TITLE PAGE

DESIGN AND CONSTRUCTION OF AN AUDIO/VIDEO TRANSMITTER

BY

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EEE/12/0838

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NOVEMBER 2017

DEDICATION

This report is dedicated to God Almighty and to my beloved parents Mr. and Mrs. Martins Idaewor.

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CERTIFICATION

This is to certify that the project **"Design and Construction of an Audio/Video Transmitter"** was originally carried out by **Adogamhe, Miracle Oshiokpamhe** of Electrical/Electronics Engineering Department, Federal University, Oye-Ekiti with matric number **EEE/12/0838.** The Project was supervised by **Engr. Temidayo Ofusori** and has not been submitted elsewhere for the award of a degree.

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ABSTRACT

The design of the wireless audio and video transmitter was done in stages taking into consideration a pre-selected desired frequency. These stages are the power supply stage, the carrier frequency generation stage, the carrier frequency pre-amplification stage, the voltage-controlled oscillation stage and the final stage which is the modulation and amplification stage. First, carrier frequency was generated in the oscillator circuit comprising of an NPN transistor C1674, a variable capacitor connected in parallel with an air-filled inductor to form a tank circuit and biasing resistors. The carrier frequency generated is then amplified in the next stage by the same C1674 transistor which acts there as an amplifier. The audio signal is modulated in the next stage which is the Voltage Controlled Oscillator (VCO) that generates a base frequency of 5.5 MHz. The video and audio signals are superimposed at the final stage and transmitted to the air through an antenna. The project is based on radio frequency propagation and the medium is free space. Power is supplied to all stages by a full wave rectifier circuit comprising of a transformer, four diodes that forms the rectifier and filter capacitor. Zener diodes were used in regulating the voltages supplied to the oscillator stages because variation of voltage is undesirable. The transmitted signal would be received by a television receiver by tuning to the Ultra High Frequency (UHF) range between 470 to 960 MHz.

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CHAPTER ONE

INTRODUCTION

1.1 Background of Project

Telecommunication encompasses the electrical communication of voice, data, and image information at a distance. There are four major methods employed in telecommunications engineering for the transmission of these signals known as transmission media. The major transmission media are via twisted pair, coaxial cable, fiber optics and radio (Freeman, 1999). Radio communication which is an unguided or wireless transmission medium is of major interest for this project.

Wireless transmission exists in three different ranges of frequencies: Frequencies in the range of about 1 GHz (gigahertz) to 40 GHz are referred to as microwave frequencies. At these frequencies, highly directional beams are possible, and microwave is quite suitable for point-to-point transmission applied in satellite communications; Frequencies in the range of 30 MHz to 1 GHz referred to as the radio range are suitable for omnidirectional applications. For unguided media, transmission and reception are achieved by means of an antenna. A television antenna for example is a specifically designed antenna for the reception of over-the-air broadcast television signal, which are transmitted at frequencies from about 41 to 250 MHz in the VHF band, and 470 to 960 MHz in the UHF band in different countries (Strontv, 2017).

Modulation enables the efficient transmission of video signal from one destination to another. In general, video modulation means that a higher frequency carrier wave is modified according to the original video signal such that the carrier wave contains the information in the video signal. Then, the carrier wave will carry the information in the form of radio frequency (RF) signal. When carrier reaches its destination, the video signal is extracted from the carrier and decoded at the receiver. In other words, the video signal is first combined with a higher frequency carrier wave so that carrier wave contains the information in video signal. The combined signal is called radio-frequency signal. At the end of this transmitting system, the RF signals stream from a light sensor and hence, the receivers can obtain the initial data in the original video signal. This project employs frequency modulation- the carrier wave is combined with audio and video signals by varying the instantaneous frequency of the wave.

Frequency modulation has several advantages over the system of amplitude modulation (AM) used in the alternate form of radio broadcasting. The most important is that an FM system is less affected by interference and other forms of electrical disturbances such as those caused by thunderstorms and car ignition systems; FM has a higher signal to noise ratio compared to AM therefore it is possible for broadcasting stations to operate at very high frequency bands. A typical block diagram of a communication system containing the basic elements is shown in the figure 1.1

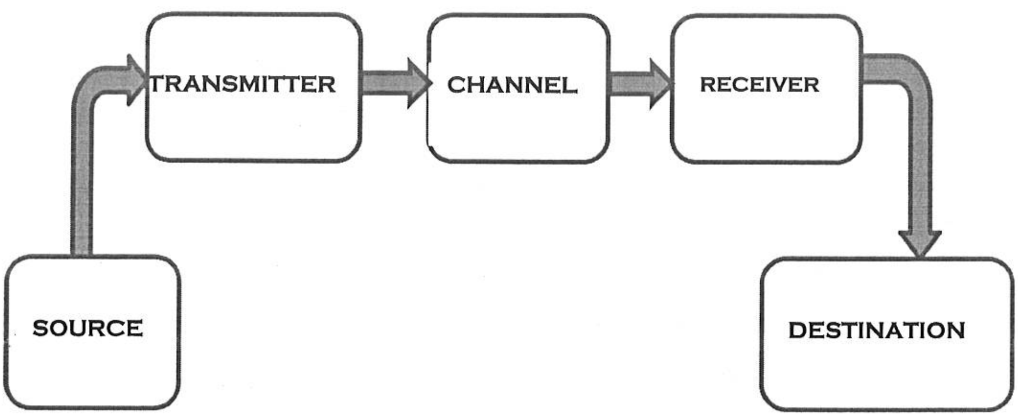

Figure 1.1: Basic Block Diagram of a Communication System

1.2 Statement of Problem

There is no time for inconveniencies in this technologically advancing world but a greater need for portability and adaptability. There have been some occasions when it is needed to hook up a video player from one room to a television set in another room in a building which entailed that all kinds of wires and plugs are first unhooked from the primary TV set; then the video player is carried from the initial location to the room where the other desired TV set is located; and then the video player is connected afresh to the desired TV set in the other room. This is a tiring and cumbersome procedure that people most times, have to hire technically-inclined individuals to do. This brings about the need of a wireless Audio/Video transmitter that would do just about the same thing the series of wires would have done without having to battle with the wires. It also offers more conveniences and even be used to set up for security cameras around the house since the video signals would be sent directly to the TV eliminating the need for cumbersome wires and cables because of the wireless signal transmission.

1.3 Motivation

My desire for knowledge in the wireless technology motivated me to embark on this project. I also saw the need to develop a device that would eliminate the cumbersome stress of unhooking and hooking wires in the house just to connect devices when a wireless device at a low cost could solve the problem.

1.4 Aim and Objectives

The aim of this project is to design and construct a wireless transmitter that allows the transfer of audio/video signals from a video player in one part of a facility to a television receiver in another part of the facility.

In order to achieve the stated aim, the objectives are:

- To design a wireless transmitter that would work over FM frequency allowing the transfer of audio/video signal over a distance of 10 metres.
- To design a wireless transmitter that would transmit within the UHF band.
- To implement a wireless device for household applications.
- To implement a functional audio/video transmitter that can be used for laboratory experiments.

1.5 Scope of Study

The scope of this project's design covers wireless real time transmission of audio and video signals in the Ultra-high frequency (UHF) range based simply on modulating unto a very high carrier frequency without any encryption of signals. The carrier frequency would be generated by an oscillator built around a tank circuit and then amplified by a radio frequency amplifier. It is this amplified signal that modulates the audio and video signals before transmission via an antenna. Only discrete components would be used for the construction of the AV transmitter.

1.6 Significance of Study

An Audio/Video (AV) transmitter is a device that can be used to transmit audio/video signals wirelessly from one location to another. The device would send the output of a source device, such as a DVD player, to a television in another part of a property, hence, providing an alternative to cable installations.

This project can be used to connect home entertainment and AV devices in a home or a business. Security cameras can also be connected to this device such that it can be utilized for video transmission from the front door of a facility with the footage being viewed at ease inside the facility. Video signals can be beamed to different TVs at a time in the home. Therefore, the wireless AV transmitter can be used to send video signal from any video source to one or more receivers in another location and also to connect security cameras for domestic use. In academic institutions, the device can be used in the laboratory for experiments related to telecommunications.

CHAPTER TWO

LITERATURE REVIEW

2.1 Review of Related Works

A number of technologies have been employed for wireless audio and video transmission ranging from radio frequency to visible light, infrared, WIFI and others which are discussed in this chapter.

Celso (1991) reported about the design and implementation of a PWM system for TV signals transmission via optical fiber using LED-PIN and multimode fiber as optical devices operating at 0.85 μm. The PWM scheme was chosen in order to construct a system with low circuit complexity for transmitting TV signals but it was only suited for applications such as videoconferencing, closed circuit TV, telesurveillance and others where high quality video was not required. The analog baseband was composed of a 4.5 MHz video signal and a 6.8 MHz FM audio carrier which modulated the width of a 15 MHz square wave subcarrier. At the transmitter, a 15 KHz audio frequency was applied to a narrow band VCO-based FM modulator, centered at 6.8 MHz. An adder circuit was used to combine the audio subcarrier with the previously low pass filtered video signal. For the PWM modulation, the reference saw-tooth was generated by integrating a 15 MHz square wave from a tuned oscillator and a fast comparator whose output was coupled to the optical source driver resulting in the PWM waveform. The optical source employed was a light emitting diode (LED) with 0.85 μm wavelength. The PWM optical carrier was then coupled to a multimode optical fiber. At the receiver, the light carrier was detected using a PIN photodiode. The electrical signal was amplified and reconstructed by another fast comparator. The PWM signal was then passed through a low-pass filter and the reconstructed composite baseband was spitted into its video and FM audio components by low and band-pass filtering respectively.

An optical fiber multi-channel audio and video signal transmission system was developed for clinical applications. The transmitter was located in the operation room while the receiver was located in the classroom. There were four audio-input signal channels, four video-input signal channels and one audio-output channel at the transmitter side and there were four audio-output signal channels, four video-output signal channels, and one audio-input channel at the receiver side. The audio and video signals at the transmitter side were modulated into PFM waveforms, converted into the optical signals and then transmitted through eight optical fiber cables. Another optical fiber was used for reception of signals and as control line for the video camera. The audio and video signals were modulated by using the PFM scheme at first, and then the PFM waveforms were converted into optical signals by using LED's. The optical signals were then transmitted through optical fiber cables without degradation of the signal quality. The receivers then converted the optical signals to electronic signals and then demodulated the PFM signals to obtain the audio and video signals, respectively (Hiroaki, Jinzhu, Koji, & Kazuyuki, 1992).

Dick, Leo, Davidse, & Arthur (1995) developed a model of a multichannel optical transmission system for video signals. The system uses time-division multiplex pulse-position modulation (TDPPM). The transmitter and receiver were realized by using a standard bipolar process where an external laser and PIN photodiode were used. While achieving a weighted signal-to-noise ratio (SNR) of 54 dB, a differential gain of 1% and a differential phase of 0.5", a maximum multiplex of sixteen channels was realized. For a launched power of 0 dBm pulse amplitude, the optical budget for a 45 dB weighted SNR exceeded 20 dB. Besides video signals, the system was able to handle other signals like the digital coded audio signals. The feasibility of a four-channel system was confirmed by measurements.

Edinond, Mohd, & Khor (2001) presented in their paper, a wireless simplex communication link which established a one-channel color video and mono audio communication with an emergency vehicle. A miniature camera, fitted with a microphone, was mounted on a modified safety helmet. Video transmitter and supply battery were carried by a pouch tightened to the paramedical's waist. The video transmitter used the Industrial Scientific Medical (ISM) frequency band of 2.4 GHz. The RF bandwidth was 20 MHz and there was an option of selecting one out of the four available frequency bands to avoid interference with any near-by emitting stations. The radiated output power realized was 20 mW, while the transmitter itself consumed 130 mA under 12 VDC. The operational temperature range was from 0 "C to 50 "C. They were able to show through field tests that the system could reliably transmit audio and video signals from a simulated accident site to an emergency vehicle.

Seiji, Yasuo, Yoshitaka, & Masakazu (2004) developed an audio and video synchronous transmission system based on IEE802.11a. They identified how IEEE802.11a spread widely as wireless transmission technologies for home PC network, but still remained an asynchronous transmission system based on Carrier Sense Multiple Access (CSMA) with Collision Avoidance (CA) and Automatic Repeat Request (ARQ) for lost packets. They proposed a method for transmitting a high quality AV stream on an IEEE802.11a network. This method was directly applied for MPEG2-TS making it suitable to be implemented on the wireless LAN chipset and for wireless AV equipment with MPEG2-TS I/O signal.

A wireless uncompressed high-definition television (HDTV) signal transmission system utilizing a 60 GHz band transmitter and two receivers was proposed and developed for indoor use. The system was capable of transmitting video signals and stereo audio signals. An output peak power of 10 mW and a minimum received power of -52 dBm were achieved. Wide beam planar antennas were used which allowed less strict alignment for the wireless equipment with a maximum transmission distance of 7 metres. Furthermore, path diversity technique was introduced to reduce the opportunities of shadowing by a human body around a television set (Maruhash, et al., 2005).

Ramesh *et al* (2010) designed a video transmission device using optical wireless communication technology. A 10Mbps optical transmission for free-space optical video data communication was presented and a channel-adaptive video streaming scheme which adjusted the video bit rate according to channel condition and transmitted video through a hybrid Free Space Optical (FSO) laser communication system. The design consisted of the interface circuit, transmitter and receiver. The transmitter was based on a circuitry that drives a laser diode emitting 635nm visible red light. The incoming light signal was focused via 10-cm-diameter lens onto a photodiode SFH203. The received signal current from the photodiode was converted to signal voltage by a resistive-feedback trans-impedance amplifier, differentiator, and limiting amplifier and consequently delivered to the interface circuit. 10Mbps Ethernet link between two personal computers situated 100 meters apart was successfully tested.

Yingie, Liwei, Yuxian & Yongjin (2013) developed a prototype of real-time audio and video transmission system using LED lamps. MATLAB program was used to simulate the illuminance distribution for two practical light source deployments. Results from experiment carried out showed that real-time high quality audio and video with the maximum distance of 3 m can be achieved through proper layout of LED sources and improvement of concentration effects. There still existed distortion comparing images before and after transmission.

Irfanullah et al (2013) developed a WiMAX based audio/video transmitter and receiver. The transmitter developed consisted of a CCD camera, audio microphone, filter, and RF amplifier. The CCD camera captured the image while the audio microphone captured the audio and then the signal was passed in its analog form to a fixed filter that would only pass a video signal of 12 MHz and a 4 KHz audio signal. The signal was then passed to a RF amplifier section where unwanted signals were removed. Amplification also took place via a C1815 transistor, which amplified the analog signal. An inductor was used at the RF amplifier section as the antenna for transmitting the video and audio signal to air. The receiver hardware consisted of a small sized monopole antenna, demodulator, video amplifier, tuner, step down transformer and TV. The monopole antenna and the tuner were connected to a 3 GHz demodulator while the demodulator was connected to a video amplifier to amplify the signals. The signals were then sent to television through a lead from amplifier.

A LI-FI based audio transmitter with home/office automation system has also been designed. The input signal used at the transmitter side was the process of voice communication through the visible light. This signal was converted to an electrical signal through a microphone and then amplified by the amplifier circuits and fed into the power LED. The light signal from the LED had a direct proportionality with the intensity of the voice signal. That is, the louder the voice input, the more the illumination of the LED. There was a light dependent resistor at the receiver side which was used to receive the light signal and generate an electrical signal that was proportional to it. A demodulator circuit processes the electrical signal which was then fed to a speaker and it reproduced the audio signal which was at the input of the transmitter side. The following observations were made after the device implementation: The maximum length of communication between transmitter & receiver was 2 meters, response time of relay was 10 milliseconds and the maximum audio output from loudspeaker varied from 85 to 95 decibel (Chinchawade & Sujatha, 2016).

In this project, a wireless video/audio transmitter that employs analog radio technology would be developed. The transmitter has the advantage of low manufacturing cost as the audio and video signals are simply modulated onto a much higher carrier frequency before transmission. The transmission would be in the TV UHF band which is between 470- 960 MHz. In comparison with digital where relatively large number of gates would be required to implement a specific function and since their switching times must be relatively short, the total power consumption and the chip area will be considerably larger. The conversion from analog to digital (ADC) and from digital to analog (DAC) becomes increasingly difficult for wideband signals exhibiting a high dynamic range. Hence, an important advantage of an analog system is that its cost will be less than that of a digital system.

2.2 Review of Fundamental Concepts

The wireless era was started by two European scientists, James Clerk Maxwell and Heinrich Rudolf Hertz. Maxwell combined the works of Lorentz, Faraday, Ampere and Gauss to present the Maxwell's equation on 1864. He predicted that electromagnet waves are propagated in free space at the speed of light. His theory was accepted twenty years later after Hertz validated electromagnetic wave (wireless) propagation through his experiment in 1886. His experiment showed how RF signals are generated, propagated and received. Guglielmo Marconi between the years 1895 to 1901 was able to show a method for transmitting and receiving information, continuing from where Hertz stopped. Other scientists in the 1890's including Nikola Tesla, Alexander Stepanovich Popov and Jagdish Chandra Bose demonstrated different forms of wireless communications. Some other scientists like Marconi started to commercialized the use of electromagnetic wave propagation for wireless telegraphs and allowed the transfer of information from one continent to another without physical connection. Ever since, a lot of revolutionary changes have occurred in the field of wireless including development of broadcast radio, television, two-way radio, AM and FM, Wi-Fi technology, cellular mobile phone systems and satellite communication (Light, 2015).

2.1.1 Radio Frequency (RF)

RF is any electromagnetic wave with a frequency between 1 MHz and 300 GHz. Common industry definitions have RF ranging from 1 MHz to about 1 GHz, while the range from 1 to about 30 GHz is called microwaves and 30–300 GHz is the millimeter-wave (MMW) region. During World War II, letters were used to designate various frequency bands, particularly those used for radar. These designations classified at the time have found their way into mainstream use. The band identifiers may be used to refer to a nominal frequency range or specific frequency ranges (Seybold, 2005).

The velocity of propagation of electromagnetic waves depends upon its medium of propagation. In free space, the velocity of propagation equals the speed of light which is approximately $3 \times 10^8\ m/s$. That is,

$$c = 3 \times 10^8\ m/s$$

Table 2.1: Frequency Band Designations (Seybold, 2005)

S/N	Frequency Band Designations	Band Designation	Frequency Range
1	Extremely Low Frequency	ELF	< 3kHz
2	Very Low Frequency	VLF	3 - 30kHz
3	Low Frequency	LF	30 - 300kHz
4	Medium Frequency	MF	300kHz - 3MHz
5	High Frequency	HF	3 - 30MHz
6	Very High Frequency	VHF	30 - 300MHz
7	Ultra-high Frequency	UHF	300MHz - 3GHz
8	Super-high Frequency	SHF	3 - 30GHz
9	Extra-high Frequency	EHF	30 - 300GHz

where c = speed of light = velocity of propagation in free space.

The velocity of propagation through air is very close to that of free space, and the same value is generally used. The wavelength of an electromagnetic wave is defined as the distance travelled by the wave over one cycle or period, denoted by the lower case Greek letter lambda. The SI unit is wavelength is in meters. Hence, the wavelength of an electromagnetic wave can be represented mathematically as follows:

$$\lambda = \frac{c}{f} \Rightarrow f = \frac{c}{\lambda}$$

where λ= wavelength of the wave; c=velocity of propagation and f= frequency

2.1.2 Antennas

Every wireless system must employ an antenna to radiate or receive electromagnetic energy. An antenna is an electrical conductor or system of conductors used for either the transmission or reception of electromagnetic energy. For transmission of a signal, electrical energy from the transmitter is converted into electromagnetic energy by the antenna and radiated into the surrounding environment (atmosphere, space, water). For reception of a signal, electromagnetic energy impinging on the antenna is converted into electrical energy and fed in to the receiver. In two-way communication, the same antenna can be and often is used for both transmission and reception. This is possible because of the fundamental principle of *antenna reciprocity*. This principle means that the antenna parameters remains unchanged for both transmit and receive or antenna characteristics remains unchanged whether it is sending or receiving electromagnetic energy (Seybold, 2005).

The Isotropic Antenna

An antenna would radiate power in all directions but would not typically perform equally in all directions. The radiation pattern is a common way to classify an antenna which is a graphical representation of its radiation properties as a function of space co-ordinates. The simplest pattern is produced by an isotropic antenna or omnidirectional antenna, a term used for an antenna that radiates equally in all directions in one plane. An example of such is a whip antenna. The power density due to an isotropic radiator is a function of the distance from the antenna and it is expressed as the total power divided by the area of the sphere. Some antenna parameters are as follows:

Antenna Gain

For a real antenna, there would be certain angles of radiation which provides greater power density than others, if measured at the same range. The directivity of an antenna is defined as the ratio of the radiated power density at a distance say d, in the direction of maximum intensity to the average power density over all angles at distance, d. This is equivalent to the ratio of peak power density at distance d, t the average power density at d:

$$D = \frac{\textit{Power density at d in the direction of maximum power}}{\textit{Mean power density at d}}$$

Thus, an isotropic antenna has a directivity, D=1. When the antenna losses are considered in the directivity, this becomes the antenna gain.

$$G = \eta \, . \, \frac{\textit{Power density at d in maximum direction}}{P_T/4\pi r^2}$$

$$G = \frac{4\pi A_e}{\lambda^2}$$

Where P_T is the power applied to the antenna terminals; $4\pi r^2$ is the surface area of the sphere with radius, r; A_e is the effective aperture area and η is the total antenna efficiency which accounts for all the losses in the antenna.

Instead of effective area, the concept of effective height is employed for linear antennas. The effective height of an antenna is the height that, when multiplied by the incident electric field, results in the voltage that would actually be measured from the antenna. The relationship between effective height and effective area is given by the formulae:

$$A_e = \frac{{h_e}^2 Z_0}{4R_r}$$

Where A_e is the effective aperture area in square meters; h_e is the effective height in meters; Z_0 is the intrinsic impedance of free space, 377 ohms; and R_r is the radiation resistance of the antenna. The physical length of an antenna is normally shorter than the effective lent due to non-uniform distribution of current over the length of the antenna.

2.1.3 Transistors

A transistor is a semiconductor device used to amplify or switch electronic signals and electrical power. It is composed of semiconductor material usually with at least three terminals for connection to an external circuit. A voltage or current applied to one pair of the transistor's terminals controls the current through another pair of terminals. Because the controlled (output) power can be higher than the controlling (input) power, a transistor can amplify a signal. The transistor is the fundamental building block of modern electronic devices, and is ubiquitous in modern electronic systems. The first practically implemented device was a point-contact transistor invented in 1947 by American physicists John Bardeen, Walter Brattain, and William Shockley. The transistor revolutionized the field of electronics, and paved the way for smaller and cheaper radios, calculators, and computers, among other things. The NPN Epitaxial Silicon Transistor is shown in the figure 2.2. It has the following parameters, collector-emitter voltage: V_{CEO}=20V; the collector dissipation: P_C (max) =250mW (Administrator, 2017).

2.1.4 Oscillators

Electronic devices require a source of energy at a specific frequency range of a few hertz or several mega-hertz; this is achieved by an oscillator. Oscillators are extensively used in electronic devices to generate high frequency wave or carrier wave in the turning stages.

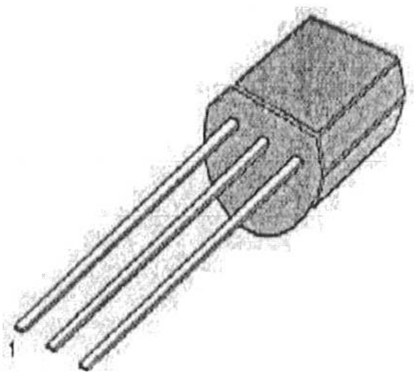

Figure 2.2: The NPN Epitaxial Silicon Transistor (Administrator, 2017)

Oscillators can produce sinusoidal and non-sinusoidal waves. Sinusoidal oscillators which produce sinusoidal waves are classified into damped and undamped oscillators. The former produces electrical oscillations whose amplitude goes on decreasing with time while the later produces electrical oscillations whose amplitude remains constant with time. Damped oscillators have most applications in electronics equipment (Uwoghiren, 2005).

The Tank Circuit

The tank circuit is a type of oscillatory circuit that consists of a capacitor and inductance coil connected in parallel which produces electrical oscillations of frequency determined by the values of L and C. Considering the circuit in the figure 2.3, the capacitor is charged from a DC source with the polarity as shown. In this position, the upper plates of the capacitor have excess of electrons. Therefore, there is a voltage across the capacitor and the capacitor has electrostatic energy. When the switch is closed as shown in figure 2.4, the capacitor will discharge through inductance and electron flow would be in the direction of the arrow. This current flow sets up magnetic field across the coil. Due to the inductive effect, the current builds up slowly towards a maximum value. The circuit current will be maximum when the capacitor is fully discharged. At this instant, electrostatic energy is zero but because electron motion is greatest, the magnetic field around the coil is maximum. Thus, the electrostatic energy across the capacitor has been completely converted into magnetic energy around the coil.

Once the capacitor is discharged, the magnetic field will begin to collapse and produce a counter EMF which will keep the current flowing in the same direction according to Lenz law. The result is that the capacitor is now charged with opposite polarity.

After the collapsing field has recharged the capacitor, the capacitor now begins to discharge, current now flowing in the negative direction as shown in the figure 2.5. The sequence of charged and discharged result is the alternating motion of electrons (oscillatory circuit). The energy is alternatively stored in the electric field of the capacitor C and the magnetic between L and C is repeated over and over again resulting in the production of oscillations.

If an ideal capacitor and inductor are used, these oscillations will sustain until the end of time. But in practical case, the inductor will have some ohmic resistance and the capacitor will have some amount of leakage. These imperfections will waste some amount of energy in between the cycles resulting in the loss of amplitude step by step and eventually the oscillations will die out. This gradual decay in amplitudes which tends to the death of the oscillation is called damping. The oscillations produced in a damped LC tank circuit will look like what is shown in the figure below. In a practical LC oscillator, an active element in an LC oscillator circuit should be applied to give necessary gain, help in attaining the required positive feedback conditions and compensate for energy lost in the tank (Circuitstoday, 2017).

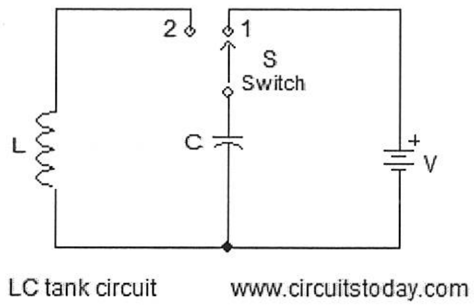

Figure 2.3: LC Tank circuit 1 (Circuitstoday, 2017)

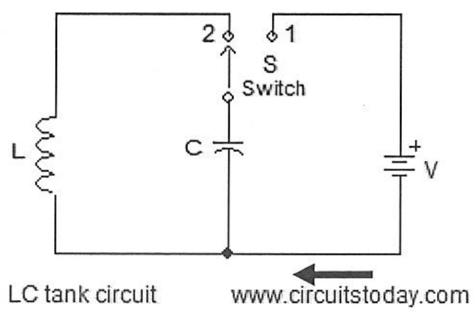

Figure 2.4: LC Tank circuit 2 (Circuitstoday, 2017)

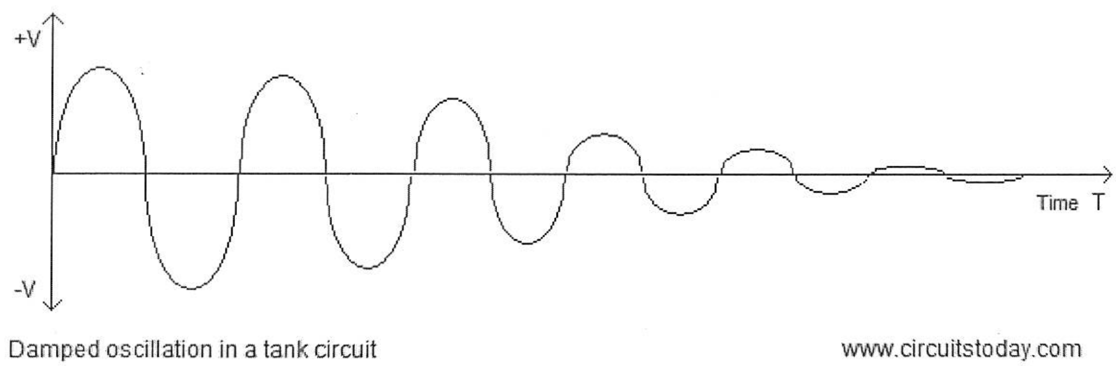

Figure 2.5: Damped Oscillation in a tank circuit (Circuitstoday, 2017)

2.1.5 Modulation

Amplitude modulation and frequency modulation are used to convert signals with frequencies in the normal audio range, from a few tens of hertz to a few kilohertz, into signals with frequencies appropriate for radio transmission, perhaps from hundreds of kilohertz up to hundreds of megahertz (Storey, 2004).

These techniques are illustrated in the figure 2.4. Here a low-frequency input signal, as shown in figure 2.6, is to be transmitted over some form of communication channel. Modulation is performed using a carrier signal of a frequency appropriate to the channel to be used. In practice, the carrier would often have a frequency several orders of magnitude greater than that of the input signal. Amplitude modulation and frequency modulation each have their own characteristics, but both have effect of shifting the frequency range of the signal. In each case, the carrier wave is being varied in some way and therefore, the resulting modulated signal is no longer a pure sinusoid. It therefore contains components at frequencies other than the original carrier. However in each case, the resultant spectrum is centered on the carrier frequency. Therefore by appropriate choice of this carrier frequency, the input signal can be shifted to any appropriate frequency band (Storey, 2004).

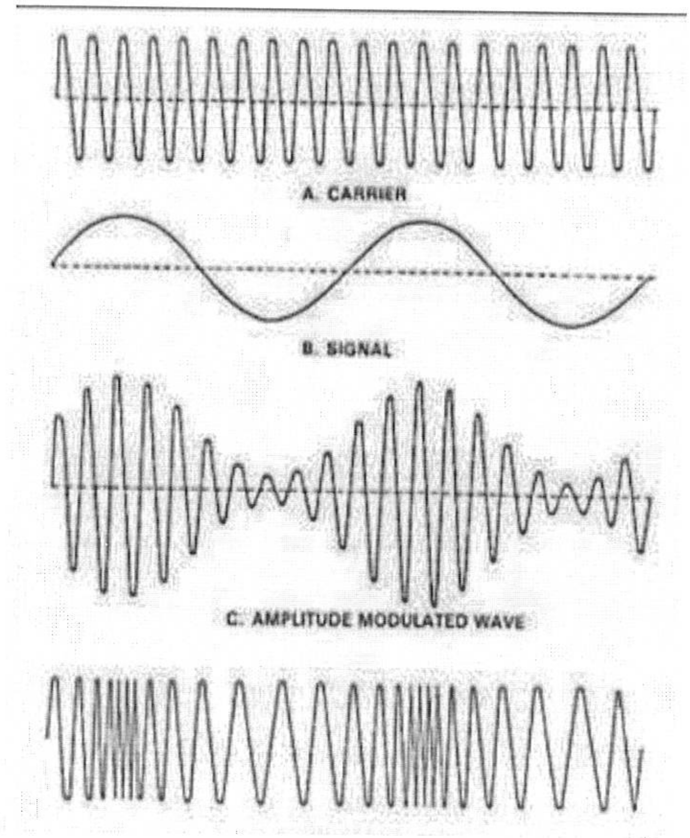

Figure 2.6: Amplitude and Frequency Modulation (Storey, 2004)

CHAPTER THREE

DESIGN METHODOLOGY

3.1 Project Block Diagram

The project was divided into five stages: Each of the stage was tested separately and confirmed that it was working properly before putting the whole circuit together. These stages which are shown in the figure 3.1 below are:

- The Power Supply Stage
- The Carrier Frequency Generation Stage
- Carrier Frequency Amplification Stage
- Voltage-Controlled Oscillator Stage
- Modulation and Final Amplification Stage

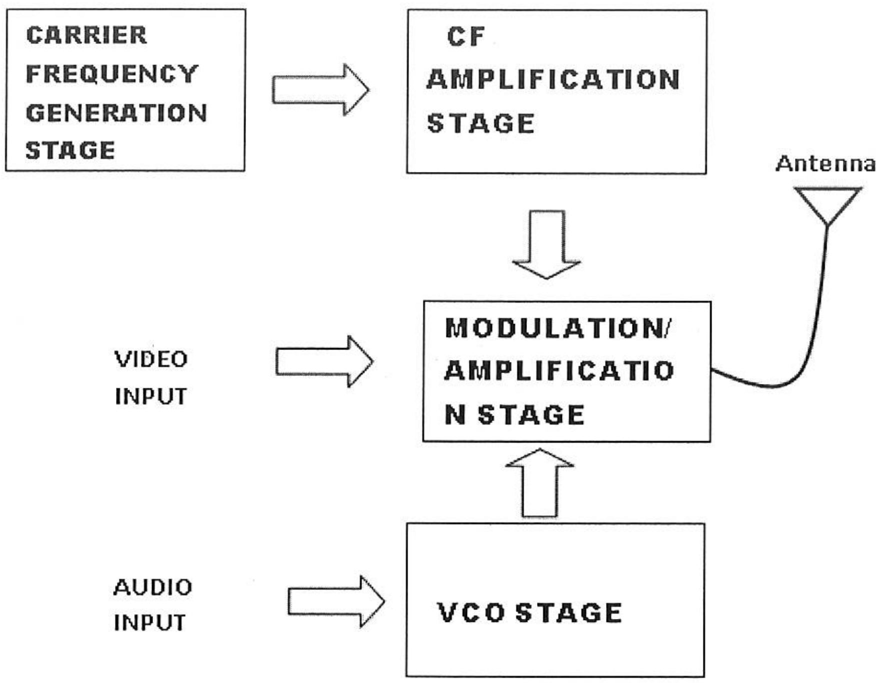

Figure 3.1: Block diagram of the Audio/ Video transmitter

3.1.1 The Power Supply Stage

This is the stage that supplies direct current (DC) to the circuit. The emitter and collector bias in a transistor circuit must be DC and battery is not suitable because of the cost of frequent replacement and also because a constant voltage is required in the oscillator circuits. The alternating current (AC) mains voltage remains fairly constant as long as there is no alteration of load. Zener diode is used to take care of alterations in load under load variation conditions acting as the voltage regulator for this application. The rectifier-filter combination is used for the design of the power supply unit. The bridge rectifier is made up of four diodes to convert the transformer secondary AC voltage into pulsating DC voltage. The pulsating DC voltage is applied to the filter capacitor C22 which removes pulsations in the DC output. Zener diodes are used at voltage regulators in different stages. The Zener diode would reduce the variations in the filtered output voltage and keeps the output voltage nearly constant so that a steady |DC voltage is supplied regardless of load current changes or changes in the input AC voltage. The circuit diagram of the power supply stage is shown in figure 3.2.

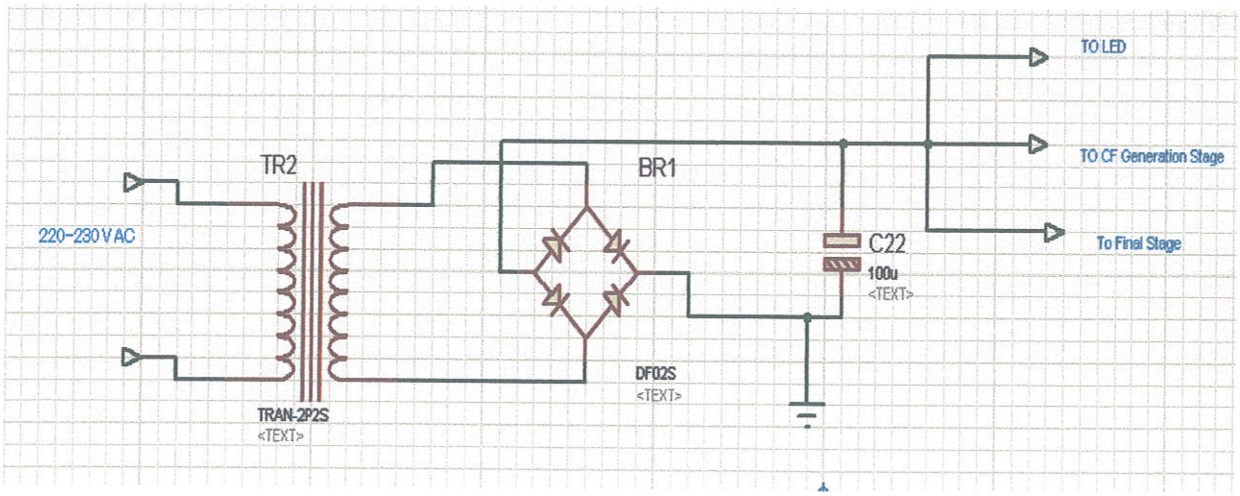

Figure 3.2: Power Supply Stage

3.1.2 The Carrier Frequency Generation Stage.

This is the stage where the carrier frequency of the circuit is generated. It consists of a tank circuit L_1 and VC_1 coupled with the C1674 NPN transistor Q_1 as shown in the figure 3.3. This stage is where the main frequency of the project is generated. Modulation would be impossible without the very high carrier frequency generated in this stage. The frequency generated is then fed the carrier frequency amplification stage through the coupling capacitor C5.

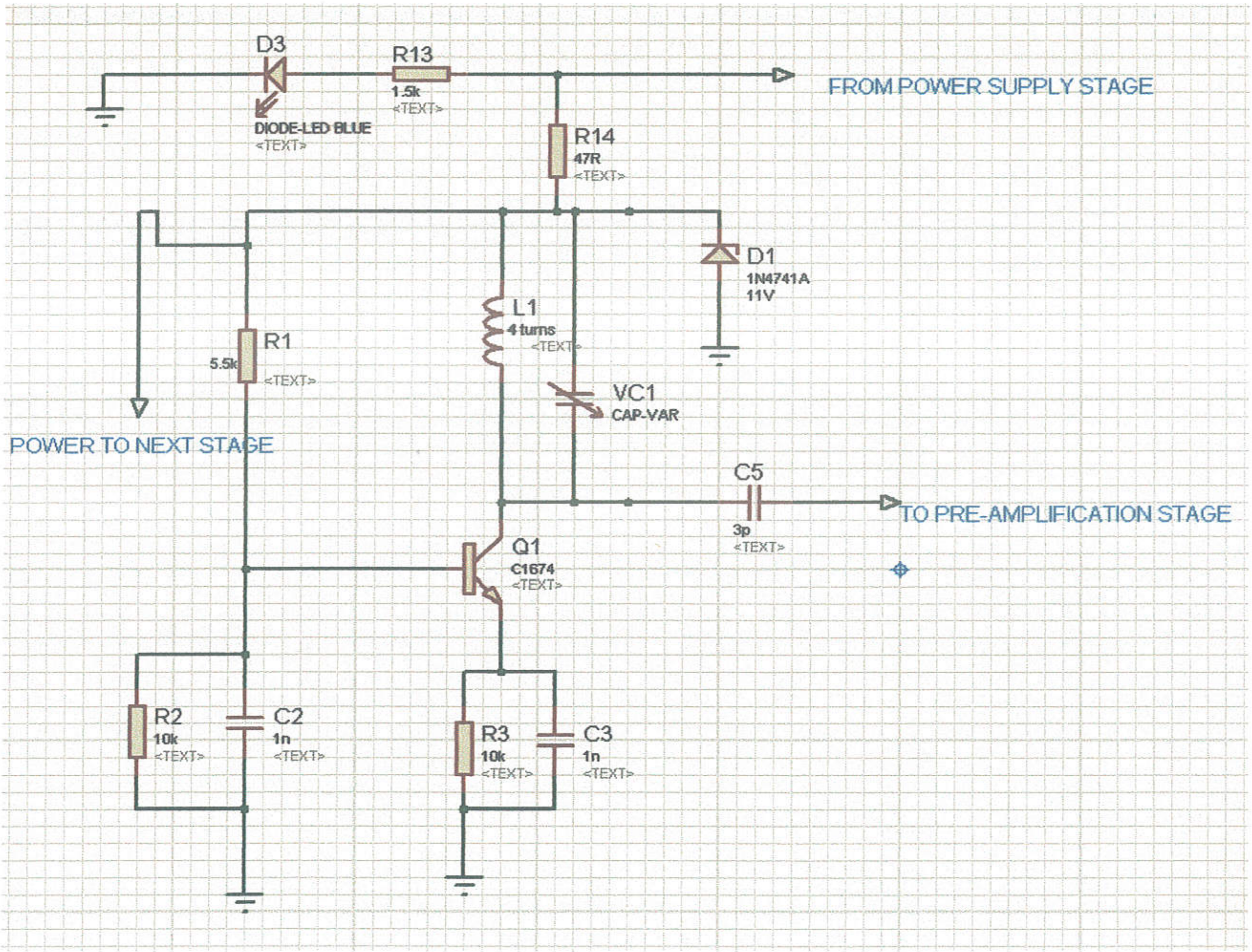

Figure 3.3: Carrier Frequency Generation Stage

3.1.3 Carrier Frequency Amplification Stage

The carrier frequency generated is amplified to a level that can drive the Modulator/Power Amplifier. The circuit is made up of transistor Q_2 , bias resistors R_4 *to* R_6 with a coupling capacitor C_7 as shown in the circuit diagram in Figure 3.4.

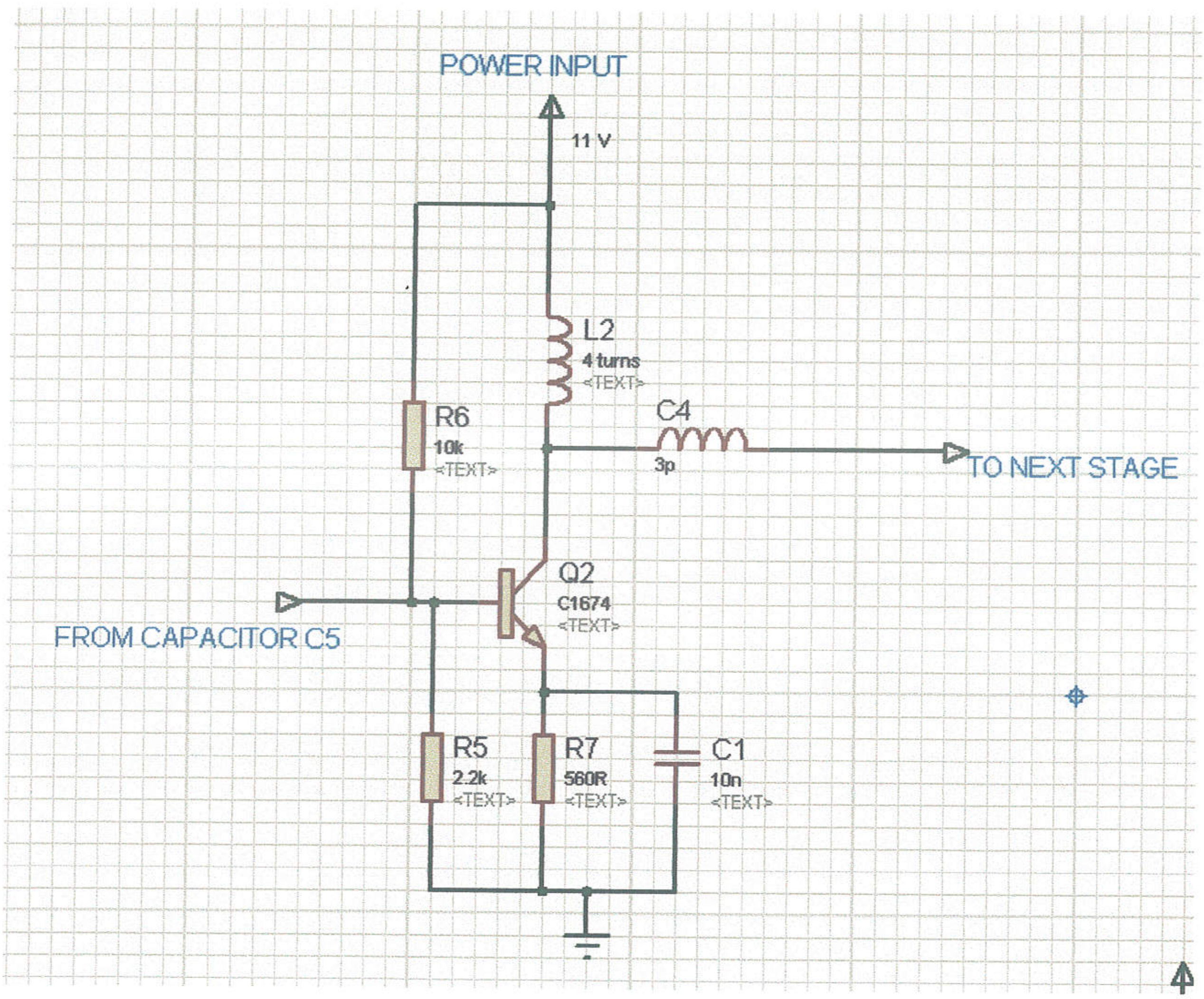

Figure 3.4: Carrier Frequency Amplification Stage

3.1.3 Voltage-Controlled Oscillator Stage

A frequency of 5.5 MHz is generated here. When there is an audio input, this frequency changes to modulate the audio signal. The circuit diagram of the VCO stage is shown in figure 3.5

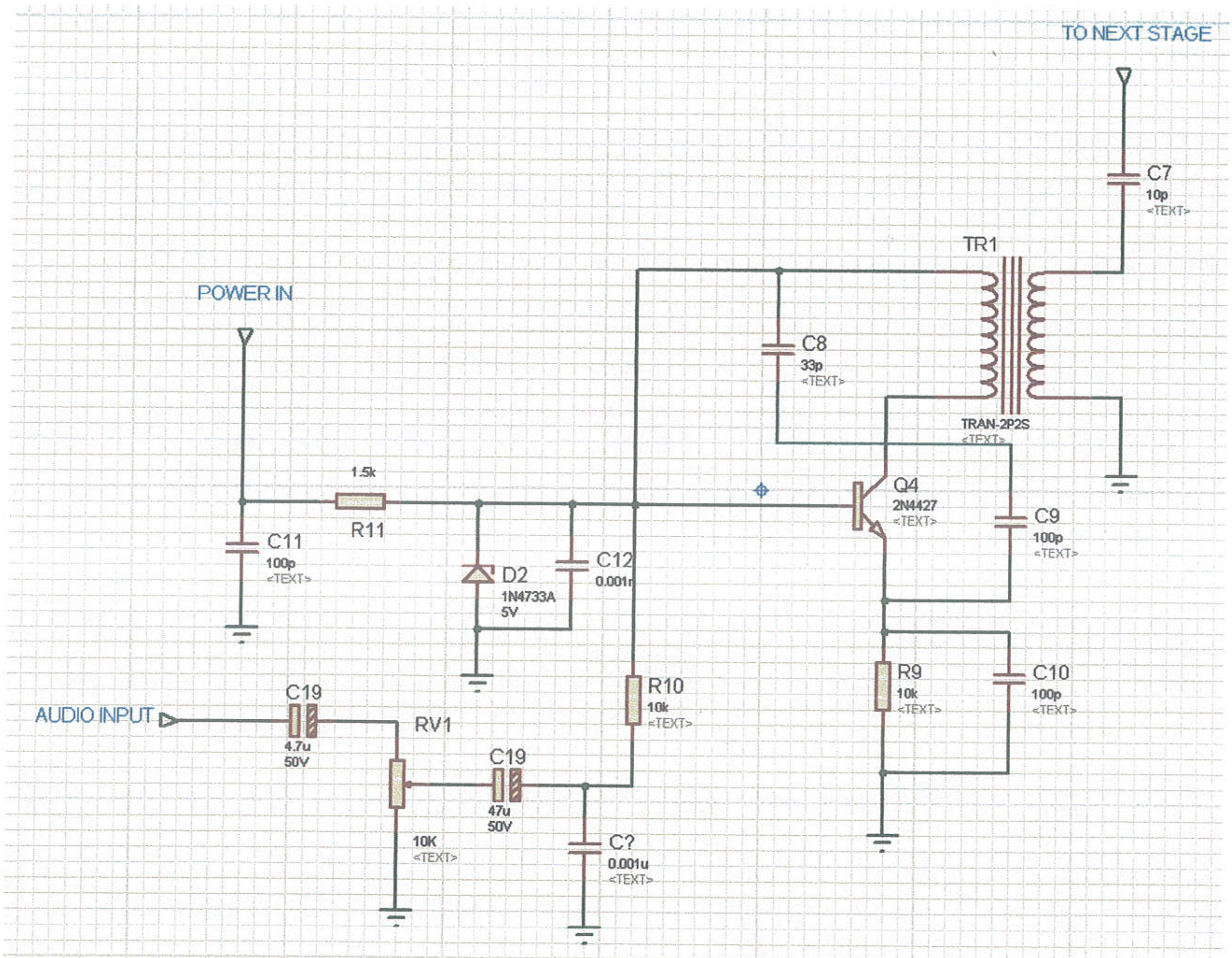

Figure 3.5: Voltage Controlled Oscillator Stage

3.1.4 Modulation and Final Amplification Stage

This is the final stage before the signal gets to the transmitting antenna. Modulation of both the audio and video signals takes places here. Also final amplification of the signal takes place before sent to the antenna for transmission. Figure 3.6 below shows the circuit diagram of this stage.

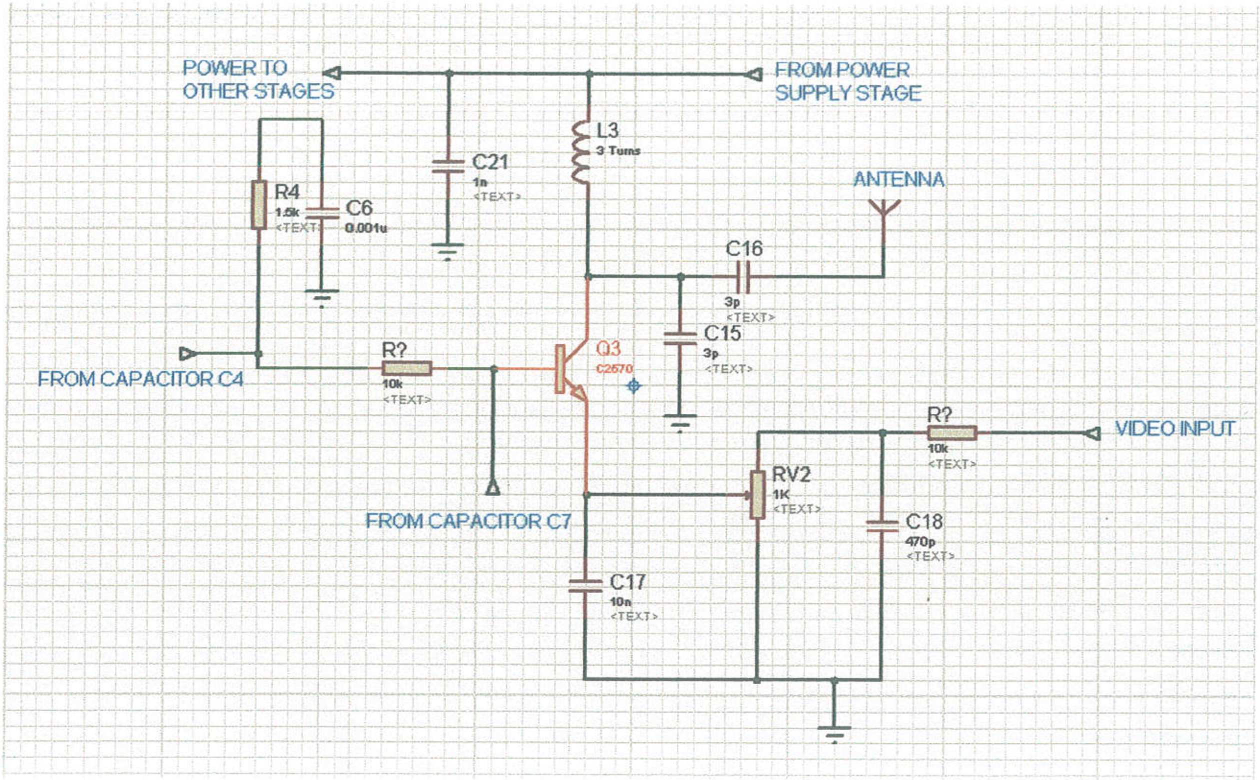

Figure 3.6: Modulation and Final Amplification Stage

3.2 Circuit Operation

The comprehensive circuit diagram of the wireless video transmitter is shown in the figure below. The carrier frequency generator circuit consists of an LC (tank) circuit made up of L1 and VC1. VC1 is a variable capacitor adjustable between (3-12pF). Since a frequency range of 450MHz-550MHz is required; the capacitance of the capacitor in the tank circuit can be adjusted. The resistors R1 and R2 are biasing the transistor Q1. Capacitors C3 and C23 makes up a divider circuit. The Zener diode ZD1 is for regulation of the DC voltage because a constant frequency is required in the circuit. This is what happens at the first stage referred to as the carrier frequency generation stage. C5 is a coupling capacitor that couples the frequency generated by the tank circuit to transistor Q2. The frequency amplification circuit is made up of

Transistor Q2, resistors R4 to R8, inductor L2 and capacitor C1, C4, C6. The resistors R5, R6 are set to the bias transistor Q2 and the capacitor C1 by-passes the frequency to the ground: this is to protect the loss of power at the resistor R7. The inductor L2 sends DC voltage to Q2.

The amplified signal is coupled through the capacitor C4 to transistor Q3, the next stage where power amplification and amplitude modulation of the video signal takes place. The modulated audio signal passes through R8 to this stage. The same R8 and R4 are the bias resistors to Q3. The inductor L3 act same as L2 but because more power is required than the rest of the circuit, power is taken from the main power supply. Capacitors C20, C21 are filter capacitors. C16 filters the current of the signal that is modulated with the modulated video signal. C17, C18, C9 and R10 are used to adjust the amplitude of the signal and VR1 is used to adjust percentage of modulation of the video signal.

The audio signal is coupled through C13 and C19 to the Q4, while RV1 is used to adjust the range frequency deviation. R11 and R12 are the bias resistors. C and C14 are the divider capacitors like C2 and C23. This stage is the VCO stage that produces a center frequency of about 5.5MHz used to modulate the audio signal by FM, which is a frequency different from the carrier frequency of the video signal. TR1 and C8 is the tank circuit where TR1 is a special coil Toko Transformer that helps to achieve the center frequency. The audio signals after FM modulation are coupled to the base of Q3 through capacitor C. Power supply to this stage is regulated to 5 volts by the Zener diode ZD2 with R3 as current limiter and C22 as filter capacitor.

The modulated audio and video signal are superimposed at Q3 and sent to the antenna after which the signals are radiated into the air. Capacitors C15 and C16 is for impedance matching.

There is an LED which indicates when the system is powered. Resistor R13 is the limiting resistor for the D3 (LED).

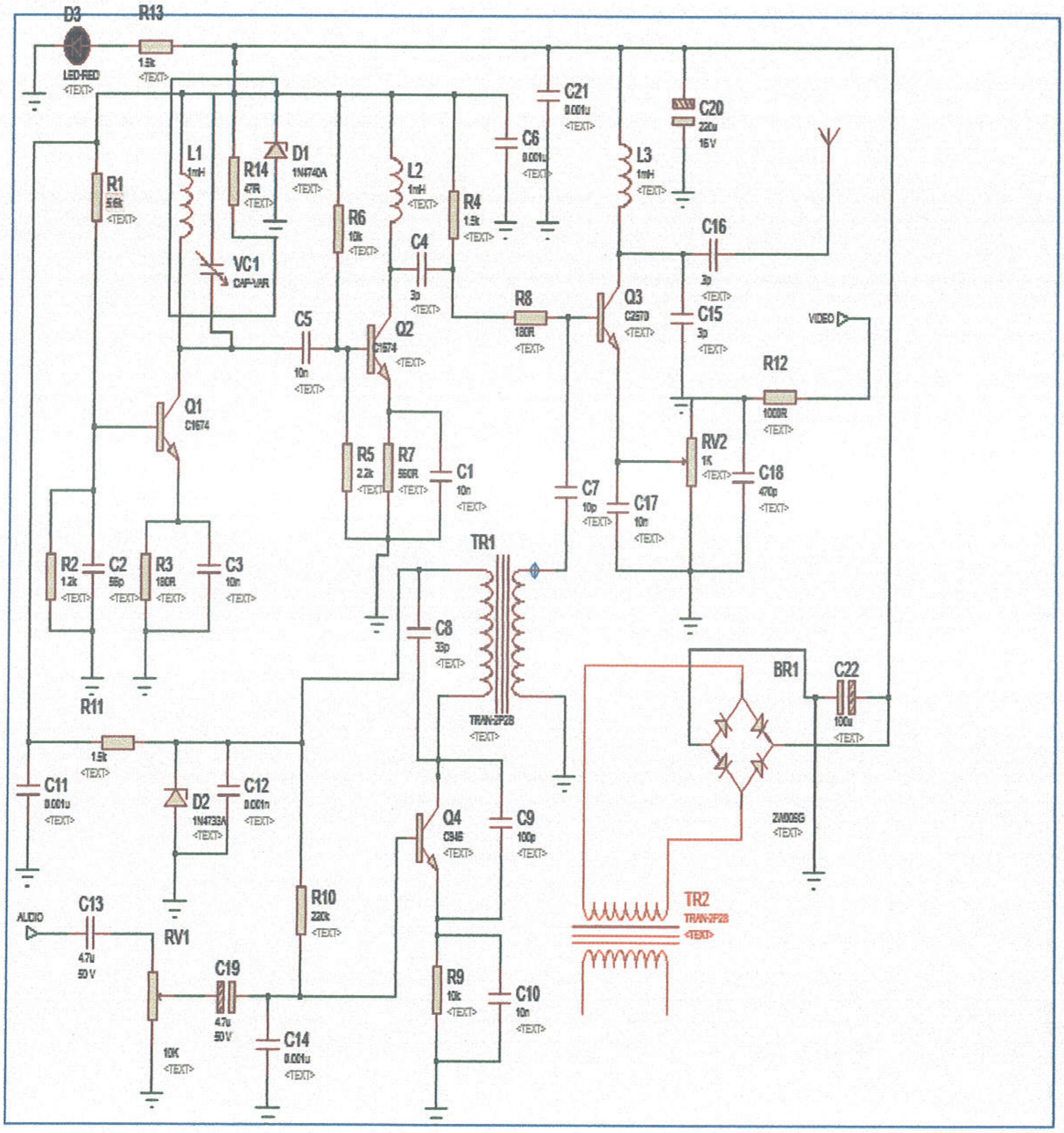

Figure 3.7: Comprehensive Circuit Diagram of the Wireless Audio/Video Transmitter

3.3 Design Calculations

3.3.1 The Carrier Frequency Generation Stage

The inductor L1 and variable capacitor VC1 makes up the tank circuit. The tank circuit generates a very high frequency signal or carrier signal. The frequency of the signal is dependent on the tank circuit and it is to be set in the UHF band between 470 and 960 MHz. The number of turns of the inductor can be calculated assuming a frequency of 500 MHz.

Hence resonant frequency, f

$$f = \frac{1}{2\pi\sqrt{L_1 VC_1}}$$

$$L_1 = \frac{1}{VC_1} \times \left(\frac{1}{2\pi f}\right)^2$$

$$L_1 = \frac{1}{30pF} \times \left(\frac{1}{2\pi \times 500 \times 10^6}\right)^2$$

$$L_1 = 3.377 \times 10^{-9}\, H$$

Inductive Reactance $X_L = 2\pi f L$

$$= 10.609\Omega$$

But

$$L_1 = \frac{\mu_0 A N^2}{l}$$

For core diameter of 6mm and length of coil is 0.05m

$$= \sqrt{\frac{L_1 \times l}{\mu_0 A}}$$

$$N = \sqrt{\frac{3.377 \times 10^{-9} \times 0.05}{4pi \times 10^{-7} \times pi \times ((6/2)^2)}}$$

$$N = 2.15 \ turns$$

Two turns was used for the inductor L1 which would generate a frequency max of 545 MHz

Calculation of the input impedance to transistor $Q_{1(C1674)}$

$$R_{in} = R_1 + (X_{C1}//R_2)$$

$$= 5.6k + (2\pi \times 545 \times 10^6 \times 30pF//1.2k)$$

$$= 5.6k + (0.1027//1.2k)$$

$$= 5600 \ \Omega$$

3.3.2 The Carrier Frequency Amplification Stage

The output of the carrier frequency generation stage is coupled to the input of transistor Q2 by the coupling capacitor C_5. R_4 and R_5 are in parallel forming a voltage divider to bias the transistor Q2, C1674. Capacitor C_6 is chosen to help prevent power loss at R_6.

3.3.3 The VCO Stage

The Voltage Controlled Oscillator (VCO) Stage serves as the audio mixer. It consists of a transformer-coupled class A amplifier built around transformer T1 as shown in figure 3.5. One section of the amplifier forms the LC oscillator while the other couples the signal to the class C amplifier in the next stage. The DC resistance of the transformer primary side, that is, the transformer coupled load is assumed to be zero. The load under AC conditions will therefore be given by:

$$R_L' = \left(\frac{n_1}{n_2}\right)^2 \times R_L$$

where $n_1/\,n_2$ is the transformer turns ratio. This arrangement has the advantage that it is a step-down transformer with $n_1 > n_2$ to give a value of $R_L' > R_L$ to provide a better power match to the device. Figure 3.8 shows the A.C load line of the transformer coupled amplifier

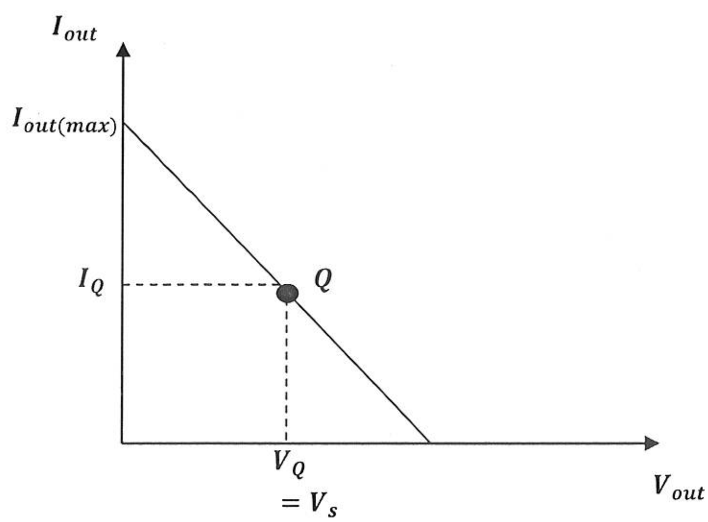

Figure 3.8: AC Load Line of the Transformer-Coupled Amplifier

If the position of the load line and the chosen Q-point is such that

$$V_{out(max)} = 2V_s$$

and

$$I_{out(max)} = 2I_Q$$

then the signal at the output can be the maximum possible value

Output Power, P_{out} is given by:

$$P_{out} = \frac{V_{out(max)}}{2\sqrt{2}} \times \frac{I_{out(max)}}{2\sqrt{2}}$$

and AC Output,

$$P_{ac} = \frac{2V_s}{2\sqrt{2}} \times \frac{2I_Q}{2\sqrt{2}}$$

$$= \frac{V_s}{\sqrt{2}} \times \frac{I_Q}{\sqrt{2}}$$

$$= \frac{V_s I_Q}{2}$$

$V_s I_Q$ is the input power. We can determine the efficiency , η

$$\eta = \frac{P_{ac}}{P_{dc}} \times 100\%$$

$$= \frac{V_s I_Q/2}{V_s I_Q} \times 100\%$$

Efficiency, $\eta = 50\%$

The efficiency of the VCO stage is 50%.

3.3.4 The Modulation and Final Amplification Stage

This stage does two things: It modulates the audio and video signals with the carrier frequency generated in the previous stage, and it amplifies the power of the modulated signal to the antenna for transmission. The transistor Q4 (C2570) was selected because of its high transition frequency, low noise figure and high power gain. Figure 3.6 shows the circuit diagram of this stage.

DC Analysis

The reactance of the inductor L3 is approximately zero. C21 is the DC blocking capacitor which keeps the DC bias current from being redirected to the load. The input voltage Vin is set at a value from the previous stage such that Q is biased in the active region.

AC Analysis

At RF frequencies, the impedance of the DC blocking capacitor is very small. Hence, the RF amplified signal will easily pass through. The total collector voltage is the sum of the DC and AC components:

$$V_{c(t)} = V_{dc} + V_{ac}$$

$$= V_{dc} - \beta I_b R \cos(wt + \phi)$$

Since $V_{dc} = 0$

$$V_c = V_{ac}$$

$$= -\beta I_b R \cos(wt + \phi)$$

Since the DC resistance is zero, the time average value of the collector voltage $V_{c(t)}$ must be equal to V_{cc} .

$$V_{cc} = \frac{1}{T}\int_{t_0}^{t_0+t} V_{c(t)}$$

The class C amplifier gives a non-linear output. Similarly, the circuit simulation on proteus gave output waveforms that record the following:

1. V_c is approximately half sinusoidal wave when Q is OFF (cut-off mode)
2. V_c is approximately zero when Q is ON (saturation mode)
3. V_c is approximately open circuit when Q is ON and signal voltage when Q is OFF

If V_{ON} is small with respect to the peak input voltage V_M, then

$$V_{cc} = V_{ON} + \frac{1}{T}\int_0^{\pi/2} V_M \cos(wt)dt$$

$$V_{cc} = V_{IN} + \frac{V_M}{\pi}$$

Since

$$\frac{1}{T}\int_0^{\pi/2} V_M \cos(wt)dt = \frac{V_M}{\pi}$$

$$\Rightarrow \quad V_M = \pi(V_{cc} - V_{IN})$$

For an input voltage of 3.2 volts from previous stage and $\boldsymbol{V_{cc}}$ remains 12 V

$$V_M = \pi(12 - 3.2)$$

$$V_M = 27.6\ V$$

The DC Power supplied by the source, P_o

$$P_o = V_{cc}\, I_o$$

where $\boldsymbol{I_o}$ is the average current. Due to the blocking capacitor, $\boldsymbol{I_o}$ flows through Q. Assuming Q is never active,

$$V_c = V_{CE(sat)} = V_{IN}$$

such that power dissipated in Q would be given as

$$P_D = V_{in} I_o$$

The power dissipated in the base at instant where Q is active is neglected since it is transitioned from saturation to cut-off and vise-versa.

Hence, the maximum efficiency of this stage is given by:

$$\eta_{max} = \left(\frac{P}{P_o}\ OR\ \frac{V_{cc} - V_{IN}}{V_{cc}}\right) \times 100\%$$

$$= \left(1 - \frac{V_{IN}}{V_{cc}}\right) \times 100\%$$

$$\eta_{max} = \left(1 - \frac{3.2}{12}\right) \times 100\%$$

$$= 73.3\%$$

The value 3.2 volts is the voltage measured from the previous stage output. 73.3% is pretty close to the class C amplifier ideal efficiency which is 73.5%.

The output power is sinusoidal for half-cycle and has a peak voltage swing of Vs, so that

$$P_{ac} = \frac{1}{2}\left(\frac{V_s}{\sqrt{2}} \times \frac{I}{\sqrt{2}}\right)$$

$$P_{ac} = \left(\frac{V_s I}{4}\right)$$

For the given inductor of L3 to meet RF requirements, three turns inductor coil was used to give an inductance of 6.39 nH.

$$X_{L3} = 20.07\ \Omega$$

Collector Current, $I_c = \frac{V_M}{X_L}$

$$I_c = \frac{12}{20.07} = 0.598\ A$$

$$P_{ac} = \left(\frac{27.6V \times 0.598A}{4}\right)$$

$$P_{ac} = 4.126\ W$$

Power density, P.D=

$$\frac{P_{radiated}}{4\pi R^2}$$

Where R is the distance covered by the transmitter

Power radiated by the transmitter is approximately 4000 mW

Power radiated in decibel (db):

$$10 \log P_{ac} = 10 \log 4.126 = 6.15\ dBW$$

For R= 5 m

Power Density $= \frac{4000 \times 10^{-3}}{4\pi \times 5^2} = 0.013\ W/m^2$

Antenna Length, $l_{antenna}$

$$l_{antenna} = \frac{\lambda}{3}$$

$$\lambda = \frac{c}{f}$$

$$\lambda = \frac{3 \times 10^8}{500 \times 10^6}$$

$$= 0.6\, m$$

$$\lambda = 60\, cm$$

$$l_{antenna} = \frac{60}{3} = 20\, cm$$

3.4 Preparing the PCB

A Printed Circuit Board was made because this would make soldering easier since it is just required to place the components on the board and solder them on the PCB. A PCB has pre-defined copper tracks, therefore, wiring is reduced in the circuit and faults arising due to loose connections are mitigated against. In making the PCB, the circuit diagram was first converted into a PCB layout using the proteus software which has a provision for PCB layout creation and design. The PCB layout created was then printed unto a glossy paper using a laser printer. The copper plate for the circuit is then cut according to the size of the printed layout. Afterwards, the copper side of the PCB is cleaned with a steel wool to remove the top oxide and photo resist layer of the copper which would allow image from the paper to stick better. The copper plate and the paper were then well aligned and heat was applied by using a pressing iron for some minutes. This transfer the ink printed on the glossy paper unto the copper plate. Afterwards, the copper plate is immersed in a ferric chloride solution for about 2 minutes.

3.5 Mounting of Components

After making the PCB, the points for components on the copper plate was drilled respectively. Components were then soldered to the PCB board.

3.6 Project Casing

This was made out of metallic casing of a radio device and the top with a thick carbon paper. The mounted components were then enclosed in the casing. The choice of the carbon paper is to reduce noise effect.

CHAPTER FOUR

TESTING, ANALYSIS OF RESULTS AND DISCUSSION

4.1 Testing

During the design and construction of this project, testing and performance evaluation was done. The former was done during and after project construction while the latter was done after the construction of the project. For the audio/video transmitter, the major tests that were carried out include the output voltage of the power supply, the frequency of transmission, the transmission range of the transmitter, input voltage the stages. Others include components measurements and continuity tests. The testing process, testing equipment used and their functions, and project management strategies are discussed in this chapter.

4.1.1 Project Simulation

This was done using the proteus software to ensure that the circuit works before proceeding to the circuit implementation. The diagram shows a screenshot of the result obtained from the circuit simulation. The yellow, pink and blue waveforms show the output obtained at the antenna, audio part and video part respectively. The LED was also lit showing that power is supplied to the circuit.

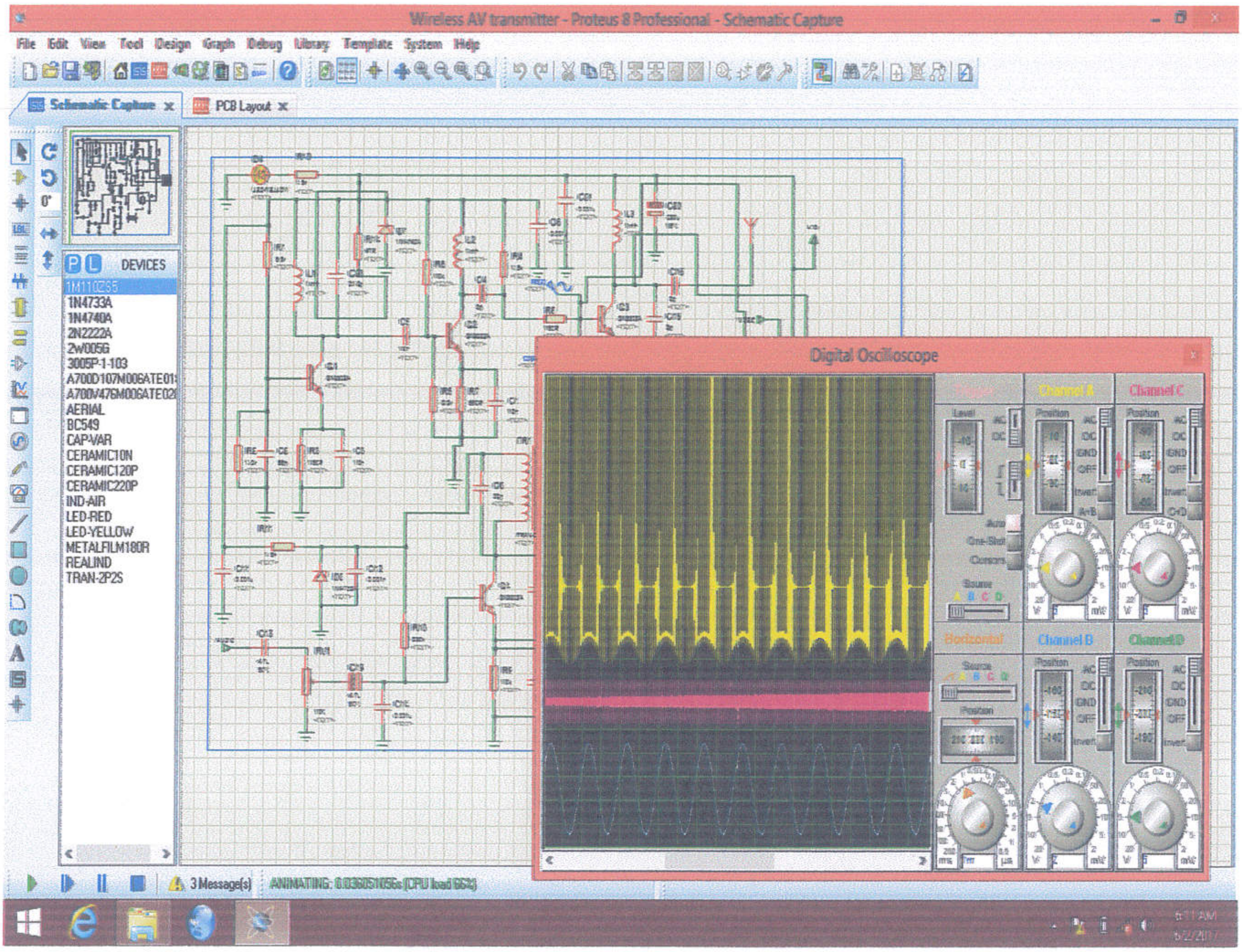

Figure 4.1: Diagram Showing the Simulation Result Obtained from the Circuit

4.1.2 Testing the Circuit on a Bread Board

The project was first tested on a board before the components were being soldered unto the PCB.

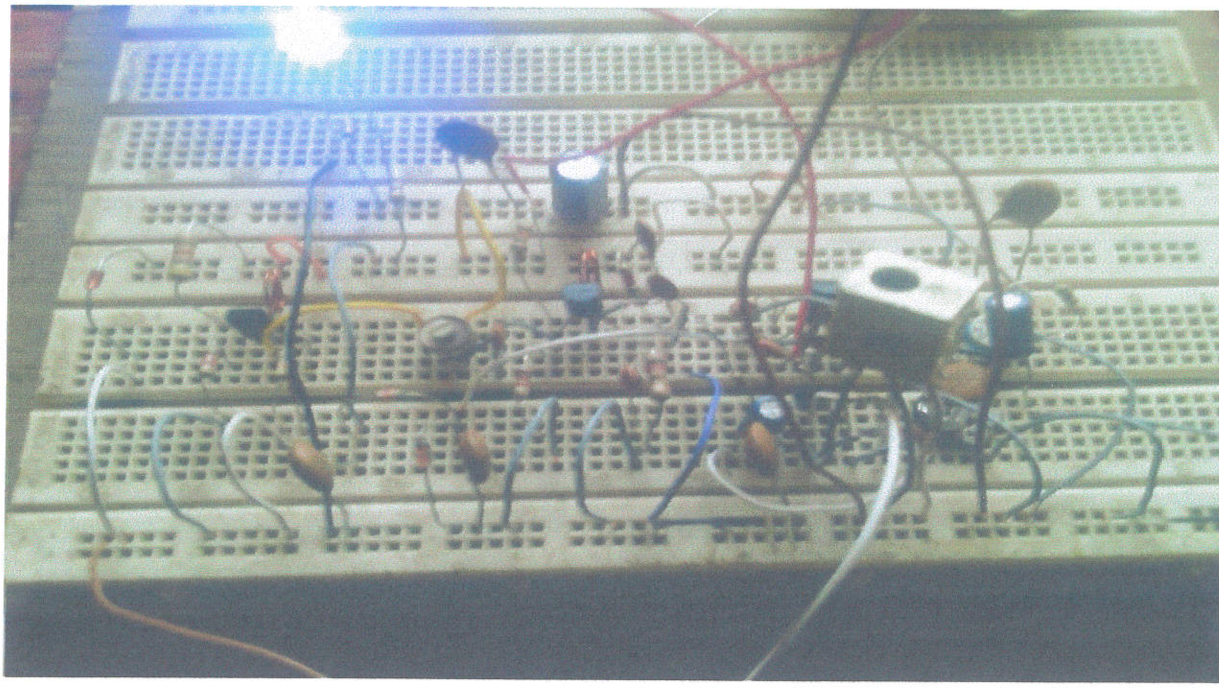

Figure 4.2: Testing the circuit on a breadboard

4.1.3 Testing Equipments

The various testing equipments used and their function are as follows:

- **Bench Power Supply**

Bench Power Supply supplies variable DC voltage. This was used to supply desired value of DC voltage during the bread-boarding stage of the project to the audio/video transmitter circuit.

- **Digital Multimeter:**

This was one of the major equipment used. Digital multimeter was used take measurements such as voltage, current, continuity and frequency.

Figure 4.3: Bench Power Supply

Figure 4.4: Digital Multimeter

- **Capacitance Meter**

Capacitance meter was used to measure the capacitance of the capacitors.

- **Radio Set**

A Radio set was used for testing the audio part of the circuit after implementation on a breadboard. This helped to check if the audio part of the circuit was functioning properly before proceeding with the project construction.

- **Oscilloscope**

Oscilloscope was used to test the output waveforms of the modulated audio/video signals after implementing on a breadboard.

- **Mini DVD Player**

After the full construction of the project, that is, after soldering and casing, the device was tested. The Mini DVD Player was used to send the video input to the wireless audio/video transmitter.

- **Television Set**

The television antenna is the receiver. A TV set from a distance was tuned to test if the video signals from the DVD player would be received.

Figure 4.5: Radio Set

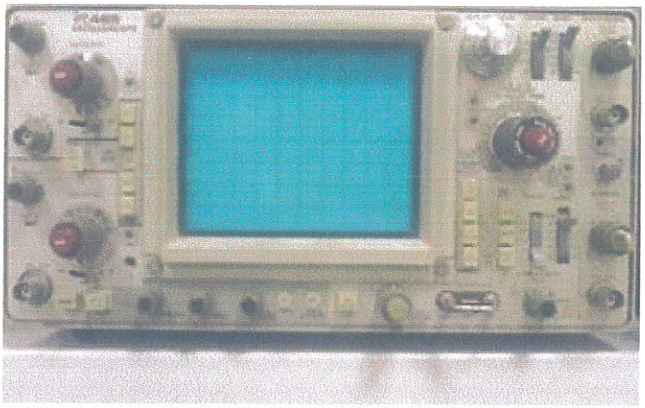

Figure 4.6: Oscilloscope

Figure 4.7: Mini DVD Player

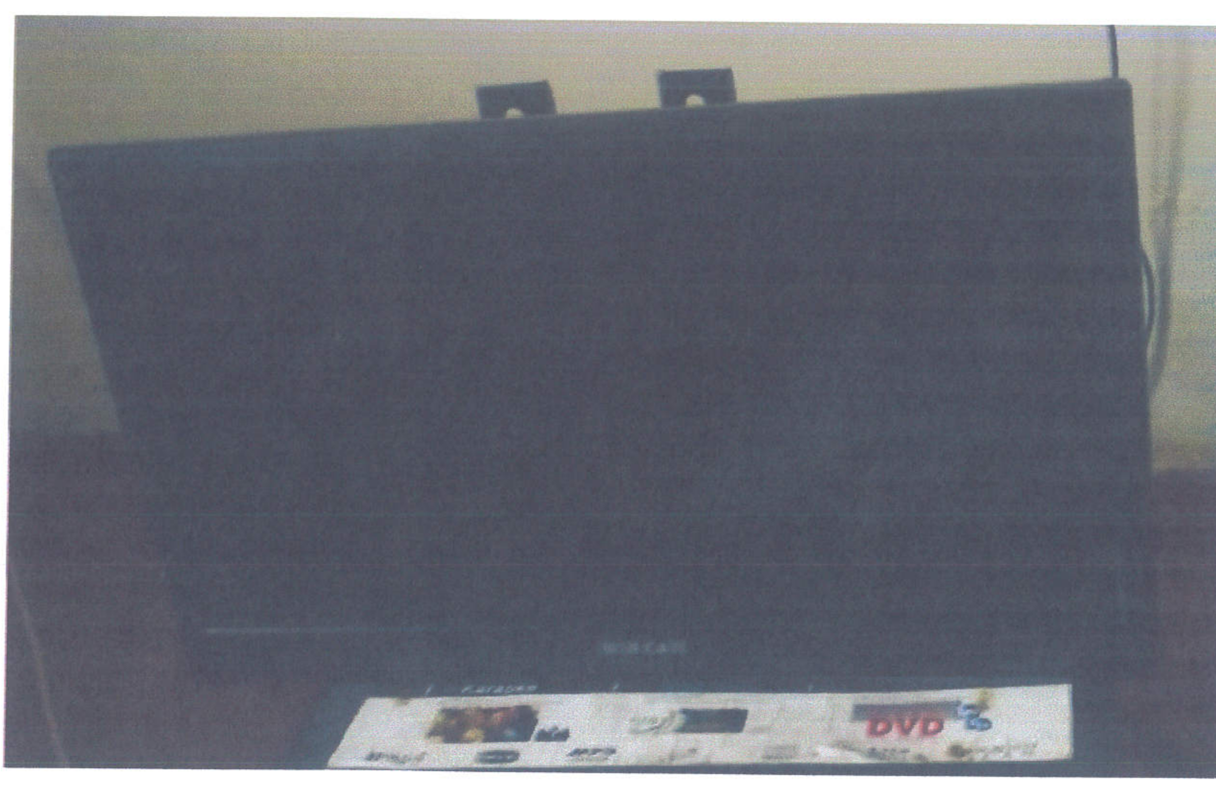

Figure 4.8: Television Set

4.2 Project Management

Project Management entails how the project process was managed. The project schedule, risk management and ethical considerations are discussed in this section.

4.2.1 Project Schedule

Figure 4.4 is a gantt chart showing how the project process went. The whole process was divided into tasks as shown in the gantt chart figure.

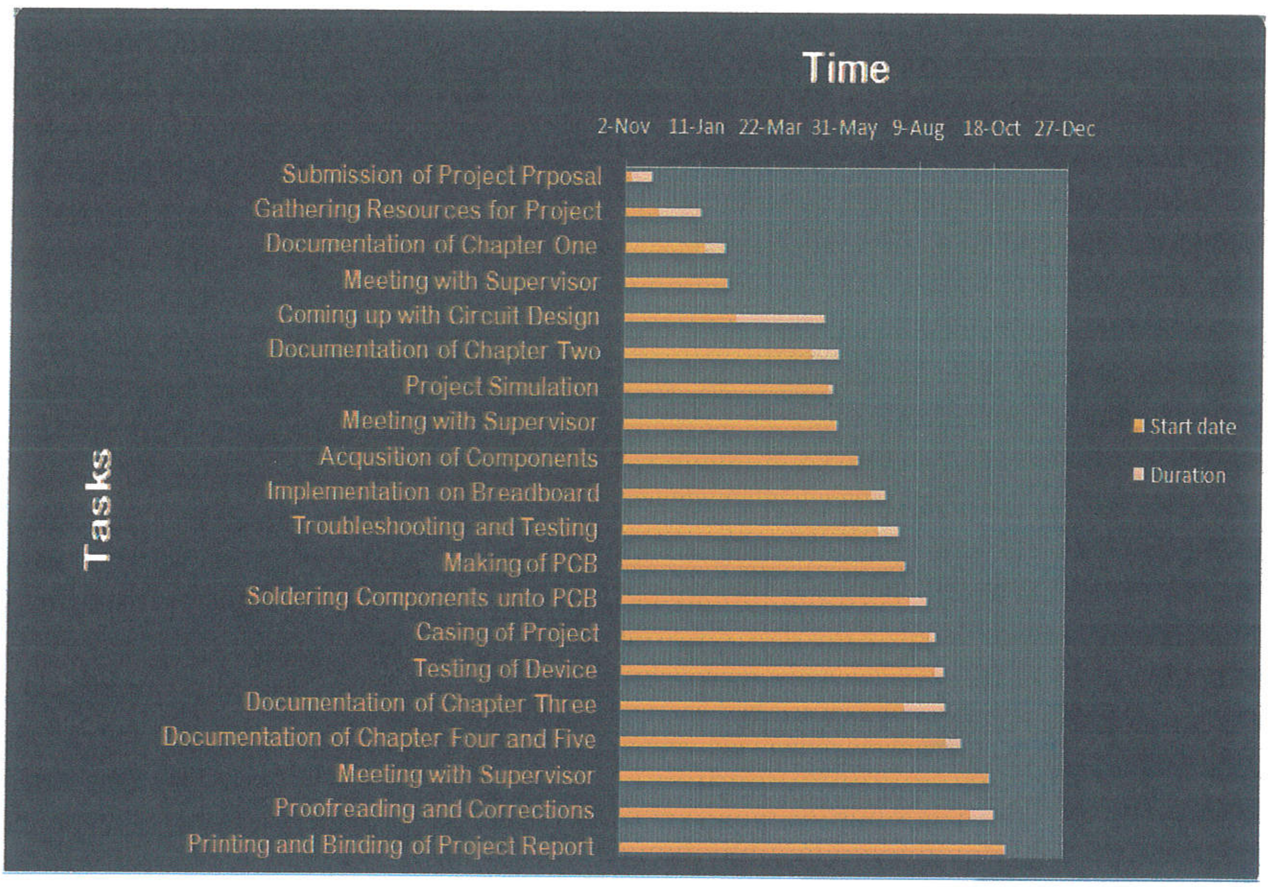

Figure 4.9: Gantt Chart

4.2.2 Risks Management

The risk of power instability in the circuit was managed by using diodes for the regulation of voltage in this circuit. This ensured that the appropriate voltage value is supplied to each stage.

4.2.3 Ethical Consideration

The frequency designation by the ITU for radio frequencies were put into consideration for this project. The UHF band has frequencies between 300MHz to 3GHz.

4.3 Results and Discussion

After the whole design and construction process of the Wireless Audio/Video transmitter, the device was realized that transmitted with a frequency of 702 MHz. This frequency was the frequency observed at reception by the TV. That is, the frequency that was tuned to for the reception of signals transmitted by the transmitter at the receiver (TV) side. The output voltage measured from the power supply was 12.6 volts while the input voltage to the carrier frequency generation stage was 11.2 volts. The device was able to transmit audio/video signal from a DVD player to a Television set(s) conveniently within a distance of 5 meters. This distance was the best distance observed at the reception varying the distance of the TV from the transmitter.

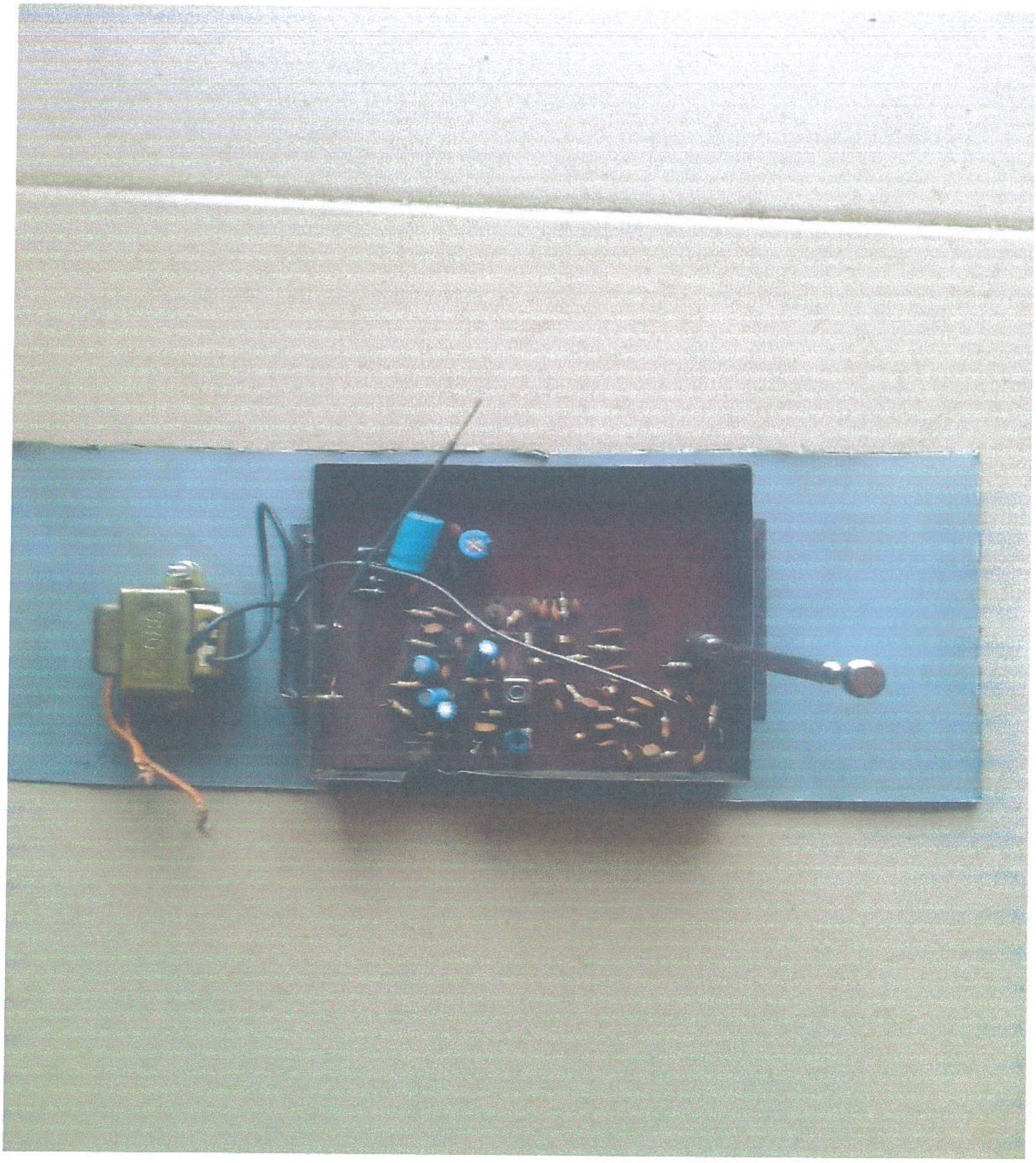

Figure 4.10: Soldered Project on PCB

Figure 4.11: Project in its casing

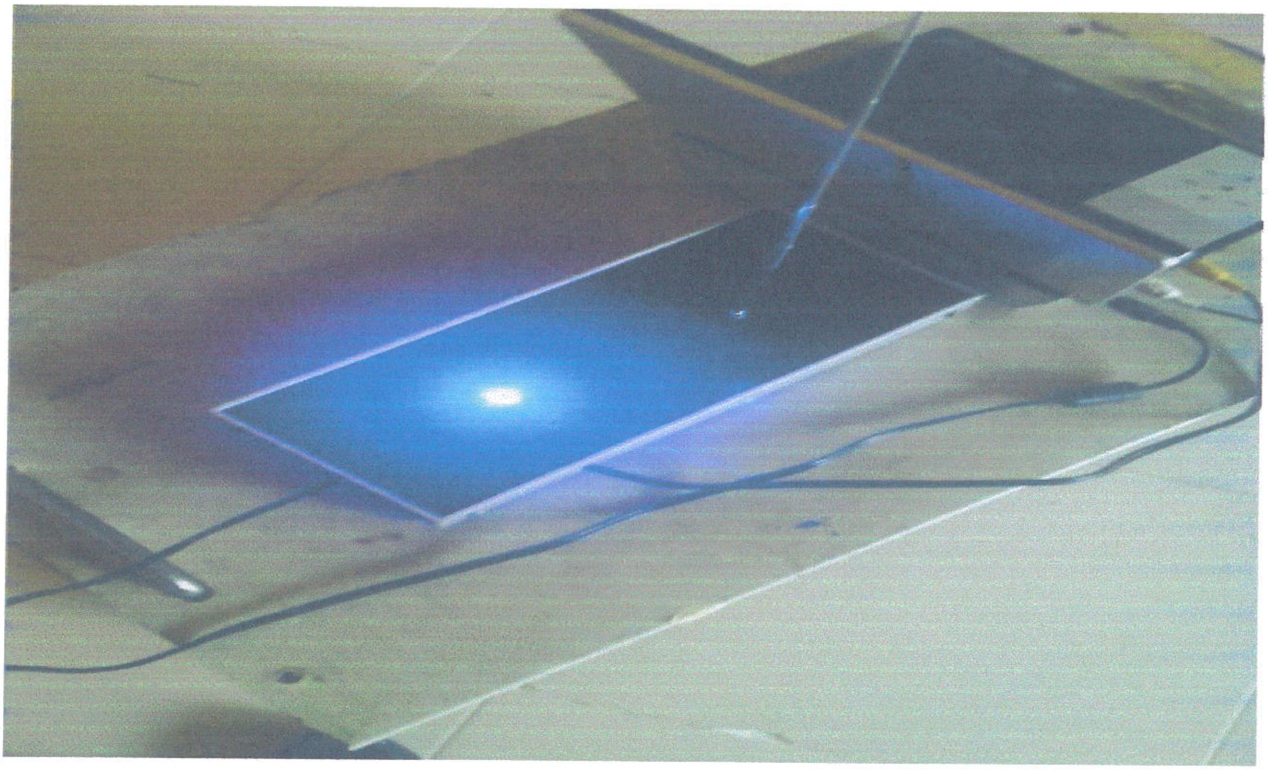

Figure 4.12: The Device Connected to the Mini DVD Player

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

The design and construction of a wireless audio/video transmitter was successfully carried out. This device was able to transmit video signals from a video player to a television receiver by tuning the receiver to a frequency of 702 MHz (UHF) within the range of 5 meters.

5.1 Contribution to Knowledge

This project, the design and construction of a wireless audio/video transmitter has indeed contributed an ample of knowledge in telecommunications. A wireless audio/video transmitter can be achieved by use of discrete components at a low cost and of desirable performance. Frequency modulation, Power amplification and knowledge about oscillators were gained during the design and construction of this project.

5.2 Limitations

A lot of challenges were faced during the period of the project development. Coming up with a design that finally worked took a good ample of time. Availability of project components was another challenge faced. The video stage gave a lot of difficulties before it finally worked. Power was another challenge because battery cell was initially used but it was unable to power the device until when a power supply circuit was designed and used to power the device. The limitation of this project is that it is subject to noise, distortion and interference. Noise generated from the discrete components affects the performance of the system. The signal quality was limited by a lot of factors which include the type of antenna used for transmission and topography.

5.3 Future Works

The range of transmission can be increased to as much as 100 meters and even more. This is possible by increasing the length of the antenna as the antenna length and transmission range have a direct relationship. Another thing is to use a Yagi antenna for transmission. However, transmission at long ranges must be approved by the Nigerian Communication Commissions to avoid interference with other licensed users. To reduce noise effects, integrated circuits can be used for the different circuit stages. A wireless power supply can also be developed for the system to improve on it and make it completely wireless. Also further research can be carried out on wireless video streaming and conferencing.

5.4 Critical Appraisal

The aim and objectives of this project was achieved. I was able to develop and implement a wireless device capable of transmitting audio and video signals from one part of a property to another. This project eliminated the need of cable for connections of TV set to a video player. The device is capable of transmitting conveniently within the range of 5 meters. The device has been implemented and tested, and the transmission quality is very acceptable for the proposed domestic application. A further advantage is the associated cost which is significantly lower when compared with commercial equipment for the same applications.

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APPENDICES

APPENDIX A: Abbreviations

AV transmitter – Audio/Video Transmitter

FM – Frequency Modulation

AM - Amplitude Modulation

PWM – Pulse Width Modulation

PFM – Pulse Frequency Modulation

RF- Radio Frequency

WIFI- Wireless Fidelity

WiMAX – Worldwide Interoperability for Microwave Access

VHF - Very High Frequency

UHF - Ultra High Frequency

ITU – International Telecommunications Union.

c - Velocity of light ($3 \times 10^8\ m/s$)

m/s – metre per seconds

f – frequency (unit is hertz)

Hz - Hertz

A_V = Voltage Gain

Rr = Radiation Resistance

Pt = Transmitted Power

Z_{out} = Output impedance

Z_{in} = Input Impedance

L = Self-inductance of the coil (unit is Henry)

C - Capacitance (unit is Farad)

μ - Micro (10^{-6})

n – Nano (10^{-9})

M – Mega (10^{6})

APPENDIX B: Bill of Quantity

The table below gives the component list and prices as used for the construction for the Audio/Video Transmitter.

COMPONENT	QUANTITY	UNIT PRICE (Naira)	TOTAL (Naira)
C1674 Transistor	2	50	100
C9452 Transistor	1	30	30
C2570 Transistor	1	30	30
IN4733A 5.1V 1W Zener Diode	1	20	20
1N4741A 11V Zener Diode	1	20	20
1k 1/4W Resistor	3	15	45
1.2k 1/4W Resistor	1	5	5
1.5k Resistor	4	5	20
2.2k Resistor	3	5	15
5.6k Resistor	1	5	5
10k 1W Resistor	2	20	40
47k Resistor	3	5	15
220k Resistor	1	10	10
1k Variable Resistor	1	30	30
10k Variable Resistor	1	30	30
3pF Capacitor	3	10	30
22pF Capacitor	2	10	20
33pF Capacitor	2	10	20
56pF Capacitor	1	10	10
10pF Capacitor	3	10	30
100pF Ceramic Capacitor	2	10	20
470pF Capacitor	2	10	20
1nF Capacitor	1	10	10
220uF Capacitor	1	10	10
0.001uF Capacitor	4	10	40
10uF, 25V Capacitor (Electrolytic)	4	20	80
4.7uF, 50V Capacitor (Electrolytic)	4	20	80
Toko Transformer	1	500	500
12V DC Transformer	1	1000	1000
IN4001 Diode	4	10	40
Antenna	1	500	500
Glossy Paper	1	100	100
Circuit Board	1	150	150
Power Cable	1 metre	100	100
Plug	1	200	200
Flexible cable	1 metre	50	50
Casing			1000
TOTAL			N 4,425