DESIGN AND CONSTRUCTION OF A SINGLE CHANNEL INTERCOM SYSTEM

BY

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A THESIS SUBMITTED TO THE DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING IN PARTIAL FULFILLMENT FOR THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF BACHELOR OF ENGINEERING (B.ENG) IN ELECTRICAL AND COMPUTER ENGINEERING OF THE FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA.

OCTOBER, 2006

Dedication

I am dedicating this project work to the Almighty God, the most high who made this project work a success and granted me the strength, grace and knowledge to execute this project successfully.

Declaration

I, Oloniyo Rufus Molu declare that this work was done by me and has never been presented elsewhere for the award of a degree. I also hereby relinquish the copyright to the Federal University of Technology, Minna, Niger State.

.... 09/10/06	
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Abstract

This project is concerned with the design and construction of a single channel intercom system. This is communication equipment which is made for use within defined vicinity like factory, institution, homes, etc. it is a modified version of the Telephone system.

This single channel intercom system considered in this project is divided into these major stages which include;

The Pre-amplifier stage and the audio amplifier stage. Each of these stages is treated in the subsequent chapters.

TABLE OF CONTENTS

CHAPTER ONE (1)

1.0 INTRODUCTION

1.1 HISTORICAL BACKGROUND

In a word of constant predation and competition, communication and expressiveness are vital for the biological survival of all living creatures. Recent studies which have dealt with the range of animal's communication have revealed that these creatures communicate by body movement or by making sounds to indicate danger, discovery or desires as the case may be.

Human being, creatures of higher intelligence were not left behind in this revolution. Primitive man developed methods of communicating with his immediate society and even longer distance.

Early methods include drumbeats, fire, smoke signals, and instruments such as the horn from animals and even through the use of some signs or omens.

As man increased in wisdom and knowledge, his methods and needs of communication have become more sophisticated and efficient. As a result of the advancement of man technically, various devices for communication have been invented. Examples of these are wire telegraphy, facsimile, telephone, intercom system, television, teleprinter, radios, etc.

1.2 OBJECTIVES AND METHODOLOGY

This project is all about the design and construction of a single channel (one-way) intercom system. The single or one-way intercom system is a means of communication within a defined vicinity such as factories, institutions, homes, etc. the word "INTERCOM" means internal communication.

"Communication" is a term that needs to be emphasised.

COMMUNICATION can be defined in electrical terms as the "Sending, Processing and Reception of signals using electrical means. Communication system can be defined as a system of sending, transmitting, processing and receiving signals. The means of communication of these systems can be radio link, optical fibre, satellite and telephone network.

The INTERCOM SYSTEM (Internal Communication System) is a simplified version of telephone system which transmits it signals through wires within a defined vicinity or area. The intercom system is a cheap and effective means of communication use in place of messengers in offices, homes, institutions, industries, factories and companies. The design of this intercom system is made to suit the specified needs of the environment in which it is to be utilised with adequate consideration for future expansion. The intercom system can either be manually or automatically controlled and operated. The manually operated intercom system such as the single channel or one-way system as will be seen in this project requires the presence of an operator at the master station to connect a caller to it port of call.

This project focuses on short distance of information and messages within a vicinity. The study of only wired telephone transmission is outlined in this project with provision for one (1) – channel or single way system which operates manually. There is need for grater communication in which a wireless communication will be more desirable, but the scope of this project specifies the design and construction of a single channel or one – way intercom system.

The single channel or one-way intercom system operates with direct current which powers the entire system. The single channel intercom system emphasised in this project consist of 2 loudspeakers, 2 microphones in which one of them serves as a remote microphone, volume control and the switch. All these components mentioned above constitute the external hard wear of the system but the internal structure will be expensively discussed in the chapter three (3) of this write-up.

When a visitor arrives at the door and wants to speak with the person inside, who has the master control, the visitor speaks through the microphone which has been given tone from the master control. As the visitor speaks tot the remote, the audio signal travels through the wire to the master control where the signal is being amplified and send as an output through the loudspeaker at master control end. The "Switch" switches over to the respective microphone and loudspeaker as the case may be. The person at the master control reacts to the caller (Visitor) by switching to his own end where he speaks through the microphone and the visitor receives the message through the other loudspeaker acting as an output for the audio signal inputted at the master control end.

The volume control regulates the volume of the output signal at the loudspeakers depending on the choice of the users.

The block diagram of a single channel intercom system is shown below;

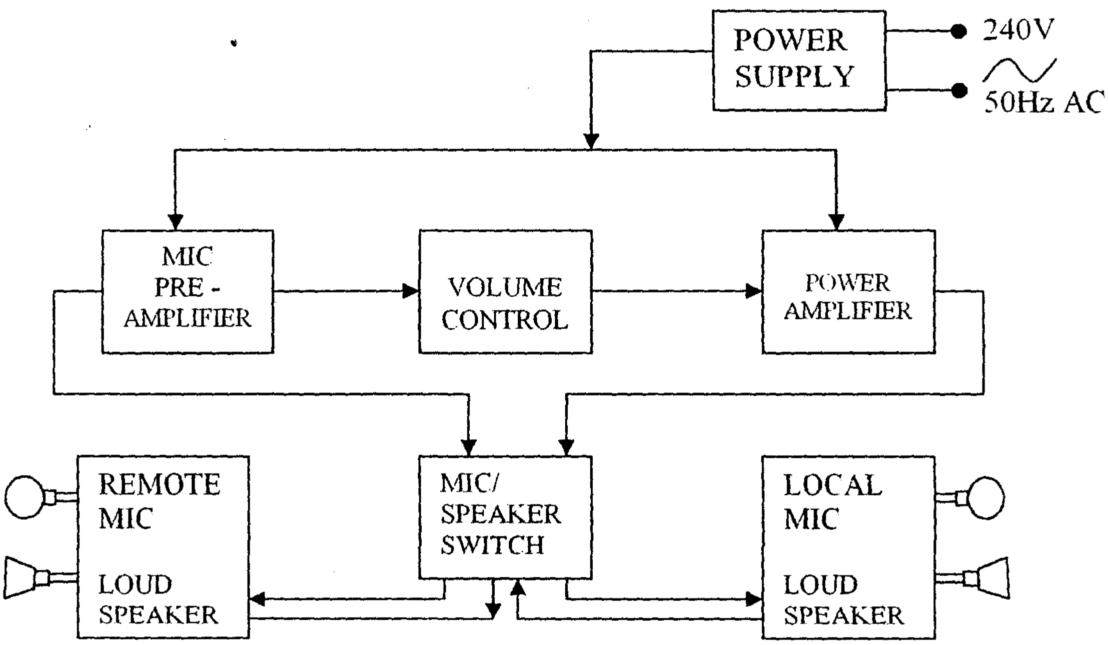


Fig 1.1 BLOCK DIAGRAM OF A SINGLE CHANNEL INTERCOM SYSTEM

CHAPTER TWO (2)

2.0 LITERATURE REVIEW/THEORETICAL BACKGROUND

2.1 BRIEF REVIEW/THEORETICAL BACKGROUND

Before the advent of modern communication systems, communication has been either through signs i.e. gesticulation to convey the message where the language has been a barrier. Other means of communication is the drumbeats, fire, smoke signal and the ram's horn. The means of communication mentioned above has limitations, because they are confined to a short distance. In an attempt to speak to somebody at a far distance one needs to speak on top of his voice which may cause disturbances. Apart from the problem, other problems include mountain barriers and some other external noises or sounds which may interface with the messages on transmission e.g. noise from moving vehicles and operating plants.

2.2 BRIEF REVIEW OF MODERN METHOD OF COMMUNICATION.

In an attempt to solve the problems encountered in old method of communication, the wire telegraphy and facsimile was invented in the eighteen forties [2]. Some decades after, telephone was also invented that was in 1876 attributed to Alexander Graham Bell [1]. Further research lead to the invention of radio, television, teleprinter and intercom system, etc. [1]

"Telegraphy": - This is the passing of message by means of signal code [2]. There are different types of code use for different telegraphy systems, but the common ones are the Morse and Murray code.

"Facsimile": - This is a system of communication in which a photograph, map, or other information is converted into signal waves for transmission [1] [2]

"Radio": - This transmits signals either in long wave (LW), medium wave (MW), short wave(SW) and frequency modulation (FM) through the means of electromagnetic radiation.[1] [2]

"Television":- This is also a means of communication where both audio and video signals are transmitted by FM (frequency modulation) and video by AM (amplitude modulation).

"Telephone": - This means of communication transmits its signal through microwave or optical fibre wires while the handset or mobile phones transmit its signal through electromagnetic waves [1]. Other means of communication include computer and other data transmission system.

The "Intercom System" is a simplified version of the telephone system which have so many applications both domestically, i.e. used at homes ands also in offices, embassy etc.[2]. The intercom system therefore plays a greater role in telecommunications. The simple design and implementation of the intercom system makes it desirable as it is also very cost effective. The intercom system has the same operating principle as the telephone system network. The distinguishing factor being the type of transmitter employed in the intercom. An intercom can either be manually operated or automatically operated as discussed in the introduction part of the text.

2.3 THEORETICAL BACKGROUND OF THE INTERCOM SYSTEM.

The complete intercom system designed consists of the following components

1. Operational amplifier (inverting or non inverting).
2. Power amplifier (IC)
3. Resistors, Capacitors and Voltage Regulator.
4. The Power Supply unit.

5. Microphones and loudspeaker.

2.3.1 OPERATIONAL AMPLIFIER

The operational amplifier is the basic building block of electronic system. The components constituting an amplifier have been changed over the years and will continue to change, but it is important to know how one amplifier loads another when they are connected in series (cascaded).

Usually the voltage amplification or power gain or frequency response obtain with a single stage amplifier is not sufficient to meet the needs of a composite electronic circuit or a load device [6]. Hence two or more single stage of amplification is used to achieve greater voltage or amplification [6]. The output of one stage serves as input of the next stage as shown in the figures below;

THE FIGURE BELOW SHOWS THE SYMBOL AND SERIES COMBINATION AMPLIFIERS.

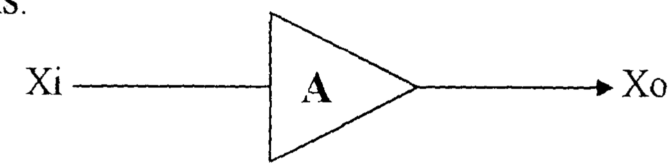


Fig. 2.1 Showing Amplifier Symbol.

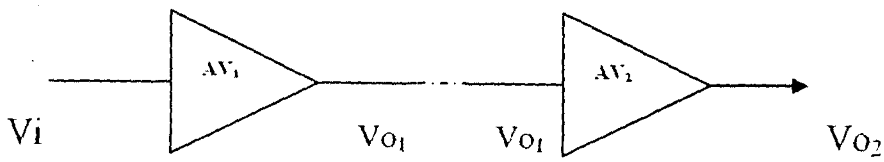


Fig. 2.2 Showing Amplifier in series.

From the figure above, the input Xi is related to the output Xo by a constant. The stage is said to have a gain A, which is given below; [5] [6]

A = Amplifier Output / Amplifier Input

= Xo / Xi

From the relationship above, it can be deduced that; as the output Xo is increased, there will come a time when Xo cannot increase anymore due to limitation of supply [5].

Thus every amplifier will be non-linear for very large output demands. [5] [10]

2.3.2 PROPERTIES OF REAL AND IDEAL AMPLIFIER

One of the most important properties required of the basic internal amplifier to be used as the heart of an operational amplifier is that it must have a high gain [9]. For analysis and design purpose, gain considered high enough to be considered as infinite.

Ideally, it is assumed that an operational amplifier has infinitely high input impedance [5] [6]. There should be a specified operating frequency at which these properties will be maintained.

Specifications area also made as the change in the environment of the amplifier's performance such as temperature changes. Real linear amplifier cannot meet the specifications of an ideal amplifier, hence properties governing the selection of an amplifier are [9] [10]

- High gain
- Wide bandwidth.
- High input impedance.
- Low output impedance.
- High degree of stability against temperature and other environmental changes.
- Minimum of adjustment set for the DC conditions.

2.3.3 THE INVERTING OPERATIONAL AMPLIFIER.

This type of amplifier has the input signal being fed into the (-ve) terminal. The (+ve) terminal of this amplifier is connected to the common rail or ground [3].

FIGURE BELOW SHOWING INVERTING OPERATIONAL AMPLIFIER

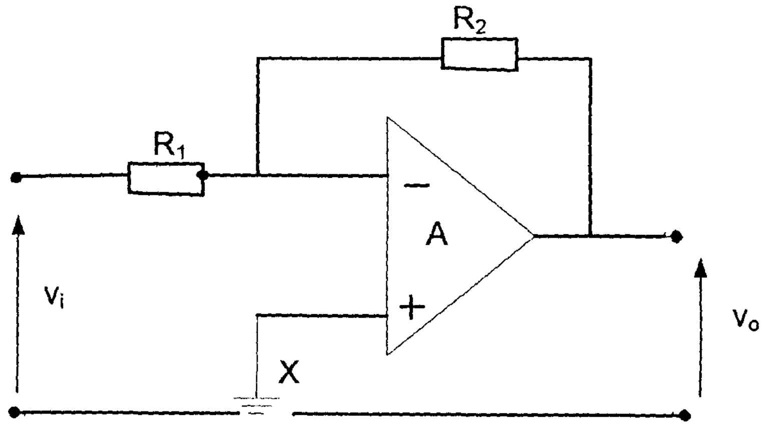


Fig. 2.3 Inverting operational amplifier.

From the diagram above, the Vi and Vo are the input and output voltage respectively which are related to each with respect to the input and the feedback resistor R_1 and R_2 respectively as;

$$A = V_0 / V_1 = R_2 \backslash R_1$$

$$Vo = V_1 R_2 / R_1$$

To calculate the overall gain, G, for amplifiers, we assume that [5]

- The internal gain A is large.
- The input resistance of the internal amplifier is infinite.
- The output resistance is zero.

If the amplifier gain A is very large for a given output signal, the signal at the (-ve) terminal is very small, and the terminal is said to be at virtual Earth [5][3]. From the figure above, terminal "X" is at a virtual earth and the current equations becomes;

$$V_i / R_1 = - V_0 \backslash R_2$$

and the overall gain becomes

$$G = V_0 / V_i = - R_2 \backslash R_1$$

By assumption, the overall gain of the operational amplifier has been shown to be independent of the internal amplifier gain A and determined entirely by the ratios of the external resistors.

The gain of the overall inverting amplifier can be adjusted by various means. It is possible to make either R_1 or R_2 variable, however, R_1 effectively determines the input resistance of the inverting amplifier, and thus it adjustment to control the gain causes the input resistance to vary.

Variations of R_2 may be achieved either by means of a potentiometer or by switching in different resistors. The input resistance is undisturbed, but caution must be taken in the connection to the very sensitive (-ve) input of the amplifier, where spurious signals can produce a large understandable output [5].

An alternative method is to vary the gain by using the circuit below which was adopted from [3].

FIGURE BELOW SHOWS THE GAIN OF AN INVERTING AMPLIFIER.

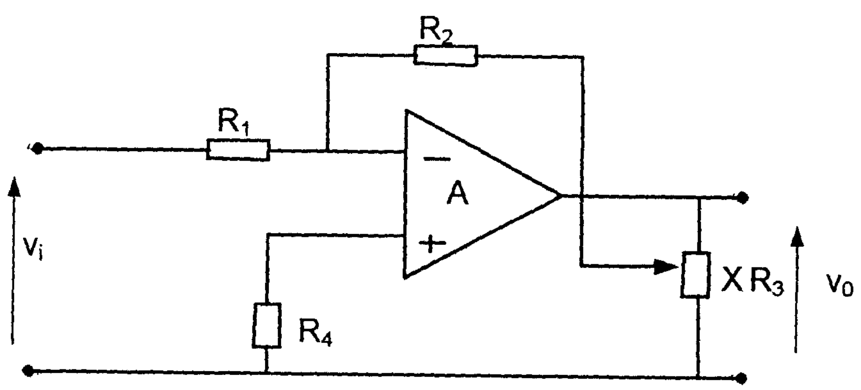


Fig. 2.4 showing the gain of the inverting amplifier.

The potentiometer is across the low impedance output of the amplifier and connected to the (-ve) negative terminal through the relatively large Resistance R_2, therefore, spurious signals affect the amplifier very much less [3].

The gain in this arrangement is given by;

$$G = - 1 / X(R_2/ R_1)$$

Where X is the faction of the output voltage Vo to which R_2 is connected.

2.3.4 OUTPUT IMPEDANCE OF THE INVERTING AMPLIFIER.

From the idealised amplifier of fig.2.3 with a large gain A and an extremely small signal at X (which is virtual earth), R_1 is connected between the input and earth. When gain A and input resistance R_1 of the internal amplifier are connected to be finite, the input current is [7] [10];

$$Ii = Vi - Vo / R_1 \quad \text{.........eqn(1)}$$

With $Vi = -Vo / A$, $Ii = Vi / R_1 + Vo/A R_1$
i.e. assumption Ii = positive(+)

$$Ii = Vi / R_1 + Vo/A R_1 \quad \text{.........eqn(2)}$$

But $$Vo/Vi = - R_2/ R_1 [1 / \{1 + 1/A (1+ R_2/ R_1+ R_2/ R_1)\}] \quad \text{......eqn(3)}$$

$$Vo = - ViR_2/ R_1 [1 / \{1 + 1/A (1+ R_2/ R_1+ R_2/ R_1)\}] \quad \text{........eqn(4)}$$

From equation (3);

Substituting equation (4) into (2), this gives;

$$Ii = - Vi [1/ R_1+ 1/ R_2 \{1/(A+1+ R_2/ R_1+ R_2/ R_1)\}] \quad \text{..........eqn(5)}$$

This further gives $Vi/Ii = R_{in}$

$$R_{in} = [1 + \{R_2 R_1/ R_1 (R_1+A R_1+R_2)\}] \quad \text{.........eqn(6)}$$

The output impedance is derived for the circuit of fig. 2.5 below which assures that R_1 is very large. The currents at nodes X and Y are given as [7]

$$V^1 - Vi / R_1 = V^1 - Vo / R_2 \quad \text{.........eqn(7)}$$

and $-AV^1 - Vo / R_o + V^1 - Vo / R_2$ ....eqn(8)

$$V^1 = R_1R_2 / R_1 + R_2[Vi/ R_1 + Vo/ R_2]$$

Eliminating from V^1 equation(8) gives

$$Vo = \{- Vi(A R_2 - R_0) / R_0 + R_1 + R_2 + AR_1\} - \{IR_0(R_1 + R_2) / R_0 + R_1 + AR_1 + R_2$$ ... eqn(9)

This is equivalent to Vo = Vi (no – load voltage gain) – I (amplifier output resistance).

The figure below shows input and output impedance of an inverting amplifier

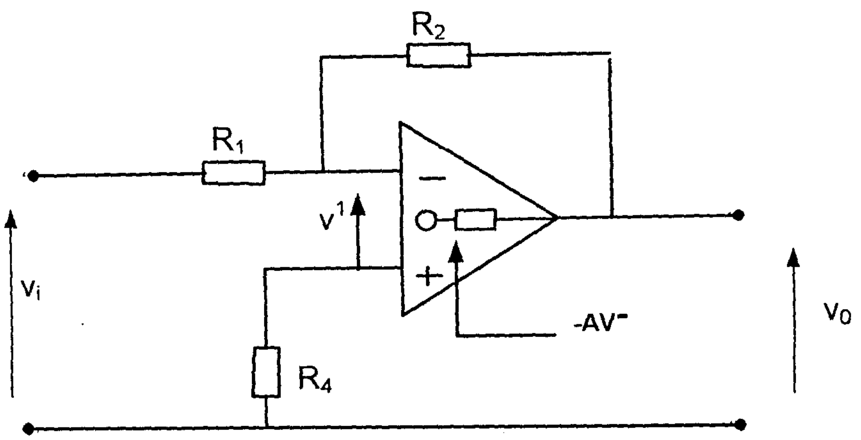


Fig. 2.5 Input and output impedance of an inverting amplifier.

When A is large, the no – load voltage gain becomes $-R_2/ R_1$, the output resistance R_0 of the overall amplifier is

$$R_0(R_1+R_2) / \{ R_0+R_2+R_1(1+A)\}$$ ....eqn(10)

2.3.5 THE NON – INVERTING OPERATIONAL AMPLIFIER

Here the signal is applied to the (+ve) positive terminal, but the circuit connection using R_2 and R_1 are still made (-ve) negative terminal [10]. One end of R_1 is joined to the earth. The figure is shown below [10].

THE FIGURE BELOW SHOWS THE CONNECTION OF A NON – INVERTING OPERATIONAL AMPLIFIER

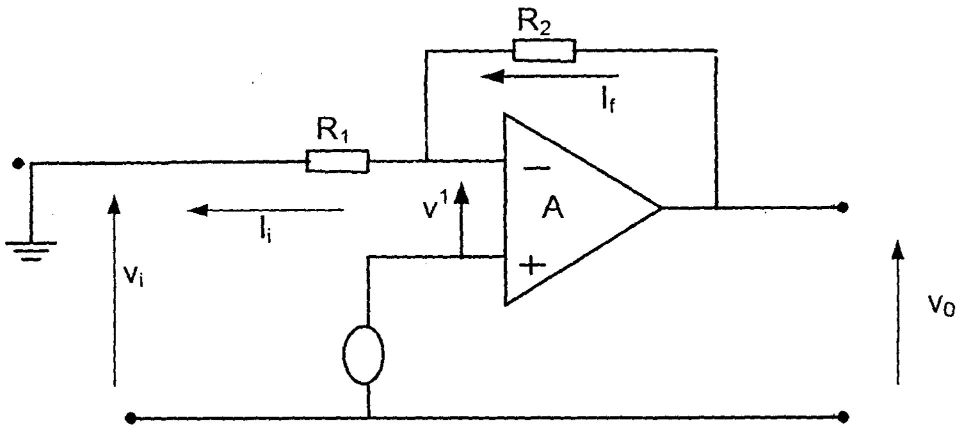


Fig. 2.6 Showing non – inverting operational amplifier connection.

2.3.6 THE GAIN ANALYSIS :

We first consider the case where input resistance R_I tends to infinity and output resistance R_1 tends to zero. The output voltage at the inverting input goes [9] [4].

$$Vi = R_1\ Vo / \{ R_1+R_2\}$$

$$V_0 / V_i = A / [1 + \{AR_1 / (R_1+R_2)\}]$$

Where A is large, $V_0 / V_i \approx 1 + (R_2 \backslash R_1)$

ALTERNATIVELY;

Considering the node Q using KIRCHOFF's CURRENT LAW (KCL)

$$I_f - I_i = 0$$

$$\text{But } I_i = V_i / R_1$$

$$V_0 = I_f R_2 + I_i R_1$$

From equation (1), $I_f = I_i = V_i / R_1$

Substitute in equation (iii)

$$V_0 = V_i R_2 / R_1 + V_i R_1 / R_1$$

$$V_0 = V_i R_2 / R_1 + V_i$$

$$V_0 = V_i (R_2 / R_1 + 1) = R_2 + R_1 / R_1$$

2.3.7 BASIC FUNCTIONS OF OPERATIONAL AMPLIFIER

The basic functions of operational amplifier are stated and analysed as thus;

1. It acts as a sign changer or inverter.

   i.e. If $R_f = R_{in}$, then the sign of input is reversed [10] [9]. The configuration is shown below;

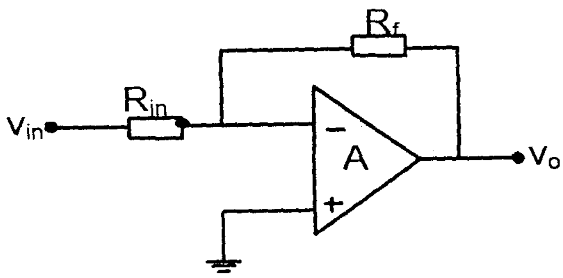


Fig. 2.7 Showing an operational amplifier as a sign changer.

If $R_f = R_{in}$, from $V_0 / V_i = -R_f / R_{in} = V_0 / V_i = -1$

$V_0 = V_i$ or $V_i = - V_0$.

2. As a scale change: If $R_f = kR_{in}$ where K is positive constant e.g (2,3,4,5........) ≥ unity then from $V_0 / V_i = -R_f / R_{in} = V_0 = kV_{in}$
3. It acts as an integrator i.e $V_0 = V_i = -1/ R_{ici}\int Vdt$ the output voltage is proportional to the integral of the input voltage.
4. As a differentiator i.e. $V_0 = R_f C_i dv_s/dt$ the output is proportional to the time derivative of the input voltage.

2.3.8 OPERATIONAL AMPLIFIER AS AN INTEGRATOR.

The figure below shows the configuration of an operational amplifier as an integrator [6] [9] [10].

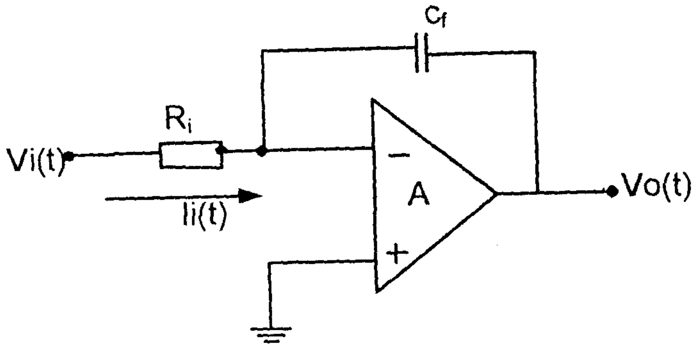


Fig. 2.8 showing op-amp as an integrator.

Consider node, P using KCL (Kirchoff's current law)

$$Ii(t) = -Ic(t) \quad \ldots\ldots\ldots (i)$$

But $$Vi(t) = Ii(t)R \quad \ldots\ldots\ldots (ii)$$

$Ii(t) = Vi(t)/R = -Ic(t)$ from equation (i) and (ii)

$$Vc(t) = 1/c\int_0^t Icdt + V^1_c(o) \quad \ldots\ldots\ldots (iii)$$

Equation(iii) derived from $V = 1/C\int_0^t Idt$

But $Ic(t) = -Vi(t)/R$ deduced from equation(ii)

Substitute Ic(t) above in equation(iii)

$Vc(t) = Vo = -1/RC\int_0^t Vi(t)/1\ dt$

i.e $Vo(t) = 1/RC\int_0^t Vi(t)\ dt$ (Integrator equation)

2.3.9 OPERATIONAL AMPLIFIER AS A DIFFERENTIATOR

The figure below shows the configuration of an operational amplifier as a differentiator [9] [7]

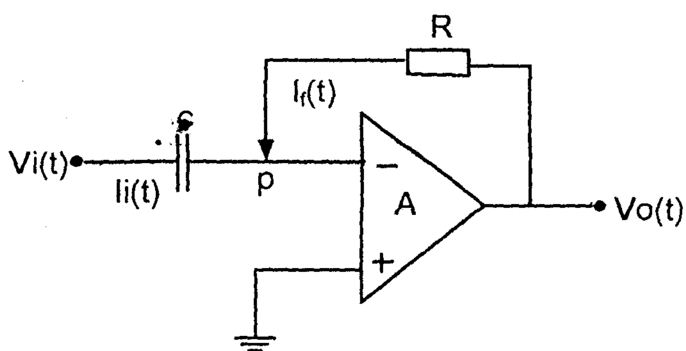


Fig. 2.9 Showing op. amp as a differentiator

Consider node P, using KCL (Kirchoff's Current Law)

$Ii(t) = -I_f(t)$ ....(i)

$Vo(t) = I_f(t)R = -Ii(t)R$ ....(ii)

But $Ii(t) = CdVi(t)/dt$ ....(iii)

From equation (ii) $Vo(t)/R = -Ii(t)$ ....(iv)

Substitute equation (iv) into equation (iii)

$-Vo(t)/R = CdVi(t)/dt$

Cross multiplying

$Vo(t) = -RCdVi(t)/dt$ (Differentiator equation).

The output voltage Vo(t) is proportional to the time derivative of the input voltage Vi(t). Other functions of operational amplifier include;

2.3.10 OPERATIONAL AMPLIFIER AS AN ADDER OR SUMMING AMPLIFIER

The figure below shows the application of an operational amplifier as an adder or summing amplifier.

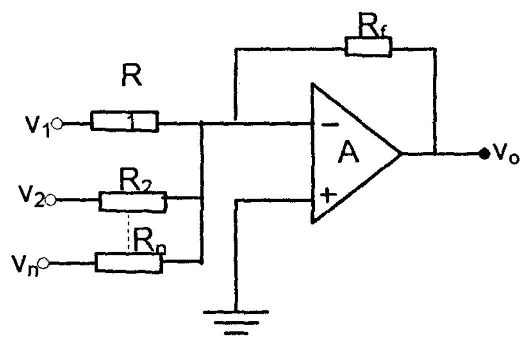


Fig 2.10 Showing op-amp as an adder or summing amplifier.

From the figure above;

$I_f = V_1/R_1 + V_2/R_2 +$ ------------------$+ V_n/R_n$

$I_f = V_0/R_f = V_1/R_1 + V_2/R_2 +$ ------------------$+ V_n/R_n$

$$I_f = V_0/R_f = \sum_{i=1}^{n} V_i/R_i$$

$$V_0 = R_f \sum_{i=n}^{n} V_i/R_i$$

Operational amplifier also acts as a voltage to current and current to voltage converters [9]. An op-amp can convert an input voltage into a proportional output current i.e. from

$$I_f + Ii = 0$$

$$\therefore \quad I_f = - Ii = -V_{in}/R_{in} = I_f$$

If a source is connected directly to the converting terminal, then the output voltage, $Vo = -I_f R_f = -I_s R_f$ and is therefore proportional to the I_{in}(input current).

2.3.11 DISTURBANCES IN THE AMPLIFIER

Disturbances can be taken to mean unwanted signals in the signals required to be transmitted. This is a problem associated with amplifiers. It can be due to various reasons as poorly fitted supplies, thermal e.m.fs in the circuit and non-linearity in the amplifier when the output is no longer directly related to the input.[5][6][7]. This is a serious problem in amplifier. The figure below shows the unwanted effect included as disturbance D.

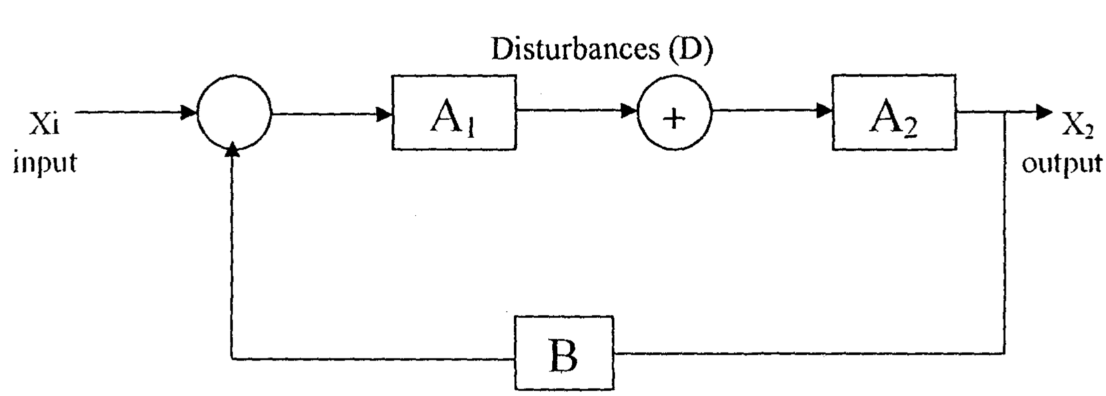


Fig. 2.11 showing the unwanted effect in amplifier.

The disturbance occurs between the input and output of the amplifier. The total forward gain is now A_1A_2. The output X_2 an be written as;

$$X_2 = \{(X_2\ A_1A_2)/(\ 1+A_1A_2B)\}\ +\ \{(DA_2)/(\ 1+A_1A_2B)\}$$

The second part of the equation shows that the disturbance has been reduced by a factor (1 + loop gain).

DA_1 is the disturbance that would have reached the output without feedback, and has clearly been reduced by a useful factor in a feedback amplifier where the loop gain is large.

When $A_1A_2B >> 1$, the above equation gives

$$X_2 = \{X_1(1/B) + D(\ 1/A_1B)\}$$

The disturbance is divided by A_1B where the unwanted signals is only divided by B . Thus the signal has been approved relative to the disturbance.

2.3.12 POWER AUDIO AMPLIFIER

The power audio amplifier is constructed on either operational amplifier 741 or other IC for amplification i.e. integrated circuit; this consists of discrete components such as transistors compact in a single and small chip in order to reduce complexity of circuit and the cost of implementation of the circuit. The integrated circuit can be produced to form a single amplifier stages or multistage amplifiers, both with the advantages of automatic compensation for temperature drift. [3][7]

The outcome is that one component can replace up to a hundred or more with a dramatic reduction in the volume taken up, i.e. the outcome is the miniaturized microcircuit which is very small, cheap and reliable. IC's can be used for amplifying direct signal as well as alternating signal.

The amplification of the input signal in a system such as single channel intercom system is actually carried out at this stage. The output signal of such a system preamplifier stage is then coupled into the audio amplifier by capacitor. The stabilization is taken into consideration while using an IC as a power or audio amplifier because any distorted signal amplified will reflect at the output.

The distortion introduced by the non-linearity of the transfer characteristic must be eliminated, hence, yielding low distortion and high efficiency to reproduce the input signal. The difference between the various IC's power amplifiers available are their maximum output power, their frequency response, their noise performance and their total harmonics distortion.

2.4 RECTIFICATION OF AC AT THE POWER SUPPLY UNIT.

AC – DC converters are rectifier circuits which convert an alternating voltage to direct voltage. They use diodes and/or thyristors to obtain a dc output voltage which can be fixed (diode rectifiers) or controlled by varying the conduction time of a control thyristor. The circuit input supply can be single phase or three phase.

Rectifying circuits divide broadly into groups, namely [9] [10] [4];

- Half wave connection
- Full wave connection.

The main concern in this project is the full wave controlled rectifier connections.

2.4.1 THE FULL WAVE CONTROLLED RECTIFIER CONNECTION

The single phase full wave controlled rectifier connections shown in the figures below have source voltages derived from transformers [9]. The current waveforms for both converters are similar and are represented in figure 2.12a for resistive load. The output current is full wave rectifier. The source current has no direct component because of its alternating symmetry. This allows the use of non – ideal sources, such as the transformer. Since there are two pulses of load current per cycle of the voltage source, these circuits are alternatively classified as "two pulse" controlled rectifier [9] [4].

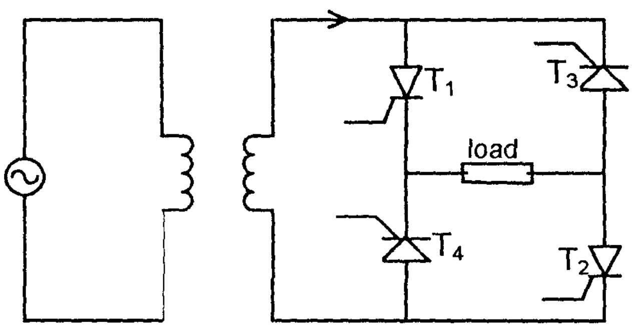


Fig. 2.12a Showing a Bridge Full wave Connection.

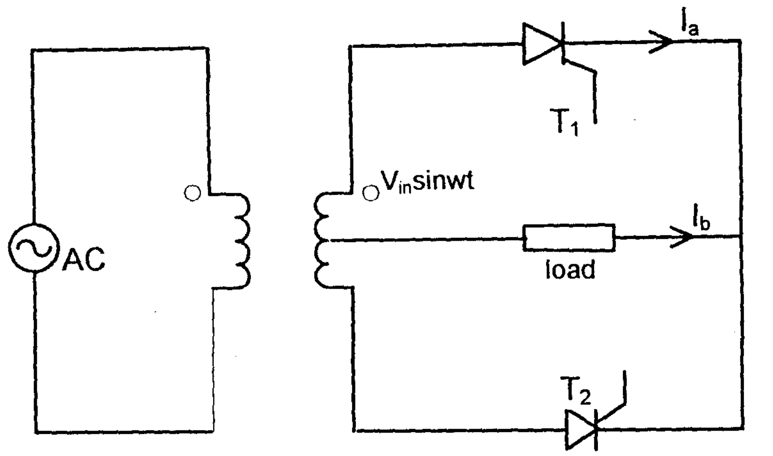


Fig. 2.12b Show a Bi-phase full wave connection.

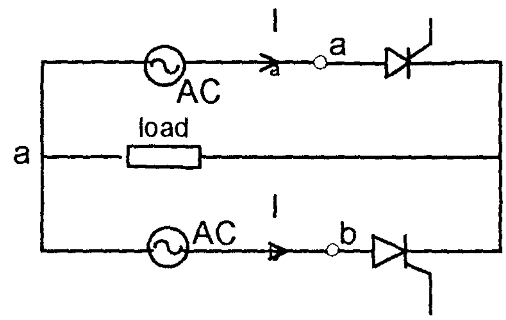


Fig 2.12c Equivalent circuit for 2.12a and 2.12b

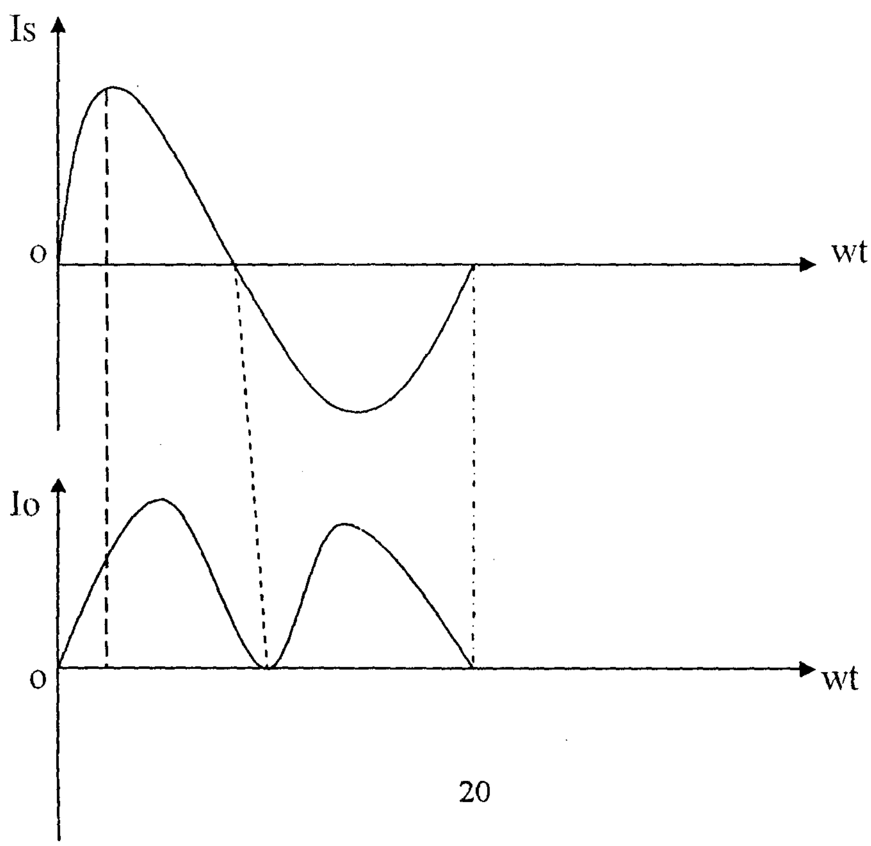


Fig. 2.12d showing the output wave forms of a full wave rectifier.

If we regard the transformers and thyristors in the circuit as ideal, the each of the two connections may be represented by the equivalent circuit of figure 2.12c where

$$Van = VmSinwt \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (i)$$

and

$$Vbn = VmSin(wt + \pi) = -VmSinwt \quad \ldots\ldots\ldots\ldots\ldots\ldots (ii)$$

We know that the thyristor T_1 in the equivalent circuit is equivalent to the series connected T_1 and T_2 in figure 12a.

2.4.2 SINGLE – PHASE FULL WAVE BRIDGE CONVERTER

In the bridge circuit of the figure below; fig 2.13a, the control devices T_1, T_2 , T_3 , andT_4 can all be thyristors or a combination of thyristors and diodes. When thyristors and diodes are combined, the resulting circuit is a semi controlled bridge converter, when all the control devices are thyristors, the resulting circuit is FULLY CONTROLLED bridge converter.

The average output voltage of the fully controlled bridge converter which converts the AC input of the transformer to a required DC output voltage is given by

$$V_{ODC} = V_{rms}\sqrt{2}[\ 1 - (1/4FRC)] \quad [6]$$

Where V_{rms} = output voltage of the transformer.

$\sqrt{2}$ is the conversion constant

F = frequency = twice the main frequency

RL = load resistance = total resistance of the circuit.

C = capacitance on the power line.

The figure below shows the full circuit diagram of a Bridge Converter Circuit.

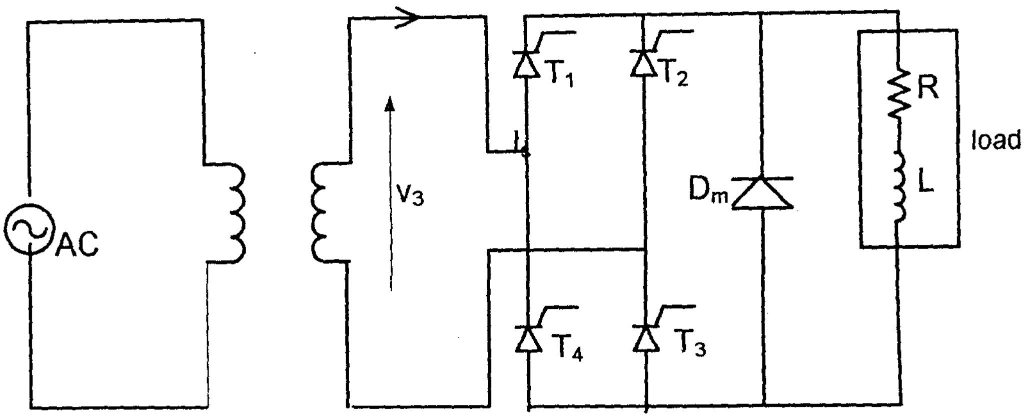
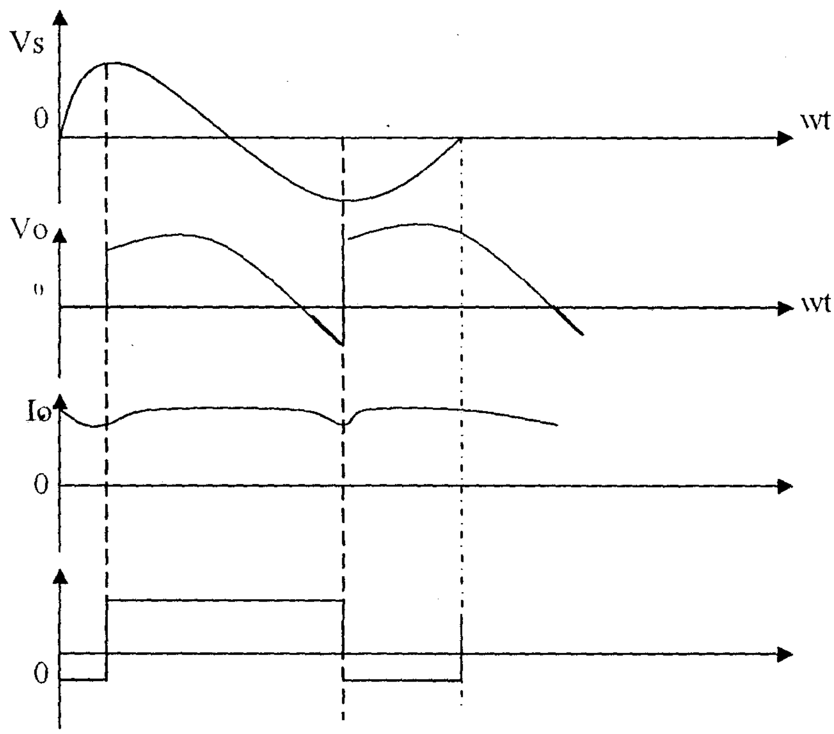


Fig 2.13a Shows a Bridge Converter Circuit.

The figure below i.e. fig. 2.13b is showing the output waveform of a fully controlled Bridge Converter Circuit.



CHAPTER THREE (3)

3.0 DESIGN AND IMPLEMENTATION WITH CALCULATIONS.

The design consists of two IC's which are 741 operational amplifier and TDA2030 which is also an amplifier acting as the power amplifier of the system while the 741 operational amplifier is audio or microphone preamplifier.

The one-way intercom system designed in this project can be divided in the following modules;

1. Power Supply Unit
2. Preamplifier Unit
3. Power Amplifier Unit
4. Speaker-Microphone Switch Unit
5. 15-V Regulator

3.1 THE POWER SUPPLY UNIT

- The power supply unit comprises of
- 15V 1A Step down transformer (rated 240V/15V)
- A packaged full-wave bridge rectifier
- A 35V 4700µf and 0.01µf Capacitors.

The power supply unit is configured as shown below;

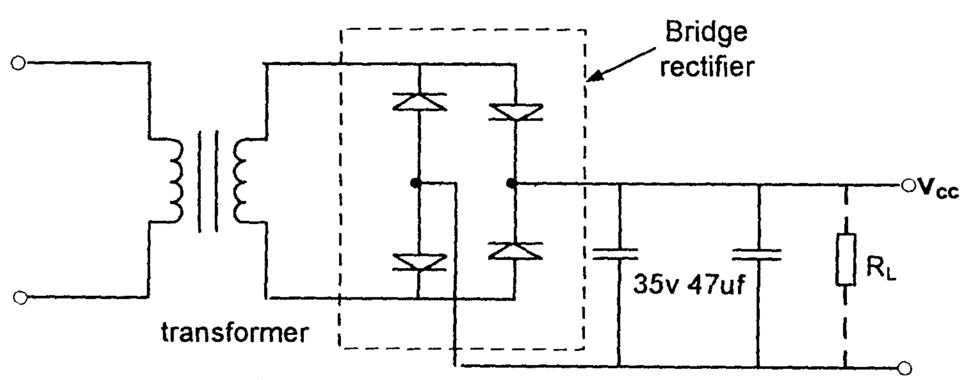


Fig 3.1 The power supply unit of the design.

From the module above which represents the power supply unit, the following calculation can be deduced;

$$V_{odc} = V_{rms}\sqrt{2}[\,1 - (1/4FRC)]$$

Where V_{odc} = The D.C output voltage

V_{rms} = The output voltage of the transformer = 15V.

$\sqrt{2}$ = The conversion constant

F = frequency of the bridge rectifier = 2 × 50 = 100Hz i.e. each two combination of the diodes in the bridge rectifier has 50Hz frequency

RL = load resistance = total resistance of the circuit.

C = capacitance on the power line (in microfarad).

From the circuit diagram, since the total resistance is high, frequency of bridge rectifier is high as well as the value of the capacitance; the expression 1/4FRC can be neglected in equation9i0 above which becomes

$$V_{odc} = 15\sqrt{2} \approx 21.21V$$

Due to inefficiency V_{odc} can be approximated to 20v since the required D.C input to power the entire circuit is 15V, a 15-V regulator was employed. The 35V 4700µf was employed to filter out AC component of the D.C output of the transformer.

3.2 THE REGULATION UNIT (7815 Regulator).

A 15V regulator was employed for the 741 preamplifier to decouple the small signal stage from the high power and high current stage.

The 15V output voltage required was obtained from the 7815 15V 1A three-terminal regulator. The modular arrangement is shown below;

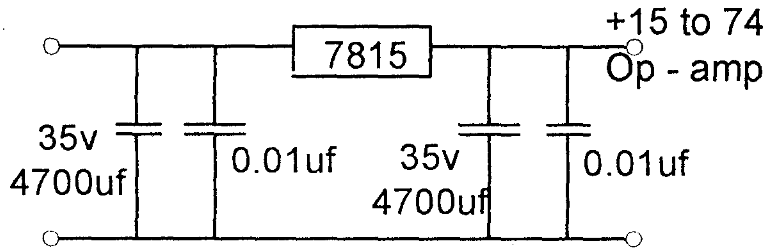


Fig. 3.2 Showing regulation unit connections.

For the 7815, Vin(max) = 35V, Vo = 15V, and Io = 1A.

The 7815 incorporates shutdown on over load, preventing the powered circuit from damage. The 0.01µf capacitors are incorporated to serve as the earthing components.

3.3 THE PREAMPLIFIER STAGE FOR THE MICROPHONE.

Due to the low output of the condenser microphones employed in the construction, a preamplifier was inserted between the microphone and the power amplifier unit driving the loudspeaker.

The pre-amplifier for the pre-amplification of the microphones output is configured as shown below;

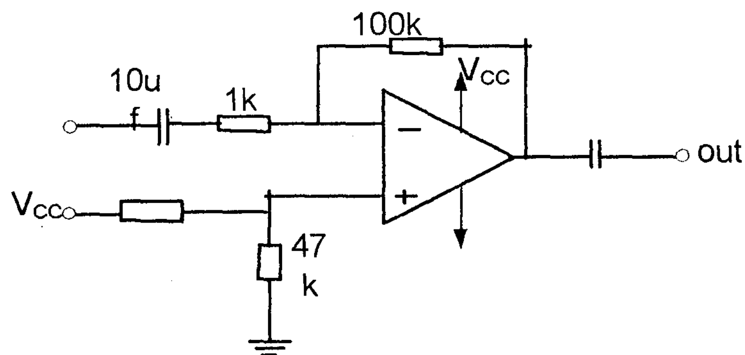


Fig. 3.3 showing the connection for the pre-amplifier stage.

Since the op-amp is operated on a single supply of +15V, it was biased so that it has Vcc/2(+7.5V) quiescent DC output level at Pin 6(Output Pin). The biasing arrangement is derived from two series connected 47KΩ resistance with a potential divider effect.

The midpoint potential is calculated as below;

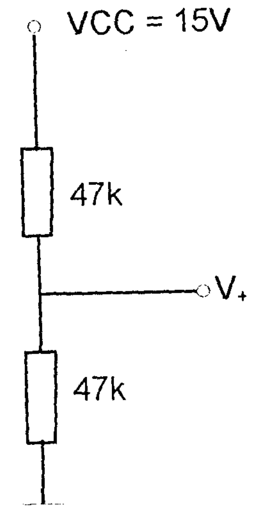


Fig. 3.4 showing the biasing arrangement of the pre-amplifier stage.

From the similar arrangement below;

The formula for the calculation for the above arrangement was deduced;

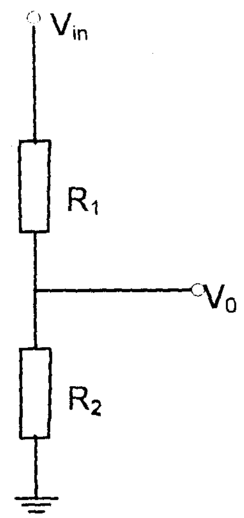


Fig 3.5 showing biasing arrangement.

Voltage (Vo) across R_1 is obtained from this relation;

$$V_0 = (R_2 / R_1 + R_2)\ V_{in}$$

Vo from figure 3.4 above was obtained as thus;

$$V_0 = (R_2 / R_1 + R_2)\ V_{in}$$

Where $R_1 = R_2 = 47k\Omega$, $V_{in} = 15V$

This implies $Vo = (47 / 47 + 47) \times 15 = 47 \times 15 / 94$

Therefore $V_o = 7.5V$.

The calculated 7.5V above was fed into Pin3(non-inverting input) of the op-amp to centre the output voltage swing around 1/2Vcc for equal symmetrical and undistorted swing.

3.3.1 GAIN CALCULATION OF 741 OP-AMP

The op-amp is used as an inverting amplifier, and its gain is simply deduced from the expression .

$$A_v = -R_i / R_f$$

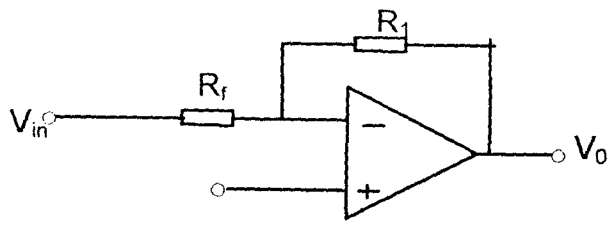


Fig. 3.6 Showing the gain can be calculated.

$$V_0 / V_{in} = A_v = -\{R_i / R_f\}$$

Where the negative sign (-) indicates a phase reversal on the output.

For this design, the expected gain of the op-amp is 100, therefore R_f was chosen to be 100KΩ and R_i as 1KΩ as shown in fig. 1.3 above;

It implies that

$$A_v(\text{gain}) = -R_i / R_f = -100/1 = -100$$

3.4 VOLUME CONTROL

The amplified output of the 741 is applied to a 100KΩ potentiometer from which the needed signal level can be tapped from the wiper contact.

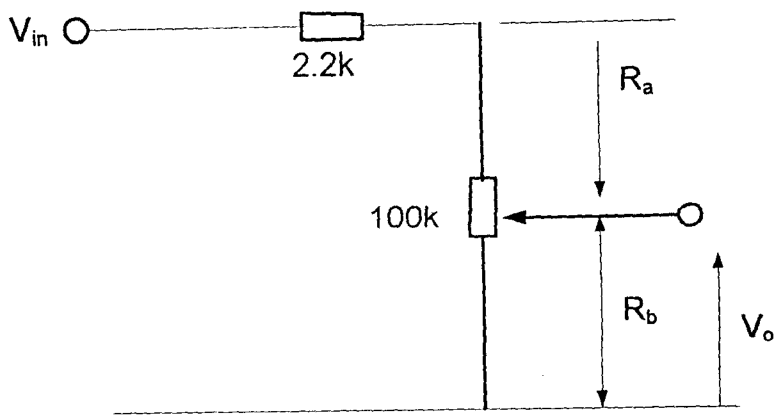


Fig. 3.6 showing the volume control.

Since the arrangement is a potential divider, the following relations apply;

$$V_{omax} = V_{in} \times 100 / (100+2.2)$$

i.e. V_{omax} = maximum voltage of the volume that can be obtained.

V_{in} = the output of the signal from the 741 op-amp.

Where V_{in} = 7.5V i.e. from the calculation for the biasing arrangement.

$$V_0 / V_i = -R_i / R_f = 100/1 = 100(\text{gain})$$

Where V_i = 7.5V,

$$V_{omax} = 7.5 \times 100 / (102.2) = 7.34V$$

$$V_{omin} = 0V = V_{in} \times 0 / (100+2.2) \times 0$$ i.e. from the minimum volume to be obtained.

For any other shaft angle for which wiper contact is not at either extreme of the potentiometer resistance

$$V_0 = V_{in} \times R_b / (R_a + R_b + 2.2k\Omega)$$

Hence by varying the ratio of R_a and R_b (by virtue of the shaft angle), various output voltage levels are obtained. This is the volume control function.

3.5 POWER AMPLIFIER STAGE.

The power amplifier is built around a TDA2030 high-power operational amplifier. It is configured for single operation and wired as below;

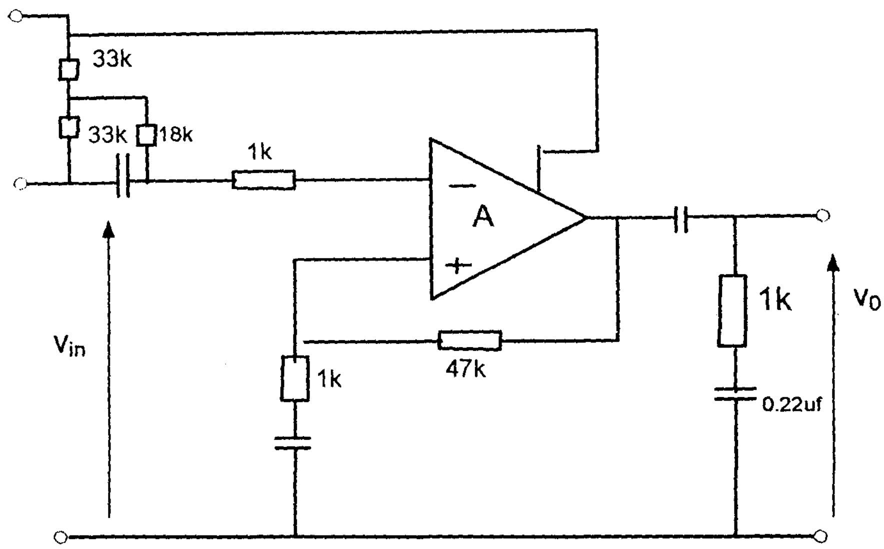


Fig. 3.7 showing the power amplifier unit arrangement.

The power amplifier is wired in the non-inverting configuration, therefore, the input – output phase relationship bears no inversion.

The op-amp is biased such that its output level at Pin 4 is centred around 0.5Vcc i.e. 1/2Vcc, with a Vcc of +21V, this yields an output DC level of +10.5V.

The input stage network was biased as shown below;

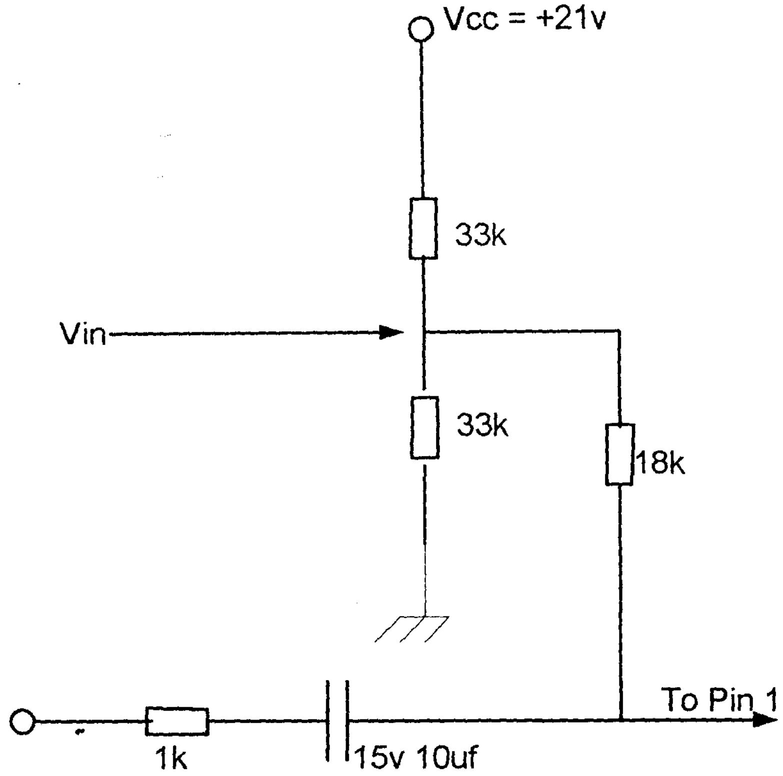


Fig. 3.8 showing the biasing arrangement.

Vin can be calculated as follows;

$$V_{in} = (R_1 / R_1 + R_2)\ V_{cc} \text{ where } R_1 = R_2 = 33K\Omega$$

$R_1 = R_2 = 33K\Omega$ was chosen in order to create a bias as desired for the TDA2030 op-amp.

$$V_{in} = (33 / 33 + 33) \times 21 = 10.5V$$

Therefore, the biasing network sources a current $I = V/R = 10.5/18K\Omega$

$$= 10.5/18000$$

i.e. $I = 0.00058A$ which was fed into the Pin one(1) as an input to the TDA2030 op-amp.

Effectively the input resistance of the amplifier is approximately equal to $18K\Omega$.

3.5.1 THE GAIN OF THE TDA2030 AMPLIFIER.

The gain for the TDA2030 amplifier can be calculated following the steps below;

Where $R_f = 47K\Omega$, $R_i = 1K\Omega$.

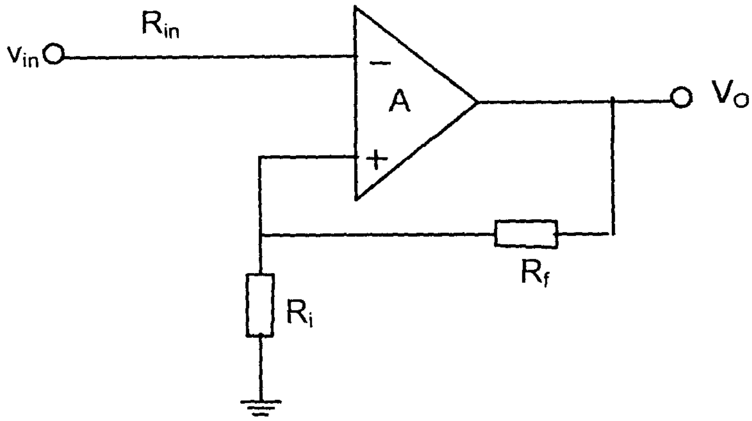


Fig. 3.9 showing how the gain can be obtained.

An operational amplifier will try to shift its output so that the differential voltage at its input, i.e. $\Delta V = (Vin(+) - Vin(-)) = 0V$.

Considering R_f and R_i as potential divider, if $\Delta V = 0$, $V_- = V_+$

i.e. $V_- = Vin$

using the potential divider theorem;

$$V(-) = V_0 R_i / R_i + R_f \text{.............................(1)}$$

Since V(+) = V(-), Equation(1) above implies

$$V_0 / 1 = V_0 R_i / R_i + R_f \text{..........................(2)}$$

From equation (2) above;

$$V_0 / V_{in} = R_i + R_f / R_i = 1 + R_f / R_i$$

$$V_0 = (1 + R_f / R_i)\, V_{in}$$

Since gain $= V_0 / V_{in} = (1 + R_f / R_i)$ ....(3)

From equation (3) above, I obtained my expected gain of 48 by making $R_f = 47\ K\Omega$ and $R_i = 1\ K\Omega$
This implies that,

The gain $V_0 / V_{in} = (1 + 47 / 1) = 1 + 47$
Therefore the gain of the TDA2030 $V_0 / V_{in} = 48$.

3.6 THE SPEAKER – MICROPHONE SWITCH.

The speaker – mic switch was included to cause the appropriate microphone/speaker combination to be connected to the circuit.

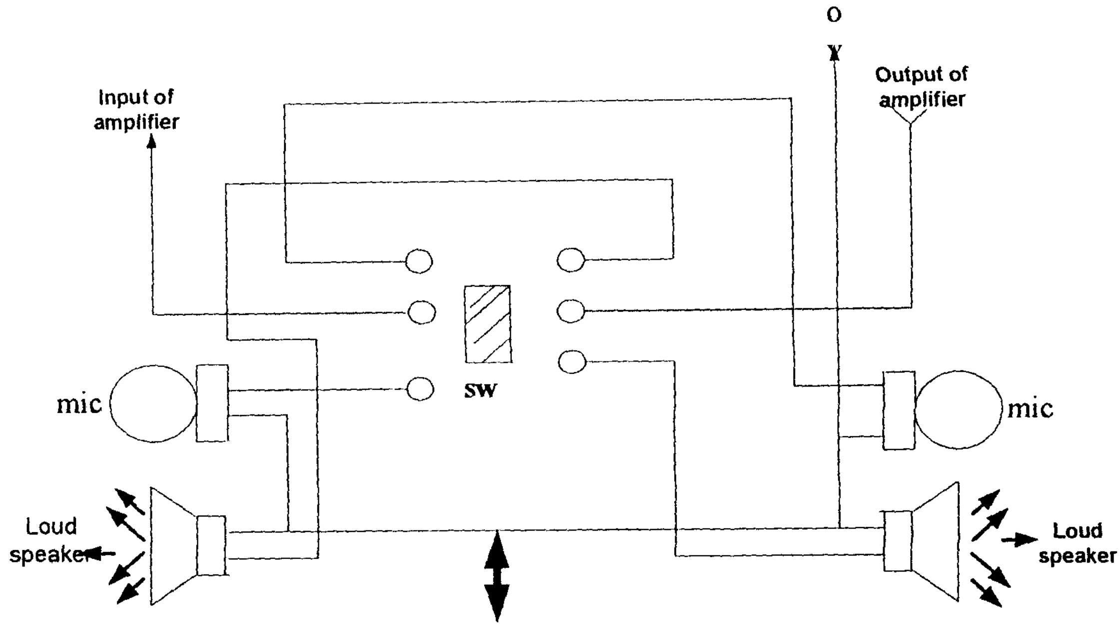


Fig. 3.10 showing the loudspeaker and microphone unit.

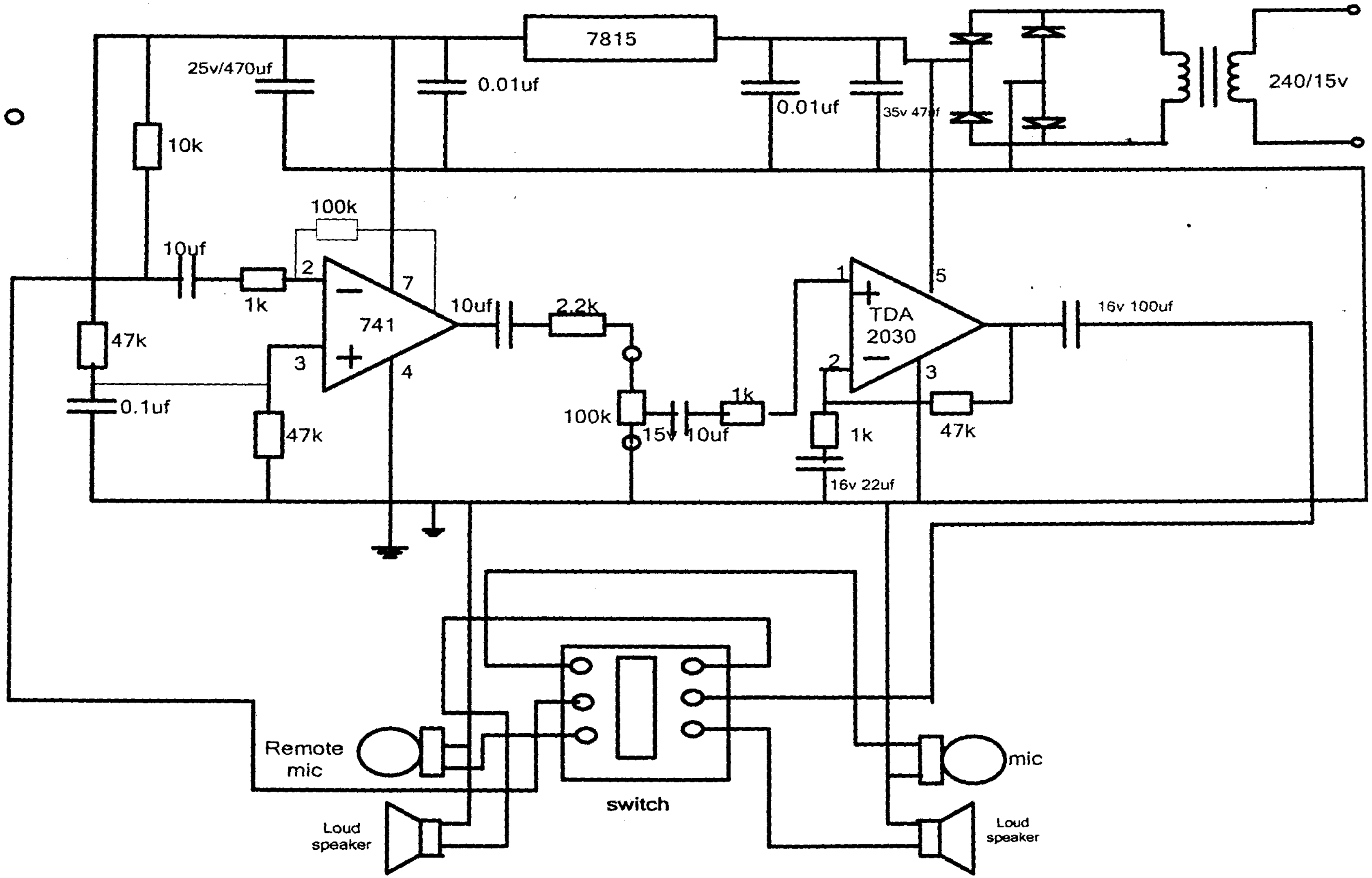
When the switch position is set to TALK, the master microphone is connected to the input of the intercom system and the slave, is connected to the output of the system.

When the switch position is reversed to LISTEN, the slave (remote) mic is connected to the input of the amplifier and the master (local) speaker is connected to the output of the amplifier.

This arrangement prevents oscillation due to acoustic feedback.

<u>**Note:**</u>

The capacitors in fig. 3.3 are all coupling capacitor i.e. the 16V 10µf coupled the input signal from the mic to the 741 op-amp while the 10µf couples the output of the 741 op-amp to the power amplifier TDA2030 via the potentiometer (variable resistor).



CIRCUIT DIAGRAM OF A SINGLE CHANNEL INTERCOM.
SYSTEM

The basic function of the coupling capacitors is to remove any d.c. components in the signal from affecting the d.c biasing of the operational amplifiers. Also, in figure 3.7, the capacitor 16V 10µf is a coupling capacitor which coupled the regulated output of the potentiometer into the power amplifier (TDA2030). Capacitor 16V 10µf serves as an earthing capacitor.

At the output of the TDA2030 op-amp, the series combination of the 1 KΩ and 0.22µf is to control the high frequency instability at the output. The 16V 1000µf coupled to the output of the TDA2030 to the microphone and loudspeaker.

The modules were then connected together to form the entire circuit diagram of the single-channel or a one-way intercom system as will be seen later on a page.

CHAPTER FOUR

4.1 TESTS

The design and construction of one-way (single-channel) intercom system was first tested on the breadboard, to ensure full workability of the entire design. The entire circuit was tested at various units using appropriate instrument which is the digital multimeter which measure both current and voltage even resistors value at various unit of the circuit for the design. The breadboard used for the pre-test is a prototype board which has well arranged pin sockets for fixing-in components. The breadboard used is ideal for testing full working of systems and components as it serves as temporary construction board.

The design and construction on the breadboard was carefully transferred to the Vero board after necessary adjustment has been done on the design setup on the breadboard.

The components from the breadboard were fixed to the Vero board by placing each pin of the component in a separate hole, and then the pin of the respective components was carefully soldered on the Vero board.

Each section or unit soldered was tested to ensure that the design was free of short circuit which may result when two or more pins of components on the Vero board are mistakenly in contact during soldering.

After the final soldering which was carefully and neatly done on the Vero board, the result of the soldering was examined by testing again using the same instrument (multimeter) for satisfaction and confirmation of accuracy of the soldering and to as well see if the values obtained were the expected values for the design.

The results obtained during the tests for the various units or stages are tabulated below;

4.1.1 THE POWER UNIT AND THE PREAMPLIFIER STAGE.

The table below shows the result obtained for the power and pre amplifier units;

TABLE 4.1 SHOWING THE RESULT AT THE POWER AND PREAMPLIFIER UNITS.

Tests	Result	
	Voltage(V)	Current(mA)
Transformer rating	240/15	1000.00
Rectified output voltage	20.90	-
Regulator(1A7815 regulator)	15.00	1000.00
Input of 741 IC(inverting op-amp)	7.48	1.50
Output of 741 IC(inverting op-amp)	- 7.50	-1.50
Biasing Voltage Vcc/2	7.50	-

FIG 4.1.2 THE POWER AMPLIFIER UNIT AND THE LOUDSPEAKER.

The table below shows the results obtained for the power and preamplifier units.

TABLE 4.2 SHOWING THE RESULT AT THE POWER AMPLIFIER AND LOUDSPEAKER UNIT.

Tests	Result	
	Voltage(V)	Current(mA)
Input of the TDA2030 IC (non-inverting configuration)	10.48	0.60
Output of the TDA2030 IC (non-inverting configuration)	10.52	0.58
Biasing Voltage Vcc/2	10.45	-

4.2 DISCUSSION OF RESULTS.

4.2.1 TRANSFORMER

The Transformer is rated 240/15V 1A i.e. 240V PHCN (Power holding Company of Nigeria) supply which was stepped down to a dc level of 15V as required for the design especially at the pre-amplified stage where voltage between the range of 14 – 16V is required for the 741 op-amp to amplify the weak signal from the microphone. Any voltage beyond this level will result to noise in the amplifier unit of this particular design.

4.2.2 THE RECTIFIER (BRIDGE RECTIFIER)

The rectifier carried out rectification of the 15V from the transformer to an approximate value of 21Vdc (Vcc) as required for the power amplifier unit. One of the voltage advantage of this bridge rectifier in this project is to convert the AC component of the voltage into DC level as desired for this design.

4.2.3 THE REGULATOR (1A 7815 Regulator).

The regulator employed in this design is the 1A 7815 regulator which was used at the pre-amplifier stage of the design in order to keep the voltage level at 15V dc which was desired as the Vcc or input voltage of the 741 operational amplifier.

4.2.4 THE 741 OPERATIONAL AMPLIFIER

The 741 operational amplifier was configured as an inverting op-amp, whose expected gain was to be 100 which determine the choice of the resistor used in its configuration for the design. The choice of the resistors used for the configuration and the input voltage (Vin), account for the values obtain in the table 4.1 for both the input and output current and voltage respectively. The biasing voltage is 7.5V which enabled the op-amp to swing between -7.5 and +7.5V.

4.2.5 THE TDA2030 IC

The TDA2030 IC (op-amp) was used as the power amplifier in the design. The TDA2030 was configured in a non-inverting mode given rise to the required gain of 48 as calculated. The choice of resistors and the voltage (Vin) input determines the values obtained in the table 4.2 above. The biasing voltage Vcc/2 is 10.5 approximately, the input voltage level required for the TDA2030 in this design in order to produce reasonable output at the loudspeaker ranges from 20 – 23V, above this range i.e. above 23V will require a more powerful loudspeaker than the 8Ω/15W to give a clear and well filtered output. Any value below the least, 20V may not be suitable for the design.

CHAPTER 5(FIVE)

5.1 CONCLUSIONS

5.1.1 SUMMARY

The design and construction of a one-way or single channel intercom system (i.e. a telephone system) carried out in this project has given adequate information/explanation on the operation on the intercom telephone systems.

The system was designed at a low cost and to have a good quality, low noise output by taking into consideration the gain and the feedback of the amplifiers.

After carrying out this work, from my result it was obvious that, there is a difference between the theoretical calculated value obtained and the practical values because of the approximations made in values of components and also due to some errors which can be described as human errors.

Finally, the construction on Vero board was cased using a floor flex plastic tile with an appropriate dimension fit for the work on Vero board.

5.2 PROBLEMS ENCOUNTERED

The problems of radio interference and noise in the amplifiers were encountered which was solved by making adjustment to the variable resistance used to set the pre-amplification.

5.3 PRECAUTIONS

Quite a number of precautions were observed in the design and construction of this project work. These precautions were taken in order to ensure that the system work well, and component were not damaged in the process of construction so as to maintain a low of construction.

Some of these precautions are;

- Proper soldering technique was applied. Stray solders were carefully removed to avoid short-circuits and bridging. High grade soldering lead was used, and heat of the soldering iron was regulated to avoid damage of the components.
- The circuit design was made to be easy to understand, noting the methods used in previous designs so as to save time and prevents much errors during experimentation.
- The values of the circuit components were ensured to very close or the same as the expected value to implement the design to obtain the desired output.
- Proper identification of component and their parts and values were made both at the time of purchase and during the circuit construction.

5.4 ACHIEVEMENTS

In conclusion, after executing this project design and construction, I know better more than ever before how important telecommunications is in this advanced age both technologically, socially and economically in the society. It also makes me to know the working principle of an intercom telephone system and to as well have an idea of how telephones operate.

5.5 RECOMMENDATIONS.

I will want to recommend to those that will work on this project to improve on the efficiency of this design and make it two-ways or more as may be desired in offices, homes and in the industries. I will also want to suggest that the analogue exchange should be replaced by a more sophisticated means of exchange which could be digital.

In a nutshell, the department should try as much as possible to make the components available in the departmental workshop and also the apparatus needed to implement the construction on both breadboard and Vero board.

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