DESIGN AND CONSTRUCTION OF TELEPHONE RECEIVER

BY

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FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA
NIGER STATE, NIGERIA

NOVEMBER, 2004

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A PROJECT REPORT SUBMITTED IN PARTIAL

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DEGREE OF BACHELOR OF ENGINEERING

[B. ENG.]

AT

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA,

NIGER STATE, NIGERIA.

NOVEMBER, 2004

DECLARATION

I do hereby declare that this project was fully presented by me, under the close supervision of Mr. S.N Rumala . This project is presented to the Department of Electrical and Computer engineering during 2003/2004 academic session.

CERTIFICATION

This is to certify that this project work was done by **Umar-F Muhammad Umar** (98/7065EE), of the Department of Electrical and Computer engineering under the supervision of Mr. S.N.Rumala . The project has been prepared in accordance with the specification governing the presentation of a B.Eng degree in Electrical and Computer engineering, Federal University of Technology Minna.

....18/18/04..........

Supervisor Date

....

Head of Department Date

....

External Examiner Date

DEDICATION

This project is specially dedicated to my late loving, caring, nice, mother Hajiya Aishatu Muhammad may ALLAH reward her with ALJANNAH FIRDAUS, Ameen summa ameen, my inspirational, caring, motivator and supportive father, Alhaji Muhammad Inuwa Umar, my uncles Alhaji Hassan Hussaini, Alhaji Hussaini Hussaini, Mallam Abdul-Kadir Sarki, Alhaji Ahmadu Aga, my aunty Hajiya Aishatu Muhammad (Aunty Uwa), Hajiya Binta Muhammad (Aunty Inno), Aunty Baby, Hajiya Maryam Muhammad, Abubakar, Zainab, Bilkis, late Ibrahim, Rabi, Abdul-Majeed, Suleiman, Muhammad-Zaharaddeen, aunties, brothers, sisters, my friends Abdullahi Ismail (Ummes) Aliyu Idris (Haji Yawale) Ahmad Tijjani Sulaiman (T.J) ,other friends too numerous to include, Muslim Ummah, and well wishers lot too many to mention. May all of you be rewarded with ALJANNAH FIRDAUS, Ameen summa ameen.

ACKNOWLEDGEMENT

I thank ALLAH, the most beneficent, the most gracious the most merciful, may he continue to send his blessings to his messenger Prophet Muhammad (S.A.W), his family his companions and all those who follow his way. Ameen summa ameen.

I would like to thank my late mother Hajiya Aishatu Muhammad who gave me a lot of words of wisdom may ALLAH reward her with ALJANNAH FIDAUS. Ameen summa amen.

I am so grateful to all those who have helped me in getting resource material on my project. in particular my father that gave sponsored me for my education and gave me all the money for my projects and some gadgets too. My special thanks to my brother Abubakar Sadiq Muhammad who sent me a lot of materials, Not forgetting my great aunty, Aunty Uwa.

I do wish to acknowledge the help of my supervisor Dr. Rumala Yisa who gave me a helping hand. I would like to give me special thanks to all my relatives, friends, cyber friends and cyber lecturers, cyber teachers too many to mention and well wishers. My regards also goes to my Head of Department Dr. M.D. Abdullahi. I thank all of you very well.

I also wish to acknowledge my group member Usman Muhammad Bida for all his contributions, my master Alhaji Hassan Kebbe, members of Usmanu Danfodio University Network (UDUNet) Sokoto.

Finally, I thank Hajiya Rabi Bosso and all her family, Alhaji Shehu Usman Dan-Umma and family, Alhaji Shehu Kagara and family for all their care and support.

ABSTRACT

Probably no means of communication has revolutionized the daily lives of ordinary people more than the telephone. Simply described, it is a system which converts sound, specifically the human voice, to electrical impulses of various frequencies and then back to a tone that sounds like the original voice. In 1831, Englishman Michael Faraday (1791-1867) proved that vibrations of metal could be converted to electrical impulses. This was the technological basis of the telephone, but no one actually used this system to transmit sound until 1861. In that year, Johann Philip Reis (1834-1874) in Germany is said to have built a simple apparatus that changed sound to electricity and back again to sound. A crude device, it was incapable of transmitting most frequencies, and it was never fully developed. The telegraph and telephone are both wire-based electrical systems, and Alexander Graham Bell's success with the telephone came as a direct result of his attempts to improve the telegraph.

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CHAPTER ONE

HISTORY OF TELEPHONE

1.1 INTRODUCTION

Technology has transformed the world we live in, a process that is accelerating all the time. Yet, the process of technological innovation is often treated as though it were mysterious and inevitable.Telephone history begins at the start of human history. Man has always wanted to communicate from afar. People have used smoke signals, mirrors, jungle drums, carrier pigeons and semaphores to get a message from one point to another. Telephone comes from the Greek word tele, meaning from afar, and phone, meaning a telephone is any device which conveys sound over a distance voice or voiced sound.

A standard dictionary defines the telephone as "an apparatus for reproducing sound, especially that of the voice, at a great distance, by means of electricity; consisting of transmitting and receiving instruments connected by a line or wire which conveys the electric current."

1.2 LITERATURE REVIEW

The telephone has been around for most of the 20th century. The electrical speech machine, now known as the telephone was created by Alexander Graham Bell in 1876.

A practical telephone was actually invented independently by two men working in the United States, Elisha Gray (1835-1910) and Scottish-born Alexander Graham Bell (1847-1922). In the 1870s, the two inventors Elisha Gray and Alexander Graham Bell both independently designed devices that could transmit speech electrically (the telephone).

Alexander Graham Bell patented his telephone first. Elisha Gray and Alexander Graham Bell entered into a famous legal battle over the invention of the telephone, which Bell won. The telegraph and telephone are both wire-based electrical systems, and Alexander Graham Bell's success with the telephone came as a direct result of his attempts to improve the telegraph.

The first telephone system, known as an exchange, which is a practical means of communicating between many people who have telephones, was installed in Hartford, Connecticut in 1877, and the first ex-change linking two major cities was established between New York and Boston in 1883. The first exchange outside the United States was built in London in 1879. The exchange involved a group of operators working at a large switchboard. The operators would answer an incoming telephone call and connect it manually to the party being called. The first automatic telephone exchange was patented by Almon Strowger of Kansas City in 1891 and installed in 1892, but manual switchboards remained in common use until the middle of the twentieth century.

The coin operated pay telephone was patented by William Gray of Hartford in 1889. The first rotary dial telephone was developed in 1923 by Antoine Barnay in France. The mobile telephone was invented by Bell Telephone Company and introduced into New York City police cars in 1924. Although the first commercial mobile telephone service became available in St. Louis, Missouri in 1946, the mobile telephone would not become common for another four decades. In 1978, American Telephone and Telegraph's (AT&T) Bell Laboratories began testing a mobile telephone system based on hexagonal geographical regions called cells. As the caller's vehicle passed from one cell to another, an automatic switching system would transfer the telephone call to another cell without interruption. The cellular telephone system began nationwide usage in the United States in 1981.

1.3 PROJECT MOTIVATION

Telephone systems are used world wide. No means of communication has revolutionized the daily lives of ordinary people more than the telephone. This technology allows us to communicate both locally and internationally. It is interesting to deal with telephone. This really made me curious on learning how the telephone works. We actually intended making a mobile (cellular) phone but due to the unavailability of components, we decided to work on the telephone receiver. By constructing or building a locally made telephone receiver we will create job opportunities to our people and make our nation a better place.

1.4 PROJECT OUTLINE

The project outline is to construct a telephone receiver for a small office or organization. Also this project is done to understand the workings of a telephone and how to design, also to reduce the cost of telephone bills.

CHAPTER TWO

SYSTEM DESIGN OF TELEPHONE

2.1 INTRODUCTION:

Advancements in telephone technology have been dramatic over the past one hundred years. What began as a manual connection, hand-cranked machine has evolved into a computer-driven electronic device that is connected all over the world by fiber optics and satellites. The telephone consists of four key components: the dialer, the ringer, the transmitter, and the receiver.

2.1.1 TELEPHONE RINGER

The ringer is the signal that a call is coming into the phone. The ringer consists of a buzzer that has an alternating current passing through it to set up the sound.

2.1.2 TELEPHONE TRANSMITTER

The transmitter is the part of the phone that the person speaks into. It is a microphone that works by compressing carbon granules. The change in pressure due to the speaker s voice increases and decreases the electrical resistance, which in turn translates sound waves into electrical impulses. The impulses are then sent to the central office to be amplified and passed back to the sending telephone. In this project we use the microphone condenser to serve as the microphone which the sound is been transmitted.

2.1.3 TELEPHONE RECEIVER

The receiver is the earpiece through which sounds are heard. As electrical impulses enter the receiver, they pass through an electromagnet (speaker). The electromagnet is inside a permanent magnet, which is near a diaphragm. Electric currents affect the diaphragm by pulling it toward and pushing it away from the permanent magnet. The movement of the diaphragm creates airwaves, which are translated into sound in the listener`s ear

2.1.4 THE TELEPHONE DIAL

There are two types of dials in use around the world. But the project we did has no dialing section, however, a brief explanation of the types of dials we have are: the most common one is called pulse, loop disconnect, or rotary: the oldest form of dialing and it's een around since the beginning of the century. The other dialing method, much more nodern is called Touch-tone, Dual Tone Multi-Frequency (DTMF) or Multi-Frequency MF) in Europe. In the U.S. MF means single tones used for system control.

ulse dialing is traditionally accomplished with a rotary dial, which is a speed governed vheel with a cam that opens and closes a switch in series with the phone and the line. It vorks by actually disconnecting or "hanging up" the telephone at specific intervals. lodern dial phones use a CMOS IC and a keyboard or a keypad. Instead of pushing your nger round in circles, then removing your finger and waiting for the dial to return before ialing the next digit, you punch the button as fast as you want. The IC stores the number d pulses it out at the correct rate with the correct make or break ratio and the switching done with a high-voltage switching transistor. Because the IC has already stored the aled number in order to pulse it out at the correct rate.

2.2 DESIGN OVERVIEW

2.2.1 A SIMPLE TELEPHONE:

A simple telephone is shown in Figure 1 below. and how it works.

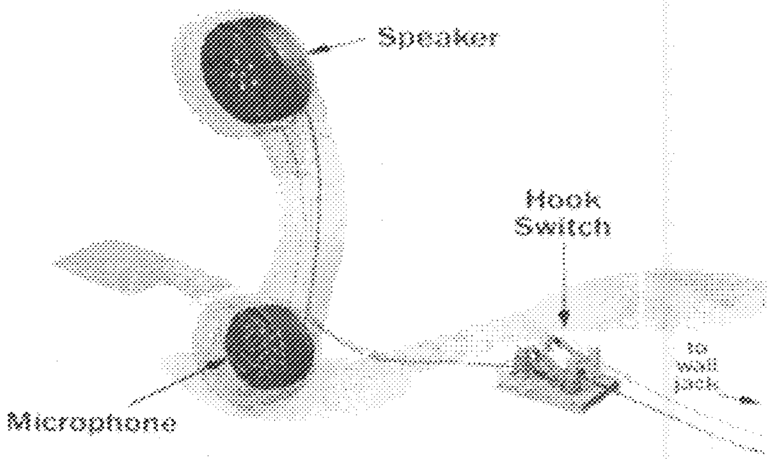

Figure 1. A Simple Telephone.

t only contains three parts:

i. A switch to connect and disconnect the phone from the network - This switch is generally called the hook switch. It connects when you lift the handset.

ii. A speaker - This is generally an 8-ohm speaker.

iii. A microphone - In the past, telephone microphones have been as simple as carbon granules compressed between two thin metal plates. Sound waves from your voice compress and decompress the granules, changing the resistance of the granules and modulating the current flowing through the microphone.

This simple phone can dial by rapidly tapping the hook switch- all telephone switches still recognize "pulse dialing." If you pick the phone up and rapidly tap the switch hook four times, the phone company's like Nitel switch will understand that you have dialed a "4 "

2.2.2 A REAL TELEPHONE:

The only problem with the phone shown on the previous page is that when you talk, you will hear your voice through the speaker. Most people find that annoying, so any "real" phone contains a device called a duplex coil or something functionally equivalent to block the sound of your own voice from reaching your ear. A modern telephone also ncludes a bell so it can ring and a touch-tone keypad and frequency generator. A "real" hone looks like this:

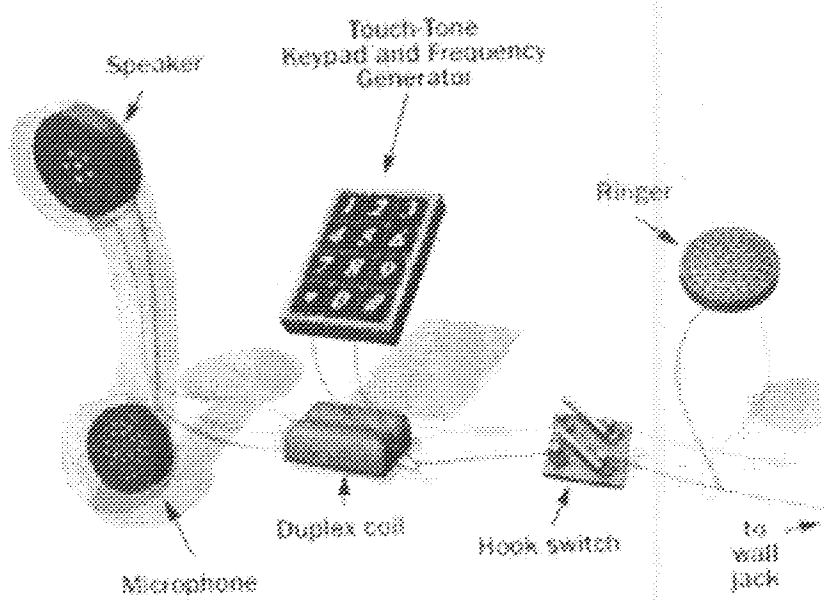

Figure 2. A Real Telephone.

In a modern phone there is an electronic microphone, amplifier and circuit to replace the carbon granules and loading coil The mechanical bell is often replaced by a speaker and a circuit to generate a pleasant ringing tone.

We are using just the telephone receiver without the dialing section that is it has no keypad. Also I used the buzzer to serve as the ringer to notify or alert if there's an in coming call. The transmitting section comprises the microphone using a single transistor to transmit or speak to the other caller.

2.3 DESIGN ANALYSIS AND CALCULATION

2.3.1 THE TELEPHONE LINE

A telephone is usually connected to the telephone exchange using a twisted pair of copper wires, this is also known as "the local loop". The wire resistance is usually expressed as Ohms per kilometer. The telephone is generally considered to be current driven, all phone measurements refer to current consumption, not voltage. The length of the wire connecting the subscriber to the telephone exchange affects the total amount of current that can be drawn by anything attached at the subscriber's end of the line.

2.3.2 TELEPHONE LINE CIRCUIT

The voltage applied to a telephone line to drive the telephone is 48 VDC, some use 50 VDC and on some modern exchanges the voltage can reach 60 volts. A phone line is balanced feed, with each side equally balanced to ground. Any imbalance will introduce hum and noise to the phone line. The voltage used is supplied by lead acid cells, coming across a power source from the telephone company, thus assuring a hum-free supply.

2.3.3 THE TELEPHONE BUZZER

This is the device that alerts you to an incoming call, it is also known as ringer. It may be a bell, light, buzzer or warbling tone. The telephone company sends a ringing signal which is an AC waveform. Although the common frequency used is 20 HZ, it can also be a frequency between 15 and 68 Hz. Most of the world uses frequencies between 20 and 40 Hz. The voltage at the subscribers end depends upon loop length and number of ringers attached to the line; it could be between 40 and 150 Volts.

2.3.4 TYPES OF TELEPHONE CABLES

Most telephone wires are one or more twisted pairs of copper wire. The most common type is the 4-strand (2 twisted pair). This consists of red and green wires, which make a pair, and yellow and black wires, which make the other pair. One telephone line needs only 2 wires. Therefore it follows that a 4-strand wire can carry 2 separate phone lines. Telephone wire comes in 2 gauges, 22 gauge and 24 gauge, 24 gauge being today's standard.There are 2 types of common modular plugs, the RJ-11 and the RJ-14. The most common is the RJ-11 which uses only 2 of the wires in a 4 (or more) strand wire. This is the same kind of plug that is used to plug telephone into the wall. This is a 1-line plug. The RJ-14 uses 4 wires and is used to handle 2 lines, or 2-line phones.

2.3.4 THE TELEPHONE NETWORK

The telephone is connected to a telephone network which is connected from a box (often called an entrance bridge) using a pair of copper wires, the pair of wires is connected to each phone jack in to the house (usually using red and green wires). If the house has two phone lines, then two separate pairs of copper wires will run from the entrance bridge to the house. The second pair is usually colored yellow and black to the house. The copper wires of the Telephone from the house are run outside to meet a thick cable. This thick cable runs directly to the phone company's switch if the switch is within the area of the house or it is run to a digital concentrator. The concentrator digitizes a voice at a sample rate of 8,000 samples per second and 8-bit resolution. It then combines a voice with dozens of others and sends them all down a single wire (usually a coax cable or a fiber-optic cable) to the phone company office. Either way, the line connects into a line card at the switch so when a phone is picked a dial tone is heard.

2.4 BLOCK DIAGRAM

The diagram below show a typical digital telephone but our construction has no dialing section. Therefore this block diagram is how a digital telephone works.

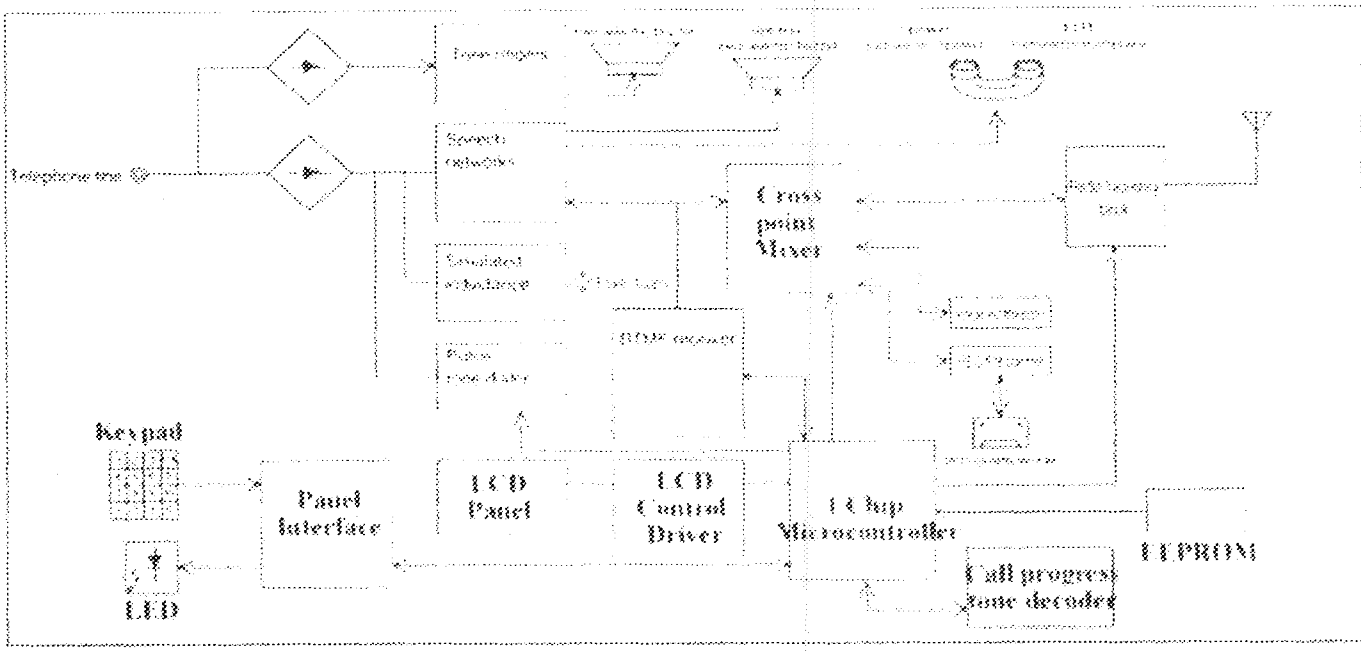

Figure 3. Block diagram of a digital Telephone

2.5 CIRCUIT OPERATION

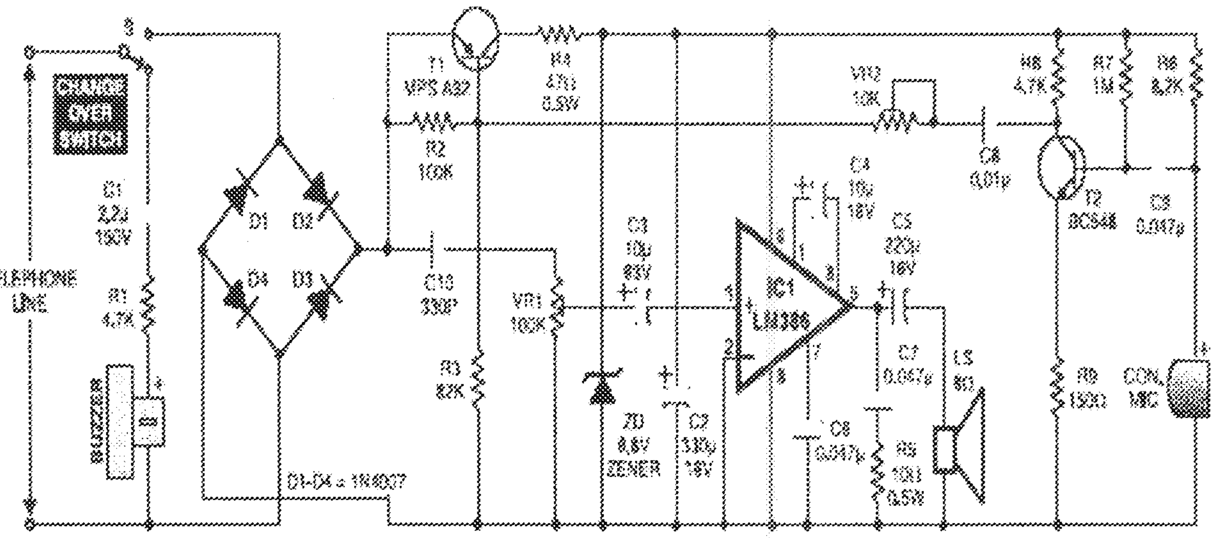

Figure. 4 Telephone Receiver Circuit

This simple telephone receiver without a dialing section is connected in parallel to a telephone line. It has no external power supply. The ringer section comprises R1, C1, and a buzzer. A bridge rectifier consisting of diodes D1 through D4 protects the circuit from any polarity change in the telephone line. PNP transistor MPS-A92 (KSP 92) (T1) is the main interface transistor. The output of T1 is regulated by zener diode ZD and capacitor C2 to get 6.8V for powering the amplifier section. This power is also used to bias the transmitter section. The transmitter section comprises transistor BC548 (T2) together with a few discrete components and a condenser microphone. The transmit signal is fed to the base of interface transistor T1. The voice input for the amplifier comes directly from the positive end of the bridge rectifier. The amplifier section is built around high-performance, low-wattage power amplifier IC LM386. This circuit is designed as a high-gain amplifier.

CHAPTER THREE

3.1 CONSTRUCTION

The circuit consists of two sections, the receiver section and the transmitter section. It consists of a single IC. The construction was done using a single Vero-board. Before the soldering commenced we first of all mounted all the components using a bread-board in case of any error. We started by testing the LM386 IC by connecting its output to the speaker and fed the input with a battery source. We then tested the IC by touching the remaining legs of the IC to hear a humming sound from the speaker. When the sound was observed the second method was by using the electrical characteristic of the IC from the datasheet of the manufacturer using the IC's datasheet. We tested the other components using both analog and digital millimeters then connected the remaining components. After testing the circuit on the bread-board, we soldered all the components using the Vero-board. The soldering of the components never took much time but connecting the jumpers did take a lot of time.

One important feature of this circuit is that the circuit derives its power directly from the active telephone lines, and thus avoids use of any external battery or other power supplies. This not only saves a lot of space but also money. It consumes very low current from telephone lines without disturbing its performance. The circuit is very tiny and can be built using a single-IC type this saves cost of building the telephone.

3.2 TESTING AND OBSERVATION

We used the digital multimeter for troubleshooting during the soldering and coupling of our project. The digital multimeter basically measures voltage, resistance, continuity, current, frequency, and temperature and transistor. The process of implementation of the design on the board required the measurement of parameters like, voltage, continuity, resistance values of the components and in some cases frequency measurement. The digital multimeter was used to check the various voltage drops at all stages in the project, and most importantly the infrared receiver stage, to help check the references in the comparator circuit.

When the telephone is off the hook, the line voltage drops from 48 Volts to between 9 and 3 Volts, depending on the length of the loop. If another telephone in parallel is taken off the hook, the current consumption of the line will remain the same and the voltage across the terminals of both telephones will drop.

When the hook switch is open, the only operations the phone is capable of is Ringing.

When the hook switch is closed, the phone is capable of transmitting sound, and receiving sound.

3.3 PREVENTIVE MEASURES TAKEN

Safety is a major factor in the design of every telephone set. To avoid the possibility of electric shock, I did not use the tools for the construction when my hands are wet. During electrical storms, there is a risk of electric shock from lightning, so I avoided using any of the tools. I made sure I used a sharp cutter when cutting the Vero-board to avoid cutting off my fingers.

The ringing voltage can be hazardous, when working on a phone wiring, so I ensure that the telephone is disconnected at the network connection point when the telephone is ringing because the telephone company may or may not remove the 48v DC during ringing.

CHAPTER FOUR

4.1 RECOMMENDATION

The design and construction of Telephone receiver was a success it made me know more about electronics, its principles and behaviors of various components.

However, the department should get a personal library connected to the internet and filled with newer books that should be ran on 24 hours basis to enable students read.

Excursions should be done to bigger electrical and electronics company for better understanding of the course. There should be a big computer room equipped with modern facilities.

Finally, the department should get a bigger lecture room for student and practical laboratory.

4.2 CONCLUSION

The aim of this project is to harness technology's ability by providing the knowledge of electrical and electronics. Also, the objective of this project is to build and examine the workings of a telephone receiver. We studied the circuit and determine how the different parts of the circuit function together to makes a telephone receiver. I got a lot of practical ideas from the design and construction of the Telephone receiver. The project was a success it also made me know the centrality of serious historical research and writings about electronics principles and behaviors of various components. The project will help progress the situation of technological advancement here in Nigeria. This Telephone receiver is handy and easy to manufacture due to the availability of the components and cost less.

I wish to thank the department, my supervisor and project co-coordinator for giving me the opportunity to do this project. However, like every aspect of engineering there is still room for improvement and further research on the project for modifications.

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7. Internet: http://www.electronics-lab.com
8. Internet: http://www.privateline.com/TelephoneHistory/History1.htm
9. Internet: http://inventors.about.com/library/inventors/bltelephone.htm
10. Internet: http://www.telephonetribute.com/tutorials.html

COMPONENTS USED (Part List)

1. IC1 LM386
2. Diodes D1-D4= 1N4007 X4
3. Zener Diode 6.8V
4. Transistors: T1 MPS A92 (KSP 92), T2 BC548.
5. Variable Resistors: VR1=100KΩ, VR2=10KΩ
6. Resistors: R1= 4.7KΩ, R2=100KΩ, R3=82KΩ, R4=47Ω 0.5W, R6=8.2KΩ, R7=1MΩ, R8=4.7KΩ, R9=150Ω.
7. Capacitors:C1=2.2μf,150V,C2=330μf,16V,C3=10μf,63V,C4=10μf,16V,C5=220μf,16V,C6=0.047μf,C7=0.047μf,C8=0.01μf,C9=0.0047μf,C10=330p.
8. Loudspeaker system 8Ω
9. Condenser Microphone.
10. Buzzer (Ringer).
11. Three pin-Switch
12. Jumpers (Wires)

3.1.2 TOOLS USED

1. Soldering Iron we used two a 60watt and 40watt
2. Digital multi-meter
3. Analog multi-meter
4. PCB Cutters
5. Soldering leads
6. Pliers: Round nose-pliers, Straight nose pliers.
7. Tweezers.

APPENDIX

Some acronyms and abbreviations used in the project;

Alternating Current (AC): a current that will flow in two different directions.

Capacitor: device which collects and stores electrical charge.

Diode: device which controls an electric current so that it can flow in only one direction.

Direct Current (DC): a current that will flow in one direction.

Hook Switch: a switch inside a telephone which closes when the telephone receiver is lifted.

Local Loop: the pair of wires between the telephone set and the telephone company central office.

Pulse Dialing: dialing system in which the number of pulses on the local loop represents the number dialed.

Receiver: part of the telephone a person holds to their ear.

Resistor: device that is used to impede electrical flow.

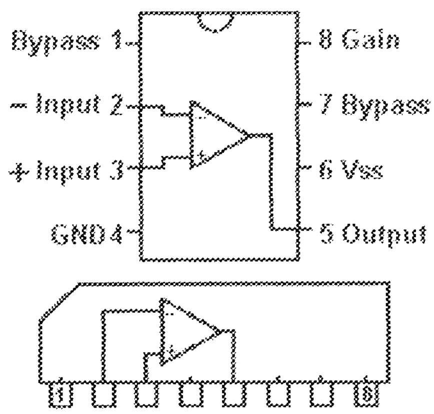
Resonator: device used to produce sound by causing.

Tone Dialing: dialing system in which a combination of two frequencies on the local loop represent the number dialed.

Transistor: device containing a semi-conductor used in electronics to control or increase an electric current.

Transmitter: part of the telephone that a person talks into.

Some Characteristics of the LM386 and its uses;



Pin out of LM386

Pin	Name	Description
1		Gain set
2		Inverting Input
3		Non Inverting Input
4	GND	Ground
5		Output
6	Vcc	Positive Voltage Input
7		Bypass
8		Gain set

APPLICATIONS OF THE LM386

1. Intercoms
2. AM-FM radio amplifiers
3. Portable tape player amplifiers
4. TV sound systems
5. Ultrasonic drivers
6. Small servo drivers
7. Power converters

Characteristic of Transistors T1 MPS-A92 (KSP-92) and T2 BC548 are shown below;

KSP92/93

Typical Characteristics

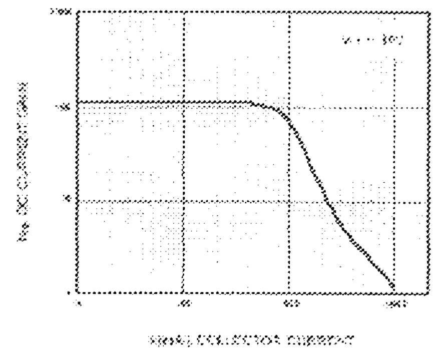


Figure 1. DC current Gain

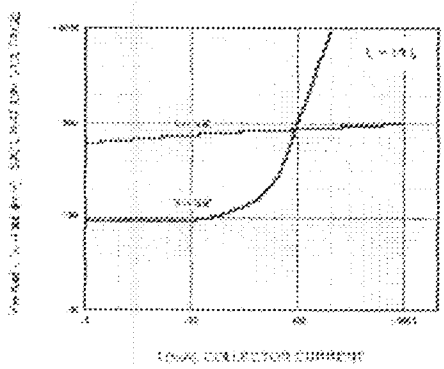


Figure 2. Saturation Voltage

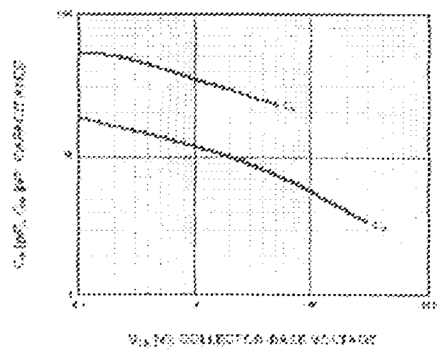


Figure 3. Capacitance

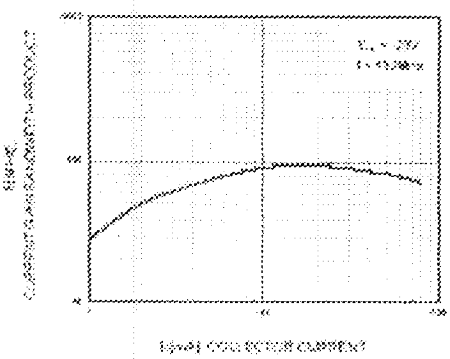


Figure 4. Current Gain Bandwidth Product

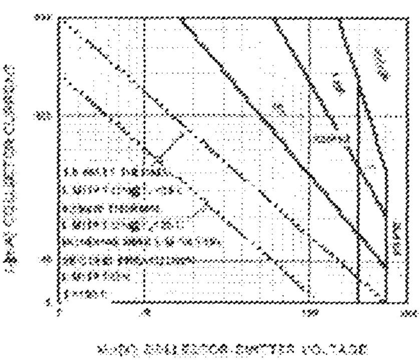


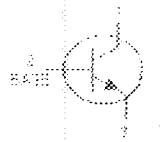
Figure 5. Active-Region Safe Operating Area

MOTOROLA
SEMICONDUCTOR TECHNICAL DATA

Order this document
by BC546/D

Amplifier Transistors
NPN Silicon

BC546, B
BC547, A, B, C
BC548, A, B, C



CASE 29-04, STYLE 17
TO-92 (TO-226AA)

MAXIMUM RATINGS

Rating	Symbol	BC 546	BC 547	BC 548	Unit
Collector – Emitter Voltage	V_{CEO}	65	45	30	Vdc
Collector – Base Voltage	V_{CBO}	80	50	30	Vdc
Emitter – Base Voltage	V_{EBO}	6.0			Vdc
Collector Current — Continuous	I_C	100			mAdc
Total Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	625 5.0			mW mW/°C
Total Device Dissipation @ T_C = 25°C Derate above 25°C	P_D	1.5 12			Watt mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	–55 to +150			°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	200	°C/W
Thermal Resistance, Junction to Case	$R_{\theta JC}$	83.3	°C/W

ELECTRICAL CHARACTERISTICS (T_A = 25°C unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector – Emitter Breakdown Voltage (I_C = 1.0 mA, I_B = 0)	BC546 BC547 BC548	$V_{(BR)CEO}$	65 45 30	— — —	— — —	V
Collector – Base Breakdown Voltage (I_C = 100 µAdc)	BC546 BC547 BC548	$V_{(BR)CBO}$	80 50 30	— — —	— — —	V
Emitter – Base Breakdown Voltage (I_E = 10 µA, I_C = 0)	BC546 BC547 BC548	$V_{(BR)EBO}$	6.0 6.0 6.0	— — —	— — —	V
Collector Cutoff Current (V_{CE} = 70 V, V_{BE} = 0) (V_{CE} = 50 V, V_{BE} = 0) (V_{CE} = 35 V, V_{BE} = 0) (V_{CE} = 30 V, T_A = 125°C)	 BC546 BC547 BC548 BC546/547/548	I_{CES}	 — — — —	 0.2 0.2 0.2 —	 15 15 15 4.0	 nA µA

REV 1

MOTOROLA

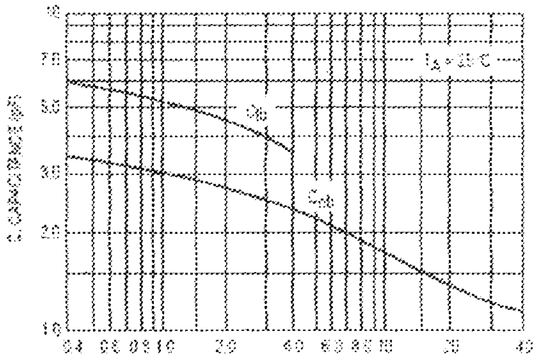


Figure 5. Capacitances

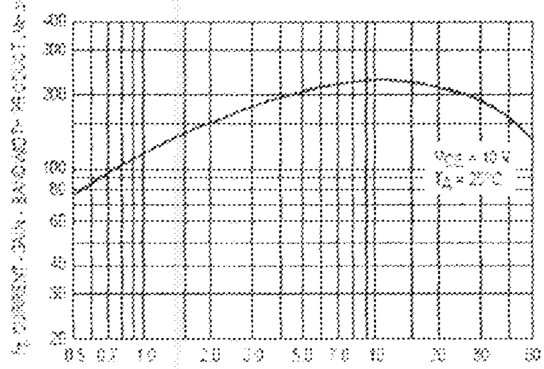


Figure 6. Current–Gain – Bandwidth Product

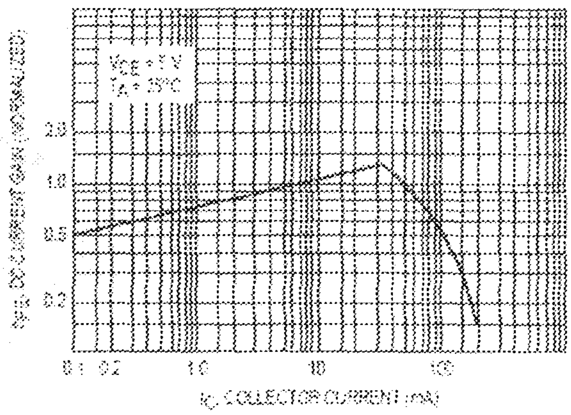


Figure 7. DC Current Gain

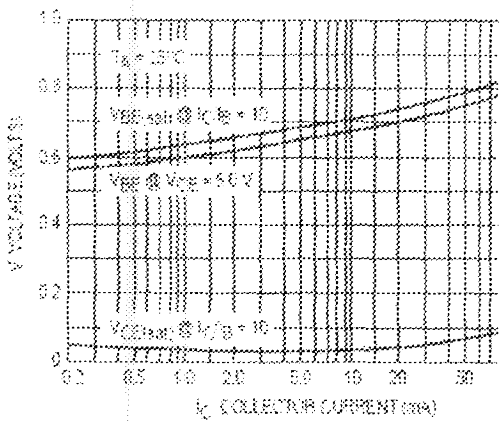


Figure 8. "On" Voltage

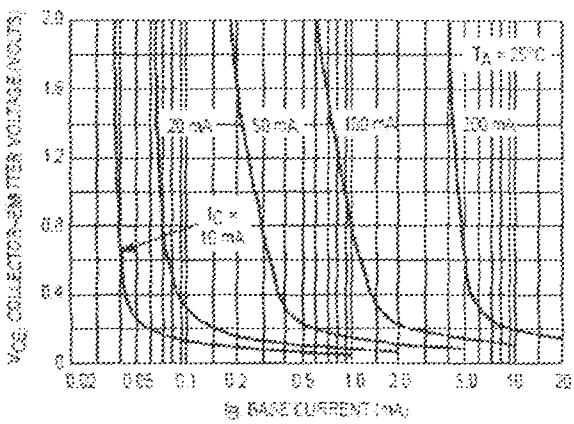


Figure 9. Collector Saturation Region

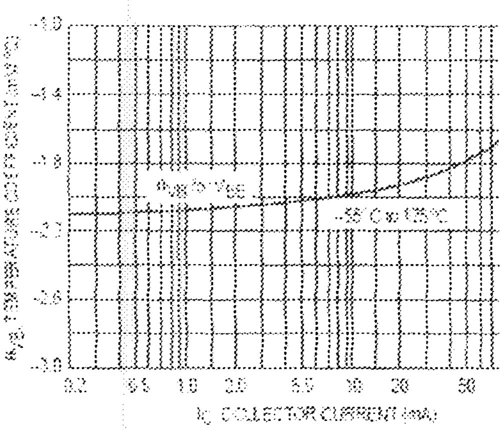


Figure 10. Base-Emitter Temperature Coef