

# **DESIGN AND CONSTRUCTION OF UHF TV SIGNAL BOOSTER**

*BY*

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AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN  
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## **DEDICATION**

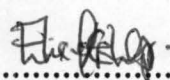
I dedicate this project to Almighty Allah, the owner and decider of faith and also to my new born  
niece, Azizat Yusuf.

## DECLARATION

I Mr. Yusuf Azeez Olaitan, hereby 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 of this work to the Federal University of Technology, Minna Niger state.

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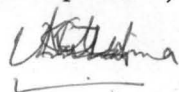
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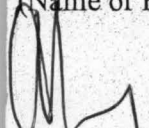
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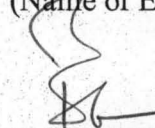
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## ABSTRACT

This project involves the construction of an electronic device that amplifies very weak signals received far away from the transmitting station. The incoming signal through the receiving antenna is matched with the internally generated signal by an oscillator circuit and the resulting signal is amplified through multi-stages of amplification after which the required audio signal is detected through a low pass filter and the amplified desired signal is fed to the television using a driver. The preamplifier consists of two devices, the amplifier component which is contained in a plastic case that is bolted on the antenna and connected directly to the antenna with a short coaxial cable lead. The power for the booster comes from the second component, a power supply unit that is mounted indoors and connected to the preamplifier unit with a larger run of coaxial cable. The complete project was then able to receive UHF signals (between 150-650MHz) within a range of 120km from the transmitter when mounted at the appropriate height.

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## CHAPTER ONE

### 1.0 INTRODUCTION

A television set usually called television or TV set is a device that is used in viewing television broadcasts. Modern television consists of a display, antenna or radio frequency (RF) input and a tuner. The existence of a television tuner in a display device distinguishes it from a monitor-which receives already processed signal. In electronics, an antenna amplifier, also called antenna preamplifier or antenna booster is a device that amplifies an antenna signal usually into an output with the same impedance as the input impedance, typically 75ohm for coaxial cable and 300ohm for twin lead cables. An antenna amplifier allows a weak radio signal to be detected; most devices that receive radio waves already have an RF amplifier stage in the front end that amplifies the antenna signal. Television signal are strongest when the TV stations broadcasting antenna and the home receiving antenna are in line-of-sight. If the line-of-sight is blocked or weakened by hills, buildings or trees, the signal, likewise will be weakened or lost. The signal will also get weaker as it travels farther from the broadcast antenna, hence the need for an antenna booster. TV antenna preamplifiers boost TV signals in poor reception area. Missing channels and a grainy video signal on the TV set can indicate that the antenna requires a preamplifier to work properly. A preamplifier on the TV antenna boosts the broadcast signal with enough strength to improve the video quality on the TV set and provide the full range of over- the-air TV channels.[15]

A prominent device which enables a television to convert the received electromagnetic waves into radio frequency signal for further processing is referred to as an active antenna. An active antenna is an antenna that has an amplifier built into it. This allows an amplifier to be close to the antenna, which minimizes transmission line losses. The design and construction of an amplifier which the active antennas used in realizing its signal

improvement for better reception at the receiver (TV set) based on the sensitivity of the receiver is the basis of this project. Antennas with built in amplifiers are usually used only for receiving, since transmitters usually have their own amplifier, which can handle the high power supplied to the transmitter.[12]

### **1.1 OBJECTIVES**

1. To be able to receive VHF-UHF signal over a long distance (120km) without interruption.
2. To enhance efficiency of reception in television.
3. To boost very weak signals.
4. To design effective, cheap and compact system for better reception.

### **1.2 AIMS**

To provide opportunity of multiple TV station selection to viewers in remote areas and far away from the transmitting station.

### **1.3 METHODOLOGY**

The power supply unit feeds the preamplifier unit with the power necessary to amplify the level of the incoming TV signal that the antenna receives. This lifts the weak signal with enough strength to allow the tuner in the TV set to receive the channel and decode the video and audio information contained in the signal.

#### **1.4 SCOPE OF WORK**

This project is the design and construction of an electronics device that boosts very weak signals received at a very far distance away from the transmitting station where very small proportion of this signal is being received at a much lesser strength than the receiver sensitivity. It operates in the VHF-UHF range (1.5MHZ-650MHZ).

#### **1.5 CONSTRAINTS**

Signal booster can cause reception problems by boosting local strong TV signals to a level which they interfere with the weaker stations that actually require amplification. Local radio stations can also cause reception problems on amplified antenna systems.

#### **1.6 SOUCES OF MATERIAL**

The source of material is majorly Internet browsing and some little additions from experience gathered in the course of carrying out the project.

## CHAPTER TWO

### 2.0 LITERATURE REVIEW/THEORITICAL BACKGROUND

#### 2.1 BRIEF HISTORY OF ANTENNA

The first experiments that involved the coupling of electricity and magnetism and showed a definitive relationship was that done by Faraday somewhere around the 1830s. He slid a magnet around the coils of a wire attached to a galvanometer. In moving the magnet, he was in effect creating a time-varying magnetic field, which as a result (from Maxwell's Equations), must have had a time-varying electric field. The coil acted as a loop antenna and received the electromagnetic radiation, which was received (detected) by the galvanometer - the work of an antenna. Interestingly, the concept of electromagnetic waves had not even been thought up at this point. In 1886, Heinrich Hertz developed a wireless communication system in which he forced an electrical spark to occur in the gap of a dipole antenna. He used a loop antenna as a receiver, and observed a similar disturbance. [4]

The word Antenna was popularized by an Italian scientist named Guglielmo Marconi. Way back 1895; this Italian scientist was doing an experiment on wireless equipment in the Alps of Salvan, Switzerland. Antenna is known to the Italians as "l'antenna central" and this also refers to a tent pole, a tent pole which Marconi later discovered that was able to serve as a device or access point in receiving and transmitting wireless signals. Marconi was the person who named "l'antenna central" as antenna as known today and which is universally known as the equipment to transmit and receive wireless signals. By 1901, Marconi was sending information across the atlantics. For a transmit antenna, he used several vertical wires attached to the ground. Across the atlantics, the receiver antenna was a 200 meter wire held up by a kite. In 1906, Columbia University had an Experimental Wireless Station where they used a transmitting aerial cage, this was a cage made up of wires and suspended in the

air, resembling a cage. The followings are major common antennas and their discovery dates; Yagi-Uda Antenna (1920s), Horn antennas (1939), Antenna Arrays (1940s), Parabolic Reflectors ( late 1940s early 1950s), Patch Antennas (1970s),PIFA (1980s). [4]

## 2.2 THEORITICAL BACKGROUND

Basically, antenna is an electrical gadget created in order to receive and transmit electromagnetic waves. Often a device called a TV antenna amplifier is used together with a TV antenna in order to boost TV signal and antennas are normally used in many ways such as in radio, television, radar, cell phones and other practice that needs the electromagnetic waves. The figure below shows the basic block diagram of a TV receiver.

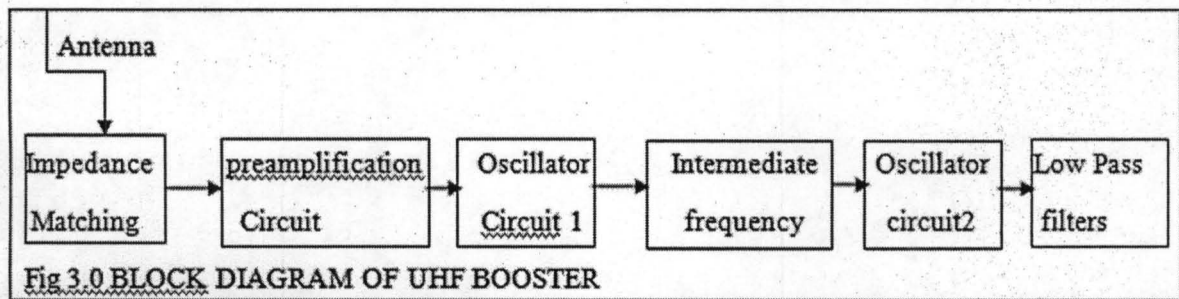


Fig 2.0 Basic block diagram of a VHF-UHF booster receiver

### 2.2.1 AMPLIFIERS

A common theme in many electronic circuits is the need to increase the level of voltage, current or power present. This need is satisfied by some form of amplifier. While this design is devoted to amplifier circuits generally, it excludes all form of circuit based on general purpose integrated circuit operational amplifiers.

### **2.2.1.1 Amplifier characteristics and specification**

Amplifier may be categorized under a number of characteristics such as frequency response, class of operation and the type of circuitry employed. The following are six general categories that are commonly used:

### **2.2.1.2 Classification according to frequency response**

1. Audio frequency amplifier: a low frequency amplifier which typically operates over the frequency range 20Hz to 20kHz
2. Radio frequency amplifier: A high frequency amplifier which is invariably frequency selective
3. Wideband: An amplifier with an extends frequency response (typically from below 10Hz to 10MHz)

### **2.2.1.3 Classification according to operating point**

1. Linear: operation is confined to the linear part of the transistor in which the output of the amplifier is directly proportional to the input
2. Non-Linear: operation extends into the non-linear part of the characteristics. This is when the linear operation of the amplifier is exceeded and the output is no more proportional to the input thereby creating additional noise to the device

#### **2.2.1.4 Classification according to signal amplitude**

1. Small signal amplifiers: Signals are of sufficiently small amplitudes for parameters to be considered constant, hence generalized small equivalent circuit may be used in circuit analysis.
2. Large signal amplifiers: Signals are of relatively large amplitude and parameters cannot be relied upon to remain constant. Small equivalent circuits are then not particularly relevant.
3. Preamplifier: A low level small-signal amplifier which precedes signal amplifier or power output stage.
4. Power amplifier: A large signal amplifier designed to develop an able level of power in a specified load.

#### **2.2.1.5 Classification according to noise and/or distortion**

1. Low noise amplifier: An amplifier which by virtue of its design and selective devices contributes a negligible amount of noise to the undergoing amplification.
2. Low distortion: An amplifier which by virtue of its design and appropriate selection of active devices contributes a negligible amount of distortion to the signal undergoing amplification.

### 2.2.1.6 Important characteristics associated with amplifiers

1. **Gain:** This is the ratio of output voltage to input voltage (voltage gain), output current to input current (current gain), or output power to input power (power gain). Gains are expressed in decibels (dB).
2. **Input impedance:** This is the ratio of input voltage to input current and is expressed in ohms. The input of an amplifier is normally resistive in the minimum of its frequency range.
3. **Output impedance:** This is the ratio of open-circuit output voltage to the short-circuit output current and is measured in ohms. Note that impedance is internal to the amplifier and should not be confused with the impedance of the load.
4. **Frequency response:** Frequency response is usually specified in terms of the upper and lower cut-off frequencies of the amplifier. These frequencies are those at which the output power has dropped to 50% (otherwise known as the -3dB points) or where the voltage gain has dropped to 70.7% of its mid-band value.
5. **Bandwidth:** The bandwidth of an amplifier is usually taken as the difference between the two cut-off frequencies.

### 2.2.2 IMPEDANCE MATCHING

This is the practice of designing the input impedance of an electrical load or the output impedance of its corresponding signal source in order to maximise the power transfer and/or minimise reflections on load. The concept of impedance matching was originally developed for electrical power but can be applied to any other field where a form of energy is transferred between a source and a load. Impedance matching to minimise reflections and maximize power transfer over a relatively large bandwidth (also called reflectionless



matching or broadband matching) is the most commonly used. To prevent all reflection of the signal back into the source, the load must be matched exactly to the source impedance. In this case if a transmission line is used to connect the source and load together, it must also be the same impedance:

$$Z_{\text{load}} = Z_{\text{line}} = Z_{\text{source}}$$

Where  $Z_{\text{line}}$  is the characteristic impedance of the transmission line

Although source and load should be totally resistive for this form of matching to work, the more general form of impedance is still used to describe the source and load characteristics. Any reactance present in the source or the load will affect the match.[11]

### 2.2.3 INTERMEDIATE FREQUENCY

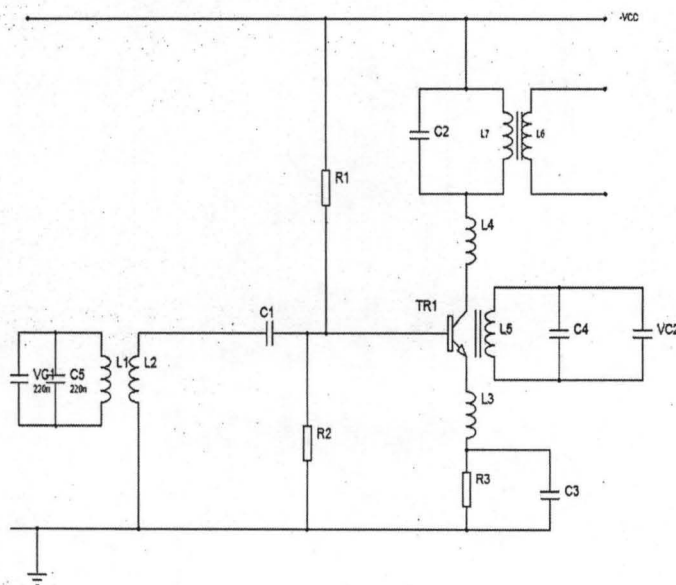
In communications and electronics engineering, an intermediate frequency (IF) is a frequency in which a carrier frequency is shifted as an intermediate step in transmission or reception of a signal, it is created by mixing the carrier signal with a local oscillator signal in a process called heterodyning resulting in a signal at the difference or beat frequency.

Intermediate frequency is used when at very high frequencies, signal processing circuitry performs poorly and active devices such as transistors cannot deliver much amplification (gain) without becoming unstable, it is also used when ordinary circuits using capacitors and inductors must be replaced with cumbersome high frequency techniques such as strip lines and waveguides before processing, so a high frequency signal is converted to a low IF for processing. Another way to use an IF in receivers that can be tuned to different stations is to convert the various different frequencies of the station to a common frequency for the processing of the signal.

Since it is difficult to build amplifiers, filters and detectors that can be tuned to different frequencies, but easy to build tune-able oscillators, superheterodyne receivers are tuned in different stations simply by adjusting the frequency of the local oscillator at the input stage and all processing after that is done at the same frequency. Without using an IF, all the complicated filters and detectors in a radio or television would have to be tuned in unison each time the station was changed, as was necessary in the early tuned radio frequency receivers.[10]

### 2.2.4 The Mixer-Oscillator circuit

One circuit commonly employed for frequency changing is the mixer oscillator. It is used in radio and TV receivers to produce the intermediate frequency and figure 2.2 shows such a circuit suitable for an am radio receiver. The RF carrier  $f_1$  is selected by tuned circuit VC<sub>1</sub>-C<sub>5</sub>-L<sub>1</sub> and fed into the base of TR<sub>1</sub> via transformer coupling L<sub>1</sub>-L<sub>2</sub> and coupling capacitor C<sub>1</sub>. The output developed across L<sub>4</sub> is fed back via transformer coupling L<sub>1</sub>-L<sub>5</sub>-L<sub>3</sub> into the emitter of the transistor. The feedback is positive, producing oscillators.



### **Fig. 2.1 Mixer oscillator circuit for r.f receivers**

The frequency of oscillation  $f_0$  is determined by the tuned circuit  $L_5-C_4-VC_2$ . The two frequencies  $f_0$  and  $f_1$  are mixed together to produce the original two frequencies as well as their sum  $f_0+f_1$  and their difference  $f_0-f_1$ . The collector load  $C_2-L_6$  is tuned to the difference  $f_0-f_1$  which is the IF.

### **2.3 LITERATURE REVIEW**

The nearly similar project that has been previously constructed which give rise to the thought of this project is the normal antenna booster that is currently in market. This booster cover both the VHF and UHF in it's construction and can only amplify signal in a distance range far more less than this project (about 50km). It's construction is similar to this project only that the construction involved the use of single amplifier stage and the selection of amplifier is based on the it's high frequency response.

### **2.4 Limitations**

Preampifier can cause reception problem by boosting local strong TV signals to a level where they interfere with the weaker stations that actually require amplification. Local radio stations can also cause reception problems on amplifier antenna system.

## CHAPTER THREE

### 3.0 DESIGN, IMPLEMENTATION AND CONSTRUCTION

UHF signal booster comprises number of stages from the input when the signal is received by the antenna to the output when the amplified RF signal is driven to the television.

The realization of this project follows the arrangement of circuit as shown in the block diagram below;

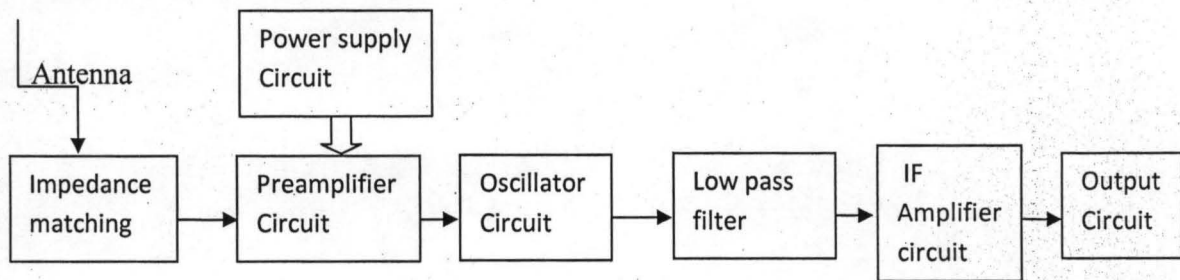


Fig3.0 BLOCK DIAGRAM OF THE DESIGN

### 3.1 PRE-DESIGN ANALYSIS

In TV broadcasting, several RF signals are impinging on the receiving antenna but most of these signals do not have enough power for the receiver to detect and only transmitters nearer to the receiver are being detected for further processing. In order for the far away signals to have sufficient strength at the receiver, an amplifier is needed to boost the signal power to meet up with the sensitivity of the receiver. To estimate the amount of amplification that is required on the received signal, the analysis of the transmission link known as link budget is required.

#### 3.1.1 Link budget

Link budget is the process of determining what is required to achieve a minimum signal level at the receiver. It is the accounting of all the gains and losses from the transmitter through the medium to the receiver in a telecommunication network system.

Received power at the receiver is given as,

$$P_R = P_T - \text{Losses} \dots\dots\dots 3.0$$

For Isotropically radiated antenna; path loss in dB is expressed below for a signal operating at 500MHZ from a distance of 120km from the transmitter.

$$L_{dB} = -20\log(\lambda) + 20\log(d) + 21.98 \dots\dots\dots 3.1$$

path loss in dB,

$$\lambda = \frac{c}{F} \dots\dots\dots 3.2$$

$$\lambda = \frac{3 \times 10^8}{500 \times 10^6} = 0.6\text{m}$$

$$d = 120,000\text{m}$$

$$L_{dB} = -20\log(0.6) + 20\log(120,000) + 21.98\text{dB}$$

$$= 4.44\text{dB} + 101.58 + 21.98$$

$$= 128\text{dBW}$$

Assuming the antenna is transmitting at 2000watts.

$$P_T(\text{dB}) = 10\log_{10}(2000)$$

$$= 33\text{dB}$$

$$\therefore \text{Received Power, } P_R = 33 - 128 = -95\text{dBw}$$

$$-95\text{dBw} = 3.16 \times 10^{-10}\text{Watt}$$

Since, amplifier is a device that amplifies the voltage level of the signal to a level at which it can have sufficient strength at the receiver, it become necessary to obtain the received voltage level of the signal at such power obtained above.

To obtain the received voltage level of the signal

Characteristics Impedance of the line

$$Z_0 = \sqrt{\frac{\mu_0}{\epsilon_0}} = \sqrt{\frac{4\pi \times 10^{-7}}{8.85 \times 10^{-12}}} = 377 \Omega/m \quad \dots\dots\dots 3.3$$

For a distance of 120km, the characteristics Impedance is

$$Z_0 = 377 \times 120,000$$

$$= 45.24 \times 10^6 \Omega$$

$$\text{Power} = \frac{\text{voltage}}{\text{Impedance}} \quad \dots\dots\dots 3.4$$

Received Voltage = Received Power  $\times$  Characteristics Impedance

$$V_R = P_R \times Z_0 \quad \dots\dots\dots 3.5$$

$$= 3.16 \times 10^{-10} \times 45.2 \times 10^6$$

$$= 0.014 \text{Volts}$$

For a Television receiver whose minimum sensitivity is  $-50dBm$ , it became necessary that the design specification should be to amplify the voltage signal to a level at which the received signal level (RSL) is equal or greater than the sensitivity of the receiver in order to have a visible communication across the link.

The voltage level required to obtain a received signal level (power) of  $-30\text{dBw}$  at the receiver which gives a enough loss margin for good quality signal reception in bad weather is expressed as shown below;

From equation 3.5,

Received Voltage = Received Power  $\times$  Characteristics Impedance

$$\text{i.e } V_R = P_R \times Z_0$$

$$P_R = -30\text{dBw}$$

$$-30\text{dB} = 10\log P_R$$

$$P_R = \text{Antilog} \left( \frac{-30}{10} \right)$$

$$P_R = 1 \times 10^{-3}\text{W}$$

$$Z_0 = 45.24 \times 10^6 \Omega$$

$$V_R = 1 \times 10^{-3} \times 45.24 \times 10^6$$

$$= 452.4\text{Volts}$$

$$\cong 452\text{Volts}$$

$$V_R (\text{dB}) = 20\log_{10} 452$$

$$= 53.1\text{dBv}$$

### 3.1.2 Antenna Height

The distance between two antennas in km with height  $h_1$  and  $h_2$  respectively is given as

$$d = 3.57 (\sqrt{kh_1} + \sqrt{kh_2}) \dots\dots\dots 3.6$$

if  $h_1$  = height of the transmitting antenna

$h_2$  = height of the receiving antenna

$$K = 4/3 \text{ (constant)}$$

With a transmitting distance of 120km and transmitting height of 200m, the corresponding receiving height is expressed below

$$120 = 3.57 (\sqrt{kh_1} + \sqrt{kh_2})$$

$$\sqrt{kh_1} + \sqrt{kh_2} = \frac{120}{3.57}$$

$$\sqrt{kh_1} + \sqrt{kh_2} = 33.6$$

$$\sqrt{kh_2} = 33.6 - \sqrt{kh_1}$$

$$\sqrt{kh_2} = 33.6 - \sqrt{1.33 \times 200}$$

$$\sqrt{kh_2} = 33.6 - 16.3$$

$$\sqrt{kh_2} = 17.3$$

$$kh_2 = 17.3^2$$

$$kh_2 = 299$$

$$\text{Therefore, } h_2 = \frac{299}{1.33}$$



$$h_2 = 225\text{m}$$

This means that a receiving antenna must be at least 220 meters high in order to receive the transmitted signal clearly.

## 3.2 DETAILED DESIGN PROCESS

### 3.2.1 Impedance Matching Circuit

With an operating frequency of 500MHZ the design of a resonance circuit that will resonate at the same frequency with an incoming signal for a proper match was arrived at using the following circuit constants

Design parameters:

choosing an inductor of 10nH, the corresponding capacitor that will resonate at 500MHZ was

obtained by the following expression

$$F = \frac{1}{2\pi\sqrt{LC}} \dots\dots\dots 3.7$$

$$\sqrt{LC} = \frac{1}{2\pi F}$$

$$\sqrt{LC} = \frac{1}{2\pi \times 500 \times 10^6} = 3.183 \times 10^{-6}$$

$$LC = 1.013 \times 10^{-19}$$

$$C = \frac{1.013 \times 10^{-19}}{10 \times 10^{-9}} = 10.13 \times 10^{-12}$$

$$C \approx 10\text{pF}$$

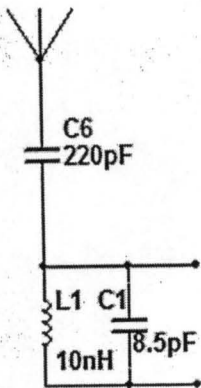


fig 3.1 impedance matching circuit

The impedance matching circuit was designed as shown above with the two circuit parameters (inductor and capacitor) connected in parallel with each other

### 3.2.2 Pre-amplification stage

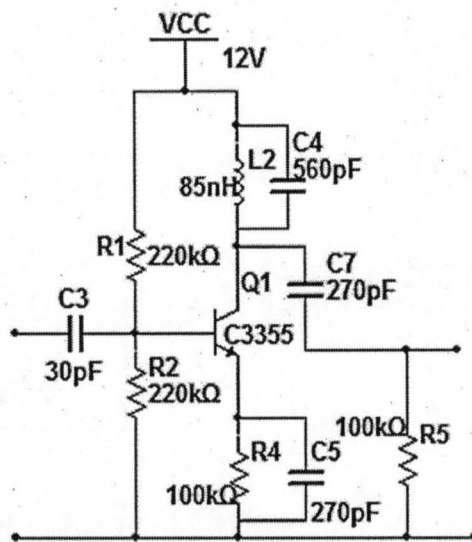


fig 3.2 pre-amplification circuit

This is the second stage of the design and it is particularly necessary in order to amplify the received signal to a level that the signal can be sensed by the booster circuit for further processing.

If the received signal = 0.014v

The output voltage of the preamplifier is as expressed below;

Preamplification gains:

Voltage Gain of common emitter configuration is given as

$$A_V = \frac{V_o}{V_{in}} = -\frac{R_{CN}}{r_e + R_E} \dots\dots\dots 3.9$$

The negative sign indicate negative feedback.

Where;

$R_{CN}$  = Voltage gain between collector to ground

$R_e$  = Emitter Internal Resistance

$R_E$  = Emitter Resistance

$$R_{CN} = R_C \parallel r_{ce} \parallel R_L$$

$R_c$  = Collector Resistance

$r_{CE}$  = Dynamic resistance between Collector & Emitter

$R_L$  = Load Resistance

From figure 3.2

$$R_C = X_{L2} \parallel X_{C4}$$

$$X_{L2} = 2\pi FL_2 = 2\pi \times 500 \times 10^6 \times 85 \times 10^{-9}$$

$$X_{L2} = 267\Omega$$

$$X_{C4} = \frac{1}{2\pi FL} = \frac{1}{2\pi \times 500 \times 10^6 \times 500 \times 10^{-12}}$$

$$= 0.568\Omega$$

$$R_C = \frac{267 \times 0.568}{267 + 0.568} = 0.567\Omega$$

$$R_L = 100k$$

$$r_{ce} = 100k \text{ (constant)}$$

$$R_{CN} = 0.567 \parallel 100000 \parallel 100000$$

$$\frac{1}{R_{CN}} = \frac{1}{0.567} + \frac{1}{100 \times 10^3} + \frac{1}{100 \times 10^3} = 1.7637\Omega$$

$$R_{CN} = 0.567\Omega$$

$$r_e = \frac{2.6 \times 10^{-3}}{I_E} \dots\dots\dots 3.10$$

But  $I_E = I_C$

$$I_C = \beta I_B$$

$$I_B = \frac{V_{CC} \times V_{BE}}{R_{th} + \beta \times R_E} \dots\dots\dots 3.11$$

From figure 3.2  $R_{th} = R_1 \parallel R_2 = \frac{220 \times 220}{220 + 220} = 110\Omega$

$$R_E = R_4 \parallel C_5$$

$$X_{C5} = \frac{1}{2\pi f C_5} = \frac{1}{2\pi \times 500 \times 10^6 \times 270 \times 10^{-9}} = 1.179 \times 10^{-3}\Omega$$

$$R_E = \frac{100000 \times 1.179 \times 10^{-3}}{100000 + 1.179 \times 10^{-3}} = 1.179 \times 10^{-3}\Omega$$

$$I_B = \frac{12 \times 0.7}{110 + 300 \times 1.179 \times 10^{-3}} = 0.076A$$

$$I_C = I_E = \beta I_B = 300 \times 0.076 = 22.84A$$

From equation 3.10,

$$r_e = \frac{2.6 \times 10^{-3}}{22.84} = 1.138 \times 10^{-4}\Omega$$

Voltage Gain of the preamplifier

$$A_v = \frac{0.567}{1.138 \times 10^{-4} + 1.179 \times 10^{-3}}$$

$$A_v = 438.6$$

$$A_v \approx 440$$

The output of the preamplifier

$$V_{out} = V_{in} \times A_v \dots\dots\dots 3.12$$

$$V_{out} = 0.014 \times 440 = 6.14V$$

### 3.2.3 Tuned Oscillators

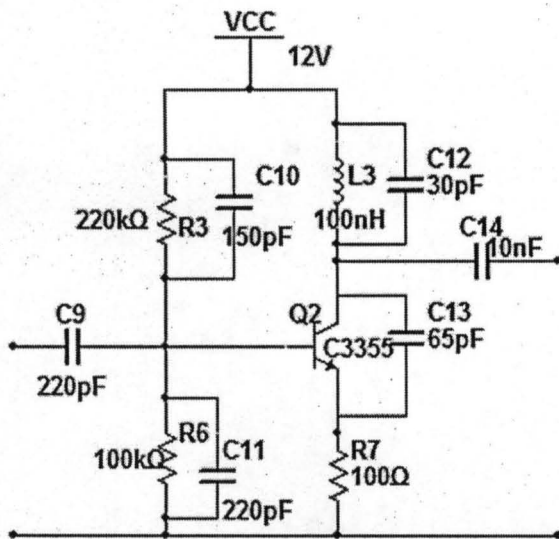
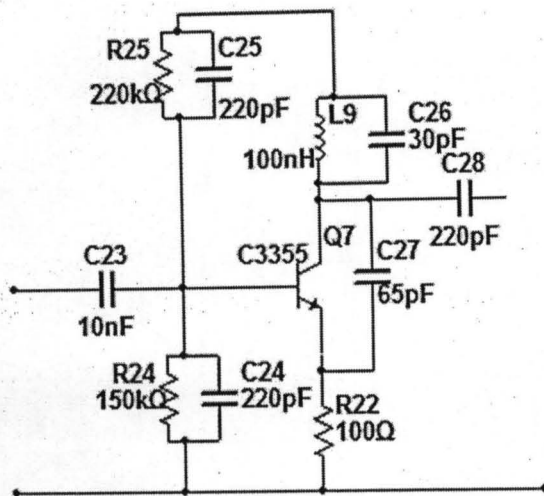


Fig 3.3 Tuned Oscillator circuit 1



**Fig 3.4 Tuned Oscillator circuit 2**

The oscillator uses inductive (L) and tunable capacitive (C) element. The frequency of its oscillation in the tank circuit is determined by the parameters of the circuit (L&C). The actual frequency is the resonance frequency (Natural Frequency of the tank circuit) which is given by

$$F = \frac{1}{2\pi\sqrt{LC}} \dots\dots\dots 3.13$$

This oscillation frequency is required in order to convert the received signal into lower intermediate frequency (IF) for processing since at very high frequency (as required in this design), signal processing circuiting performs poorly and also the transistor cannot deliver much application (gain) without becoming unstable.

**3.2.4 Intermediate Frequency (IF) stage 1**

IF is created by mixing the incoming signal with a local oscillator signal in a process called heterodymics, resulting in a signal at the lower band for further amplication before final detection is carried out.

Design of the local oscillator if the incoming signal has a frequency

$$F_1 = 500\text{MHz.}$$

$F_0$  = local oscillator frequency

$$F_0 = \frac{1}{2\pi\sqrt{LC}}$$

Choosing an inductor of  $L=10\text{nH}$

To obtain  $F_0$  of about 545MHz, the corresponding capacitance is given by the expression below

$$545 \times 10^6 = \frac{1}{2\pi\sqrt{LC}}$$

$$\sqrt{LC} = \frac{1}{2\pi \times 545 \times 10^6} = 2.92 \times 10^{-10}$$

$$LC = (2.92 \times 10^{-10})^2$$

$$C = \frac{8.53 \times 10^{-20}}{10 \times 10^{-9}}$$

$$C = 8.53\text{Pf}$$

$$C = 8.53\text{pf}$$

Based on the above calculated value of capacitance, a variable capacitor (Tuner capacitor) of 10-2pF was used in the design.

$$F_0 = 545\text{MHz}$$

$$F_1 = 500\text{MHz}$$

Upper band frequencies,

$$F_0 + F_1 = 545 + 500 = 1.045\text{GHz}$$

Lower band frequency

$$F_0 - F_1 = 545 - 500 = 45 \text{ MHz}$$

The high frequency signal of 1 GHz is filtered off by the low pass filter (LC) circuit connected to bypass the high frequency and allow only the low frequency signal due to its high reactance.

### **3.2.5 Design of the second local oscillator**

Another reason for using the second frequency (IF) is that it makes the receiver to be turned into different stations (selectively) by converting the various different frequencies of the stations to a common frequency for processing. Since it is difficult to build amplifiers, filters and detectors that can be tuned to different frequencies, then designing of a tunable oscillator becomes a necessity at the output stage of this design

Design of second local oscillator:

If the output of the amplification stages (incoming signal to the second local oscillator) is 45 MHz i.e  $F_1 = 45 \text{ MHz}$

Choosing an inductor of 10 nH

Choosing a capacitor of 30 pF

$$F_0 = \frac{1}{2\pi\sqrt{LC}} \dots\dots\dots 3.14$$

$$F_0 = \frac{1}{2\pi\sqrt{10 \times 10^{-19}}}$$

$$F_0 = 290 \text{ MHz}$$

Upper band frequency

$$F_1 + F_0 = 290 + 45 = 335 \text{ MHz}$$



Lower band frequency

$$F_1 - F_0 = 290 - 45 = 245 \text{ MHz}$$

The upper band frequency was filtered off by the low pass filter circuit of the output circuit.

### 3.2.6 Time constant

Time constant of oscillator 1 is the time it takes for the oscillation to resume after no oscillation period. From fig. 3.3

$$T_C = R_3 \times C_{11} \dots\dots\dots 3.15$$

$$= 220 \times 10^3 \times 220 \times 10^{-12}$$

$$T_C = 4.8 \mu s$$

### 3.2.7 At Oscillation 1

The higher band frequency of 1.045GHz of the intermediate frequency (IF) was filtered off by the de-coupler arrangement of the transistor and only the lower band frequency which contains the real information was fed through the base of the transistor (negative feedback) and sent through the six stages of amplification in order to deliver the signal with a sufficient power enough to be sensed and processed by the output circuit.

Delay time of the oscillation:

In order for the information to be meaningful, the rate of oscillation should not be continuous since communication of meaningful information required 'listening time' or a day time- the time at which there is no oscillation.

Behaviour of oscillation delay time:



fig.3.5 diagram of oscillation and delay time

No oscillation time = delay time

Since the minimum voltage required to turn ON a silicon transistor is 0.67v, when the transistor is ON it shows that there is no oscillation and oscillation period means the transistor is inactive

No oscillation condition;

Using voltage divider theorem,

From figure 3.6b below,

$$V_b = \frac{R_1 \times V_{CC}}{R_1 + R_2} \dots\dots\dots 3.16$$

Where  $V_{cc}$  is the supply voltage

$$V_b = \frac{100 \times 12}{220 + 100}$$

$$= 5.75v$$

When there is no oscillation,  $V_b > 0.67$ , therefore the transistor is ON

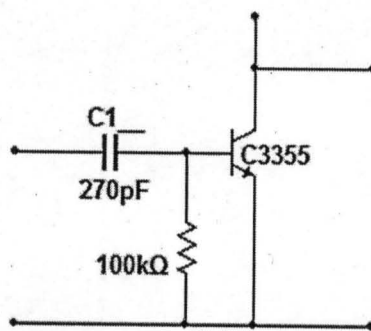


Fig.3.6aOscillation

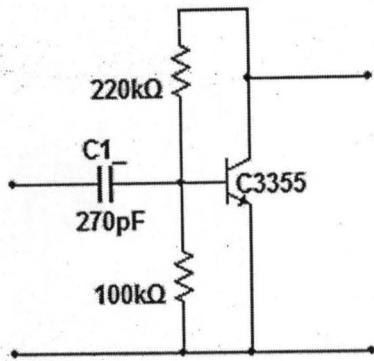


Fig. 3.6b No Oscillation

From figure 3.6a

Using voltage divider theorem,

$$V_B = \frac{R \times V_{CC}}{R + X_C} \dots\dots\dots 3.17$$

$$X_C = \frac{1}{2\pi f C_1}$$

$$= \frac{1}{2\pi \times 500 \times 10^6 \times 220 \times 10^{-12}} = 1.45\Omega$$

$$V_B = \frac{1.45 \times 12}{1.45 + 220 \times 10^3} = 7.89 \times 10^{-5}V$$

Since the base voltage,  $V_B$  is less than 0.67v the transistor is off and the tank circuit starts to oscillate.

### 3.2.8 IF amplification stage 2

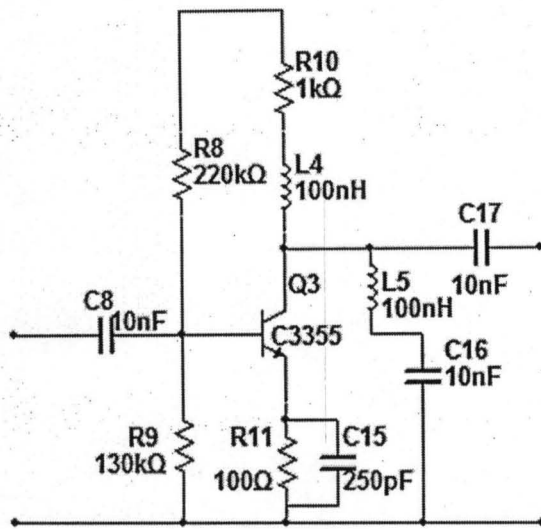


Fig. 3.7 IF amplifier circuit

To obtain the voltage gain of the first intermediate frequency amplifier stage using common emitter configuration (because of its high gain), the expression below was used for the design:

Voltage gain of the amplifier,

$$A_V = \frac{V_{out}}{V_{in}} = - \frac{R_{CN}}{r_e + R_E} \dots\dots\dots 3.18$$

Where:  $R_{CN}$  is the total resistance between collector to ground =  $R_C \parallel r_e \parallel R_L$

$R_E$  is the emitter resistance

$r_e$  is the emitter internal resistance, and the negative sign indicates that there is a phase reversal between  $V_{in}$  and  $V_o$  ( $180^\circ$  phase shift)

$$R_{CN} = R_C \parallel r_e \parallel R_L$$

Where;

$R_C$  = collective impedance

$r_{ce}$  = dynamic resistance between collector and emitter = 100k

$R_L$  = load resistance

$$R_C = \sqrt{R^2_1 + X^2_{L1}} \dots\dots\dots 3.19$$

$$X_{L1} = 2\pi FL_1 = 2\pi \times 500 \times 10^6 \times 100 \times 10^{-9}$$

$$X_{L2} = 314.2\Omega$$

$$R_C = \sqrt{100^2 + 314^2}$$
$$= 1048\Omega$$

$$R_L = R_3 = 100K$$

Also,

$$r_{ce} = 100k$$

$$R_{CN} = 1.05 \parallel 100000 \parallel 100000$$

$$\frac{1}{R_{CN}} = \frac{1}{1.05} + \frac{1}{100} + \frac{1}{100} = 0.972\Omega$$

$$R_{CN} = 1.028K\Omega$$

$$r_e = \frac{2.6 \times 10^{-3}}{I_E}$$

But  $I_E = I_C$

$$I_C = \beta I_B$$

$$I_B = \frac{V_{CC} \times V_{BE}}{R_{th} + \beta \times R_E} \dots\dots\dots 3.20$$

From figure 3.2  $R_{th} = R_5 \parallel R_6 = \frac{220 \times 130}{220 + 130} = 81.7k\Omega$

$$R_E = R_2 \parallel X_{C2}$$

$$X_{C2} = \frac{1}{2\pi F C_2} = \frac{1}{2\pi \times 500 \times 10^6 \times 1250 \times 10^{-12}} = 1.27\Omega$$

$$R_E = \frac{100 \times 1.27}{100 + 1.27} = 1.26\Omega$$

$$I_B = \frac{V_{CC} \times V_{BE}}{R_{th} + \beta \times R_E}$$

$$I_B = \frac{12 \times 0.7}{81.7 \times 10^3 + 300 \times 1.26} = 1.02 \times 10^{-4} A$$

$$I_C = I_E = \beta I_B \dots\dots\dots 3.21$$

$$= 300 \times 1.02 \times 10^{-4} = 0.0307 A$$

$$r_e = \frac{2.6 \times 10^{-3}}{0.0307} = 0.085\Omega$$

Voltage Gain of the preamplifier

$$A_V = \frac{1028}{0.085 + 1.26}$$

$$A_V = 764$$

For seven stages of IF amplification, the above value is multiplied by 7 in order to obtain the total of the SEVEN cascaded amplification total gain,

$$A_V = 764 \times 7 = 5348$$

$$A_v = \frac{V_{out}}{V_{in}} \dots\dots\dots 3.22$$

$$V_{out} = A_v \times V_{in}$$

Where  $V_{in}$  is the output of the preamplifier and is given as 6.16

$$i.e V_{in} = 6.16V$$

$$V_{out} = 5348 \times 6.16 = 32943.68V$$

$$V_{out} \approx 32950v$$

The new received power,  $P_R$

$$\text{New } P_R = \frac{V_{out}}{Z_0} \dots\dots\dots 3.23$$

$$P_R = \frac{32950}{45250000} = 0.000728 \text{ watts}$$

$$P_R = -30 \text{ dBw} \quad \text{but } \text{dBm} = \text{dBw} + 30$$

Therefore the power delivered to the receiver,  $P_{out} = 0 \text{ dBm}$

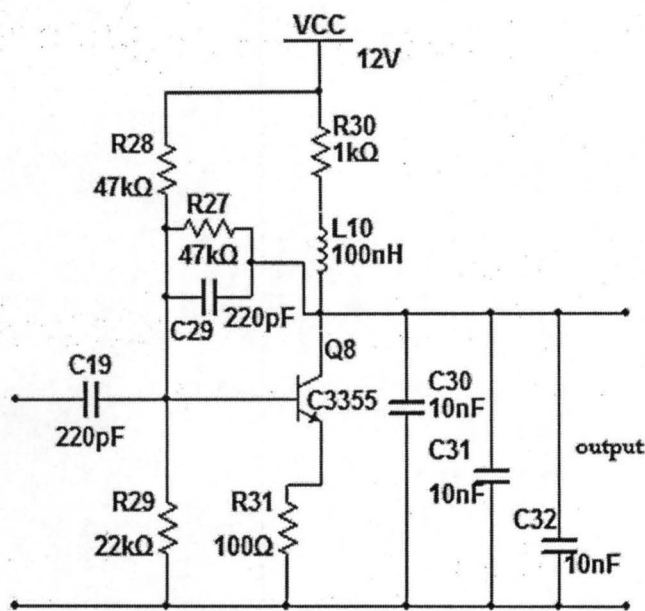


Fig. 3.8 Output circuit

### **3.3 Project construction**

After the design was neatly arranged on the breadboard and the output circuit has been tested to deliver the desired output result, the soldering of the various components was started on the veroboard adopting modular arrangement.

The first stage of the design which comprises the RC tank circuit was built on the veroboard as shown on the impedance circuit block diagram (figure 3.0) by connecting the resistor and capacitor in such a way as to resonate at the same frequency (500MHZ) with the incoming signal. The second stage which is the preamplification stage designed and soldered as shown in the preamplification circuit diagram using transistor C3355 connected with resistor, capacitor and inductor to achieve amplification. The first oscillator circuit was then built to generate a high frequency signal in order to obtain an intermediate frequency signal for processing while the next module of the design which consists of six stages of IF amplification was designed and soldered on the veroboard using six different transistors that are configured to amplify the signal six times. The second oscillator was then built to receive the desired information at a common frequency for easy selectivity of the TV receiver and lastly the output circuit was designed to amplify the received signal further using C3355 transistor and three numbers of large value capacitor was connected to the output circuit to filter off the high frequency signal and other noise. The output circuit was finally connected to the TV receiver RF inlet to display the received signal.



### 3.4 DESIGN OF POWER SUPPLY CIRCUIT

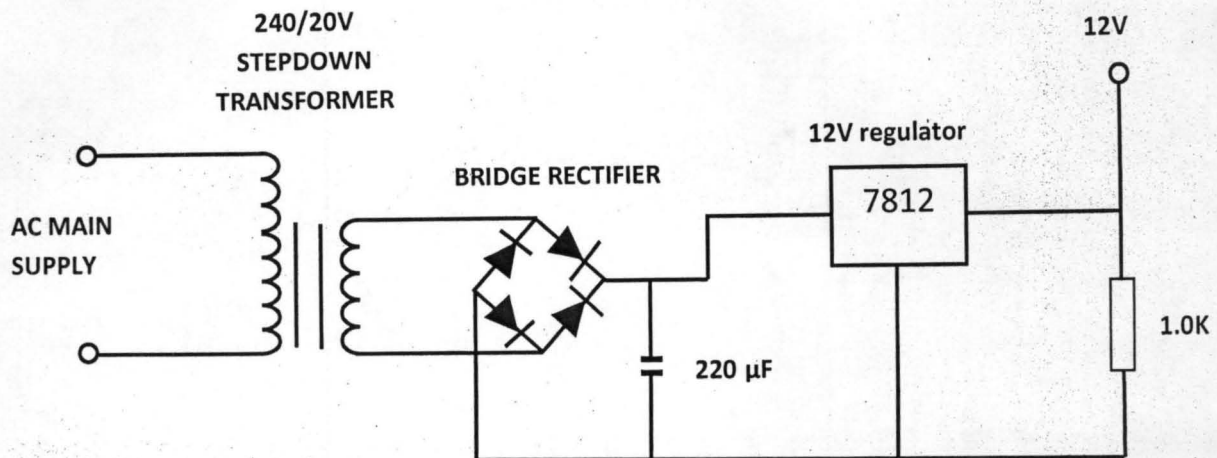


Fig.3.9 Power supply circuit

The power supply comprises basically about four (4) components: Transformer, rectifier, filter and a voltage regulator.

#### 3.4.1 Selection of transformer

Since that a.c power supply rating of Nigeria is 220-240V,50HZ, a step down transformer of 230V primary voltage and 12V secondary voltage with secondary current rating of 300mA (a.c to d.c rectified voltage, 12V) rating is used. The transformer is assumed to have a unity power factor (i.e. ideal situation).

The load resistance,  $R_L$  is given as,

$$R_L = V/I = 12/0.3 = 40\Omega$$

$$\text{Turns ratio (k)} = V_s/V_p = 12V/240V = 1/20 = 1:20$$

Or  $0.05 < 1 \Rightarrow$  a step down transformer

$$\text{d.c current, } I_{dc} = (2I_{rms}\sqrt{2})/\pi$$

$$= (2 \times 300 \text{mA} \times \sqrt{2}) / \pi$$

I<sub>d.c.</sub> approx. = 270mA is the maximum secondary current that can flow.

The voltage across the bridge diode is V<sub>dc</sub>, where V<sub>d.c.</sub> = V<sub>rms</sub>√2. But since

$$V_s = V_{rms} \Rightarrow$$

$$V_{d.c.} = 12\sqrt{2} = 16.97$$

### 3.4.2 Selection of rectifier diodes

The diode used is IN4007 because of its low peak inverse voltage (PIV) of about 50V. and a bridge rectifier is used because it helps to further lower the PIV.

Because in either positive or negative half cycle we have two diodes, the diodes forward voltage (V<sub>f</sub>) or the d.c. across the rectifier (V<sub>dc</sub>) diodes is multiplied by 2, i.e.,

$$PIV = 2 \times V_{dc} = 2 \times 17 = 34V$$

PIV=34V is used for the design which is less than the 50V rated PIV. Note V<sub>f</sub> is taken as 0.7V for general design calculation and is less than 1.1V i.e. V<sub>f</sub> = 0.7V and V<sub>f</sub> < 1.1V.

The peak inverse voltage is the maximum reverse voltage a diode can withstand before it breaks down since the output voltage of the transformer is 12V with d.c. voltage of 17V, the bridge rectifier diode of PIV above V<sub>dc</sub> (17V) is needed which can handle 500mA. IN4007 diodes are selected to achieve this PIV (PIV of IN4007 = 50V)

### 3.4.3 Selection of filtering capacitor

The output of the bridge rectifier has ripples whose voltage V<sub>R</sub> is calculated as,

$$V_R = V_{PP} - V_{RMS}$$

Where  $V_{PP}$  = peak voltage of the secondary

$V_{rms}$  = root mean square voltage

$$\text{Also } V_r = I_{d.c} / 2fc$$

Where  $f$  = Frequency of the power supply in HZ

$C_1$  = capacitance in farad, Capacitor  $C_1$  should have the capability to filter all ripples voltages in the supply.

$I_{dc}$  = d.c current

$$V_{PP} - V_{RMS} = I_{dc} / 2fc$$

$$C_1 = I_{dc} / 2fc (V_{PP} - V_{RMS})$$

$$I_{dc} = 300\text{mA}, f = 50\text{HZ}, V_{pp} = 17\text{V}, V_{RMS} = 12\text{V}$$

$$C_1 = 300\text{mA} / (2 \times 50(17-12))$$

$$C_1 = 600 \mu\text{F}$$

Hence, an electrolytic capacitor of capacitance greater than  $600\mu\text{F}$  (i.e.  $2200\mu\text{F}, 35\text{V}$ ) was selected for better filtration, bearing that the higher the value of the capacitor the lesser the ripples.

#### 3.4.4 Selection of voltage regulator

For optimum operation of the circuit, it is necessary to have a good regulated voltage. Therefore 7812 regulator IC was selected for the purpose because of its high quality precision.

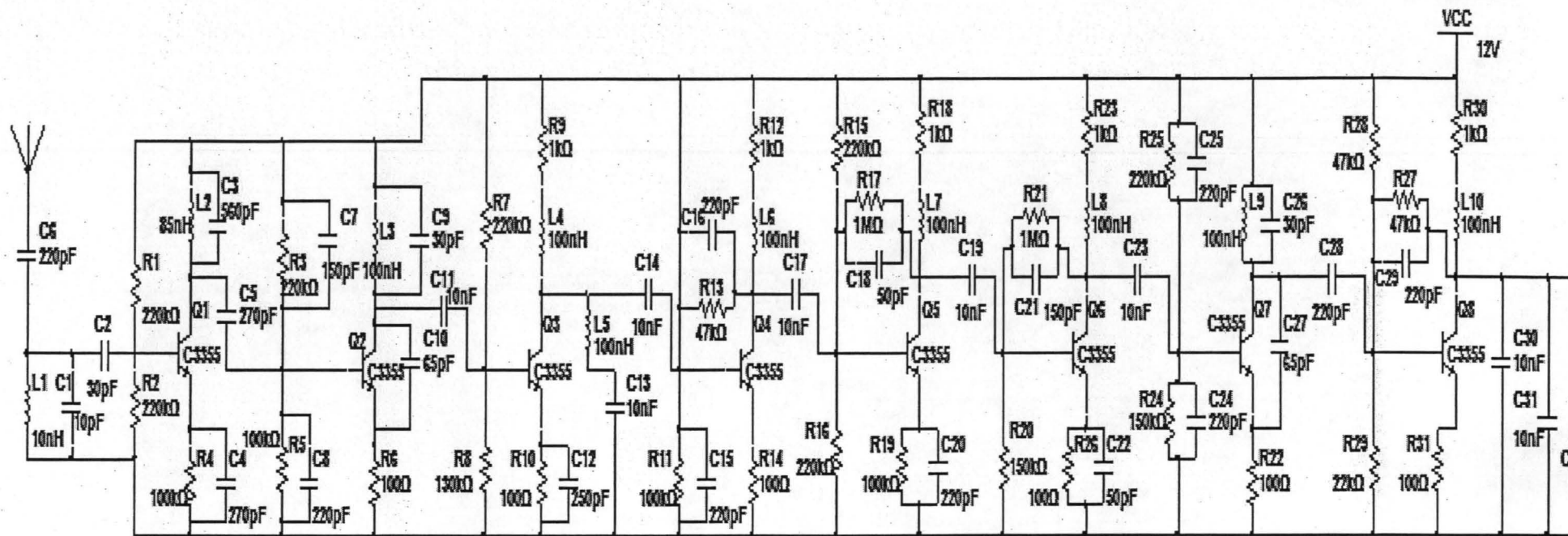


Fig. 3.10 Complete circuit diagram of the project

## CHAPTER FOUR

### 4.0 Tests and Results

The realization of this project was achieved by employing module design approach and combining different modules into a single design. The following tests were carried out in the course of design to ensure desired output;

- The power supply was tested to check for the voltage ripples which could cause serious interference to the circuit and it was found that the ripples has been reduced to the bearest minimum to be used to supply power to the circuit
- The sensitivity test of the design was carried out and the result obtained showed a clear, audible and spotless picture of the desired station which confirm good sensitivity level of the design.
- The voltage level of the output signal was tested to ensure sufficient signal strength is delivered to the receiver and the voltage level was found to have been amplified to a level greater than the minimum sensitivity of the TV receiver which determines the feasibility of the transmission link.
- Continuity test of the entire soldered circuit was carried out to ensure no short circuit or partial contact at any point in the circuit.
- The receiving height test was also carried out by mounting the complete packaged circuit on a pole at a height lesser than the estimated height and a less clearer signal was received.

#### 4.1 Problems encountered

Noise and interference were the major factor that caused serious setback to the realization of the design. These losses includes; noise generated locally by the circuit oscillation effect, noise from non communication systems, noise from low frequency signals, inference from strong nearby station that outbound their frequency due to high boosting effect (near-far-effect), interference from adjacent stations and interference from power supply ripples.

## CHAPTER FIVE

### 5.0 Conclusion

The result obtained from the design calculation shows that a much higher signal level is received at the output of the circuit. This means that the signal has been amplified to a level sufficient enough to be detected and further processed by the receiver. It shows that a very weak signal received at the circuit input which ordinarily could not be sensed by the TV receiver has been made to have enough strength to be detected even by a device having a lesser sensitivity than the television hence, the VHF-UHF booster circuit can be used for diverse applications.

### 5.1 Recommendation

The construction of this project was done based on the design that could be used in a normal terrain environment and not a design meant for a highly mountaneous terrain such as Minna. In a further design, it is recommended that student should carry out a thorough predesigned path analysis that could cater for the negative effect of signal fading resulting from several obstacles obstructing the reception of the signal at a long distance from the transmitter.

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