test and Results:

The test was done with respect to the distance covered and its operations as follows;

- The constructed Infrared transmitter was used in conjunction with the receiver unit to determine the distance of coverage and this was done by placing the two units apart
- The transmission is reliably detected when the receiver unit responds as it should.

- A measure of the distance over which reliable operation is guaranteed was measured and seems to lie between 8 and 10 meters.

4.3 Photographic plates Signals and Casings:

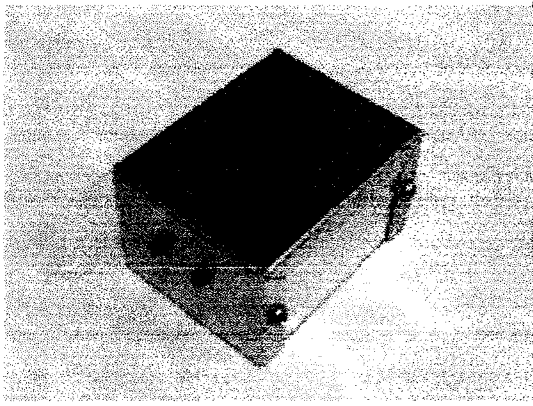


Fig 4.1 Photograph of transmitter casing

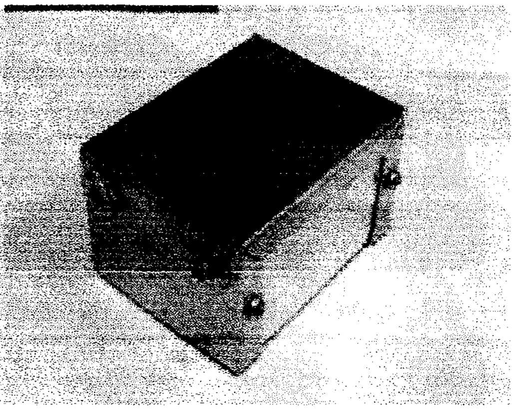


Fig 4.2 Photograph of receiver casing

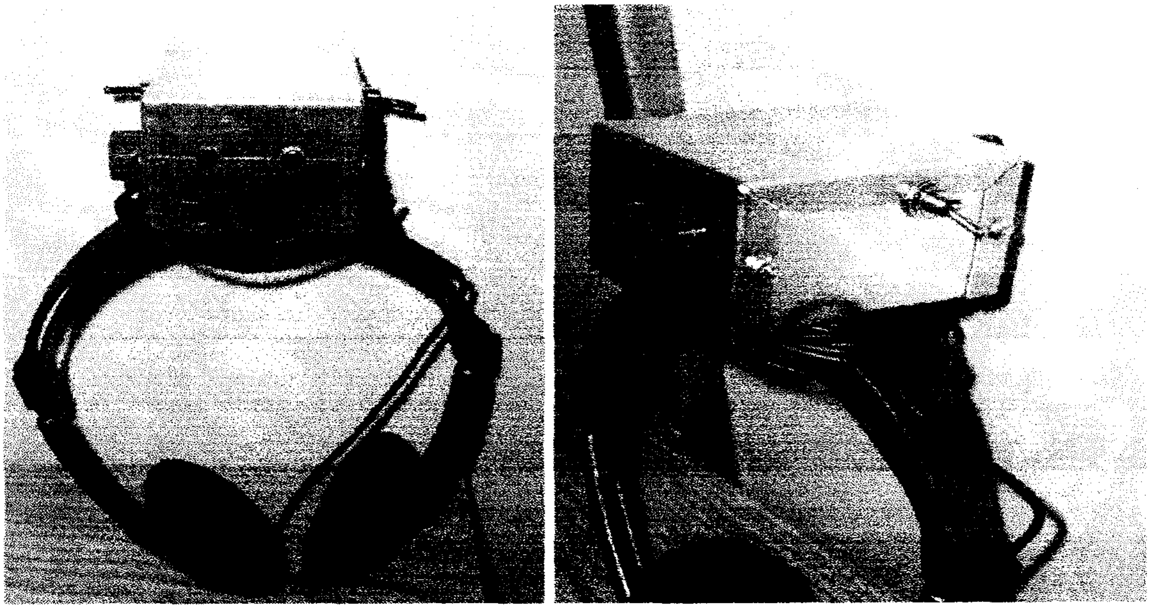


Fig 4.3 Front and Top view of IR wireless headphone

Chapter Five

Conclusion

5.1 Summary:

This project was based on "Design and Construction of Infrared wireless headphone. It was aimed at improving the existing technology of headphones, such as portability, comfortability, sensitivity and reception range.

The infrared wireless headphone consists of two (2) major stages; The Transmitter and The Receiver, and there mode of operation at the various stages of the project.

5.2 Recommendation:

It is a statement of fact that when a circuit has been design, there are no hundred percent guarantees that the circuit will work and as such instead of a student going to purchase the components for testing the work ability of design circuit, the computer simulation can be resorted to, hence I recommend that best methods of simulation should be incorporated to the syllabus.

I would also like the department to buy and stock the departmental workshop and the library with computer systems, equipment and components necessary for various projects. This is because; there are many well designed circuits on ground that could not be implemented simply because of unavailability of components and equipments.

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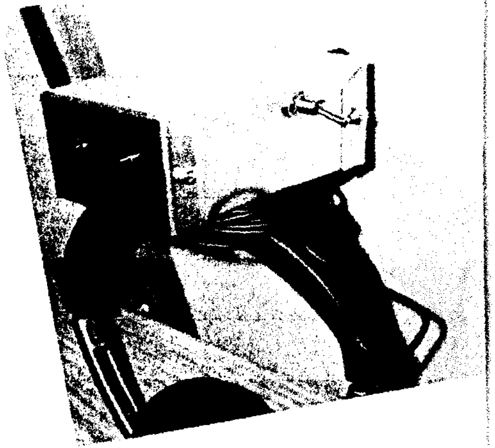
[10] Christopher P. Hiszpanski hiszpans@its.caltech.edu Wireless Infrared Headphones Project Documentation. Msc422.sping 2005pp 5-7,pp 8-9.

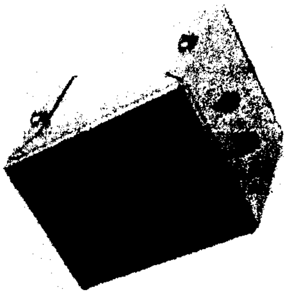
Operation Manual Of IR Wireless Headphone:

This project consist of the design and construction of the PWM Transmitter and Receiver using Infrared technology.

Mode of operation: The Transmitter is connected to your output device using dual head cable cord, while the headphone is connected to the Receiver. With all the connection rightly connected as described the Transmitter and thé Receiver are powered and place in the same line of sight. With this a good audio sound can be enjoyed with fewer disturbances.



The Receiver



The Transmitter