DESIGN AND CONSTRUCTION OF A SIMPLE SHORT WAVE (SW) RECEIVER

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CERTIFICATION

This work was carried out entirely by Suleiman Zubair, Reg. No. 97/6201EE. It was submitted and duly approved as satisfying part of the requirements of the Electrical and Computer Engineering, Federal University of Technology Minna, for the award of Bachelor of Engineering (B. Eng.) Degree in Electrical and Computer Engineering.

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DEDICATION

This work is dedicated to Allah, The Originator of existence for His infinite mercy over me, and then to my beloved parents, - Alh. Ismaila Zubair and Mallama Zainab Zubair - for their support, concern and encouragement, and to my brothers and sisters.

ACKNOWLEDGEMENT

My deep and sincere appreciation goes to my supervisor, Mr. S. N. Rumala for being not only a supervisor but also a father. Thank you for all the experience, kindness and understanding. It is my pleasure to work under you again.

I wish to express my profound gratitude to my dear sisters Ramatu, Asmau, Fatimah, Wali, Zainab and my brothers Abdurahman, Ismail and Muhammad for their support, prayers and love.

I am also very grateful to my classmates and friends who assisted me in one way or the other in the course of this work, especially to Khalil Ibrahim, Isa Sadiq and Yahaya Salihu.

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Suleiman Zubair

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ABSTRACT

Over the last twenty years or so, a good number of short-wave radio designs have been published. Nearly all of them have used expensive coils and air-spaced tuning capacitors, and have output suitable only for crystal earpieces, or high impedance headphones.

This project combines the advantages of these previously circuits whilst using home made coils and capacitors and having the benefit of a built-in-loudspeaker.

It is a TRF (Trained Radio Frequency) design covering approximately 1.6MHz to 30MHz in three bands. The audio output is provided by an IC amplifier capable of supplying over one Watt when operated from a nine volt dc supply.

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CHAPTER ONE

GENERAL INTRODUCTION

1.1 INTRODUCTION

Radio is a part of everyday life. Personal radios, car stereos, and clock radios are just some of the many kinds of radio receivers we use. Since the time it was invented, less than 100 years ago, radio has become one of our most popular and reliable forms of communication.

In addition to entertainment and information, radio has important uses in transportation, public safety, and industry. It is also used in national defense, space travel and exploration, information processing and many other areas.

Radio is an electronic technology that makes communication possible between two points without any wires connecting those points. (Before the invention of radio, communication by telephone and telegraph required a wire to carry the message between sender and receiver.) With radio waves, a signal representing sounds or other types of information can be carried through the air, outer space, or along the ground. These signals travel at the speed of light, so messages can reach any place in the world in about a second.

Communicating by radio involves three (3) steps:

(1) Converting or changing sound or other information into electrical signal.

(2) Transmitting the signal, and

(3) Receiving the signal.

Radio use generally fall into two types – broadcast radio, which primarily offers entertainment and information for mass audiences, and two-way radio, used to communicate between two points, often with just one person at each point. [6]

1.2 THE BASIC PRINCIPLES OF RADIO

All radios today, however, use continuous sine wave to transmit information (audio, video, data). The reason for using continuous sine waves today is because there are so many different people and devices that want to use radio waves at the same time. Each different radio signal uses a different sine wave frequency, and that is how they are all separated.

Any radio set-up has two parts:

- The TRANSMITTER
- The RECEIVER

The transmitter takes some sort of message (it could be the sound of someone's voice, picture for a TV set, data for a radio modem for whatever), encodes it onto a sine wave and transmits it with radio waves. The receiver receives the radio waves and decodes the message from the sine wave it receives. Both the transmitter and receiver use antennas to radiate and capture the radio signal.[10]

1.3 LITERATURE REVIEW

It was Maxwell's work at king's College London that proved the existence of the electromagnetic wave. Most of his work was theoretical, however, and he was never able to prove the existence of electromagnetic waves in practice. He published three main papers between 1855 and 1864 and finally summarized his work in a book entitled "Treatise on Electricity and Magnetism", (Lan Poole, 1998). It was not until much later; Heinrich Hertz proved the physical existence of these waves. (Andrew Crisell, 1997). He carried out several lectures and demonstrations where he showed and induction coil generating a spark across the spheres connected to it, proving that electromagnetic waves were present.

As reported by Poole, (1998) the English Scientist, Sir Oliver Preece, carried out more trials and by 1894, he had improved the experiments so much that a signal can be detected several hundred meters away. At around this time, Marconi started to experiment with these electromagnetic waves at his parent's home in Balogna, Northern Italy. In the summer of 1895, he managed to transmit a signal over two kilometers away. Through lack of interest from the Italian Ministry of past, Marconi decided to come to England where considerably more attention was paid to his work. In 1896, Marconi demonstrated his experiments to representatives from the post office, war office, and navy. The navy was potential for communication at sea, and showed considerable interest. Lan Poole (1998) reports in his book that Marconi also wanted to investigate the possibilities for long distance communication. An initial experiment succeeded in transmitting a signal across the English Channel and finally on 12 December 1901, the first transmission across the Atlantic was achieved. The next few years saw great advances in the technology involved in radio transmission and reception with significant breakthroughs involve development and crystal detectors.

The First World War broke out in 1914 bringing with it a new need for radio communications. The technology advanced further still as great effort by both sides was put into developing better receivers and transmission techniques.

Marconi made the first regular commercial broadcasts from his Chelmsford radio station. His station began broadcasting a half-hour daily schedule of speech, music and news on 23rd February 1920. He was forced to close his station due to interference, however is re-opened in February 1922 licensed as 2MT and was allowed to broadcast a 15-minute program. This program was so successful that he opened a new station in the center of London in May of the same year licensed as 2LO. This station was later taken over by the British Broadcasting Corporation in November of that year. These facts are reported in a Lan Poole Publication (1998).

Broadcast radio up until with the early forties, used the AM (Amplitude Modulation) transmitting technique. This was the basis for all audio broadcasting until FM or Frequency Modulation was commercially introduced in America at the start of the forties. However, it was not until the early seventies, that FM began to become more predominant, finally attracting larger audiences than AM at the end of the seventies.

It was the American Edwin Armstrong who first started to investigate the idea of varying the transmitted signals frequency rather than its amplitude. In 1935, Armstrong demonstrated that FM radio was capable of producing for better quality transmissions over its AM counterpart. He set up his own FM station in 1939 to demonstrate this significant increase in audio quality, and soon after these first FM broadcasts, there was considerable interest from commercial stations who applied for licenses of their own on the FM broadcast band.[9]

1.4 PROJECT OBJECTIVE/MOTIVATION

The aims and objectives of this project, "Design and Construction of SHORT-WAVE (SW) RECEIVER" are:

(a) To develop a simple and effective low cost receiver by applying circuit techniques.

(b) To stimulate the interest of upcoming students to take up research topics in radio technology taking into consideration this effective do-it-yourself circuit.

(c) To make fellow students appreciate the applications of circuit techniques.

1.5 PROJECT OUTLINE

Chapter one:- This chapter gives a general introduction to radio, its uses and other applications of radio. It also gives an overview of the project introducing its functional units. The literature review on research on the field, of radio is also contained in this chapter. Other topics featured were the aims and motivations to this project and an outline of the entire content of the project chapter by chapter is also contained in this chapter.

Chapter two: - This chapter deals with the overall system design. This is expanded in details from module-to-module.

Chapter three: - Construction, testing and results. This chapter gives the details of how the project was implemented; the bests carried out the and the corresponding results of the tests are also featured in this chapter.

Chapter four: - conclusions, recommendations, references and appendix. This chapter contains the student's view of what has been achieved with reference to the aims and objectives or the project, the goals met and the difficulties or limitations encountered. Recommendations on how the project can be improved upon were also outlined here. Other materials consulted were outlined under the reference. The circuit diagrams are contained in the appendix.

CHAPTER TWO

DESIGN PROCEDURE

2.1 INTRODUCTION

If you take a look through some of the current short wave receiver and equipment catalogues, you can hardly fail to notice that all the short wave sets on offer are pretty complex. Virtually all the receivers now have a built-in microprocessor to control everything, together with digital displays, synthesized tuning, multitimers, etc. This is just the relatively inexpensive portable set and the "proper" communications receivers are even more complex with features such as external computer control, digital signal processing, and just about every other feature imaginable.

We have probably reached the stage where it is not possible for the home constructor to genuinely compete with sophisticated ready made receivers, but this is not to say that it is not possible for the enthusiast to enjoy building and using short wave receivers.

The more traditional forms of receiver will not give the same level of performance as a ready made set costing hundreds or thousands of naira, but sets such as these are still capable of receiving numerous transmissions to short wave listening, or have used expensive equipments and would like to try something more challenging, a basic do-it-yourself receiver has a lot to offer.

2.2 DESIGN PROCEDURE

The design procedure for implementing the SW receiver is diagrammatically illustrated with the aid of the schematic diagram below.

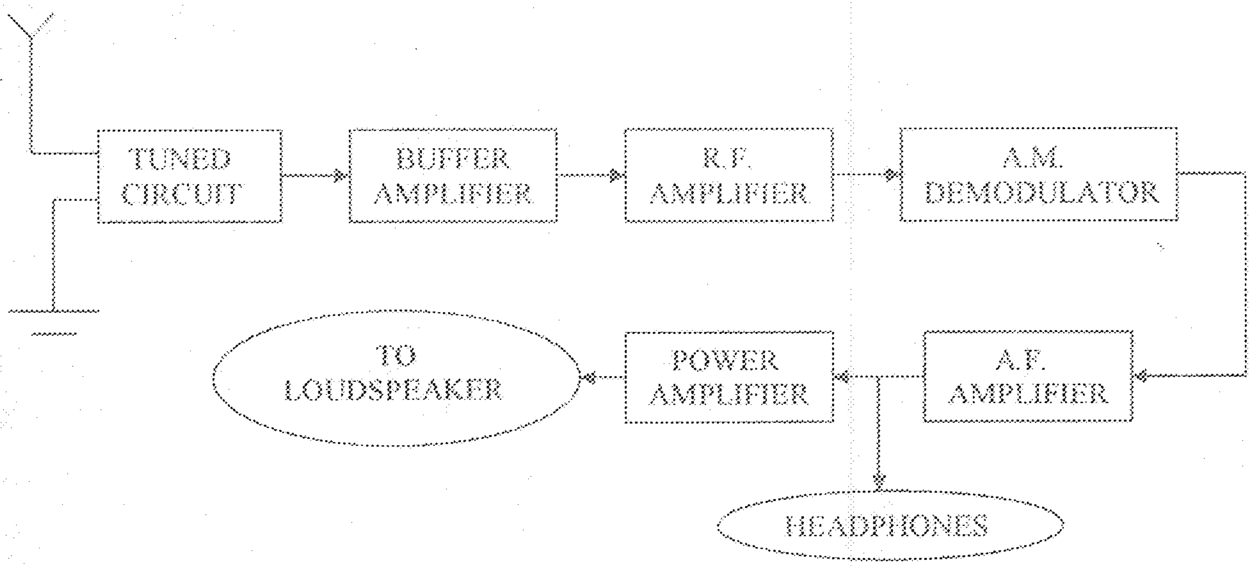

Fig. 2.0: Block diagram of simple short wave (SW) receiver

The design was approached by breaking the whole system into functional subunits that could be implemented individually.

The functional subunits are as shown in figure 1.2. The circuit was implemented in a bottom to top implementation mode.

2.3 SYSTEM OPERATION

The receiving aerial which can be regarded as a signal generator picks up the radio waves converts it to minute electrical signal and send it to the next stage (i.e. tuned circuit).

At the tuned circuit is where the channel selection takes place and further passes the chosen channel to the next stage, the Buffer amplifier stage.

In this stage, the signal just receives a little amplification and the radio frequency (R.F.) signals are then channeled to the RF amplifier where the major amplification of the received signal is carried out so as not to be lost.

The original signals are detected in the demodulation stage and the R.F carrier wave is filtered away. The output of this stage provides only the Audio Frequency (AF) signal which is actually what is needed.

The signal at this point is very weak and cannot even be used to drive a pair of headphones. Hence it has to be amplified to have enough gain to be able to drive a pair of headphones and a loudspeaker.

The amplification in this stage is achieved in two stages for the needed output.

2.4 RECEIVER SPECIFICATIONS

The design featured here is a T.R.F. (Turned Radio Frequency) set. A receiver of this type operates by providing all the gain and selectivity at the reception frequency with no frequency conversion and intermediate frequency stages being used.

The gain and selectivity of the circuit is increased by coupling a small amount of one of its output stages back into the input in a positive feedback. This process is called regeneration.

This design covers a frequency range of about 5MHz to 15MHz, which includes the most popular short wave broadcast bands. It is possible to plug in alternative coil units which bring in coverage of the low frequency bands around 1.6MHz to 5MHz and the high frequency bands from 15MHz to 30MHz.

Results on the high and low frequency bands might not be very good with a simple short wave receiver of this type, and results on the high frequency bands are very much dependent on good propagation conditions whatever receiver you use.

2.5.0 POWER SUPPLY UNIT

Power needed to drive the system is a positive volts (9V) d.c. supply.

The power is obtained from ac to regulated 9Volts dc supply. This choice (not withstanding the inability to totally filter out a.c. ripples) was made so as to maximize the economy of this simple set to its best.

A provision was also made for a 9-Volts battery. This makes for convenience to the outdoor listener, and makes the design more portable.

2.5.1 AC-TO REGULATED DC SUBUNIT

This is accomplished with the help of a transformer rectifier, filter, and a voltage regulator. Below is a block diagram of the power supply.

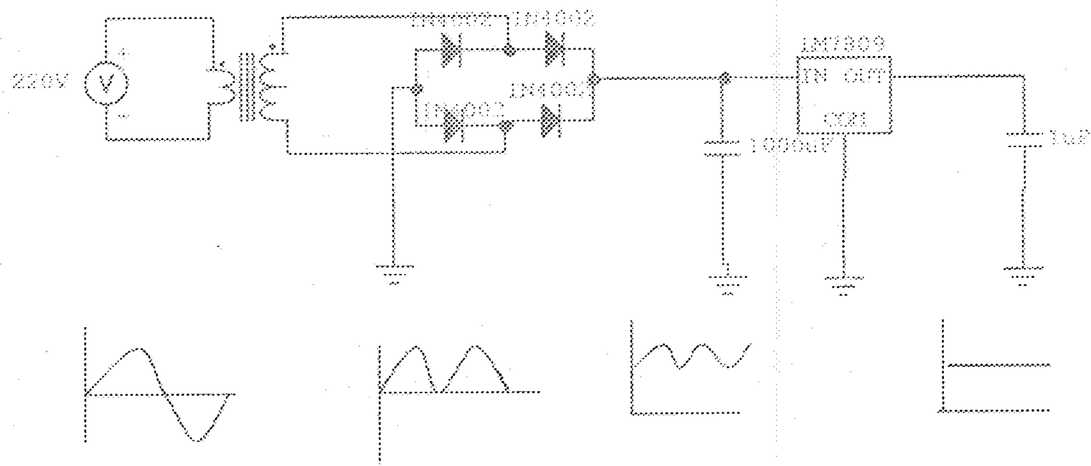

Fig. 2.1: Complete circuit diagram of power supply unit with corresponding output wave forms.

2.5.1.1 STEP DOWN OF AC INPUT BY TRANSFORMER

Its job is to step-down the ac supply voltage to just the requirement of the solid-state electronic devices and circuits fed by the dc power supply. For this design, (for a 9Volt supply), a dc 12VX1 500mA transformer was employed. This rating was chosen because the supply voltage from NEPA around the vicinity this work was carried out was always around (170-195Volts).

$$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{I_s}{I_p}$$

$N_P:N_S = 240:12 = 20:1$

2.5.1.2 RECTIFIER CIRCUIT

It is a circuit which employs one or more diodes to convert ac voltage into pulsating dc voltage. The full wave bridge rectifier was employed for this design. It requires four diodes connected as shown in figure 2.1.

The ON and OFF actions of the four diodes bring about the rectification of the input a.c. volage. For $V_{rms} = 12V$

$$V_m = \sqrt{2} \times V_{rms} \qquad \text{------------1.1}$$

$$V_m = \sqrt{2} \times 12 = 16.97V$$

$$V_{dc} = \frac{2\ V_m}{\pi} \qquad \text{------------1.2}$$

$$V_{dc} = \frac{2 \times 16.97}{\pi}$$

$$V_{dc} = 10.80V$$

2.5.1.3 FILTER

The function of this circuit element is to remove the fluctuations or pulsations (called ripples) present in the output voltage supplied by the rectifier. Voltage as ripple-free as that of a dc battery is not attainable but approaches it so closely that the power supply performs as well.

The ripple present in the output d.c. voltage can be represented by:

$$V_{ripple} = I/fC \qquad \text{------------1.3}$$

V_{ripple} = Peak-to-peak ripple voltage

I = d.c. load current

f = ripple frequency

C = capacitance.

The smaller the ripple is the better. This is achieved by increasing the discharging time constant.

$$Td = R_L C \qquad \text{------------1.4}$$

T_d = discharging time constant

R_L = load resistance

C = capacitance

2.5.1.4 VOLTAGE REGULATOR CIRCUIT

Its main function is to keep the terminal voltage of the dc supply constant even when,

(i) ac input voltage to the transformer varies (deviation from 220V are common, or

(ii) The load varies.

A single IC (7809) 9Volts voltage regulator was used.

The nine volts (9V) regulator employed is the 7809IC regulator. The IC provides a constant 9V at 1A.

Pin 1 = INPUT d.c. voltage (10.80V)

Pin 2 = Ground

Pin 3 = Regulated output (9.0V)

2.5.2 BATTERY BACKUP SUBUNIT

Batteries are closed electrochemical power sources. They convert chemical energy from reactants incorporated unto a device during manufacture. They have the advantage of being portable and ripple free. However, their voltages are low, they need frequent replacement and are expensive as compared to conventional dc power supplies.

2.6. THE TUNED CIRCUIT

The aerial picks up the radio waves from the transmitter and converts them into minute electrical signals. Whoever designs a receiver to work from an open aerial usually has no control or knowledge of the electrical characteristics of the aerials that may be used; the arrangement often has to work well enough over a wide range of frequency; and the selectivity and tuning of the receiver has to be taken into consideration.

Taking into consideration that open-wire aerials usually have substantial capacitance, and because the amount is unknown (it could be hundreds of PF) and varies with frequency and with the size of the aerial connected, and even a few PF can mistune the circuit seriously, a simple method of coupling able to take care of these was employed.

This method ensures that whatever aerial is used, the capacitance it adds to the tuned circuit must be less than C_4. And the range of signal strength brought in by aerials of different sizes is to some extent leveled out, for the layer the aerial the more its coupling is reduced by the capacitance C_3 (12pF) being so much less than its own. At the same time the effects of diverse aerial resistances are reduced. [1]

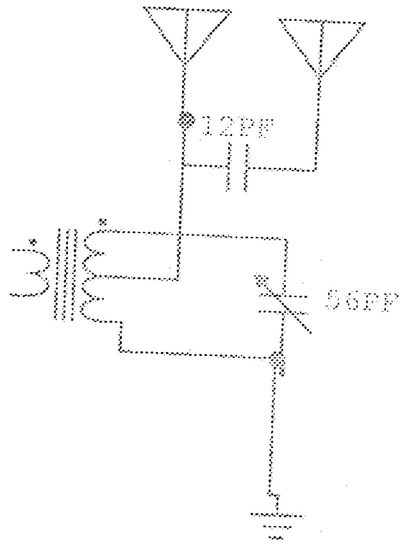

Fig. 2.5(a): The small series capacitance method of coupling employed in the design.

Based on the coupling technique employed in this design, it (the receiver) will work quite well using a short aerial, making the receiver suitable for portable operation.

An earth connection can boost signal levels, but this is optional and does not help much at higher frequencies.

The input signal from the aerial is fed to a tuned circuit, and it is this that provides most the receiver's selectivity.

The tuned circuit employed in this project is the parallel resonant type which just consists an inductor connected in parallel with a capacitor. The capacitor is a variable type, and this provides for the tuning control.[1]

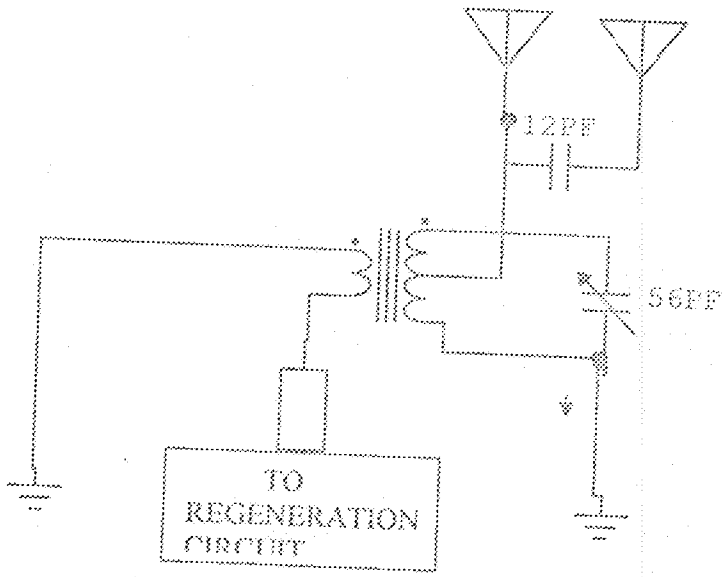

Fig. 2.6: Circuit diagram of the parallel tuned circuit

The area of consideration in any receiver is its selectivity and sensitivity. And the chief means of obtaining selectivity is the tuned circuit.

The selectivity of a tuned circuit is its ability to pick out signals of one frequency from all others. A quantity related to selectivity and sensitivity or a receiver is the magnification of the circuit (Q). Signals picked up by a receiving aerial are seldom more than a few millivolts and are often only microvolts, so (except from a powerful sender at short range) they are two weak to operate a detector satisfactorily, and hence need to be magnified. Although tuned circuits are not necessarily associated with amplification, they almost invariably are. Both selectivity and sensitivity are improved by increasing the Q of a tuned circuit.

The Q of a circuit is the ratio of its reactance (either inductive or capacitive) to its series resistance, which is the same as the ratio of its dynamic resistance to its reactance.

$$Q = \frac{X}{R} = \frac{R}{X} \qquad \text{-----------------}1.5$$

From the equation, for Q to increase r has to be considerably reduced. The provisions made for the reduction of r in this design is the regeneration circuits.[1]

REGENERATION FEEDBACK NETWORK SYSTEM

Feeding some of the output signal back to the input results in an effective boost in the input signal. However, the boost is greatest at the centre of the receiver's pass band where the gain is highest, and there is the most feedback.

A positive feedback is employed because losses that damp out oscillations in tuned circuit can be completely neutralized by energy fed to it at the right moment in each cycle (i.e. positive feedback).

Unfortunately, advancing, the regeneration control slightly too for results in the set breaking into oscillation, making proper reception impossible. In order to obtain good results from a T.R.F. receiver, it is essential that the regeneration level be kept just below the point at which the circuit breaks into oscillation.

In the tuned circuit resonance takes place at the frequency that makes the reactance of the coil equal that of the capacitor;

$$2\pi f_r L = \frac{1}{2\pi f_r C} \qquad \text{------------------1.6}$$

Where f_r is used to denote the frequency of resonance. L is the inductance of the coil, while C being the capacitance of the capacitor.

Since the circuit is to be tuned through a range of frequencies; the lower frequency of the required range is chosen as f_r and the maximum capacitance of the variable tuning capacitor is taken as C.

The value of the capacitor employed in the design is 36pF - 36pF.

From equation 2.1, making L subject of formular;

$$2\pi f_r L = \frac{1}{(2\pi f_r)^2 C} = (2\pi f_r)^{-2} C^{-1} \quad \text{-----------------1.7}$$

For frequency band: 1.6MHz to 5MHz:

$f = 1.5MHz$

$\therefore L = 2\pi(1.6 \times 10^6)^{-2} (56pF)^{-1}$

$L = 176.79\mu H$

For frequency band; 5MHz to 15MHz

$f = 5MHz$

$\therefore L = 2\pi(1.6 \times 10^6)^{-2} (56pF)^{-1}$

$L = 2.01\mu H.$

WINDING OF THE INDUCTOR COILS

In winding the inductor coils to specifications of inductances as calculated above, a computer program was employed. Some of the features of the program are;

It calculates the inductance for a specified number of turns of a particular wire gauge to be wound on a specified diameter.

Hence the method of random selections was made of number of turns until an approximate convergence of the needed inductance was arrived at.

The gauge of the wire used was '36' (CORE 36). Below is an illustration of the programme. Also, a micrometer screw gauge was used to measure the diameter of winding to be used.

At most frequencies, this arrangement of the tuned circuit employed in this design has low impedance and it effectively short-circuits the input signals to earth. At and close to its resonance frequency the impedance is much higher, and signals at these frequencies are able to pass through to the subsequent stage.

2.7 THE BUFFER STAGE

This stage is a buffer amplifier which ensures that the tuned circuit feeds into high impedance. A low load impedance would tend to broaden the response of the tuned circuit, giving poor selectivity.

A J.F.E.T. transistor (TR1) (2N5668) performs this role in the design. The J.F.E.T is used in a conventional source follower circuit (the F.E.T. equivalent of a bipolar emitter follower stage).

identity, a buffer should have high input impedance. If it does, almost all the Thevenin voltage from the tuned circuit appears at the buffer input. The buffer should also have low output impedance. This ensures that all its output voltage reaches the input of the next stage (ie, amplifier stage).

The source follower is an excellent buffer amplifier because of its high input impedance (well into the megohms at low frequencies) and its low output impedance (typically a few hundred chains). The high input impedance means light loading of the previous stage. The output impedance means that the buffer can drive heavy loads (small load resistances). [5]

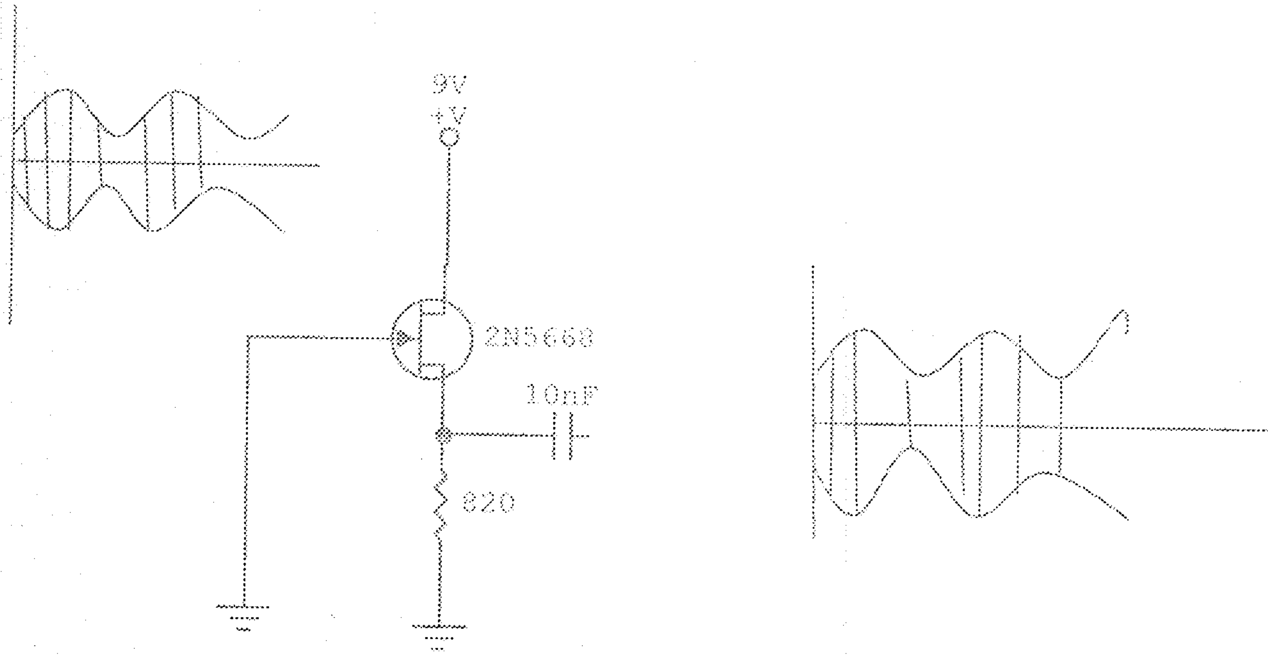

Fig. 2.7: Circuit diagram of the J.F.E.T. Buffer Amplifier

The input signal drives the gate and the output signal is coupled from the source by a capacitor (C_4) to the load resistor. The source follower has a voltage gain less than 1.

The a.c. source resistance is defined as r

$R_s = R_3//R_L$ ——————1.8

R_s = source resistor (Ω)

R_L = load resistor (Ω)

Also the gain (A) is defined as

$$A = \frac{g_m \times r_s}{1+g_m r_s}$$ ——————1.9

g_m = Transcnductance

$$g_m = g_m \left(1 - \frac{V_{GS}}{V_{GS(off)}}\right) \quad \text{------------------2.0}$$

where,

g_m is the transconductance when the voltage between the gate and source (V_{GS}) is equal to O.

From data sheets;

	$V_{GS(off)}$	I_{DSS}	g_m	R_{DS}
2N5668:	-4V	5mA	2,500μS	800Ω

when V_{GS} = 0; g_{m0} occurs;

$$g_m = g_m \left(1 - \frac{0}{-4}\right)$$

$\therefore g_m = g_{m0} = 2{,}500\mu S$

$\Rightarrow \quad (V_{GS(off)}, g_{m0}) = (-4V, 2500\mu S)$

The value of V_{GS} = 0.023V being the voltmeter reading.

$$g_m = g_{m0}\left(1 - \frac{0.023}{4}\right)$$

$g_m = 2500 \times 10^{-6} [1-5.75 \times 10^{-3}]$

$g_m = 2485.63\mu S$

$\Longrightarrow \quad Q(-0.023V, 2485.63\mu S)$

The load line and corresponding Q-point for this circuit is as below:

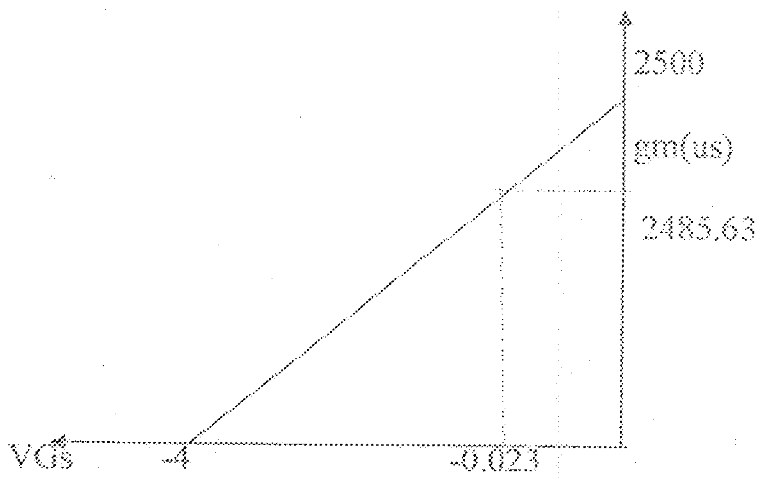

Fig. 2.8: Graph of load line and Q point of the J.E.F.T. transistor

A capacitor (C_4) couples the output of T_{R_1} to a simple common emitter amplifier based on transistor T_{R2}.

$$A = \frac{g_m \times r_s}{1+g_m r_s} \quad \text{------------------} 2.1$$

$r_s = R_S // R_L$ (a.c. source resistance)

$R_S = 820\Omega$

$R_L = 430K$

$r_s = 820//430K$

$= 818.43\Omega$

$\therefore A = \dfrac{(2485.63\mu S)(818.43)}{1 + (2485.63\mu S)}$

$A = 0.99 \times 10^{0}$

The a.c. equivalent circuit is as shown below

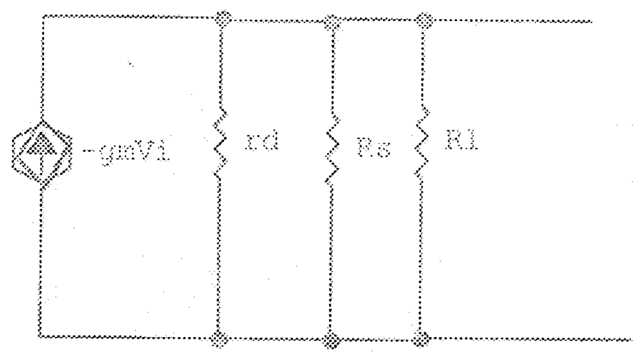

Fig.2.9 AC Equivelent circuit for TR1

$r_0' = \dfrac{r_d}{1+g_m r_d} //R_L \cong \dfrac{1}{g_m} // R_L$

$r_0' = \dfrac{1}{(2485.63\mu S)} //430K$

The modified a.c. equivalent circuit is as shown

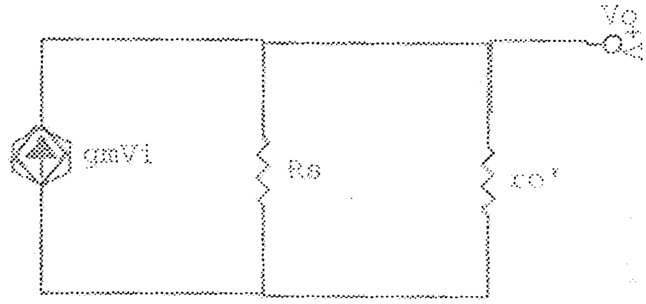

Fig2.10 The Modified AC Equivalent circuit.

2.8 THE AMPLIFIER STAGE (RF AMPLIFICATION)

The next stage is an amplifier, and it is this stage that provides much of the receiver's gain. The selectivity provided by a single tuned circuit operating at a high frequency is not very great, and without assistance it will not give usable results.[7]

To both boost the gain of the circuit and greatly improve its selectivity, a positive feedback from the output of the amplifier to the input of the tuned circuit (i.e. regeneration as already discussed in sec. 2.5.1.1)

The transistor used in the amplifier stage is the BC550. The transistor (TR2) was connected in a collector and emitter feedback. This connection relatively makes the Q-point stable.[5]

Another capacitor (C_3) couples some of TR2's output signal to variable attenuator (variable resistor (VR1)), and from here it is coupled back to the input of the circuit by way of a small coupling winding on T_1.

Below is the circuit diagram of this amplifier stage.

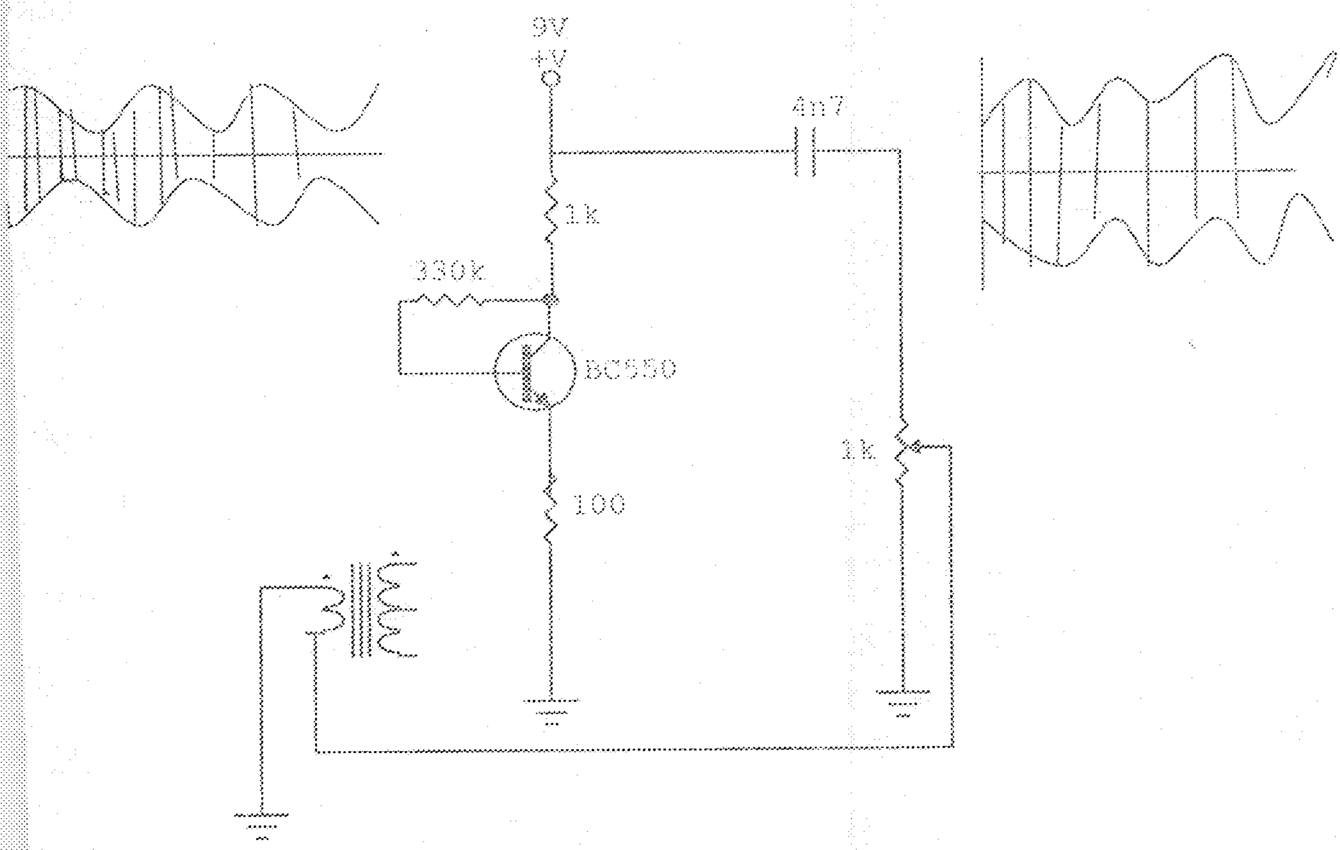

Fig. 2.11: Circuit of the common emitter amplified connected in a collector and emitter feedback

$V_{CC} = 9V$

$R_L = 1K$ (load resistor)

$R_B = 330K$ (base resistor)

RE = 100Ω (emitter resistor)

When;

At $I_C = 0$, $V_{CE} = V_{CC} = 9V$

At $V_{CE} = 0$; $I_{C(sat)} = \dfrac{V_{CC}}{R_L + R_E}$ ----------------2.2

$$I_{C(sat)} = \frac{9}{(1000 + 100)} = 8.18mA$$

$(V_{CE}, I_{C(sat)}) = (9V, 8.18mA)$

For Q point,

$I_C = \dfrac{V_{CC}}{R_L + R_E + R_B/\beta}$ ----------------2.3

β = Transistor gain

β = 701

$$I_C = \frac{9}{100 + 1000 + 330 \times 10^3 / 701}$$

$I_C = 5.73mA$

$V_{CE} = V_{CC} - I_C(R_L + R_E)$ ----------------2.4

$= 9 - 5.73 \times 10^{-3}(1000+100)$

$V_{CE} = 2.7V$

$Q(V_{CE}, I_C) = Q(2.7V, 5.73mA)$

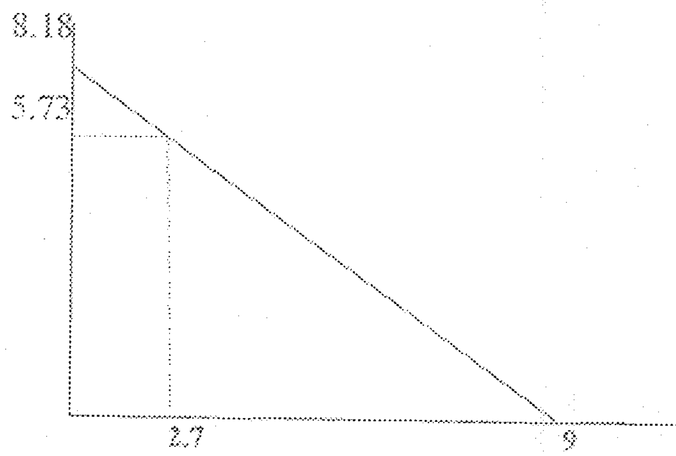

Fig. 2.12 Loadline for TR3 showing Q point.

There is an inversion of the signal through TR_2 but the phasing of T_1 is such that it provides a further inversion so that the required feedback is obtained. VR1 controls the amount of feedback applied over the circuit.

The a.c. equivalent circuit can be derived from the following C.E. a.c. parameters.

Input resistance of the base

$R_{in(base)} = R_B//\beta r_e'$ ----------------------------------2.5

AC load resistance

$r_L = R_E//R_L$ ----------------------------------2.6

input resistance of the emitter diode (for germanium diodes)

$$r_e' = \frac{25Mv}{I_E}$$

Voltage gain

$$Av = \frac{r_v}{r_e} = \frac{r_L}{r_e'} \quad \text{----------------------------------2.7}$$

power gain

$A_p = A_i \times A_v$

$G_p = 10\log_{10}A_p$ (db)

$\Rightarrow r_L = R_E//R_L = 100//1K = 90.90\Omega$

$A_i = \beta = 701$

$$r_e' = \frac{25mV}{I_E}$$

$$I_B = \frac{I_C}{\beta} = \frac{5.7mA}{701} = 8.13\mu A$$

$\therefore I_E = I_B + I_C = 5.7mA + 8.13\mu A$

$= 5.7mA$

$$\therefore r_e' = \frac{25mV}{5.7mA} = 4.39\Omega$$

$\Rightarrow \beta r_e' = 4.39 \times 701 = 3074.56$

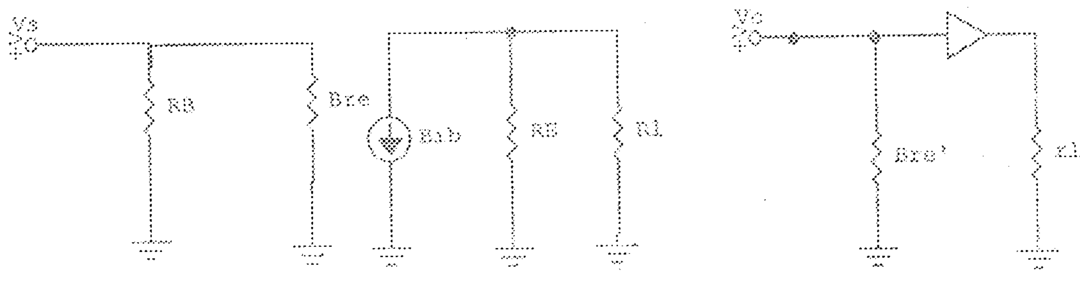

Fig2.12.(a)AC Equivalent circuit for TR2. **(b) Modified AC Equivalent circuit.**

Voltage gain

$$A_V = \frac{r_L}{r_e'} = \frac{90.90}{4.39} = 20.71$$

Power gain

$$A_P = A_i \times A_V = \beta \times A_V = 701 \times 20.71$$

$$= 14515.01139$$

$$G_P = 10\log_{10}A_P = 41.62\text{dB}$$

2.9 DEMODULATION STAGE

The process of recovering AF signal from the modulated carrier wave is known as demodulation or detection.

The demodulation of an AM wave involves two operations:

(i) Rectification of the modulated wave and

(ii) Elimination of the RF component of the modulated wave.

audio input voltage. The capacitor (C_6) is used for coupling in this case (i.e. coupling the amplifier stage to the detector).

Diodes D_1 and D_2 are fed with the main output signal from TR2, and these form the conventional A.M. demodulator circuit.

Germanium diodes are preferable to the more common silicon types in this application, due to the lower forward voltage drop of germanium diodes.

The average voltage in the radio signal is always zero, because the positive half cycles are cancelled out by negative half cycles of equal value.

The diodes then carry out a half-wave rectification and the average voltage when varies in sympathy with the audio modulation voltage.[2]

The RF carrier wave is then filtered out by the capacitor (C_7) – an RF by-pass capacitor, (i.e. lowpass filtering), and leaves a replica of the original audio signal.

The d.c. Component of the remaining signal is shunted out through VR2 (which provides the load resistance) because it cannot pass through the blocking capacitor (C_{10}). But the low, frequency AF signal can easily get through C_{10} and becomes available across the output.

Signals obtain at the points A and B as indicated in figure 2.11(a) are as given respectively.

Fig. 2.14

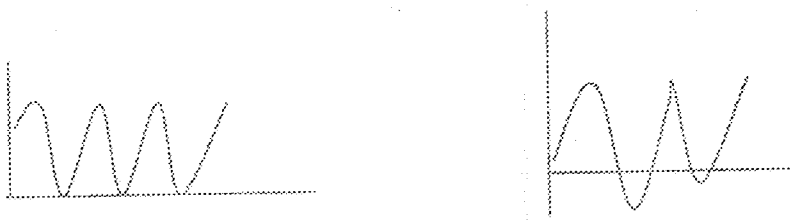

Fig. 2.14: (a) DC and AF signal at point A (b) DC filtered out leaving AF signal

2.10 AUDIO FREQUENCY AMPLIFICATION

Capacitor C10 couples the audio signal from VR2 to the input of a second common amplifier (TR3). After some further amplification, the signal provides sufficient drive for a pair of headphones. The transistor TR3 was connected as a collector feedback. This configuration ensures a relatively stable Q-point.

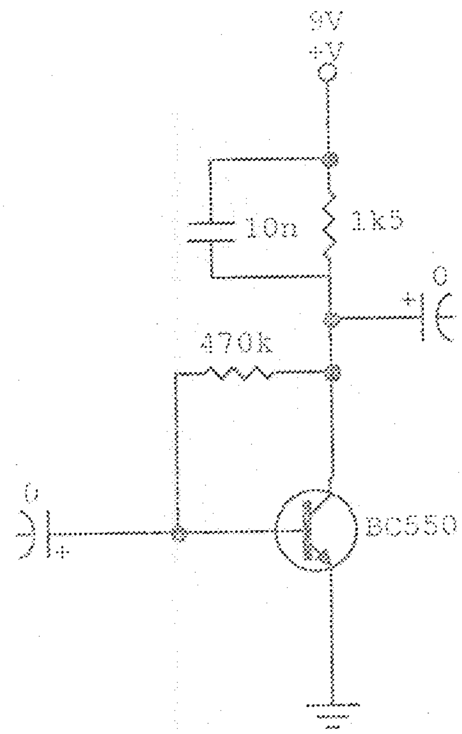

Fig. 2.15: Circuit diagram of the common emitter amplifier

VCC = 9V, (supply voltage)

β = 701, (gain of transistor)

R_B = 470K (Base resistor)

$$I_{C(sat)} = \frac{V_{CC}}{R_L} \qquad \text{------------2.8}$$

$$IC = \frac{V_{CC} - V_{BE}}{R_L + R_B/\beta} \approx \frac{VCC}{R_L + R_B/\beta}$$

$$V_C = V_{CC} - I_C R_L \qquad \text{------------2.9}$$

β = 701

V_{CC} = 9V

$R_L = 1.5K$

$R_B = 470K$

At $I_C = 0$, $V_{CE} = V_{CC} = 9V$

At $V_{CE} = 0$, $I_{C(sat)} = \frac{V_{CC}}{R_L}$

$I_C = \frac{9}{1.5K} = 6mA$

For Q-Point

$I_C = \frac{V_{CC} - V_{BE}}{R_L + R_B/\beta} \cong \frac{V_{CC}}{R_L + R_B/\beta}$

$I_C = \frac{9}{1.5K + 470K/701} = 4.15Ma$

$V_C = V_{CC} - I_C R_L$

$= 9 - (4.15 \times x 10^{-3})(1.5 \times 10^{3})$

$V_C = 2.78volt$

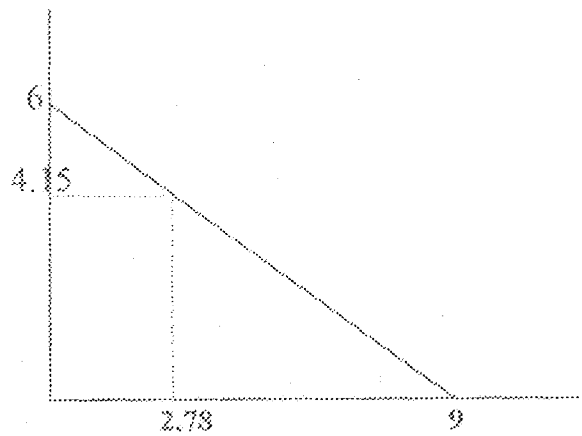

Fig 2.16 Load line for TR3 showing the Q point

The equivalent a.c. model of TR3 can be implemented as below;

$r_{in(base)} = R_B / \beta r_e'$

$$= \frac{(470K)(1.5K)}{470K + 1.5K}$$

$$= 1495.23$$

$Ai = \beta = 701$

$$r_e' = \frac{25mV}{I_E}$$

$I_E \cong I_C$

$$\therefore \; r_e' = \frac{25mV}{4.15mA}$$

$$= 6.02\Omega$$

For the voltage gain;

the speaker rating used was 8Ω 2W

$\therefore R_C = 8\Omega$

Voltage gain thus is;

$$Av = \frac{8}{6.02}$$

$$= 1.328$$

$A_p = 701 \times 1.328$

$$= 930.928$$

POWER GAIN

$G_P = 10\log_{10} 930.928$

$$= 29.69 \approx 30dB$$

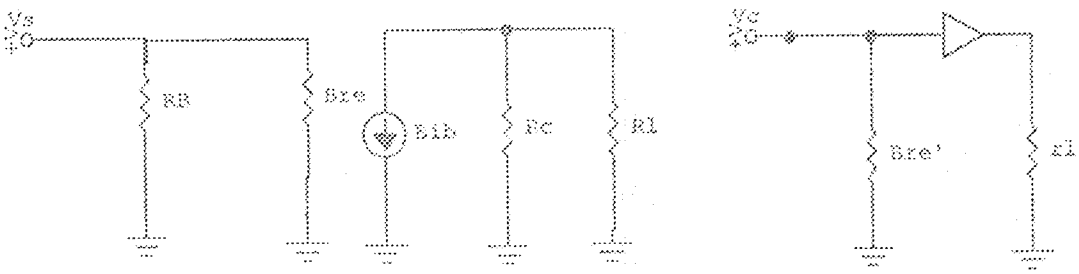

Fig2.17(a) AC Equivalent circuit for TR3 **(b) Modified AC Equivalent circuit**

In order to get an output sufficient to drive a loudspeaker, the audio signals from the AF amplifier stage has to be further amplified.

The amplifier circuit employed for this purpose is build around a single IC. The TBA820M can produce over one watt into an eight ohm speaker providing a very good loud signal.

Of the components surrounding IC1, capacitors, C13, C14 and C16 are supplied decoupling capacitors. C20 is the output coupling capacitor. R10 and C19 provide a type of feedback known as "bootstrapping" which temporarily boosts the positive supply voltage to the IC.The benefit of this is higher power and lower distortion. R11 and C18 provide a controlled tool at high frequencies and ensure that the circuit is stable. C17 sets the high frequency response of the circuit. Its value can be increased to reduce adjacent signal whistles if required. The remaining components R9 and C15 set the maximum gain of the circuit. [8]

CHAPTER THREE

3.0 CONSTRUCTION AND TESTING

In constructing the simple SW receiver, all design specifications were strictly adhered to. The construction was executed modularly and relevant tests were carried out on each module before proceeding to constructing the next stage.

3.1 CONSTRUCTION DETAILS

Construction involved the bringing together of all the components as specified in the design. It also included the encasement of the components to give the finish.

The instruments/tools and materials employed for and during the construction are as follows:

SOLDERING IRON: This provided the needed heat to melt the lead which holds the components in place on the Vero board when it solidifies.

LEAD SUCKER: This was employed when there was need to desolder a joint. It was the principles of suction pressure to remove pre-melted lead in a soldered joint.

BREAD BOARD: This is the board on which the circuit was set up on a temporary basis to ascertain the workability before it was permanently transferred to a Vero board.

VERO BOARD: This is a plastic cover laid with perforated strip of copper wires. After every adjustment to the design while on breadboard, it was finally transferred to this board.

MULTIMETER: This is a multi-function electronic measuring instrument employed in the measurement of voltage, current, capacitance and checking for continuity.

Other tools and materials include, lead, pliers, picking tools, IC suckers, jig saw, planes, files, measuring tape, screw driver, wood glue, etc.

The construction was first made on a breadboard and then transferred to the Vero board. The power supply unit was constructed on a different Vero board from that of the main circuit.

3.1.1 CONSTRUCTION OF THE POWER SUPPLY UNIT

This unit consists of a switch, an indicator light, two filter capacitors, a bridge rectifier (consisting of four (4) power diodes) and a regulator. The primary side of the 12V transformer was connected via a fuse to the inputs of the bridge rectifier. The positive and negative outputs were then connected to the positive and negative sides of the 100μF capacitor. The output was passed to the regulator (7809). The output was then passed to the 1μF, 16V capacitor. The positive of this capacitor was connected to the V_{CC} or the main circuit via a red jumper while the negative was connected to the main circuit ground via a black jumper.

For the battery backup which is only to be connected when the a.c. supply is not in use, a double head battery clip was appropriately connected to red and black jumpers.

3.1.2 CONSTRUCTION OF THE TUNED CIRCUIT

This was done by winding the appropriate number of windings (as given from the inductance calculator) on an empty biro case. The inductor was fastened to the biro case with the aid of mocking tape. Both free ends were then made bare with a razor blade and finally connected in parallel with the tuning capacitor.

The two-pins on the same side of the tuning capacitor was joined together, hence the input into the capacitor was through two terminals.

The aerial connection was made to be variable as the reception might demand.

3.1.3 CONSTRUCTION OF BUFFER AMPLIFIER STAGE

The J.F.E.T transistor was mounted on an improvised transistor socket. The transistor sockets were made by splitting an I.C. socket into two. The drain was the connected to the V_{CC} railing, while the source was grounded via the 820Ω resistor. The input (gate) was connected to the other terminal of the tuned circuit.

3.1.4 CONSTRUCTION OF THE RADIO FREQUENCY AMPLIFIER STAGE

The pins were identified and duly mounted on the improved socket. The collector was then feed into the base through the 330K resistor. The collector was connected to the V_{CC} railing via an 1K resistor, while emitter was grounded via the 100kΩ resistor. The buffer stage was then coupled to the RF amplifier via the 10nF capacitor.

The regenerative feedback circuit which consist of the 1K variable capacitor was coupled to the collector of the common emitter amplifier by the 100nF capacitor while the output was fed into other section of the coil T_1

3.1.5 CONSTRUCTION OF THE DEMODULATION STAGE

This stage which consists of the diodes and the 10nF filter capacitor was coupled to the capacitor of the R.F. amplifier through a 4n7F capacitor.

The anode of one of the diodes was connected to the cathode of the second diode. The anode of the second diode was grounded while the cathode of the first was connected to the 10nF capacitor which was then grounded. The connection point of the two diodes was then connected to the 4n7F capacitor.

3.1.6 CONSTRUCTION OF THE AUDIO FREQUENCY AMPLIFIER STAGE

This stage consists of two sub stages. The first amplification was achieved through a transistor (TR3) while the second amplification was achieved through the use of the IC TBA820M.

The transistor (TR3) was also mounted on the improvised socket after the pins were identified. The emitter was fed into the base through the 470K resistor. The base was coupled to the volume control resistor via a 1μF capacitor. (One terminal of the volume control was grounded while the other was connected to the cathode of the demodulator output.) The emitter was grounded while the collector was connected to the V_{CC} railing via the capacitor 10n and the resistor 1K5 connected in parallel.

The earphone was fed from the output of this stage. The positive end of the input to the collector (via the 100μF) while the other was grounded.

The pins of the IC were identified and were appropriately connected as shown in the diagram.

The output speakers were also appropriately connected with respect to the inputs and outputs.

3.1.7 CONSTRUCTION OF RECEIVER CASING

The entire circuit was housed in a wooden casing. A wooden casing was chosen for reasons of economy and ease of drilling holes. It is made of plywoods ¼" and ½" thick. The appropriate holes and cuts were made to house the tuning and tuning and volume control. Also holes were made for the power LED. Figure 3.1 shows a diagrammatic sketch of the casing.

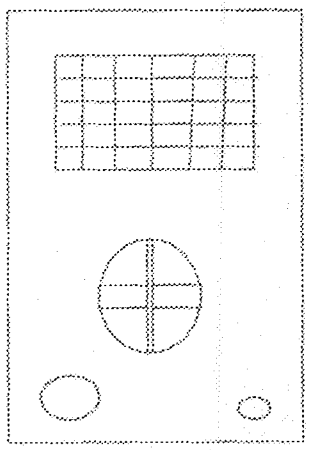

Fig. 3.1 Sketch of the Casing.

3.2 CONSTRUCTION PRECAUTIONS

1. Multiplication of faults in stages was avoided by testing every stage during construction.
2. All excess soldering were removed.
3. All solders bridge was broken.
4. Polarities of capacitors were properly observed before connection was made.
5. Burning of the board by over heating was avoided as much as possible.
6. I.C. sockets and transistor sockets were used to avoid breaking of component's pins.

7. Shiny soldering was ensures.

8. Soldered points were tested to ensure continuity.

3.3 TESTING PROCEDURE AND RESULTS

The testing was carried out of three stages; the power supply stage, the amplification stage and overall testing of the system.

3.3.1 TESTING OF THE POWER SUPPLY STAGE

The output of the power supply was measured by the means of a mulit-meter and a 9volts (d.c.) stable output was recorded.

3.3.2 TESTING OF THE AUDIO FREQUENCY AMPLIFIER STAGE

The speakers were connected to the output of the circuit after it was being powered, and it a humming sound from the speakers was observed.

3.3.3 TESTING OF THE OVERALL SYSTEM

After all the functional modules were probably coupled together, the system was powered. Immediately, a hissing/cowling sound was heard. This sound varied in magnitude as the regeneration control was (VR1) was varied. This proved that there existed a positive feedback.

As the tuning control was varied, a gradual change in frequency of the output was observed.

3.4 PROBLEMS ENCOUNTERED

In the course of this project, some problems were encountered. These include:

1. Unavailability of components as specified by the original design. This led to the use of close alternatives and hence increased the receiver's output deviations from the expected one.
2. Erratic power supply blown down the pace of the project.
3. Unavailability of some important devices like the inductance meter. This led to the use of approximated valued which were not accurate and also introduced error.
4. Due to time constraint, some good features that would have further enhanced the project could not be added
5. The problems of stray capacitances which (due to connections, and other components) has a lot of effects on a sensitive circuit like this had to be put on with.

CHAPTER FOUR

CONCLUSION AND RECOMMENDATIONS

4.1 CONCLUSION

From the results of the tests carried out and the processes passed through, it is obvious that the aims and objectives of this project was achieved.

A variation in frequency of tuning was achieved via the outputs and a positive feedback was also achieved.

Cheap and readily available components made the system cost effective and hence affordable.

4.2 RECOMMENDATIONS

The following recommendations can enhance and further enlarge the scope of this project.

1. Instead of the analogue tuning employed for this sample design, the possibilities of employing digital tuning (while still maintaining simplicity) should be explored. Although presently the area digital tuning is still very demanding for a simple

project like this, it is a field that demands research so as to be made simple.

2. The project can be incorporated into the system (i.e. a radio card) so that tuning, programming and all other functions can be controlled through the use of the mouse. This really widens the scope of this project.
3. Rather than making just an SW receiver, the FM receiver can still be incorporated into it by just making some inclusions into the circuit.

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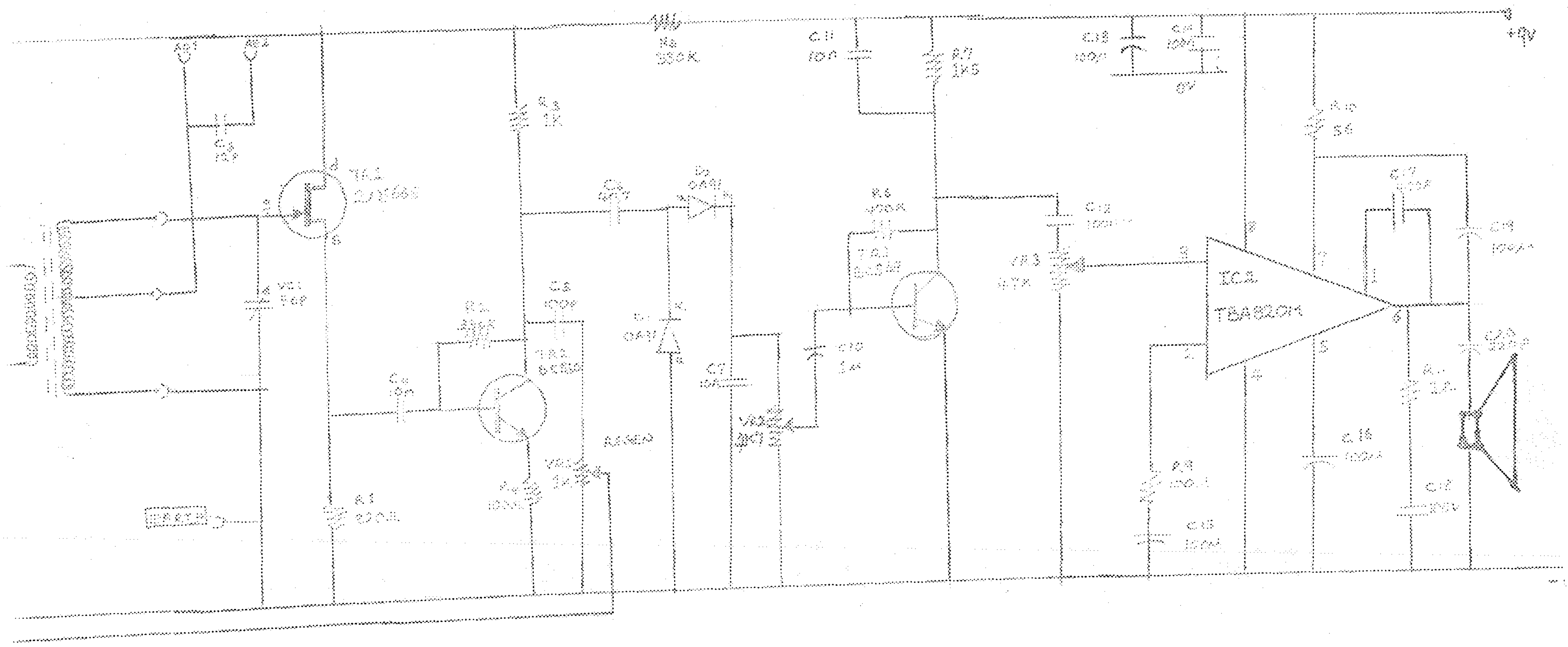
+9V
R8 330K
R7 1K5
R3 1K
0V
R10 56
IC2
TBA820M
VR3 47K

Steve Moshier's Inductance Calculator v0.1

Geometry of coil:
1 Circular solenoidal current sheet
2 Straight round wire
3 N-turn circular loop
4 Circular toroid, circular winding
5 Multi-layer square solenoid (low precision)
6 Circular torus ring, rectangular winding
7 Multi-layer circular solenoid
8 Single-layer circular solenoid of round wire
9 Single-layer square solenoid
10 Wire gauge calculation
11 Change units to centimeters (now inches)
Choose menu item number (1) ?