DESIGN AND CONSTRUCTION OF A 150WATT AUDIO POWER AMPLIFIER

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A Thesis Submitted to the Department of Electrical and Computer Engineering, Federal University of Technology Minna, Niger State, Nigeria.

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DEDICATION

I hereby dedicate this project work to God the Father in whom there is no darkness and the giver of life and strength, who saw me through it all. Also to my mum, Mrs. C. Donwa for her selfless help and support.

CERTIFICATION

This is to certify that this project design and construction of a 150watts audio power amplifier was carried out by Donwa Victor (2000/9820EE) under the supervision of Engr. M.S. Ahmed for the award of bachelor of engineering (B.Eng) degree in electrical/computer engineering federal university of technology MINNA Niger State.

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Name of External Examiner

Signature and date

Acknowledgement

At this point I'll like to acknowledge the fact that it is this great God that has given me the grace to be able to get to this point in life where I'm coming to the end of my study here in federal university of technology, Minna . for this I say thank you Lord I'm forever grateful. Also I'll like to acknowledge my most wonderful guardians Mrs Mary Kolo and Mrs Leah Able Yisa. Honestly speaking if not you two I don't where I'll be right now, you've been supportive, kind, and your homes have become my home due to your hospitality and kindness.

My sincere appreciation goes to my honorable supervisor Engr. M.S. Ahmed for his intensive supervision, useful suggestions and advice given to me during the course of this project.

I also would want to acknowledge the head of department, Electrical and Computer Engineering, Engr, M. Abdullahi, Engr. Y. Adediran and other lecturers in the department; Mr. Rumala, Mr. Kolo just to mention but a few, you have been a source of inspiration to me through impacting knowledge, and through which this project has been written.

Equally important is my elder brothers and sisters jerry, Chris, Emmanuel, Henry, Patricia, Eunice and Esther. Only God can reward you for your love, care and wise advice. Also are my friends who have stood by me through it all Charles Ileogben, Ayegba Adegbe, simon Odo, just to mention but a few. May God Greatly reward and give you your heart desire.

ABSTRACT

This project titled, "Design and Construction of 150watts audio power amplifier" is designed to produce a greatly amplified output audio signal irrespective of how small or low the audio input the signal may be. it allows the use of auxiliary (cd and cassette player). with little distortion .

This was achieve with the use of the D880,2N3055, and MJ2055 transistors as the major components.

In order to facilitate a better understanding of the thesis, clear and precise drawings, illustrations and references are incorporated in the thesis. this makes it to a vast extent self explanatory.

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CHAPTER ONE

INTRODUCTION

Since the discovery of signal generation, it became crucial at a point in time that the signals generated, however small they may be, be transmitted from one point and be received at another point, no matter the distance between the two points, without the signal being distorted or attenuated. This got engineers and scientists into thinking of a way of carrying out this process (i.e. transmission of signals from one point to another). This led to the discovery of "Amplifiers". The term *amplifier* is very generic (that's to say it is suitable for a broad range). In general, the purpose of an amplifier is to take an input signal and make it stronger (or in a more technically correct term, increase its *amplitude*) [1]. Amplifiers find application in all kinds of electronic devices designed to perform any number of functions. For example, public address systems (indoor and outdoor), radios, phonographs, television receivers, telephone receivers, industrial control equipment just to mention but a few. There are many different types of amplifiers, each with a specific purpose in mind. For example, a radio transmitter uses an RF Amplifier (RF stands for Radio Frequency); such an amplifier is designed to amplify a signal so that it may drive an antenna. They are either linear or non-linear. Linear amplifiers are used for audio and video signals, whereas non-linear amplifiers find use in oscillators, power electronics, modulators, mixers, logic circuits, and other applications where an amplitude cut-off is desied.[4] But for this project the focus of the use of amplifiers is on *Audio Power Amplifying*.

The term Audio means the range of frequencies which our human ears can hear. The range of human hearing extend from 20Hz to 20 kHz. Therefore, audio amplifiers amplify electrical signals that have the frequency range corresponding to the range of human hearing. This project employs the use of transistor audio power amplifier. A transistor audio power amplifier is a transistor amplifier which raises the power level of the signals that have audio frequency range. [3]. In audio power amplification, the first stages are small signals either voltage or current being amplified from a few milli volts or milliamp up to a signal of several volts or amp. The final stage is a large signal or power large enough to drive the load, in this project the load is a loud speaker. This project is designed to give a maximum power output of 150watts.

1.1 AIMS AND OBJECTIVES

The aims of this project design are as follows:

- operation within the current, voltage and power limits of the transistor as provided by the manufacturer.
- Low noise and portable.
- stable operation within a temperature range
- Low or reduced distortion which can be used in a lecture room or theatre .

CHAPTER TWO

2.0 LITERATURE REVIEW

During the period 1904-1947 vacuum tube was undoubtedly the electronic device of interest and development. In 1904, J.A.Fleming introduced the vacuum-tube diode. Shortly after, in 1906, Lee De Forest added a third element, called the control grid to and_television provides great stimulation to the tube industry. Production rose from about one million tubes in 1922 to about one million in 1937. In the early 1930s, the four-element tetrode and five-element pentode gained prominence in the electron-tube industry. In the years to follow, the industry became one of primary importance, and rapid advances were made in design, manufacturing techniques, high-power and high-frequency applications, and miniaturization.

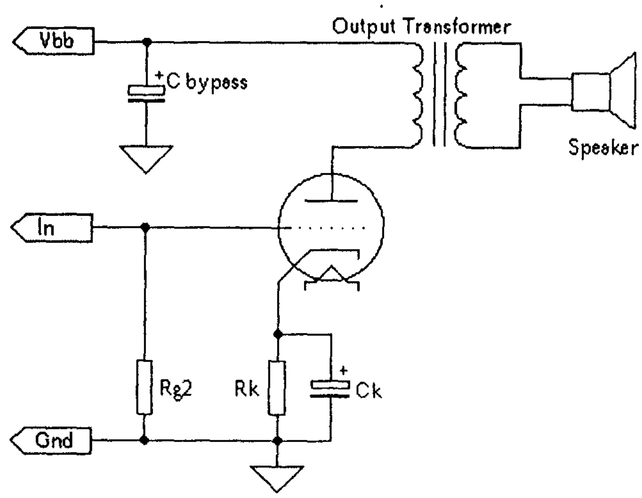

Fig 2.1 Basic Valve Power Amplifier

Figure 2.1 shows a very basic valve power amplifier, using a triode in "single-ended" mode. The output transformer converts the high voltage, high impedance plate circuit of the valve to a low voltage, low impedance signal for the loudspeaker. Because the primary of the output transformer must carry the full DC quiescent current of the valve (which will be a large, high current unit), it needs a very large core of laminated steel.

Interestingly, these inefficient and high distortion amplifiers have made a comeback in recent years. However in the heyday of the valve, the efficiency and distortion of these circuits was such that they were replaced in nearly all installations by more efficient and lower distortion circuits, such as that shown in Figure 2.2

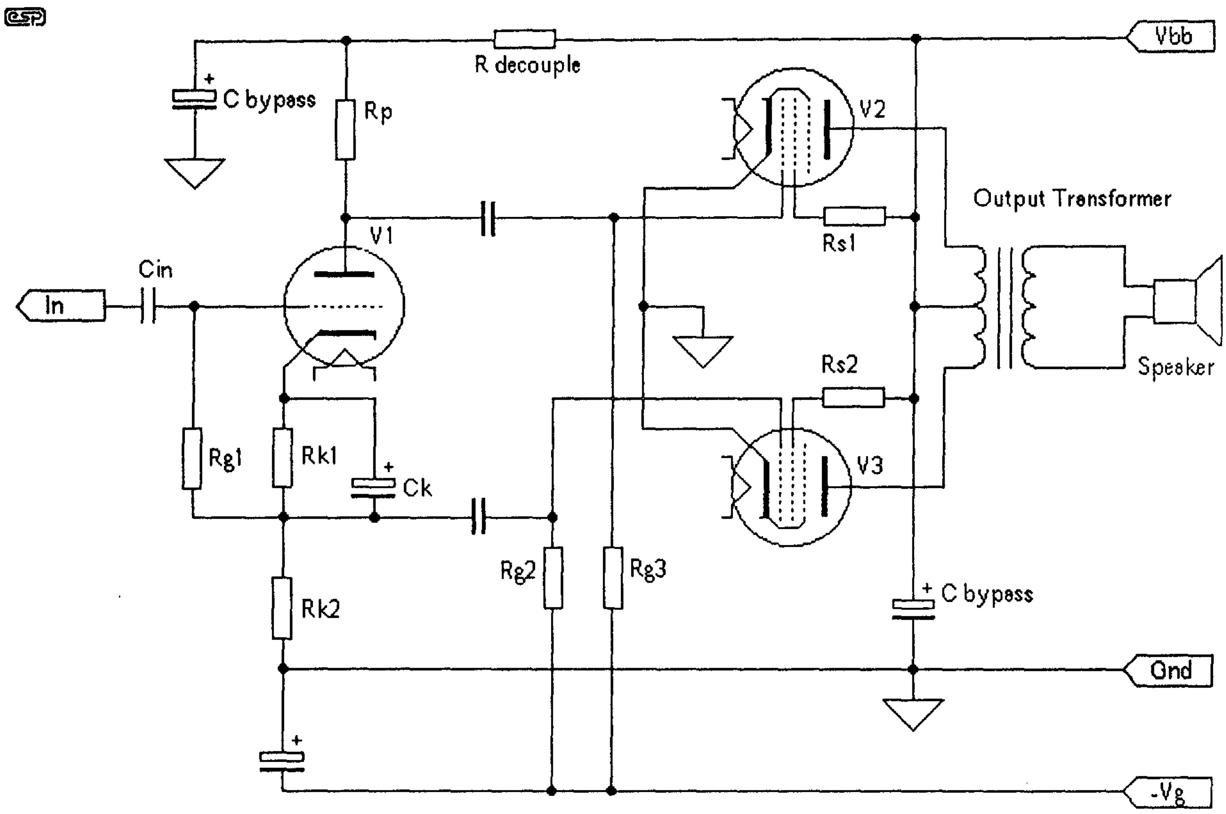

Figure 2.2- Push-Pull Valve Power Amplifier

The valves shown for the output are called pentodes (from penta - five), having 5 electrodes instead of the three for a triode. The second grid (called the screen grid, or just screen) increases the gain of the valve dramatically, while the third grid, the suppressor, prevents what is called "secondary emission" from the plate. The screen accelerates the electron flow so much that electrons bounce off the plate, or dislodge others. The addition of the screen gives the valve some nice characteristics, such as much higher gain, but also some nasty ones (lower linearity, more distortion), which the suppressor counteracts to some degree. The suppressor grid is almost always connected internally to the cathode. It is not uncommon for designers to connect pentodes as triodes, by connecting the screen and plate together.

The first stage of the circuit is interesting, and is called a phase splitter. It is a combination of a voltage amplifier and a current amplifier, having equal values of resistance in each circuit (i.e. Rp = Rk2). Because all valves have the same "polarity", they cannot be used like transistors or MOSFETs, but must be driven with their own signal of the correct polarity.

The incoming signal is therefore sent "as is" to one valve (from the cathode circuit), and is inverted for the other - hence the term push-pull. As one valve "pushes" the anode current lower, the other simultaneously "pulls" it higher. In a properly designed circuit, the two output valves will pass the signal between them with little disturbance. Any disturbance in this region is called crossover distortion, because it happens as the signal crosses over from one valve to the other.

Notice something else quite different. The cathodes of the output valves are connected directly to earth, and the grids are supplied with a negative bias from a separate -ve power supply. This is the most common method of biasing output valves in high power circuits, having a much greater efficiency than cathode biasing.

For many large output valves, it is not even considered a good idea to use cathode biasing, because the amount of negative grid voltage required is too high. Voltages of up to -60V are not uncommon with high power pentodes or another common type, beam power tetrodes (I will not cover these in more detail, but there is much information to be found on the web). Using cathode bias for this sort of voltage is inefficient and reduces the output power dramatically.

The problems that befall valves are many:

- Fragility - The glass envelopes are very thin, and are easily broken.
- Limited life - Even if a valve is operated well within its ratings, it still has a finite life. The main causes of valve failure are cathode emission degradation (happening all the time), and gas, when small amounts of air "break" the full vacuum.
- They are microphonics - All valves tend to be slightly microphonic, which is to say that they act as a microphone. This can cause additional colouration to the signal if the sound from speakers vibrates the amplifier.
- High Voltage - Having to ensure that the 600V DC typical of a high power amp does not "flash over" valve bases is a constant headache, and ensuring that these voltages are kept well away from small fingers is mandatory. High voltage capacitors are also more expensive than lower voltage ones.
- Heaters - Valve cathodes must be operated at the correct temperature so they emit electrons properly, and "boil off" contaminants. If the heater voltage is too low, the cathode will become poisoned, and the valve is useless. The heater power used is all wasted, in that none of it is turned into sound.
- Expensive Output Transformers - The output transformer for a valve amp is expensive, bulky and heavy. It introduces its own distortion components, which are difficult (or impossible) to eliminate completely.
- Heat - All valve amps run hot. The valve will not work unless it is hot, and the heat causes problems for other components, shortening their life. The heat is all wasted energy.
- Damping - Valve amplifiers, nearly all, have a low damping factor, caused by a relatively high output impedance. Speakers must be very well damped indeed to work well with any valve amp, or the bass will become poorly defined, and crossover networks (which rely on a very low amp impedance) may not work as well as intended.

On the positive side, valve amplifiers have a "warm" sound, partly because of the low order harmonic distortion introduced. A good valve amp will also have a very wide bandwidth, and will have an easy job driving loads that cause solid-state equipment to have severe heat burn (or just blow up on the spot).

At low levels, valve equipment has vanishingly small distortion levels, and when all is said and done, there is something nice about little glass tubes, with little lights inside, making your music.[5]

On December 23, 1947 however, the electronics industry was to experience the advent of a completely new direction of interest and development. It was on the afternoon of this day that Walter H. Brattain, John Bardeen and William Shockley demonstrated the amplifying action of the first transistor at the Bell telephone laboratories. The advantages of this three-terminal solid-state device over the tube were immediately obvious. It was smaller and light weight, had rugged construction, and was more efficient since less power was absorbed by the device itself; it was instantly available for use, requiring no warm-up period; and lower operating voltages were possible. It will be formed that all amplifiers (devices that increase voltage, current or power level) have at least three terminate with one controlling the flow between two other terminals. In a transistor amplifier, small variation in the base-to-emitter voltage produces greater changes in the emitter current and the collector current, and high amplification is possible. [6]

This is a project that gives an audio amplification with very minimal distortion, high quality output and very little noise, so little that it can be hard to notice, simple to build for those who would love to build for there own personal use. There has been a lot of audio amplifier project by different individuals; in fact,

some are so high tech that you can find it difficult to build it for your own personal use. The power ratings that are available are 300watts, 100watts and 80watts just to mention a few, but none have worked on 150watts. This audio power amplifier is very portable and suitable for home use especially for music lovers like myself.

2.1 THEORETICAL BACKGROUND

2.1.0 DC POWER SUPPLY

It is a known fact that most electronic devices and circuits require dc source for their operation. If only a small amount of power is needed, batteries can be used to deliver a dc supply since they have the advantage of being portable and ripple free [7& 8]. But these batteries deliver small amount of power which can only be used in equipments like calculators, watches, multimeters, and so on.

However, they need constant replacement and are expensive as compared to conventional dc power supplies. Since the most convenient and economical source of power is the domestic AC supply, it is advantageous to convert this ac voltage to dc voltage[8]. The process by which ac voltage is being converted to dc voltage is called 'RECTIFICATION'. Starting with an ac voltage, a steady dc voltage is obtained by rectifying the ac voltage, then filtering to a dc level and finally regulating to obtain a desired fixed dc voltage [9]. This is accomplished with the help of a

- Transformer
- Rectifier
- Filter
- Voltage regulator

The block diagram shown below contains the parts of a typical power supply.

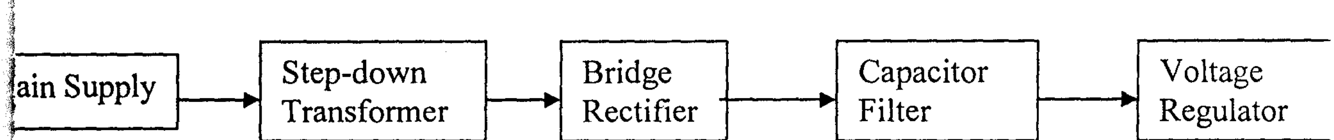

Fig. 2.3 The Block Diagram of Power Supply Unit

2.1.1 Transformer

A transformer can increase or decrease voltage or current level according to the turns ratio as explained below. In addition, the impedance connected to one side of transformer can be made to appear either larger or smaller (step-up or step-down) at the other side of the transformer depending on the square wave of the transformer winding turn ratio. Now for an ideal power transfer (100%) from primary to secondary, that is, no power losses are considered.

2.1.2VOLTAGE TRANSFORMATION

The transformer can step-up or step-down a voltage applied to one side directly as the ratio of the turns (or number or windings) on each side. The voltage transformation is given by

$$\frac{V_2}{V_1} = \frac{N_2}{N_1} \text{ -- equation 2.1}$$

where N_2 = number of turns in secondary

N_1= number of turns in primary

The equation shows that if the number of turns of wire on the secondary side is larger than on the primary, the voltage at the secondary side is larger than the voltage at the primary side and vice versa[8].

2.1.3 Rectifier

Now, as earlier said, its job is to convert ac voltage into pulsating dc voltage by employing one or more diodes. The P-N junction diode's ability to switch current in only one direction makes it ideal for converting two-direction alternating current into one-direction direct current. The three basic rectifier circuits are the half-wave rectifier, the full-wave centre-tapped rectifier, and the full-wave bridge rectifier [9]. In this project, the type of rectifier being employed is the full-wave bridge rectifier.

It is the most frequently used circuit for electronic dc power supplies. It requires four diodes and available in three distinct physical forms:

- Four discrete diodes
- One device inside a four-terminal case
- As part of an array of diodes in an IC.[7]

It has a ripple factor of rectified signal of

$$r = \frac{\text{ripple voltage (rms)}}{\text{dc voltage}} = \frac{V_r\,(\text{rms})}{V_{dc}} = 0.482$$

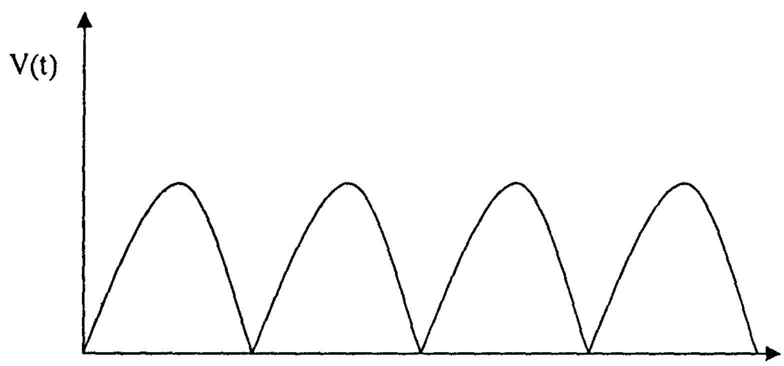

Fig 2.4 Waveform Of A Rectified Dc Voltage

2.1.4 VOLTAGE REGULATOR

Regulated power supply can be achieved by using a voltage regulator circuit. A regulator is an electronic control circuit, which is capable of providing a nearly constant dc output voltage, even if there are variations in load or input voltage. In this design, a LM7812 voltage regulator IC is used to provide the regulation and also to provide 12v supply.

2.1.5 **Filter**

The filter in a dc power supply converts the pulsating dc output from the half-wave or full-wave rectifier into an unvarying dc voltage. There of three types: the capacitive filter, the RC filter and the LC filter. For this project what was used is an RC filter.

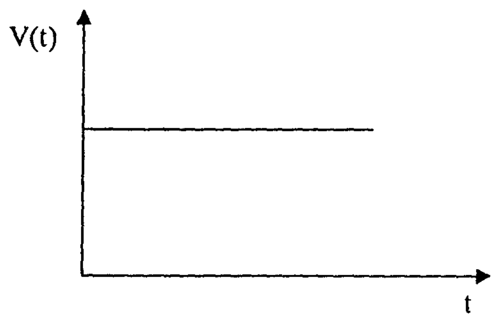

Fig 2.4 Waveform Of Filter Dc Voltage

2.2 Transistor Audio Power Amplifier

The function of a practical power amplifier is to amplify a weak signal until sufficient power is available to operate a loudspeaker or other output device. To achieve this goal, a power amplifier has generally tree stages via voltage amplification stage, driver stage and output stage. Fig 2.5 shows the block diagram of a practical power amplifier.

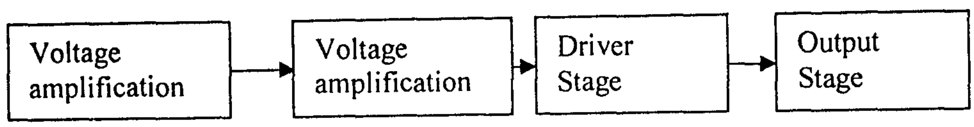

Fig 2.5 Block Diagram Of A Practical Power Amplifier

(i) Voltage amplification stage: The signals found in practice have extremely low voltage level (<10mV). Therefore, the voltage level of the weak signal is raised by two or more voltage amplifiers. Generally, RC coupling is employed for this purpose.

(ii) Driver stage: The output from the vast voltage amplification stage is fed to the driver stage. It supplies the necessary power to the output stage. The driver stage generally employs class A transformer coupled power amplifier. Here, concentrated effort is made to obtain maximum power gain.

(iii) Output stage: The output power from the driver stage fed to the output stage. It is the portion which actually converts the weak input signal into a much more powerful "replica" which is capable of driving high power to a speaker. It feeds power directly to the speaker or other output device. [1]

2.2.1 Classification of Power Amplifier

Amplifiers are classified according to their mode of operation i.e. the portion of the input cycle during which the collector current is expected to flow. They are classified as :

(i) class A amplifier (ii) class B amplifier (iii) class C amplifier

For this project, the class of amplifier being used are the class A amplifier which use a centre tap transformer. The collector current flows at all times during the full cycle of the signal. This type of amplifier uses JBT (Joint Bipolar Transistors) with the common emitter mode.

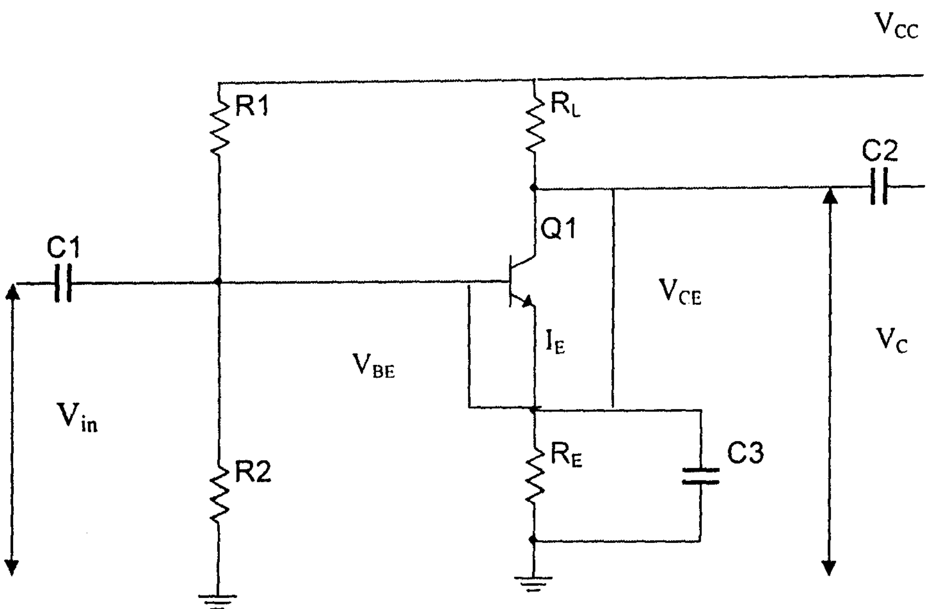

Fig 2.6 A class A Amplifier in common-emitter mode

In Fig 2.6, R_1, R_2 and R_E are the biasing resistors and R_L the load resistor. The first thing to do is choosing the right transistor with a view to power-handling and frequency requirements. The transistor parameters, as given by the transistor manufacturer, are then studied on the basis of which a suitable operating point (collector current and voltage) is the determined. The output loop equation gives:

$$V_{CE} = V_{CC} - I_C(R_L + R_E) \qquad (2.1)$$

This is the equation of the *load line* for an operating point with quiescent (no signal) collector current I_C and quiescent collector voltage $V_C = V_{CE} + I_C R_E$ (measured with respect to the earth terminal). For equal swing of collector current from I_C to 0 at cut-off state and from I_C to $V_{CC}/(R_L + R_E)$ at saturation state, the following equation is obtained:

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

$$I_C=\frac{1}{2}V_{CC}/(R_L+R_E) \qquad (2.2)$$

Equations (2.1) and (2.2) give:

$$V_{CE}=V_{CC}/2 \qquad (2.3)$$

where V_{CE} is the quiescent collector-emitter voltage. In the single-stage amplifier of Fig. 4.5 the input signal, say, from a moving coil microphone, is coupled to the base of the transistor through a capacitor C_1, the purpose of which is to block the flow of any d.c. current that would otherwise interfere with the bias conditions. For the same reason the output of the amplifier is coupled to the next stage of amplification through a blocking capacitor C_2. A large value decoupling (electrolytic) capacitor C_3 shunts the resistor R_E at audio frequencies so that it does not form part of the input and output circuits. Note that electrolytic capacitors must be connected with the correct polarity.

The a.c. current gain is $h_{fe} = (\Delta I_C/\Delta I_B)$, where (ΔI_C) denotes change in I_C and (ΔI_B) denotes change in I_B. For all practical purposes h_{FE} and h_{fe} may be considered as equal, being 100 to 1,000 depending on samples of different types or same type of transistors. Note that from the point of view of a.c. the internal resistance of the power supply is negligible, until when it starts to drain out or when the current drawn is too large. Sometimes a large electrolytic capacitor is put across the battery to decouple its internal resistance (a.c.-wise).[10]

2.2.2 Distortion in An Amplifier

The choice of d.c. operating point affects the shape of the output waveform. Selecting an operating point too near either the cut-off region or the saturation region can cause clipping of the output voltage. Going into 'cut-off' results in clipping of the positive wave at the supply voltage V_{CC} going into 'saturation' results in clipping of the negative wave near 0v.

Any distortion at the input stage of an amplifier will be amplified by the succeeding stages. It is therefore desirable that the input stage is properly biased to introduce the minimum distortion, if at all.

The best position for the operating point for the output stage of an amplifier is one which gives equal maximum swings about the operating point. However, even if the operating point has been correctly chosen, too large an input signal can cause distortion of both the positive and negative swings of the output voltage. In severe cases a sinusoidal output would be clipped so much as to appear like a square wave.

It is important to ensure that the input signal to the output amplifier is not too large as to cause clipping of the output signal. This may be achieved with a volume control if placed at the input stage. It may also be accomplished with an automatic gain control (a.g.c.) circuit whereby the output voltage is kept more or less constant for wide variations of the input voltage.[10]

2.2.3 Noise in an Audio Amplifier

Noise in an audio amplifier is any electrical disturbance that can cause an unwanted sound. Some noise is picked up from electrical equipment, such as antenna, hum from the public a.c. supply, breaking of contacts, sparks, statics, lightening etc. Such external noises can be suppressed by proper earthing, electric and magnetic screening, filtering and correct layout of wires and components as in a printed circuit board.

After excluding all extraneous noises, there will still remain unwanted residue generated in the amplifier circuit itself. This internal noise is from the motion of electrons and electric currents in the resistors and transistors.[10]

CHAPTER THREE

3.0 Design and Implementation

This chapter describes how each part of the design came about and also will be making references to the theories which were elaborated in the previous chapter. This synthesis process requires a clear understanding to the characteristics of the device, the basic equations for the network, and a firm understanding of the basic laws of circuit analysis. Here calculations and reasons will be for the use of each value of each component being used and the aim at which it was hoped to achieve. So below is the block diagram of the working principle of each stage of the project, so the block diagram will be use to give each stage analysis.

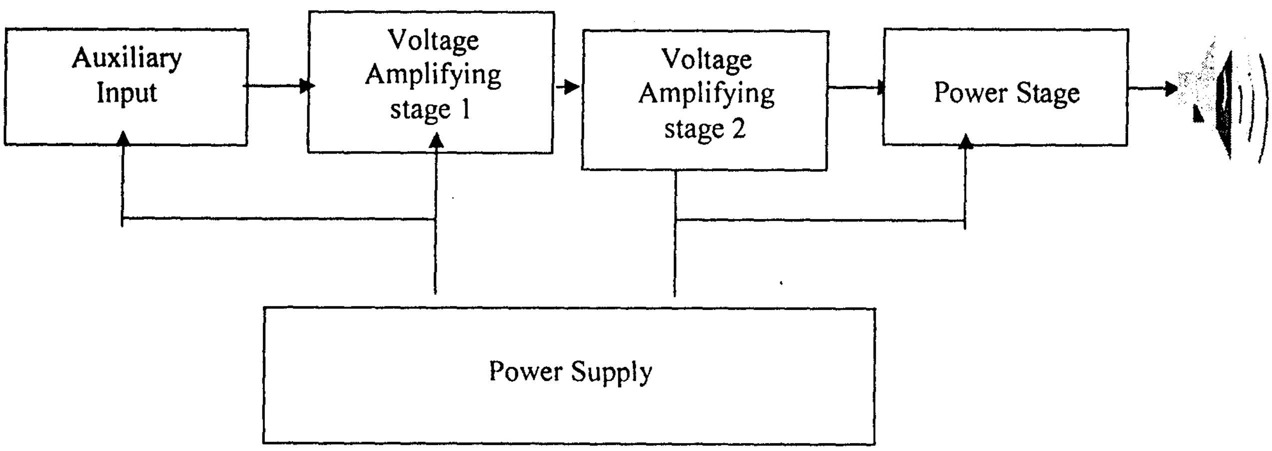

Fig.3.1 Block Diagram of a 150watt Power Amplifier

3.1 Mode of Operation

The working principle of the audio power amplifier is clearly depicted by the block diagram above. Now when there is an input signal from the auxiliary input whose source is signals whose output voltage range are quite high (i.e. output signal from a cassette player, CD player etc). It is fed into the voltage amplifying which is made up of two stages to raise its voltage level before it is being fed into the driver stage. From the driver stage to the power stage before being fed into a speaker to give the audio output.

Therefore as can be seen from the block diagram shown in figure 3.1, the stages of analysis will be as follows;

(i) The Power Supply Stage

(ii) Voltage Amplifying Stages

(iii) Driver Stage

(iv) Power Stage

3.2 The Power Supply Stage

Now from the theory stated on power supply for electronic devices and circuits, they require dc supply. For this project, the dc supply is to use a step-down transformer of 220/240 to 35v, 50Hz. The input voltage which is an ac supply was connected to the primary of the transformer and the output obtained from the secondary. The output was now rectified using four discrete diodes 1N4001(ie one device in a four terminal case). In filtering, an RC filter was incorporated. In the choice of value of resistor and capacitor, these calculation were carried out; now a capacitive reactance of one was required i.e.

$X_c = 1.$

$$Xc = \frac{1}{2\pi fc} \qquad (3.1)$$

To get the value of C which is the value of the capacitor, we make C the subject of formula from equation 3.1; this gives us

$$C = \frac{1}{2\pi fXc} \qquad (3.2)$$

Since we know that the value for f which stands for frequency is 50Hz, applying to equation 3.2,

$$C = \frac{1}{2 \times 50 \times \pi \times 1} = 3183.09 \times 10^{-6} = 3183.09\mu F$$

But standard capacitors on sale in the market are not available at 3183.09μF but are either in 3300μF and 22000μF. If 3300μF was chosen, it will have a high discharge time; but if 22000μF is used, it will have a lower discharge time. Below the circuit diagram of the power supply unit of this project. An LM7812 was incorporated into the circuit which serve as a voltage regulator and to provide 12v power supply used to operate the cooling fan . The circuit arrangement of the power supply is shown in figure 3.2.

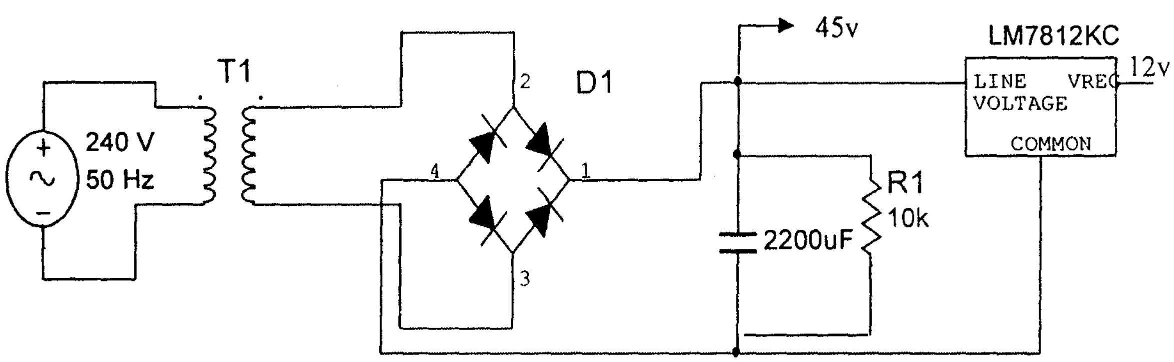

Fig 3.2 Power Supply Circuit Arrangement

3.3 Voltage Amplifying Stages

These stages use class A amplifiers for its operation which do give a high voltage gain on any signal that is been fed in at its input. It gives maximum voltage amplification to the input signal, and the reason for having two stages of amplification is to raise the input voltage to a certain level high enough to be fed into the driver stage and then onward to the power stage.

The auxiliary input here refers to the input from compact disc players (CD player), audio cassette player and ipod players just to mention but a few of these kind of input. To get a maximum output from the amplifier, the input voltage must be close to 1v. Therefore, the analysis of these stages will be carried out by one analysis to represent both stages. These analysis are the Dc analysis and Ac analysis.

3.3.1 DC Analysis

The essence of this type of analysis is to know the operating point and the condition of the amplifier operation; that is to say, if the amplifier is working in the saturation, active or cut-off region

the voltage drop across the base (ieVb) is obtained by

$$Vb = \frac{R_2 \times V_{CC}}{R_1 + R_2} \qquad (3.1)$$

$$Vb = \frac{5.6K \times 45}{(82 + 5.6)K} = 2.87v$$

Next is to obtain the emitter voltage. Also it is assumed that for most silicon transistors, the base to emitter voltage drop (Vbe) is approximately 0.7v.

therefore,

$$Ve = Vb - Vbe \qquad (3.2)$$

$$Ve = 2.15 - 0.7 = 1.45v$$

the emitter current (i.e. Ie) will be obtained thus

$$Ie = \frac{V_E}{R_E} \qquad (3.3)$$

$$Ie = \frac{32.17}{330} = 6.59mA$$

Assuming that the collector current (i.e. Ic) equals the emitter current

i.e. Ie = Ic (3.4)

the operating point which is the voltage drop across the collector to emitter Vce will be given as

Vce = Vcc-IcRc – Ve (3.5)

Where

Vcc = supplied dc voltage

Rc = resistor across the collector

Ve = voltage across the emitter

applying equation 3.4 to 3.5, it will yield

Vce = Vcc- IeRc-Ve (3.6)

$$Vce = 45 - \left(6.59 \times \frac{3.3\kappa}{\kappa}\right) - 2.17 = 21.06v$$

3.3.2 AC Analysis

The ac analysis helps to determine the voltage gain.

The first point of call is to obtain the ac resistance of the emitter(re)

$$re = \frac{25mV}{I_E} \qquad (3.7)$$

where

re = ac resistance of the emitter

therefore, the voltage gain for this amplifying stage is obtained by using the equation 3.8 since emitter resistor is being bypassed.

$$Av = \frac{R_L}{r_e} \qquad (3.8)$$

Where

Av = voltage gain

$$r_E = \frac{25m}{6.59m} = 3.79\Omega$$

since we've gotten the value for the input resistance, we can now find the voltage gain,

$$Av = \frac{330}{3.79} = 87.07$$

It can be seen that the voltage gain is so high from the output of the amplifier stage into the driver stage. Below shows the circuit diagram of the voltage amplifying stage.

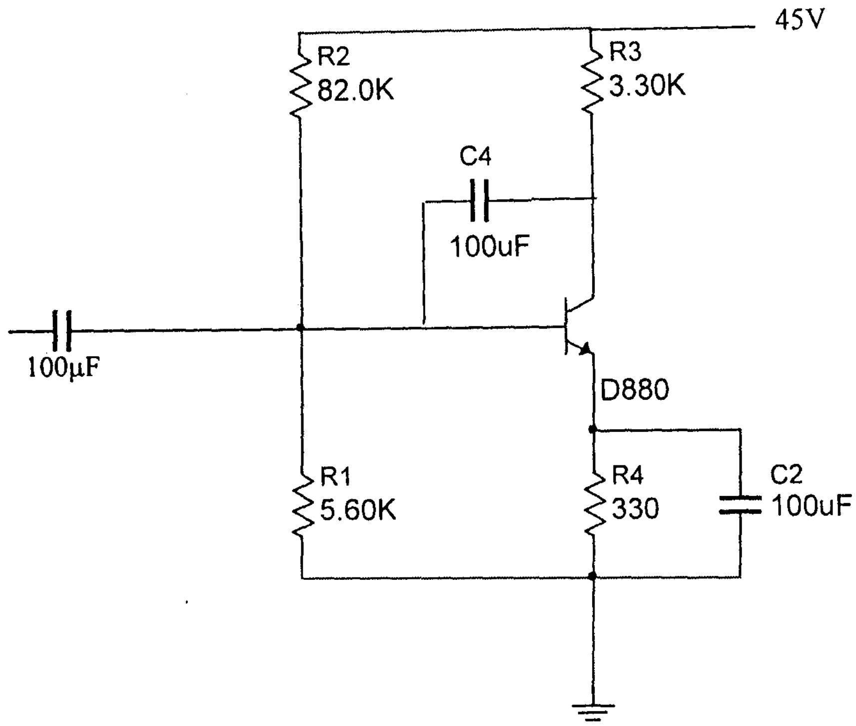

Fig 3.3 Circuit Diagram Of The Auxiliary Input Amplifying Stage

3.4 Driver Stage

This stage forms the last stage of amplification before it is sent into the output stage for final passage unto the speaker connected to it to give the required audio output. In this, what is being amplified is the current to boost the output stage, so for that purpose a Darlington pair was incorporated . It is the connection of two transistors together to get a high current gain. It comes in single package or by the combination of two transistors together to obtain the pair. For this project, a simply combination of two transistors of the same make and model was to give the pair. The result is that it behaves like a single transistor with beta equal to the product of the two transistor betas. For a Darlington transistor the base-emitter drop is twice normal.[11]. The essence of the resistor R, is to prevent leakage current through Q1 from biasing Q2 into conduction ; its value is chosen so that Q1's leakage current (nanoamps) produces less than a diode drop across R, and so that R doesn't sink a large proportion of Q2's base current when it has a diode drop across it.

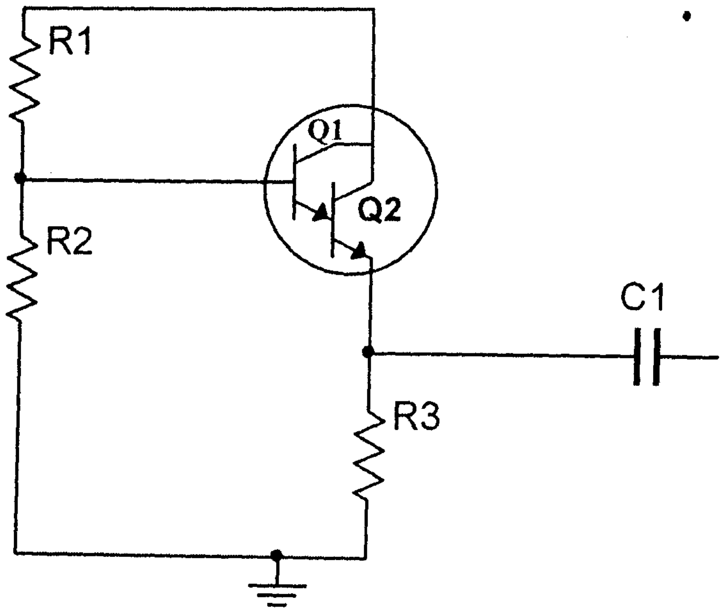

Fig 3.4 Circuit Diagram of the Driver Stage Darlington Pair

3.4.1 DC ANALYSIS

$$Vb = \frac{R1 \times R2}{R1 + R2} \times Vcc \qquad (3.9)$$

$$Vb = \frac{22 \times 22}{22 + 22} \times 45 = 495V$$

$$Ve_{(Q2)} = Vb - 2Vbe \qquad (4.0)$$

$$Ie_{(Q2)} = \frac{Ve}{Re} \qquad (4.1)$$

$$Vce_{(Q2)} = Vcc - Ve_{(Q2)} \qquad (4.2)$$ [12]

Where

Vb_1= voltage drop across the base of transistor1

$Ve_{(Q2)}$ = emitter voltage across transistor2

$Vce_{(Q2)}$ = voltage across collector-emitter across transistor2

$Ie_{(Q2)}$ = emitter current from transistor2

Applying equation 4.0 to equation 4.2, we can obtain the operating point for the Darlington,

$Ve_{(Q2)} = 495\text{-}1.4 = 493.6v$

$$Ie_{(Q2)} = \frac{493.6}{2.2K} = 224.36mA$$

$Vce_{(Q2)} = 45 - 224.36m = 44.77v$

The current gain is obtained by taking the product of their respective beta

$Ai = \beta 1 \times \beta 2$

Where

Ai = current gain

Since they are of the same make, their beta value will be the same,

$\therefore Ai = 120 \times 120 = 14400$

3.5 Power Stage

The output stage essentially consists of a power amplifier and its purpose is to transfer maximum power to the output device. If a single transistor is used in the power stage, it can only be employed as class A amplifier for faithful amplification. Unfortunately, the power efficiency of a class A amplifier is very low (about 35%). In order to obtain high output power at high efficiency, push-pull arrangement is used in the power stage. Two transistors Tr1 and Tr2 are placed back to back with both transistors operated in class B, where one amplifies the positive half-cycle of the signal while the other transistor amplifies the negative half-cycle of the signal. In this way, output voltage is a complete sine wave [12]. Now the function of the resistor R is to bias the circuit while the diode helps prevent crossover distortion. The circuit diagram of the arrangement is shown below.

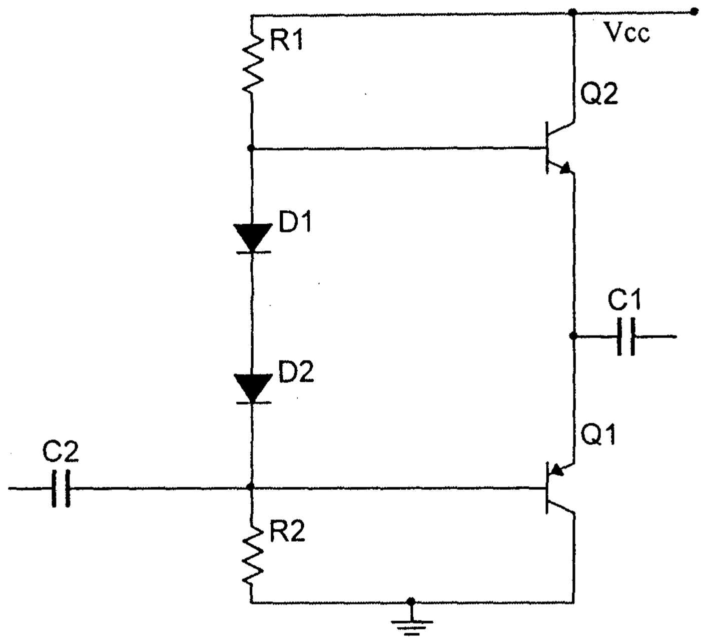

Fig 3.5 Push-pull Configuration

In the design of any power amplifier, it is demanded that one bear in mind the output power, the load value and the supply voltage. The supply of the power amplifier is given as 45v. This determines the maximum possible audio power that can be delivered into the load which is a 6Ω load speaker.

Chapter four

Testing, Result and Discussion

The circuit design of each of the stages, the component layout was first sited taking good note of component spacing direction and proximity. The components layouts for each of the stages were first done on paper before being setup on a breadboard for testing to see if it will give the desired output before transferring the circuit design unto a Vero board. Extreme care was taken while soldering components. The resistors, the capacitors and last of all the transistors were soldered on the Vero board. All soldering were done using 60/40 type core and a 25watts soldering rod. Care was also taken when soldering the semiconductors because if their polarity is mistaken by interchanging them would bring about no output at any of the output point in each of the stage of amplification.

A wooden box was carved to carry both the transformer for the power supply and the Vero board containing the circuit.

4.1 Testing

When the entire circuit design had been constructed, tests were carried out by applying an input signal fed into the mic input section and the auxiliary input section, not simultaneously anyway, i.e. one at a time for each of the input section, into the circuit. The voltage and the current rating of each stage of the signal input was noted and recorded in order to know the magnification of amplification. This was done with the help of a digital multimeter. Also it was noticed that the complementary transistors that were been used (i.e. 2N3055 and mj2055) were generating heat so a heat sink was incorporated as well as a fan to cool the transistors so that they don't get blown up at the end of the day.

4.2 Result

The results obtained during the testing of the prototype were satisfactory. The graph obtained for each of the stages (that is, the voltage amplifying stages) shows that the transistors where working at the active region with little distortion.

4.3 Discussion of Results

Going by the result obtained it was observed that the voltage amplifying stages actually amplified the voltage to a high level with little amplification of current. it was the power amplifying stage with the driver stage that actually amplified the current and power output of the input signal, hence the input signal was greatly amplified.

CHAPTER FIVE

5.1 Conclusion

The primary objective of an engineer is to endeavor to deliver the best product or the most efficient service at the lowest cost to its consuming public. Going by the scope of this project which is to amplify an input signal to give an output of 150watts, it was achieved with some little limitation.

5.2 Recommendations

However, for further work on similar project, integrated circuits (IC) and highly quality components should be used to improve the quality of amplified output signal of the system.

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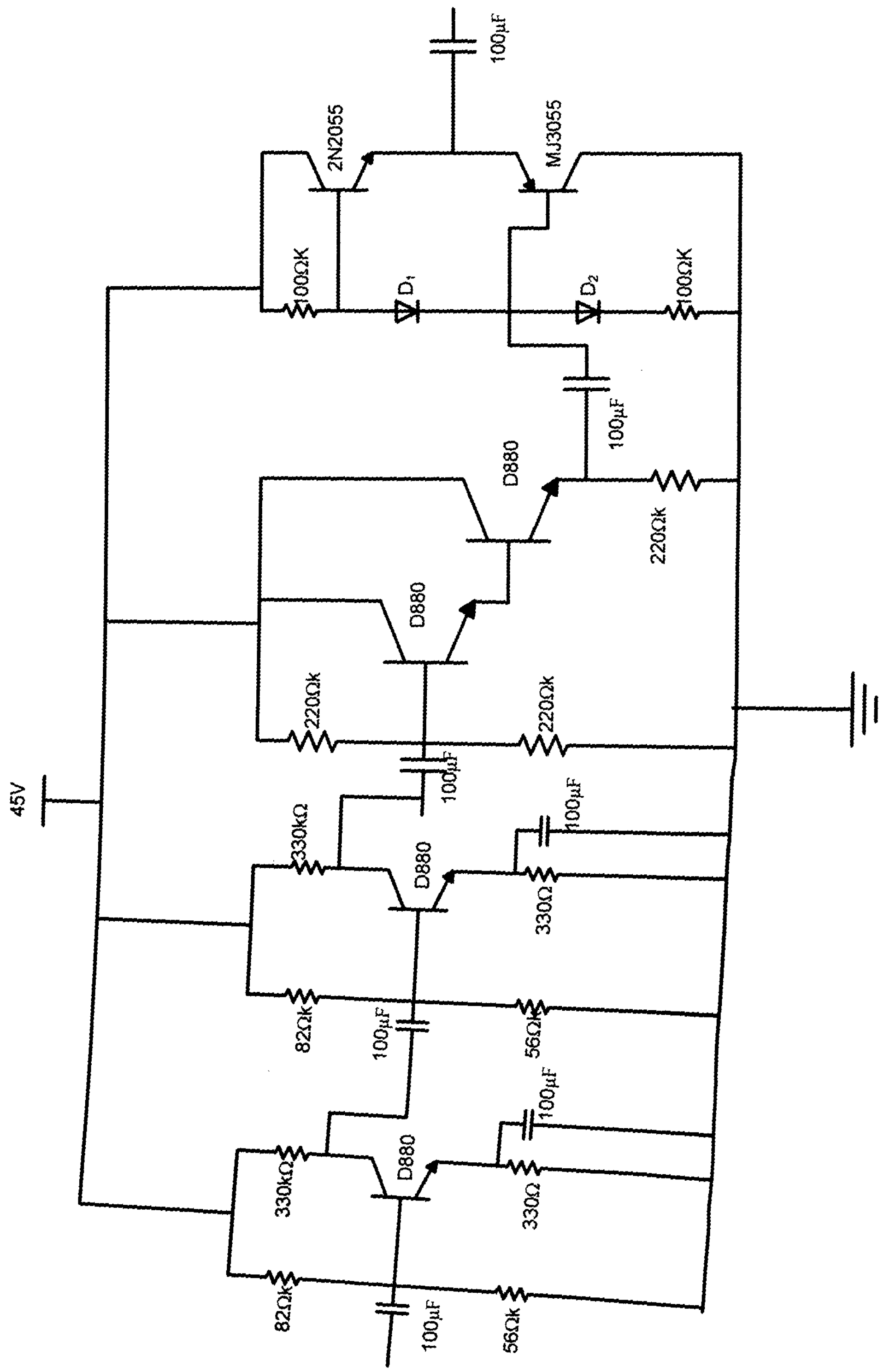
APPENDIX



Circuit Diagram