DESIGN AND CONSTRUCTION OF A VOICE ACTIVATED BUG

OGBONNAYA KINGSLEY OBINNA

2004/18848EE

ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE.

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A THESIS SUBMITTED TO THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY MINNA, NIGER STATE.

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Table of Contents

DEDICATION

This project is dedicated to God, my beloved family and in loving memory of my late nephew Jerry Ogbonnaya.

DECLARATION

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

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ABSTRACT

The voice activated bug, here designed and constructed, to detect audio signals via two electret microphones, the signals are amplified, rectified then sent to the power switching section. This section is switched ON on detection of appreciable audio signal, after the signal is modulated and the radio frequency (RF) amplified the signal is radiated over the antenna to receivers that are tuned to its frequency. The bug transmits on a frequency of 94.0MHz, within a radius of 50m.

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

It is hard to imagine a what the world would look like without the constant exchange of huge quantity of information. It is currently disseminated by various means such as newspapers, telephone and the internet. However the fastest way, and sometimes the only way, is by radio. This is where the transfer is by electromagnetic waves, travelling at the speed of light. In radio communication, a radio transmitter comprises one side of the link and the radio receiver on the other. No conductor of any kind is needed between them, and that is how the expression **Wireless Link** came into being. In the early days of radio engineering the terms **Wireless Telegraph** and **Wireless Telephone** were also used, but were quickly replaced with **Radio Communication** or just **Radio** [1].

1.2 STATEMENT OF PROBLEMS

We live in a world where crimes increase is on the high with little hope to apprehend suspects. The trend of corruption has increased, sometimes due to vital information that can be used to prosecute being unavailable.

This project work will therefore attempt to answer the following questions: how can crimes suspects be apprehended with ease and investigation done without posing a danger to the investigator? How can important information be brought out to the limelight in good condition?

To answer these and many more questions motivates this project.

1.3 AIMS AND OBJECTIVES

The aim of this project is to design and construct a voice activated wireless electronic bug that can take surveillance of audio signals and transmit such signals via radio waves.

To achieve this goal, the objectives considered are:

(1) The device should be easily setup and require minimum maintenance.

(2) The device should have a power saving tool to enhance battery life by using the voice activation feature.

(3) The device should enhance safety of the user.

(4) The device should be mobile and cost effective by using radio waves for transmission instead of transmission cables.

1.4 METHODOLOGY

Power Supply System

Electret Condensor Microphones

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1.4 METHODOLOGY

Power Supply System

Electret Condensor Microphones

A Microphone Preamplifier

A Voice Activation Switching System

FM Modulator

RF Amplifiers

Due to operational requirements, a battery powered supply scheme was adopted. To maximize battery power an auto turn-on/turn-off to the RF section was adopted. The auto turn-on/turn-off feature saves power by disconnecting the transmitter when no appreciable voice signal is picked up.

A 2- microphone arrangement was adopted for voice pickup to ensure a wider coverage than is possible with a single microphone, also the electret condensor microphones are used because of the high sensitivity. The low-level microphone signal was amplified by a two stage amplifier built around an LM358 operational amplifier. For power switching, the audio signal was rectified by an IN4148 diode and fed to voice activation switching system.

In the voice activated switching system, the power to the transmitter and modulator was held OFF (at about 1.2V) until the microphones pick up sound signals loud enough to enable transmission. The system works on the premise that the audio signal can be processed and used to control an electronic switch which in turn control the power, which then supplies power to the RF stage.

The RF stage comprises of a single-stage base reactance modulator and two RF amplifiers. The microphone audio signal is fed into the base-emitter junction of C9014 (Q3) transistor to produce a modulation of the collector current.

The generated FM wave is amplified by the C9014 (Q5 and Q6) transistors and eventually radiated over an antenna.

1.5 BLOCK DIAGRAM REPRESENTATION

Figure 1.1 shows the block diagram representation of the voice activated bug.

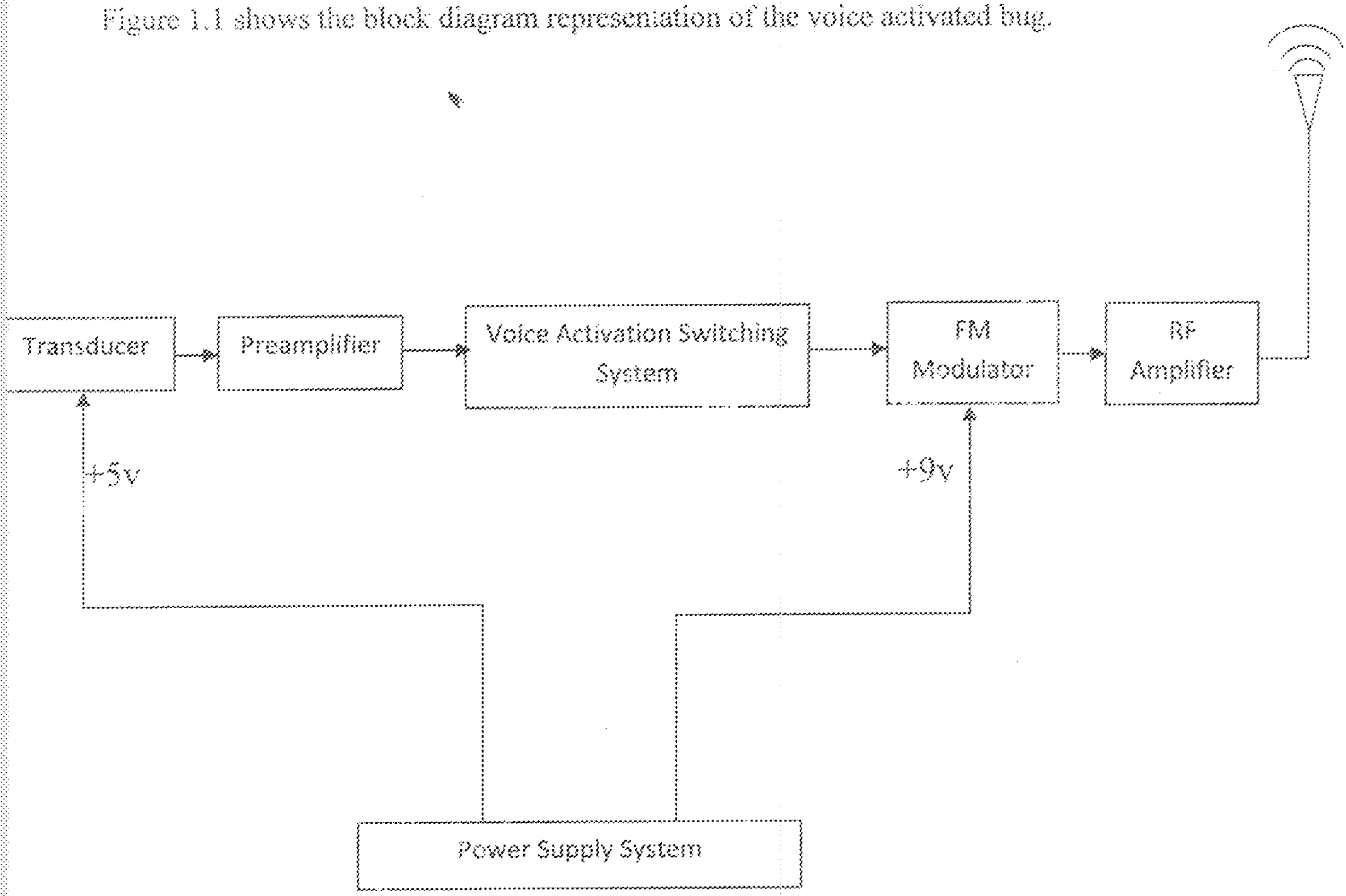

Figure 1.1: Block diagram of a voice activated bug.

1.6 PROJECT OUTLINE

The project report is outlined thus; chapter one states the problem, the aim of the project, the methodology involved and the block diagram representation. Chapter two highlights the literature review, which talks about the historical background of radio communication and bugs, there classifications and other related materials used in the course of this project. Chapter three comprises the circuit design and analysis.

Chapter four constitutes construction and testing, the results obtained and some of the difficulties encountered. Chapter 5 concludes the project and states recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 HISTORICAL BACKGROUND OF BUGS AND RADIO SYSTEM

The pioneers of radio were Popov and Marconi, but the place of honor belongs to Nikola Tesla, who demonstrated wireless broadcasting in1893, at the Franklin Institute. Figure 1.2 shows the arrangement of this broadcast system. Tesla's idea was to produce electromagnetic waves by means of oscillatory circuits and transmit them over an antenna. A receiver would then receive the waves with another antenna and the oscillatory circuit being in resonance with oscillatory circuit of the transmitter. This represented the ground work of today's radio communications. In 1904 John Flemming created the diode, and in 1907 Lee De Forest invented the triode. That year can be considered the birth of electronics, with the triode being the first electronic used in a circuit for signal amplification.

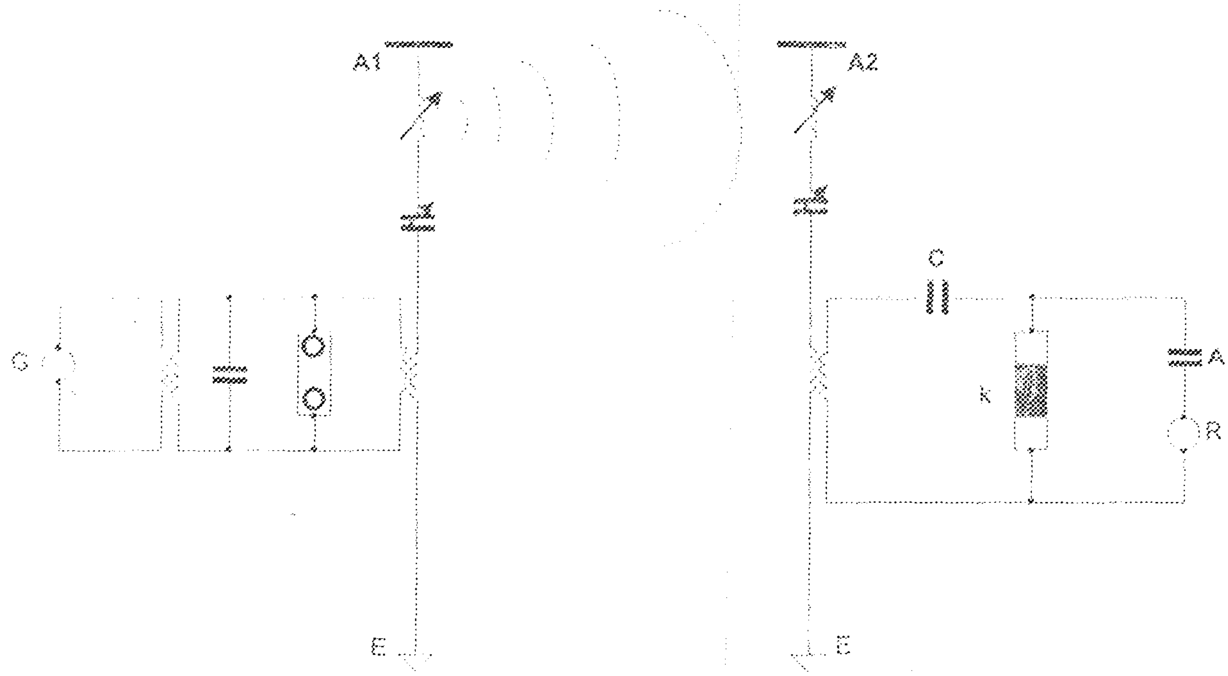

Figure 2.1: Electrical diagram of Telsa's radio transmitter & receiver from 1893

Rapid development of radio engineering over the ensuing years produced many innovations and after the First World War a huge number of radio stations emerged. At the time TRF (Tuned Radio Frequency) receivers were used. Compared to modern receivers they had poor selectivity and sensitivity, but back then they fulfilled the demands. The number of radio stations was much less than today and their transmitting power was much smaller. The majority of listeners were satisfied with the reception of only local stations.

However, as the number of stations increased, as well as their transmitting power, the problem of selecting one station out of a jumble of stations, was becoming increasingly more difficult. It was partially solved with an increase in the number of oscillatory circuits in the receiver and the introduction of positive feedback, but the true solution was the introduction of the **superheterodyne receiver.** This was accomplished by Lewy (1917), and improved by E.H. Armstrong (1918). An enormous impact on the world of radio was the invention of the transistor by Bardeen, Bretten and Schockley, in 1948. This reduced the size of the radio receiver and made truly portable sets a reality. This was followed by the introduction of the integrated circuit, enabling the construction of devices that not only proved better in every way than those using values, but also new designers.

Modern radio receivers differ greatly from the "classical" type, however the working principles are the same. The only significant difference is the way the receiver is tuned to a station. Classical devices used variable capacitor, coil or varicap diode, with the frequency read from a scale with movable pointer. In modern devices the adjustment is done with a frequency synthesizer controlled by a microprocessor and the reading is displayed by an optical readout.

The inclusion of the microprocessor enables any one of a large number of pre-tuned stations to be selected and displayed and the use of a remote control makes the receiver even more user friendly [1].

2.2 BUGS

The most common type wireless eavesdropping device, the "BUG" is a covert listening device placed into an area, hidden from the targeted individual, that transmits audio to a remote location, where that information can be directly monitored and/or recorded. The basic bug is comprised of a small, tiny microphone, electrets or condenser type, which is used to change sound waves into electrical signals, then amplified by electronic circuitry which is then modulated and transmitted.

2.2.1 CLASSIFICATION OF BUGS

There are three main classifications of bugs:-

1) Active Bug – this type of bug is the simplest, as its transmitter remains on or active all of the time.
2) Passive Bug – this type of bug can be triggered to turn on whenever it is needed, to save battery life and be more difficult to detect
    * Visual Activated Bug – is only triggered to transmit when the light source changes
    * Burst Video Bug – this bug is triggered from any outside signal source, directly from the eavesdropper or may be triggered at certain time intervals.
3) Wired Bug – physically separated camera from transmitter, where the actual CCD lens may be installed in one area, and the transmitter into another.

Some common different types of operational bugs that are used in RF are;

* Simple audio modulation and transmission – easily picked up by a simple receiver or scanner.
* Digitally encoded transmission – received by a special receiver with decoder.

- Spread Spectrum transmission – otherwise known as frequency hopping, as this type of modulation changes the actual centre frequency of transmission many times a seconds in which a specialized receiver is used to intercept. This makes the overall finding of the bug`s transmitting frequency difficult.
- Single or Double modulated side band (SSB, DSB) – where the modulation of the signal is found only in the sidebands of the transmission. Can only be received with a special receiver or equipment tuned to the modulation of the carrier.
- FM, NFM, WFM, or AM – Common types of modulation such as Frequency Modulation, Narrow-Band Modulation, Wide-Band Modulation or Amplitude Modulation.

Overview of all wireless Bugs are enumerated below:

- Small in physical size and can be disguised as almost anything. Devices can also be installed directly into a premise.
- Transducer audible sounds into an electrical impulse, which is then amplified, modulated and transmitted to a remote location for monitoring.
- They emit radio waves of some type.
- Usually lower powered to medium powered RF transmitters.
- They are powered by batteries or leech power from the AC wiring in a residence or DC power in a vehicle.
- Are received by some type of special radio receiver.
- Can be found with an "All Band Receiver" or counter-surveillance receiver [2].

2.3 RADIO COMMUNICATION SYSTEMS

The capability of radio waves to provide almost instantaneous distant communications without interconnecting wires was a major factor in the explosive growth of communications during the 20th century. With the dawn of the 21st century, the future for communications systems seems limitless. The invention of the vacuum tube made radio a practical and affordable communications medium. The replacement of vacuum tubes by transistors and integrated circuits allowed the development of a wealth of complex communications systems, which have become an integral part of our society. The development of *digital signal processing* (DSP) has added a new dimension to communications, enabling sophisticated, secure radio systems at affordable prices.

In this book, we review the principles and design of modern single-channel radio receivers for frequencies below approximately 3 GHz. While it is possible to design a receiver to meet specified requirements without knowing the system in which it is to be used, such ignorance can prove time-consuming and costly when the inevitable need for design compromises arises. We strongly urge that the receiver designer take the time to understand thoroughly the system and the operational environment in which the receiver is to be used. Here we can outline only a few of the wide variety of systems and environments in which radio receivers may be used.

Figure 2.2 is a simplified block diagram of a communications system that allows the transfer of information between a *source* where information is generated and a *destination* that requires it. In the systems with which we are concerned, the transmission medium is radio, which is used when alternative media, such as light or electrical cable, are not technically feasible or are uneconomical. Figure 2.2 represents the simplest kind of communications system, where a single source transmits to a single destination. Such a system is often referred to as a *simplex* system. When two such links are used, the second sending information from the destination location to the source location, the system is referred to as *duplex*. Such a system may be used for two-way communication or, in some cases, simply to provide information on the quality of received information to the source. If only one transmitter may transmit at a time, the system is said to be *half-duplex*.

Figure 2.3 is a diagram representing the simplex and duplex circuits, where a single block *T* represents all of the information functions at the source end of the link and a single block *R* represents those at the destination end of the link. In this simple diagram, we encounter one of the problems which arise in communications systems—a definition of the boundaries between parts of the system. The blocks *T* and *R*, which might be thought of as transmitter and receiver, incorporate several functions that were portrayed separately in Figure 2.2.

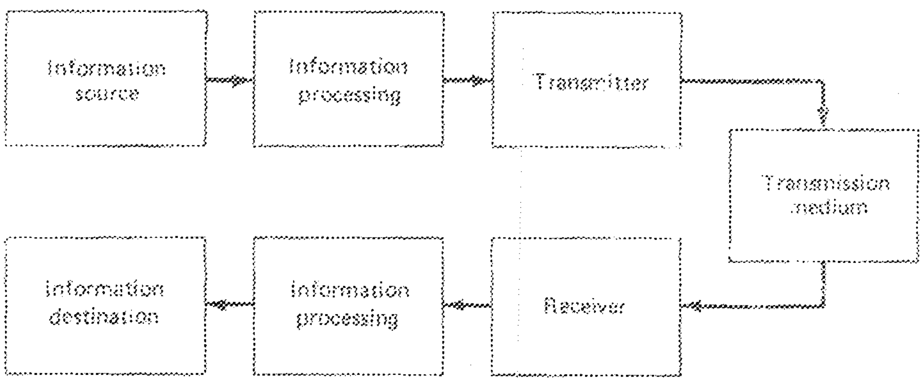

Figure 2.2: Simplified block diagram of a communications link.

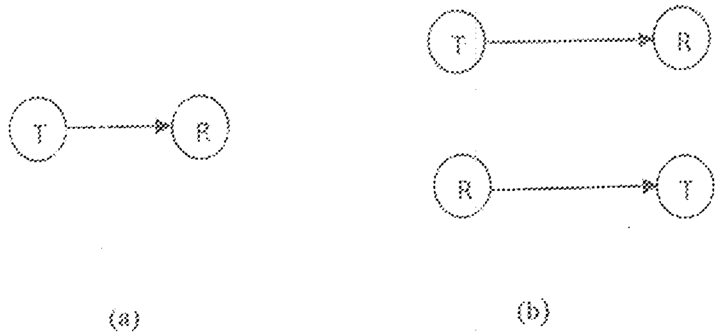

Figure 2.3: Simplified portrayal of communications links:

(a) Simplex Link (b) Duplex link [3].

2.4 RADIO FREQUENCY RANGES

The spectrum of radio waves is divided into ranges having a width of one decade, as indicated in Fig. waves below 300MHz are often called radio frequency (RF) waves. Ultrahigh frequency (UHF) and super-high frequency (SHF) waves (300MHz to 30GHz) are called microwaves. Often the boundary between RF waves and microwaves is set to 1GHz. The microwave range is further subdivided into bands according to waveguide bands. Extremely high frequency (EHF) range is called the millimeter-water range and the frequency range from 300GHz to 3000GHz the sub-millimeter-wave range.

The interaction of electromagnetic waves with matter depends on the energy of photons. In general, shorter waves corresponding to energetic photons interact more strongly than longer waves. The photons of radio waves have low energies; for example, at 1000GHz the energy is only 4×10^{-3}eV (1eV = 1.6×10^{-19} Ws = 1.6×10^{-19} J), the energy needed to ionize molecules in biological tissue is at least 12eV. Thus, ultraviolet [8].

Table 2.1: Radio Frequency Ranges

Name of Frequency Range and Abbreviation	**Frequencies**
Very Low Frequency (VLF)	3-30KHz
Low Frequency (LF)	30-300KHz
Medium Frequency (MF)	300-3000KHz
High Frequency (HF)	3-30MHz
Very High Frequency (VHF)	30-300MHz
Ultrahigh Frequency (UHF)	300-3000MHz
Super-high Frequency	3-30GHz
Extremely High Frequency (EHF)	30-300GHz

2.5 TRANSMITTERS

Essential components of a radio transmitter include an oscillator generator for converting commercial electric power into oscillations of a predetermined radio frequency; amplifiers for increasing the intensity of these oscillations while retaining the desired frequency; and a transducer for converting the information to be transmitted into a varying electrical voltage proportional to each successive instantaneous intensity. For sound transmission a microphone is the transducer; for picture transmission the transducer is a photoelectric device.

Other important components of the radio transmitter are the modulator, which uses these proportionate voltages to control the variations in the oscillation intensity or the instantaneous frequency of the carrier, and the antenna, which radiates a similarly modulated carrier wave. Every antenna has some directional properties, that is, it radiates more energy in some directions than in others, but the antenna can be modified so that the radiation pattern varies from a comparatively narrow beam to a comparatively even distribution in all directions; the latter type of radiation is employed in broadcasting.

The particular method of designing and arranging the various components depends on the effects desired. The principal criteria of a radio in a commercial or military airplane, for example, are light weight and intelligibility; cost is a secondary consideration, and fidelity of reproduction is entirely unimportant. In a commercial broadcasting station, on the other hand, size and weight are of comparatively little importance; cost is of some importance; and fidelity is of the utmost importance, particularly for FM stations; rigid control of frequency is an absolute necessity. In the U.S., for example, a typical commercial station broadcasting on 1000 kHz is assigned a bandwidth of 10 kHz by the Federal Communications Commission, but this width may be used only for modulation; the carrier frequency itself must be kept precisely at 1000 kHz, for a deviation of one-hundredth of 1 percent would cause serious interference with even distant stations on the same frequency [4].

2.6 OSCILLATORS

In a typical commercial broadcasting station the carrier frequency is generated by a carefully controlled quartz-crystal oscillator. The fundamental method of controlling frequencies in most radio work is by means of tank circuits, or tuned circuits, that have specific values of inductance and capacitance, and that therefore favor the production of alternating currents of a particular frequency and discourage the flow of currents of other frequencies. In cases where the frequency must be extremely stable, however, a quartz crystal with a definite natural frequency of electrical oscillation is used to stabilize the oscillations. The oscillations are actually generated at low power by an electron tube and are amplified in a series of power amplifiers that act as buffers to prevent interaction of the oscillator with the other components of the transmitter, because such interaction would alter the frequency. The crystal is shaped accurately to the dimensions required to give the desired frequency, which may then be modified slightly by adding a condenser to the circuit to give the exact frequency desired. In a well-designed circuit, such an oscillator does not vary by more than one-hundredth of 1 percent in frequency. Mounting the crystal in a vacuum at constant temperature and stabilizing the supply voltages may produce a frequency stability approaching one-millionth of 1 percent. Crystal oscillators are most useful in the ranges termed very low frequency, low frequency, and medium frequency (VLF, LF, and MF). When frequencies higher than about 10 MHz must be generated, the master oscillator is designed to generate a medium frequency, which is then doubled as often as necessary in special electronic circuits. In cases where rigid frequency control is not required, tuned circuits may be used with conventional electron tubes to generate oscillations up to about 1000 MHz, and reflex klystrons are used to generate the higher frequencies up to 30,000 MHz. Magnetrons are substituted for klystrons when even larger amounts of power must be generated [4].

2.7 OPERATIONAL AMPLIFIERS

Operational amplifiers are highly stable, high gain dc difference amplifiers. Since there is no capacitive coupling between their various amplifying stages, they can handle signals from zero frequency (dc signals) up to a few hundred kHz. Their name is derived by the fact that they are used for performing mathematical operations on their input signal(s).

Figure 2.6 shows the symbol for an operational amplifier. There are two inputs, the inverting input (-) and the non-inverting input (+). These symbols have nothing to do with the polarity of the applied input signals.

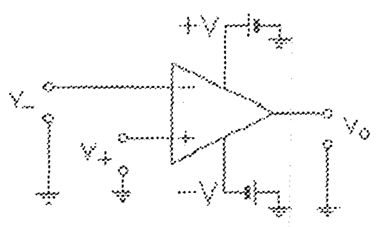

Figure 2.4: Symbol of the operational amplifier. Connections to power supplies are also shown.

The output signal (voltage), V_o, is given by:

$$V_o = A(V_+ - V_-) \quad (2.1)$$

V_+ and V_- are the signals applied to the non-inverting and to the inverting input, respectively. *A* represents the open loop gain of the operational amplifier. *A* is infinite for the ideal amplifier, whereas for the various types of real operational amplifiers, it is usually within the range of 10^4 to 10^6.

Operational amplifiers require two power supplies to operate, supplying a positive voltage (+V) and a negative voltage (-V) with respect to circuit common. This bipolar power supply allows operational amplifiers to generate output signals (results) of either polarity. The output signal (V_o) range is not unlimited. The voltages of the power supplies determine its actual range. Thus, a typical operational amplifier fed with -15 and +15 V, may yield a V_o within the (approximately) -13 to +13 V range, called Operational Range. Any result expected to be outside this range is clipped to the respective limit, and operational amplifier is in a saturation stage.

Because of their very high open loop gain, operational amplifiers are almost exclusively used with some additional circuitry (mostly with resistors and capacitors), required to ensure a negative feedback loop. Through this loop a tiny fraction of the output signal is fed back to the inverting input. The negative feedback stabilizes the output within the operational range and provides a much smaller but precisely controlled gain, the so-called closed loop gain.

Circuits of operational amplifiers have been used in the past as analog computers, and they are still in use for mathematical operations and modification of the input signals in real time. A large variety of operational amplifiers is commercially available in the form of low cost integrated circuits.

There is a plethora of circuits with operational amplifiers performing various mathematical operations. Each circuit is characterized by its own transfer function, i.e. the mathematical equation describing the output signal (V_o) as a function of the input signal (V_i) or signals (V_1, V_2, ..., V_n). Generally, transfer functions can be derived by applying Kirchhoff's rules and the following two simplifying assumptions:

1. The output signal (Vo) acquires a value that (through the feedback circuits) practically equates the voltages applied to both inputs, i.e. v+ ≈ v-.
2. The input resistance of both operational amplifier inputs is extremely high (usually within the range 106-1012 MΩ, for the ideal operational amplifiers this is infinite), thus no current flows into them [5].

2.8 NOISE

Whether you operate a radio receiver, or some piece of scientific or medical instrumentation, noise interferes with acquiring desired signals. Noise is bad. After all, radio reception and other forms of signals acquisition are essentially a game of signal-to-noise ratio (SNR). The actual values of the desired signal and noise signal are not nearly as important as their ratio. If the signal is not significantly stronger than the noise, then it will not be properly detected [7].

The quality of radio signal is not only degraded by the propagation losses: natural or manmade electrical noise is added to them, reducing their intelligibility.

Atmospheric noise includes static from thunderstorms which, unless very close, affects frequencies below about 30MHz and noise from space is apparent at frequencies between about 8MHz to 1.5 GHz.

A type of noise with which radio engineers are continually concerned is thermal. Every resistor produces noise spread across the whole frequency spectrum. Its magnitude depends upon the ohmic value of the resistor, its temperature and the bandwidth of the following circuits. The noise voltage produced by a resistor is given by:

$$E_n = \sqrt{4kTBR} \qquad (2.2)$$

Where

E_n = noise voltage, V (RMS)

k = Boltzmann's constant

= 1.38×10^{-23} Joules/Kelvin

T = Temperature in Degrees K

B = bandwidth of Measurement, Hz

R = Resistance in Ohms

An antenna possesses resistance and its thermal noise, plus that of a receiver input circuit, is a limiting factor to receiver performance.

Noise is producing in every electronic component. Shot noise – it sounds like falling lead shot – caused by the random arrival of electrons at, say, the collector of a transistor, and the random division of electrons at junctions in devices, add to this noise [6].

Among the noises are a steady low-frequency note (about two octaves below middle C) commonly produced by the frequency of the alternating-current power supply (usually 60 Hz) becoming impressed onto the signal because of improper filtering or shielding; hiss, a steady high-frequency note; and whistle, a pure high-frequency note produced by unintentional audio-frequency oscillation, or by beats. These noises can be eliminated by proper design and construction. Certain types of noise, however, cannot be eliminated. The most important of these in ordinary AM low-frequency and medium-frequency sets is static, caused by electrical disturbances in the atmosphere. Static may be due to the operation of nearby electrical equipment (such as automobile and airplane engines), but is most often caused by lightning. Radio waves produced by such atmospheric disturbances can travel thousands of kilometers with comparatively little attenuation, and inasmuch as a thunderstorm is almost always occurring somewhere within a few thousand kilometers of any radio receiver, static is almost always present. Static affects FM receivers to a much smaller degree, because the amplitude of the intermediate waves is limited in special circuits before discrimination, and this limiting removes effects of static, which influences the signal only by superimposing a random amplitude modulation on the wave. Digital and satellite radio greatly reduces static [4].

2.8.1 DOPPLER EFFECT

Doppler effect is an apparent shift of the transmitted frequency which occurs when either the receiver or transmitter is moving. It becomes significant in mobile radio applications towards the higher end of the UHF band and on modulated systems.

When a mobile receiver travels directly toward the transmitter each successive cycle of the wave has less distance to travel before reaching the receiving antenna and, effectively, the received frequency is raised. If the mobile travels away from the transmitter, each successive cycle has a greater distance to travel and the frequency is lowered. The variation in frequency depends on the frequency of the wave, its propagation velocity and the velocity of the vehicle containing the receiver. In the situation where the velocity of the vehicle is small compared with the velocity of light, the frequency shift when moving directly towards, or away from, the transmitter is given to sufficient accuracy for most purposes by:

$$F_d = \frac{V}{CF_t} \qquad (2.3)$$

Where

F_d = Frequency shift, Hz

F_t = Transmitted frequency, Hz

V = Velocity of vehicle, m/s

C = Velocity of light, m/s

Examples are:

- 100km/hr at 450 MHz, frequency shift = 31.6Hz
- 100km/hr at 1.8 GHz – personal communication network (PCN) frequencies – frequency shift = 166.5Hz.

* Train at 250km/hr at 900MHz – a requirement for GSM pan-European radio-telephone – frequency shift = 208 Hz [6].

CHAPTER 3

DESIGN AND IMPLEMENTATION

The high intensity electronic bugging system was designed around the under-listed subsystems:

- High sensitivity electrets condenser microphones (2)
- Microphone Amplifiers
- Voice – Activated Power Switch
- Short – Range FM Modulator/Transmitter
- Power Supply.

3.1 POWER SUPPLY

A DC power source was opted for in line with the design requirements. The power source was obtained from a 9V DC battery pack. For stability, the microphones, microphone amplifier, and the modulator were operated off a 5-Volt regulated power supply derived from the 9V DC input via a 7805 regulator. The system supply voltages are shown in Figure 3.1:

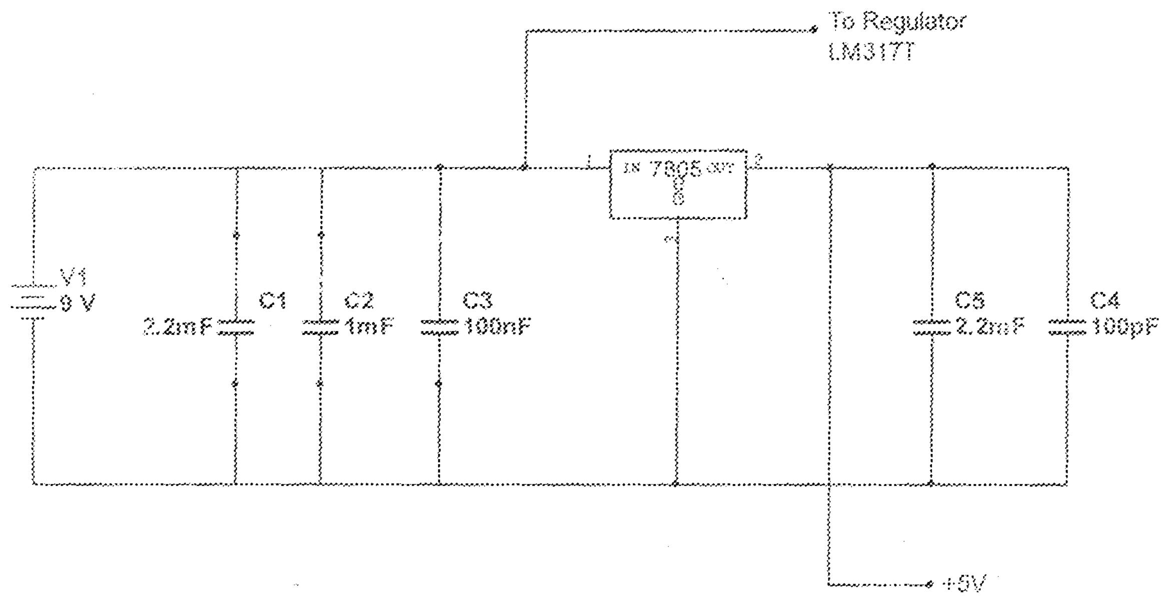

Figure 3.1: 5V Power Source

A total capacitance of 3200μF was placed across the DC rail. The 3200μF capacitance was by-passed by a 0.1μF capacitor. The buffered DC was fed into a 5-Volt supply which powered the low-voltage arm of the system.

3.2 HIGH-SENSITIVITY MICROPHONES/AMPLIFIER

Two electrets (capacitor) microphones were used instead of carbon microphones as they exhibited superior noise/sensitivity performance. The microphones were biased on via the 5-Volt supply as shown in Figure 3.2.

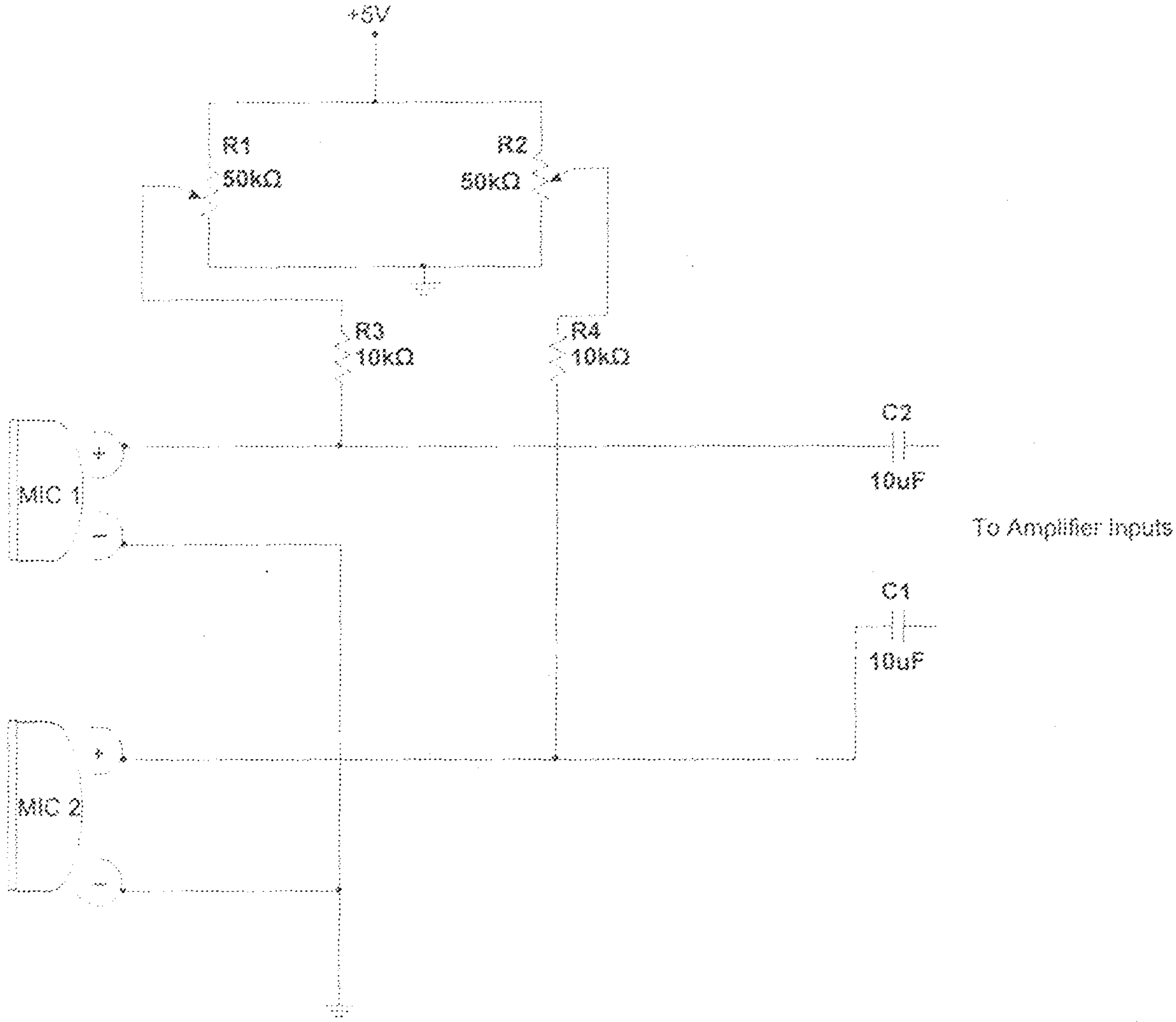

Figure 3.2: Microphones Biasing Network

A fixed-bias voltage was not used to carter for different microphone characteristics. Two 50KΩ pots were used, between the 5V supply and ground, to provide the DC bias potential to the microphones via 10KΩ resistance. The 50KΩ pots were adjusted to yield the best audio quality.

3.3 MICROPHONE AMPLIFIERS

A single-stage amplifier was used to boost the signal strength of the microphones. The amplifier was configured as shown in the Figure 3.3:

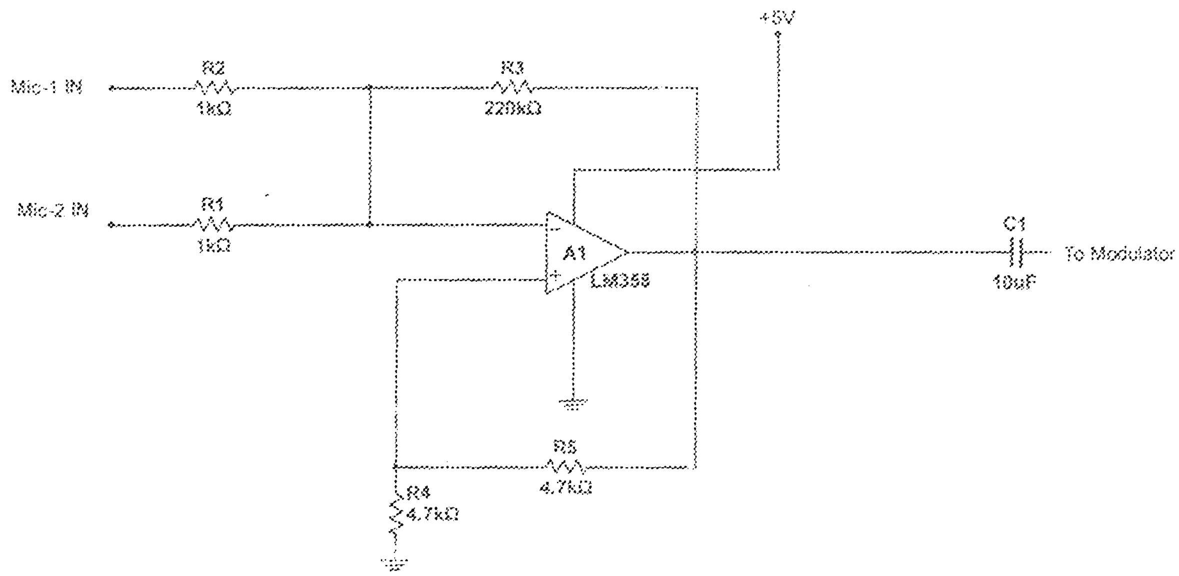

Fig 3.3: Microphone Amplifier

An LM358 device was used as the active element in the amplifier setup. It was configured as an inverting amplifier with a gain set to a maximum of about;

$$\frac{Rf}{Ri} = \frac{-220K}{1K} = -220 \quad (3.1)$$

The actual gain is a little lesser than the calculated due to the internal impedance of the microphones.

The internal block diagram of LM358 is shown in Figure 3.4:

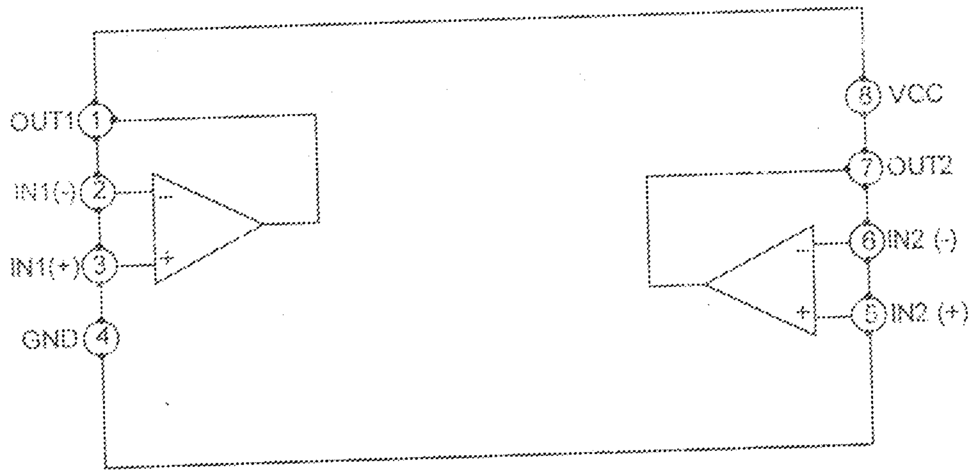

Fig 3.4: Internal Diagram of an LM358 Amplifier

The LM358 consist of two independent, high gain, internally frequency compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltage. Operation from split power supplies is also possible and the low power supply current drain is independent of the magnitude of the power supply voltage.

Application areas include transducer amplifier, DC gain blocks and all the conventional OP-AMP circuits which now can be easily implemented in single power supply systems.

The amplified output was fed into the modulator input. The amplifier was biased with its input at $^1/_2$Vcc, i.e. 2.5V by a potential divider network comprising two 4.7KΩ resistances as indicated in Figure 3.3, its output was coupled via a 10μF capacitance into the modulator, and also AC-DC converter controlling the voice activated switching (VAS) system.

3.3 VOICE ACTIVATED SWITCHING SYSTEM

For maximal battery power conservation, a voice activated switching system was implemented. In the voice activated switching system, the power to the transmitter and modulator was held OFF (at about 1.2V) until the microphones pick up sound signals loud enough to enable transmission.

The system works on the premise that the audio signal can be processed and used to control an electronic switch which in turn control the power.

The voice activation switching implementation in Figure 3.5:

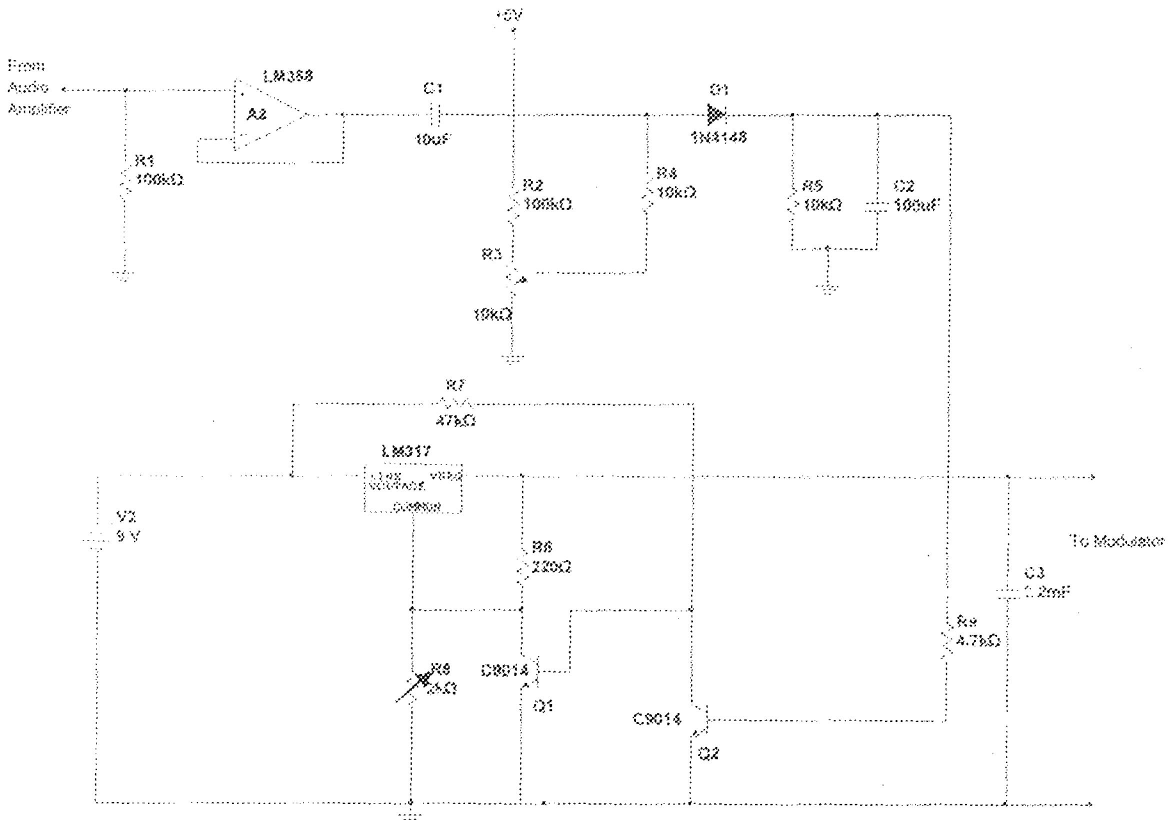

Fig 3.5: Voice Activation Switching Implementation

An LM317 regulator was used as the power controlled element. The regulator is adjustable, with an output voltage determined by the relation given below:

$$V_o = 1.25\left(1 + \frac{R2}{R1}\right) \tag{3.2}$$

The regulator accepts input voltages from about 3V – 35V. in figure 3.5 above, the output voltage was set to 6V by a 2KΩ resistance. Two NPN transistors were used to control the regulator.

The control voltage was derived from the amplified microphone voltage. The audio level from microphone ampLifier A1 was buffered by A2, and converted to a DC voltage by a IN4148 small-signal diode. For increased sensitivity, the signal diode was placed on the threshold of conduction by a bias voltage derived from a 10KΩ potentiometer and a 10KΩ resistance connected to the anode. The diode was biased by a voltage level of about 0.4V by the adjustment of the 10KΩ pot. The audio level from the amplifier simply rides on this voltage level to switch on Q2.

The AC audio level was rectified by the IN4148 and smoothened by an RC network of a 100KΩ and 100µF parallel combination, yielding a decay time of approximately 10seconds.

The control voltage, in the presence of an audio signal arriving at the microphones, biases on Q2, which robs Q1 of its base-bias, releasing the LM317 device from its shutdown mode.

The modulator/amplifier system is thus powered at about 6V until approximately 10seconds after the audio level arriving at the microphones is too low to be processed or transmitted.

3.4 FM SUBSYSTEM

A simple reactance modulator FM system was implemented. Modulation was achieved by the analog input voltage varying the collector-emitter capacitance of Q3, a C9014 NPN transistor.

The modulator was configured as in Figure 3.6:

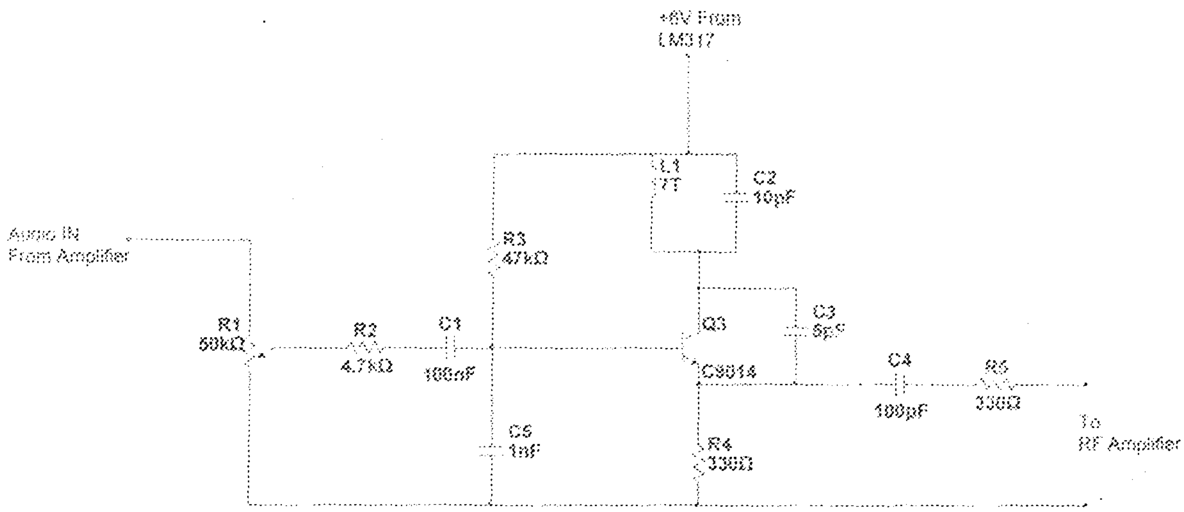

Fig 3.6: FM Modulator

The audio from the amplifier was applied to a 50KΩ potentiometer where its value was adjusted to prevent over-modulation and unavoidable distortion.

The audio was applied to the base-emitter junction of Q3 to modulate its C_{CE} as depicted below. Q3 was configured in the common-base mode for high-frequency oscillation by the 1nF capacitance between its base and ground.

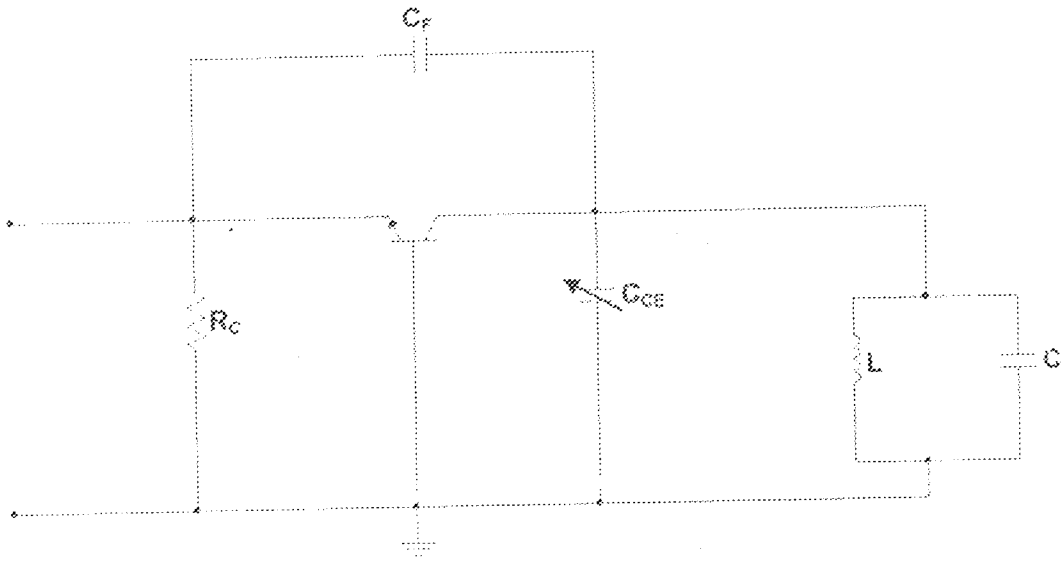

Fig 3.7: Common Base Configuration

To achieve frequency deviation, C_{CE} was adjusted in value, and directly C_T of the LC tank circuit, by the analog audio voltage.

Changes in I_b cause corresponding changes in I_e, which in turn varies with C_{CE}. The variation in C_{CE} changes the total capacitance of the tank, causing a deviation, ΔF_O from the centre frequency, f_o.

The frequency of oscillation, unmodulated is given by the expression:

$$F_{OSC} = \{\frac{1}{2\Pi\sqrt{L(CT)}}\}\ Hz \quad (3.3)$$

$$C_T = C + C_{CE}\ \text{(unmodulated)}$$

However, with an input audio voltage, C_{CE} is altered. Therefore,

$$F + \Delta F_O = \frac{1}{2\Pi\sqrt{L(C+\Delta C)}} \quad (3.4)$$

Where

$\Delta C = C_{CE} \pm \Delta C_{CE}$

Since C_{CE} is strictly dependent on I_C, which is dependent on I_B, variations in I_B directly causes corresponding variations in I_C which alters the tank capacitance, and its generated frequency.

The tank inductance was made using 7 turns of 22 copper wire. A fixed capacitance of 10pF was connected in parallel with the inductance. With no modulation, a centre frequency of about 94MHz was obtained. A 5pF capacitance between Q3's collector and emitter provided positive feedback required to sustain oscillation. The oscillatory current developed a voltage across the 330Ω emitter resistance which is amplified by Q4, Q5, and Q6.

3.5 RF AMPLIFIERS

A two stage amplifier was used to boost the modulator output. The amplifier was configured as in Figure 3.8:

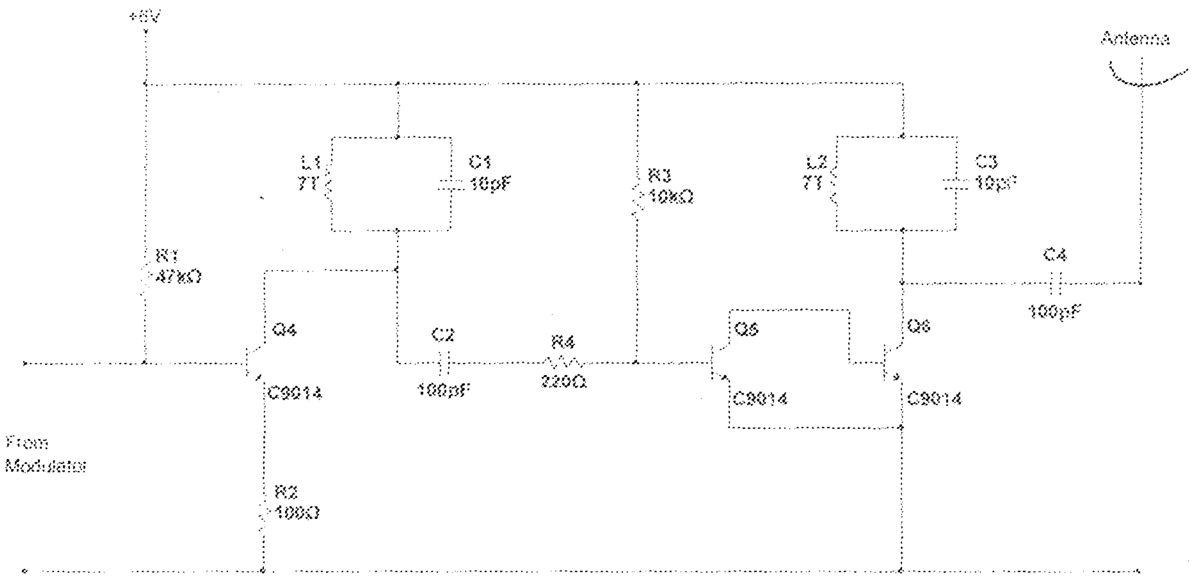

Fig 3.8: RF Amplifiers

C9014 low-power transistors were used in the final RF stages to minimize power consumption. A single transistor with tank circuit components identical to the oscillatory tank circuit was placed immediately after the modulator. Its collector was fed, via a high value coupling capacitance, into the input circuit of the final amplifier stage comprising two C9014 transistors in parallel for added current handling. The transmitted audio was radiated over a 60cm antenna.

CHAPTER FOUR

TESTS, RESULTS AND DISCUSSION

4.1: TEST AND RESULTS

The following voltages were recorded during transmission from the amplifiers;

Table 4.1: Table of Input and Output Voltages Recorded

Component (Transistors)	Input Voltage (V)	Output Voltage (V)
Stage 1	2.04	2.28
Stage 2	2.11	2.64

$$\text{Voltage gain (G)} = \frac{Output\ Voltage}{Input\ Voltage} \qquad (4.1)$$

$$\text{Voltage gain of first stage } (G_1) = \frac{Output\ Voltage}{Input\ Voltage} = \frac{2.28}{2.04}$$

$$G_1 = 1.12$$

$$\text{Voltage gain of second stage } (G_2) = \frac{Output\ Voltage}{Input\ Voltage} = \frac{2.64}{2.11}$$

$$G_2 = 1.25$$

Total Voltage Gain, $G = G_1G_2$ (4.2)

$$= 1.12 \times 1.25$$

$$= 1.4$$

Decibel gain (dB)

dB gain $GV = 20\log_{10} \frac{Output\ Voltage}{Input\ Voltage}$ (4.3)

dB gain $GV_1 = 20\log_{10} \frac{2.28}{2.04}$

First Stage dB gain $GV_1 = 20\log_{10} \frac{2.28}{2.04}$

$$GV_1 = 20\ (\log_{10}2.28 - \log_{10}2.04)$$

$$GV_1 = 20 \times (0.048)$$

$$GV_1 = 0.97dB$$

Second Stage dB gain $GV_2 = 20\log_{10} \frac{2.64}{2.11}$

$$GV_2 = 20\ (\log_{10}2.64 - \log_{10}2.11)$$

$$GV_2 = 20 \times (0.097)$$

$$GV_2 = 1.95dB$$

Total decibel gain = $GV_1 + GV_2$ (4.4)

$GV = 2.92dB$

4.2 DISCUSSION OF RESULTS

From the tests and results carried out above, it is discovered that the strength of the audio signals picked up by the condenser microphones depend on the gain of the two stage amplifiers which are connected in series.

The transmitting range of the voice activated bug is 50m radius from the device. The frequency at which it transmits is 94.0MHz.

4.3 DIFFICULTIES ENCOUNTERED

1. Problems in correcting and adjusting the inductor to the proposed frequency for transmission.
2. Bridging of close terminals of components during soldering.
3. Mistakes in identification of pin configurations of various components like voltage regulator, transistors e.t.c.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1: CONCLUSION

This project (design and construction of a voice activated bug) was designed as a surveillance device to transmit audio signals (conversation, music, information e.t.c.) at a frequency of 93.0MHz via frequency modulated (FM) radio wave.

5.2: RECOMMENDATIONS

This project work is recommended for use at home, office, during meetings, investigations and interviews for security purpose, to retrieve and document information for use. It can be used by security agents, journalist, private investigators etcetera.

It can be improved upon by;

1. The use of laser microphones to increase sensitivity to audio signals.
2. Increasing its range of transmission.
3. Making its signal of transmission confidential through coding or signal encryption.
4. The use of microcontrollers, so as to miniaturize the project and digitize it.

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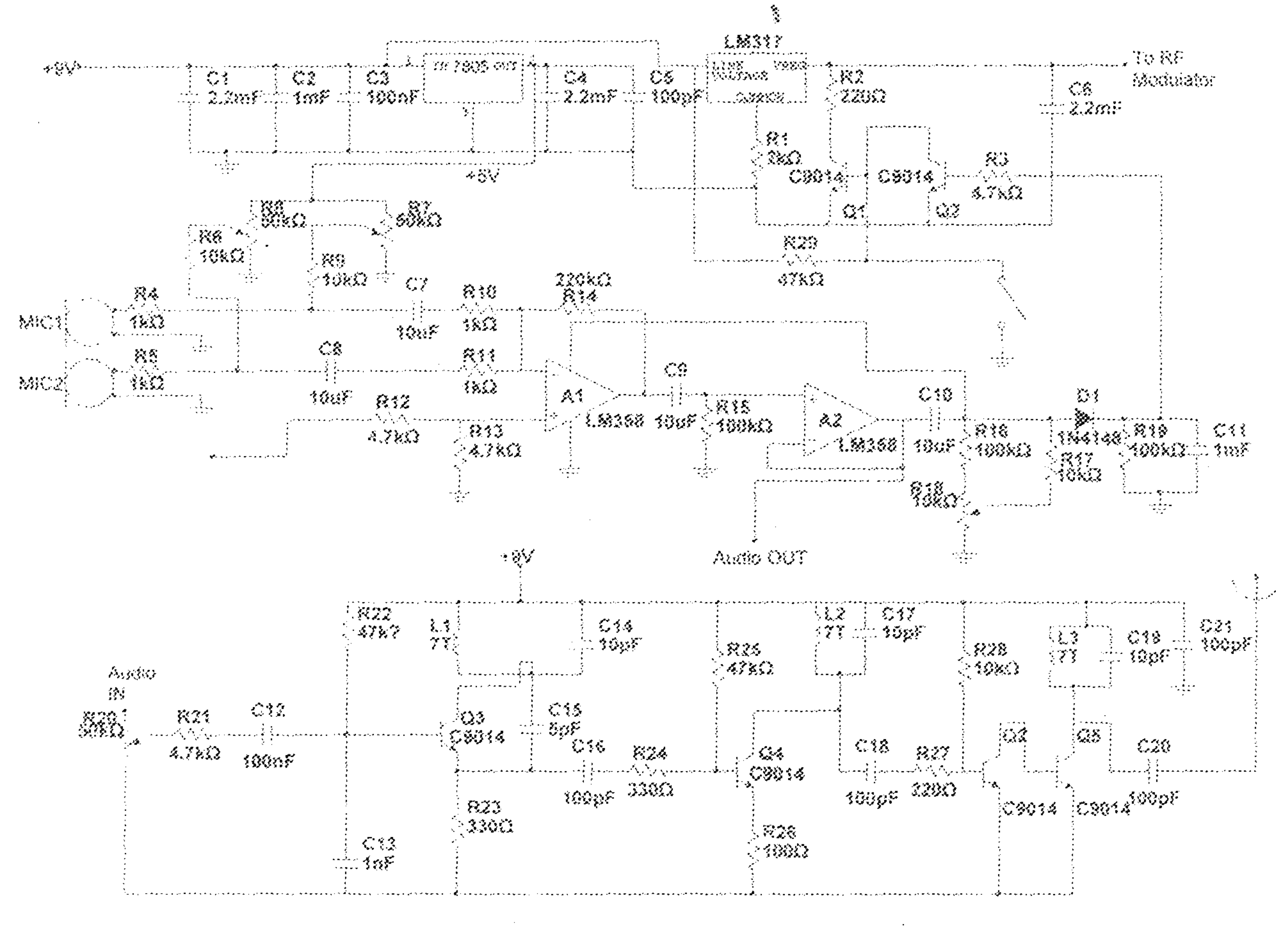
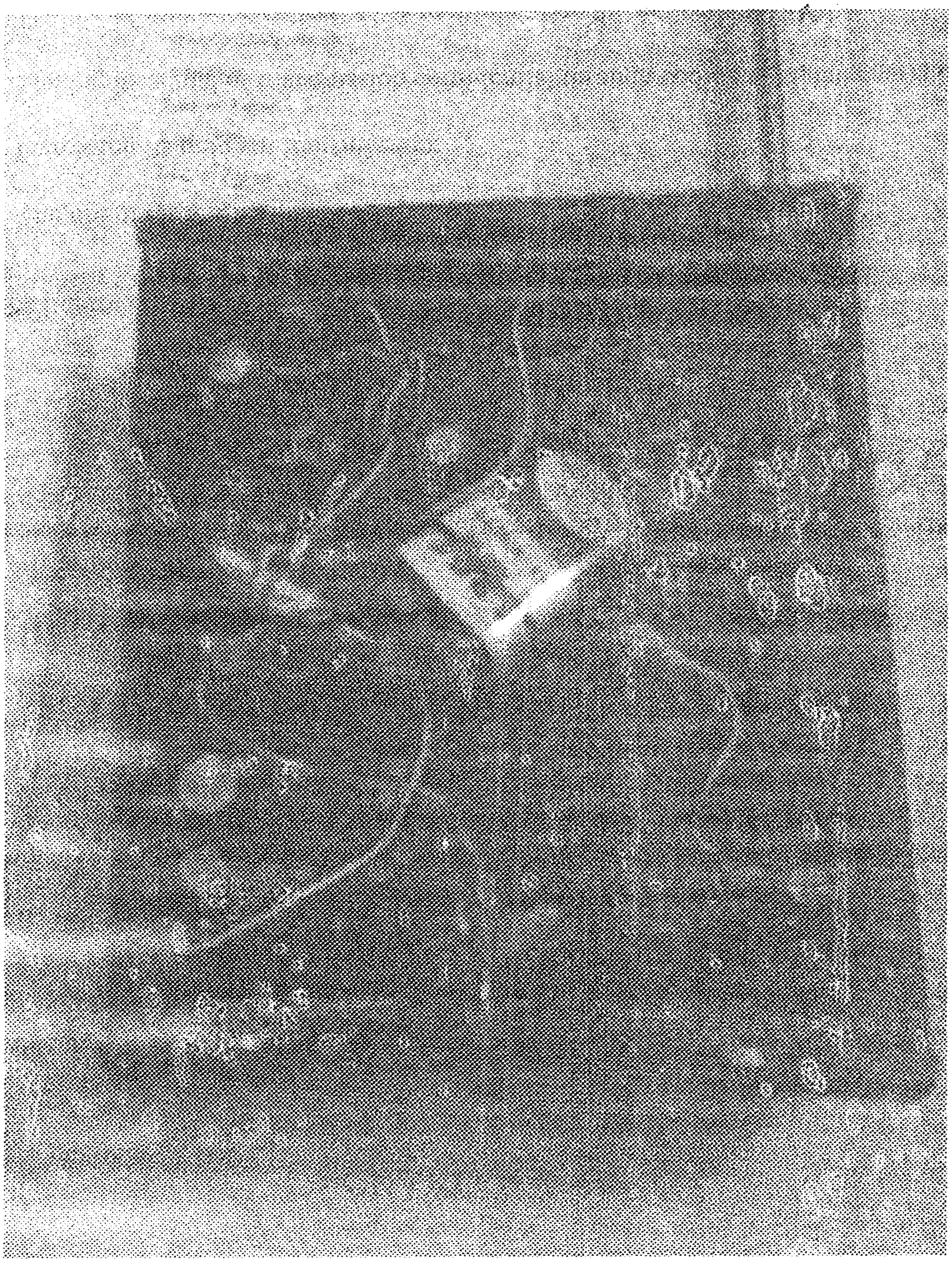
APPENDIX 1



Complete Circuit Diagram of a Voice Activated Bug

APPENDIX 2



Picture of the Assembled Circuit of a Voice Activated Bug