DESIGN AND CONSTRUCTION OF CONTINUITY TESTER AND CUT POINT DETECTOR

BY

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NIGER STATE.

OCTOBER, 2006.

DEDICATION

To my Father, Lord, God and my all, who loved me when I hated HIM and gave me life and an assured and wonderful future.

To my parents, who nurtured and gave me all it takes to be who I am now and to my brothers and sister.

Declaration

I, ODURUKWE CHIJIOKE, 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.

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ACKNOWLEDGMENT

Firstly, I give glory, praise and thanks to my HEAVENLY FATHER who picked me up from the miry clay and set me upon THE SOLID ROCK.

I wish to recognize those who helped to make my project a success. This includes: My parents DR & MRS S. O. ODURUKWE may God bless and keep you both. My brothers and sister: CHINAKA, CHINEDU, and CHIOMA thanks for being there for me. MR ABRAHAM USMAN, my wonderful, humble, intelligent, encouraging, accessible and supportive supervisor did more than give credence to my work..

My friends too numerous to mention, its nice knowing you all. My group study members, it was worth while learning together. FCS and Chapel of Grace, I appreciate every time we spent together.

ABSTRACT

This project report describes the design and construction of a continuity tester and cut point detector used in testing for continuity in printed circuit boards PCB as well as detecting the cut point in faulty insulated cables and cables buried in the ground or walls. The operational principle of this project is based on mutual induction between cable under test and the sensing probe of the cut point detector which are electrically isolated. This is accomplished by powering the test cable with the live line of an alternating voltage source. This induces an alternating magnetic flux around the cable which in turns induces an alternating voltage in the probe sufficient to clock the CMOS frequency divider IC. The frequency divider divides the frequency by ten and its output is fed to an astable multivibrator which gives an audible and visual indication for continuity.

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Chapter One

General Introduction

1.0 Introduction.

The past few decades has witnessed tremendous advancement in the field of science and technology anchored on the development in the electronics and computer world. In all of this, it is the duty of the engineer to ensure that these advancements are undertaken and maintained with the available minimum resources. Micro electronics is a term not far fetched. It entails the ability to miniaturize very complex electronic circuits into small chips. These chips are interconnected with other chips and discrete electronic components via the tracks of a printed circuit board (PCB). The PCB is not a very expensive material, the cost comes from the chips placed on them.

The non functionality or malfunctioning of an entire board can be caused just by a simple crack or cut on the copper tracks linking the chips or a short (short circuit) between the pins of the chips among other causes. One of the solutions to a problem of this kind is to discard the faulty board and replace it with an entire new one, but this will be tantamount to acute wastage of resources. On the other hand, a little troubleshooting wouldn't be a bad idea. To do this, one very important test equipment is a continuity tester.

Continuity in an electrical circuit means that there is a path of negligible or very small resistance for current to flow through, while an open (open circuit) stands for no path at all or a path of very high resistance. Both continuity and opens are diagnosed using a continuity tester.

In printed circuit boards, after a fault of an open (discontinuity) has been diagnosed between two points, the actual point of cut or discontinuity can be detected by

.1.2 Cut point detector.

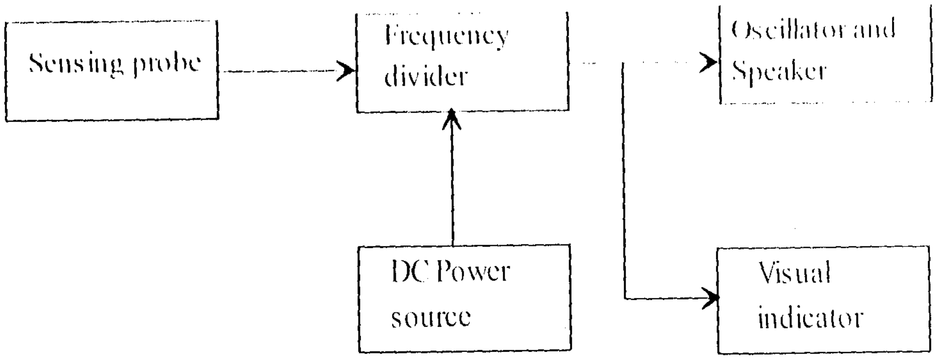

Fig 1.2 block diagram of cut point detector module

The cut point detector is used in testing for continuity in insulated cables and also detects the cut point in such faulty cables. It is required that the cable under test be powered with the live line of an AC power source. The cut point detector senses the electromagnetic field around the powered cable through the probe. The frequency is divided by ten and then passed to the indicators which are both audible and visual.

1.2 Objectives Of The Project.

The objectives of the project and other functions it can accomplish are:-

i) To test for continuity and opens in both analogue and digital circuits on a printed circuit board (PCB).

ii) To test for continuity in insulated cables or cables buried in plastic or ground.

iii) Detect high voltage alternating current and the electromagnetic field from such sources.

iv) Detect the cut point in faulty discontinuous insulated cables and buried cables.

1.3 Methodology.

The design of the cut point detector was first conceptualized and then the continuity tester. The construction was done based on modular construction in which each module of the project was constructed separately and then tested. The two main modules are the continuity tester and the cut point detector module and each of these modules are further subdivided into smaller modules that define the principle guiding the operation of the project. After the operation of individual modules was confirmed to be working according to design and expectation, the two separate modules were joined together and packaged since they operated hand in hand and are powered from the same source.

1.4 Scope.

The inspiration of the project was birth after having experienced and considered the high rate of wastage that occurs as a result of negligence in troubleshooting minor fault in electronic gadgets, and also the trouble undergone when a cut occurs in an insulated cable.

In as much as the objectives of the project were achieved, there are still some limitations which are explained below.

1.4.1 Continuity Testing.

In testing for continuity, small resistance values are regarded as continuous. This is because every conductor including the best conductor has a level of resistance which is proportional to its length. In other to accommodate this, an amount of resistance was assumed as continuous which can be varied by the user.

In testing for opens, high resistance values were regarded as opens. This is also because of the above reason.

1.4.2 Cut Point Detection.

In detecting the cut point in a faulty cable, the cable in question if not a power cable must be electrically isolated from the original circuitry. This is because the cut point detection involves the powering of the cable with a high voltage alternating current which may be harmful to the circuitry in which the cable is located.

In buried cables, the material covering the cable and the depth causes a limitation. This is because such materials can act as a shield to the electromagnetic field generated by the alternating current flowing through the cable.

1.4.3 Detecting High Voltage and Fields.

The detection of high voltage AC and field from such sources are limited to AC sources which must be within the frequency range of 20 Hz to 200Hz. In as much as the circuit can detect beyond this range of frequencies, the indicators may not be both audible and visible to the user.

Chapter Two

Literature Review/Theoretical Background

The discovery of the light bulb by Thomas Edison and the D.C battery by Alessandro Volta provided a means of continuity indication. The circuit diagram below shows a simple method of testing continuity using the battery and the bulb.

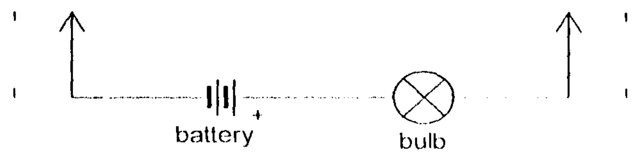

Fig 2.1 the circuit diagram of a simple continuity tester[1]

In the diagram, when the two flying leads from the bulb and the battery setup are connected between two points, the bulb will light indicating continuity between the points. If it doesn't light then it indicates an open circuit (discontinuity) between the points. One of the disadvantages of such a circuit is that the current generated by the battery which may be up to a few amperes depending on the battery type and bulb flows through the circuit under test. This large amount of current can be harmful to some electronic components in the circuit.

As technology advanced, better bulbs more suitable for this purpose were developed such as the light emitting diode (LED). This modified the previous circuit into a much better and safer continuity tester. The schematic diagram is shown below

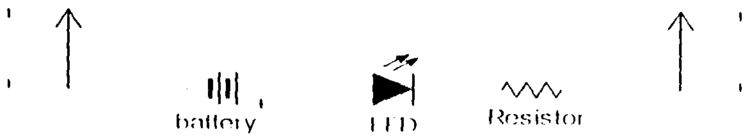

Fig 2.2 continuity tester using light emitting diode[2]

In the above circuit, the problem of high current flowing through the circuit under test is minimized to about 20mA. This is achieved by using the appropriate resistor which limits the current depending on the voltage source.

for a voltage source of 6 volts, a voltage drop of 2.5 is requires across the LED and a current about 20mA

$$\text{Series resistor value} = \frac{6 - 2.5}{20m} = 175\,\Omega$$

With the leads placed between two points the LED will glow if there is continuity between the two points.

The principle behind the operation of the two circuits discussed above is simple. Every circuit requires a complete path for current to flow, a continuous circuit under test provides a path that completes the circuit, so that conventional current can flow all round from the battery's positive terminal through the LED, resistor, circuit under test and back to the negative terminal of the battery. This flow of current causes the LED to glow. But for an open circuit there is no complete path for current flow through, hence the LED doesn't glow.

The invention of basic electronic measuring instrument paved the way for better ways of continuity testing. This is done with the use of the ohmmeter which measures the resistance of the circuit under test. An ohmmeter works on the principle of ohm's law (V=IR) in which resistance is a ratio of the voltage and current.

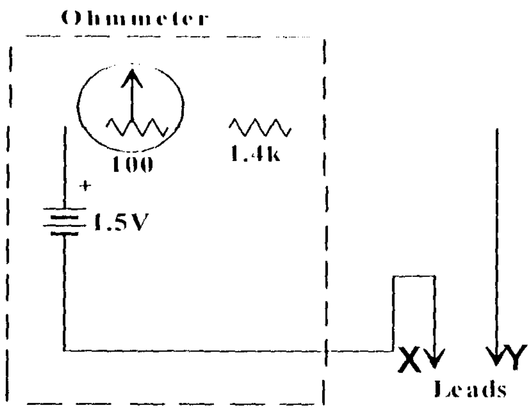

Fig 2.3 basic meter movement used as ohmeter

The circuit consists of the basic meter movement combined with a battery and a current limiting resistance as shown above[3]. The ohmmeter leads X-Y are connected across two points in the circuit under test after switching off the power in the circuit. The ohmmeter battery provides the current for the meter movement which depends on the external resistance. For a continuous circuit the resistance is very small and so the meter pointer will indicate low resistance, but for an open circuit the pointer indicates infinity. Some other multi-purpose meters called multimeters operate based on the same principle and can be used to measure more than one electrical quantity by adjusting the selection knob to the desired quantity of measurement. Example: voltage, current, resistance etc.

The digital multimeter is also used for continuity testing and operates on the same principle as the analogue multimeter only that in this case it's not a pointer indicating the measurement value rather the actual digits are displayed on the meter screen. The basic layout of the digital multimeter is shown below.

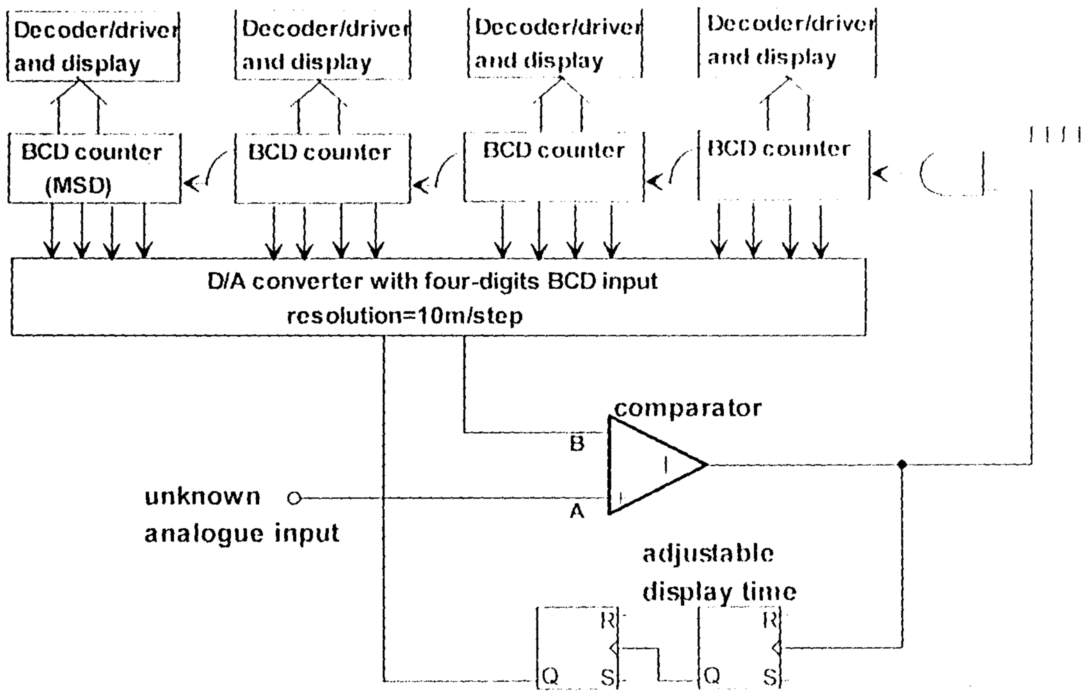

Fig 2.4 simple continuous reading digital meter

The four cascaded BCD counters provide the digital input to a BCD type D/A converter. Each BCD counter feeds a decoder\driver and associated display. It follows that each digit of the count is continuously being displayed as the counter runs up from 0000 to 9999. When the counting has ended, the display is held for a time so that we can observe it. The counting time is so rapid that we can scarcely observe the changing display and normally the first effect we can observe is the steady display[4].

The clock pulses are gated into the counter along with the comparator output. As long as input A>B, the output of the comparator is 1(high) and the counter continues to receive pulse from the clock. With each clock pulse the counter advances a step and B goes up another 10m. Eventually B>A by not more than 10m, but this is sufficient to make the comparator output go to 0(low) and the AND gate is disabled. This prevents further clock pulses from entering the counter which therefore cannot advance further.

At this point, we have the counter holding data equivalent to the unknown analogue input A. As soon as the comparator output goes low to 0, it also triggers a form of set-reset relay ready to repeat the cycle of events.

In using the digital multimeter to test for continuity, the selection knob is set to the resistance setting and the two probes are places across the two points to be tested. If there is continuity, it displays the digit 0000 or the equivalent resistance value between the two points and for open it displays 1. Some digital multimeters are equipped with an additional audible indicator that sounds a continuous high pitch tone indicating continuity and none (no tone) for opens. Another types of continuity testers is the latching continuity tester, which is used in testing for continuity in vibration induced problems where shorts or opens are not maintained long enough for non latching continuity testers to respond[5].

Cut point/fault location in insulated cables and underground cables are done using so many hi-tech instruments that involve microprocessor operations. These includes echometer; artificial neutral network, which uses two main simulators, one with the EMTDC software using the Bergeron model for cable and the other MATLAB software using the Pi model; Dynatel™ 965DSP units, which uses the integral resistance measuring bridge or a time domain reflectometer (TDR); 3M™ 1342 Far End Device II for detecting and diagnosing cable faults, and facilitates remotely controlled measurement termination at the other end of the pair being tested; DC Hi-Pot Adapter, a very valuable tool for locating faulted cables in an underground loop[6].

Fault detection in fiber optical cables is not left out. The Clauss Fiber Continuity Tester provides you with a high intensity, long-lasting green LED light source that transmits light instantly and accurately down the fiber compatible with both single mode and multimode fiber, it can achieve a test distance of up to 2km in multimode fiber testing.[7] OTDR (Optical Time Domain Reflectometer) is very fast, producing a scan within one second of pressing the scan button. Among its many features is an easy to use Zoom that enables the user to observe the entire link, or zoom in on defects. Others include Fiber Optic Video Microscope, etc. All these are hi tech equipments whose principles of operation are beyond the scope of this project.

The continuity tester and cut point detector that have been constructed here is capable of testing for continuity on the printed circuit board and insulated wires as well as detect or locate the cut point or fault point in such a cable. It gives an audible and visual indication in both cases. The working of the project is broken down into two main modules and the block a diagram showing the basic make up of each module is shown below.

2.1 Continuity tester module.

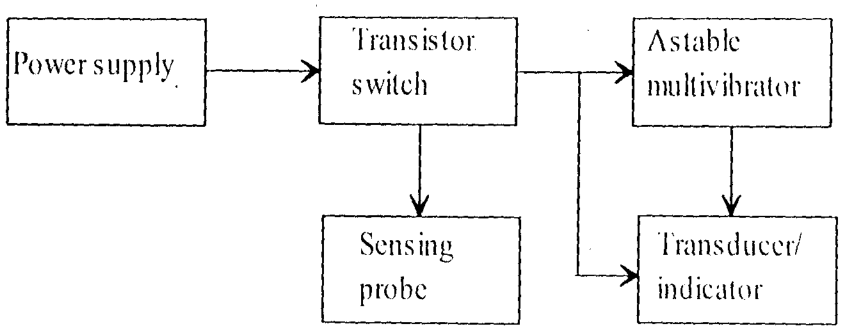

Fig 2.5 continuity tester module block diagram

2.1.1 Power supply.

The power supply is from a 6F22 9volts battery which is a dry cell made up of primarily the positive and negative electrode and an electrolyte. It is a primary cell because the individual cells are connected in series (internally) and are capable of converting stored chemical energy in them into electrical energy through the process of electrolysis. The stored energy is inherently present in the chemical substance and doesn't need charging or recharging[3]. Although it can not be recharged, its life span some times can be long depending on the load that is connected to them and they supply constant current and voltage within this time. They also have the advantage of being small and light, and as such can be carried around in portable equipments.

2.1.2 Transistor switch.

The transistor is a PN junction component manufactured from a single piece of semiconductor crystal. The two junctions give rise to three regions called the emitter, base and collector which provide the tree terminal of the component. As a transistor switch it is used in controlling a relative large current between or voltage across two terminals by means of a small control current or voltage applied at a third terminal. It operates in the cutoff region where virtually no current flows through the transistor and in the saturation region where sufficient amount of collector flow[8]. The basic operation of a simple BJT (bipolar junction transistor) switch is illustrated in fig 2.6

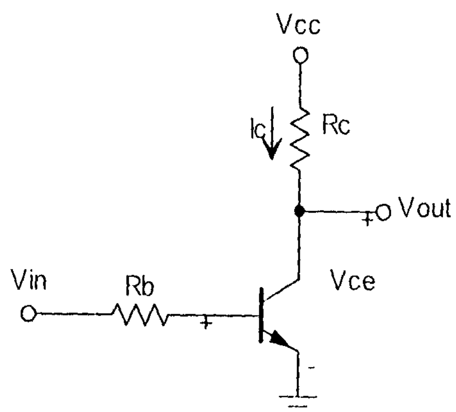

Fig 2.6 simple circuit diagram of transistor switch

Considering the load-line line equation at the collector circuit, we have

$$V_{CE} = V_{CC} - I_C R_C \quad \text{and} \quad V_{OUT} = V_{CE}$$

Thus, when the input voltage V_{IN}, is low (below 0.6V) the transistor is in the cutoff region and little or no current flows, and

$$V_{OUT} \quad V_{CE} \quad V_{CC}$$

When V_{IN} is large enough to drive the transistor (above 0.6V) into saturation region, a substantial amount of collector current will flow and the collector emitter voltage will reduce to the small saturation value, $V_{CE\,SAT}$, which is typically a fraction of a volt.

2.1.3 Testing probe.

The testing probe is the part of the equipment that makes contact with the circuit under test. It has a metallic conducting pointed tip which aids contact and conduction between the circuit and the equipment and also an insulated handle to isolate or protect the user from electrical contact which may otherwise be dangerous.

2.1.4 Astable multivibrator.

This device is useful in generating, storing and counting circuits. They are also called a free running relaxation oscillator which are basically two-stage amplifiers with positive feedback from the output of one amplifier to the input of the other. This feedback is supplied in such a manner that one transistor is driven to saturation and the other to cutoff. It follows that the saturated transistor is driven to cutoff and the cutoff transistor is driven to saturation leaving no stable state but two quasi-stable (half-stable) state between which it keeps oscillating continuously of its own accord without any external excitation. The basic circuitry of an astable multivibrator consists of two symmetrical collector coupled transistors. These provide two CE amplifier stages, each providing a feedback to the other. The feedback ratio is unity and positive because of 180^0 phase shift in each stage. Hence the circuit oscillates. The circuit diagram and the output wave form is shown in fig 2.7

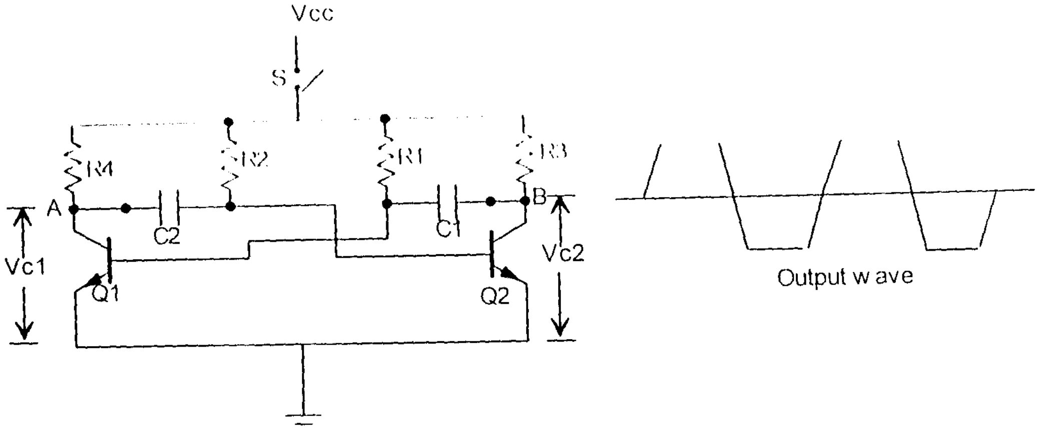

Fig 2.7 circuit diagram and output wave of asymmetrical coupled AMV

The transistor Q1 is forward biased by Vcc and R1 whereas Q2 is forward biased by Vcc and R2. The collector emitter voltage of Q1 and Q2 are determined respectively by R4 and R3 together with Vcc. The output of Q1 is coupled to the input of Q2 by C2 whereas output of Q2 is coupled to Q1 by C1.

The operation of the circuit is made easier knowing that when Q1is ON, Q2 is OFF and when Q2 is ON, Q1 is OFF. When the power is switched on (switch s closed), one of the transistors start conducting before the other (or slightly faster than the other).this is because the characteristics of no two seemly similar transistors can be exactly alike. Suppose that Q1 starts conducting before Q2. the feedback system is such that Q1 will be very rapidly driven to saturation and Q2 to cutoff.

The following will occur:

i. Since Q1 is in saturation, Vcc drops across R4, hence Vc1 0 and point A is at zero potential.

ii. Since Q2 is in cutoff, it conducts no current and there is no drop across R3. Hence point B is at Vcc.

iii. Since A is at 0V, c2 stats to charge through R2 towards Vcc.

iv. When the voltage across C2 rises sufficiently, it biases Q2 in the forward direction so that it starts conducting and is soon driven to saturation.

v. Vc2 decreases and becomes almost zero when Q2 gets saturated. The potential at point B decreases to almost zero. This decrease is applied to the base of Q1 through C1. Consequently, Q1 is pulled out of saturation and is soon driven to cutoff.

vi. Point B is now at 0V, C1 starts charging through R1 towards Vcc, and finally

vii. When the voltage of C1 increases sufficiently, Q1 becomes forward biased and starts conducting. In this way, the whole cycle is repeated[3].

2.1.5 Transducer.

Transducers are devices that convert physical quantities or conditions into electrical signals and vice versa. In most instrumentation systems, the input or output quantities (such as temperature, force, displacement, luminosity, etc) are non-electrical. For using electrical methods of measurement, such non-electrical quantities require to be converted into the equivalent/corresponding electrical signal (such as voltage, current, resistance frequency, etc) using transducers. Any transducer basically consist of two elements

i) **Sensing element:** it is the part of the transducer which senses or responds to a physical quantity or change in physical quantity.

ii) **Transduction element:** this is that part of the transducer which transforms the response of the sensing element to electrical signal.

Some examples of transducers include audio transducers (microphone, speakers, buzzers, etc. that operate based on principle of electromagnetic induction), light transducers (bulbs, LED, LDR, etc), etc.

2.2 Cut-point detector module.

The cut-point detector module consists of a DC power source (battery), sensing probe, frequency divider, oscillator, and transducer/indicator. The power source, oscillator and transducer/indicator are shared by the continuity tester module and cut-point detector module and are as explained above. The combination of the sensing probe and frequency divider form a magnetic field detector.

In Oersted's experiment in 1820, he discovered that when a current carrying conductor was placed above a magnetic needle and in line with the latter, the needle was deflected clockwise or anticlockwise depending upon the direction of current[4].

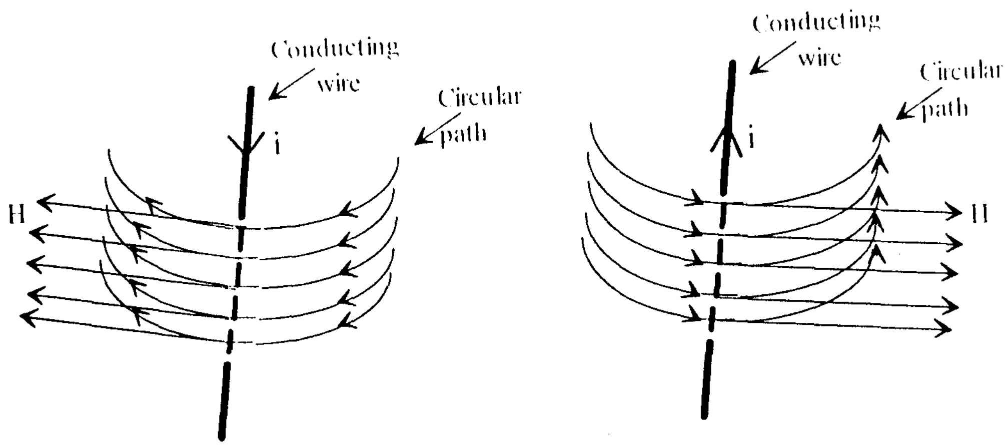

Fig 2.7 the right hand rule convention [8]

The convention for showing the relationship between the direction of current flow and the magnetic flux is determined by the familiar right-hand rule. This rule states that if the direction of current I points in the direction of the thumb of one's right hand, the resulting magnetic field encircles the conductor in the direction of which the other four fingers would encircle it. Magnetic field intensity H is unaffected by the material surrounding the conductor but the flux density depends on the properties, since $B = \mu H$. Thus the flux density around the conductor would be far greater in the presence of a magnetic material than if the conductor were surrounded by air[8].

The physical basis for the cut point detection is mutual induction between the faulty cable and the sensing probe of cut point detector linked by a common magnetic flux. If the faulty cable is connected to a source of alternating voltage, an alternating flux is setup around the cable as long as there is continuity. When the probe of the cut point detector is brought close to the cable, a path of high magnetic reluctance (air) is established which produces mutually-induced e.m.f (according to faraday's law of electromagnetic induction). This induced e.m.f which depends on the reluctance of the magnetic path is very small when compared to the alternating voltage in the cable, but is sufficient to clock the CMOS divide by ten counter IC which acts as a frequency divider. The output signal from the CMOS IC goes to a NAND gate and then to the oscillator for an audio and visual indication.

Chapter Three

Design and Implementation

The continuity tester and cut point detector was designed not only to indicate continuity in printed circuit boards (PBC) but with the capability of indicating continuity in insulated and buried cables. This was achieved using modular design and construction. The entire project is divided into two different modules; continuity tester module and cut point detector module.

3.1 Continuity Tester

This module of the project is used for continuity indication between two exposed parts of a circuit. Fig 3.1 shows the entire circuit diagram of this module

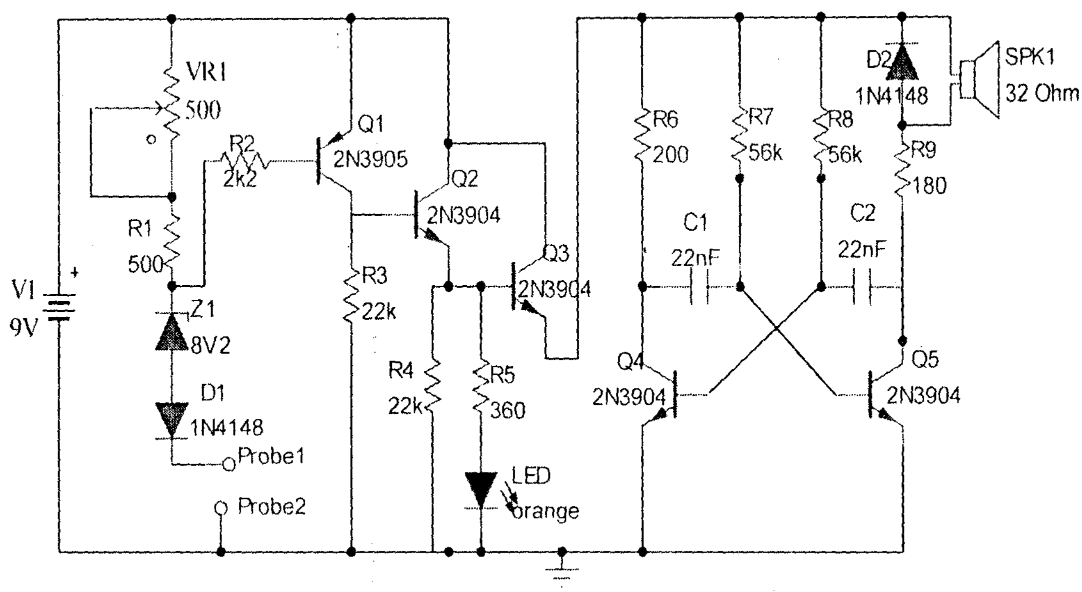

Fig 3.1 circuit diagram of the continuity tester module

The above circuit gives both an audible and visual indication for continuity and none for opens or discontinuity.

3.1.1 Power Source.

The power source for the circuit is a 9 volts alkaline battery. This was chosen because the continuity tester is a portable test equipment that consumes very little power and as such can be powered through a battery for a very long time.

3.1.2 Current limiter.

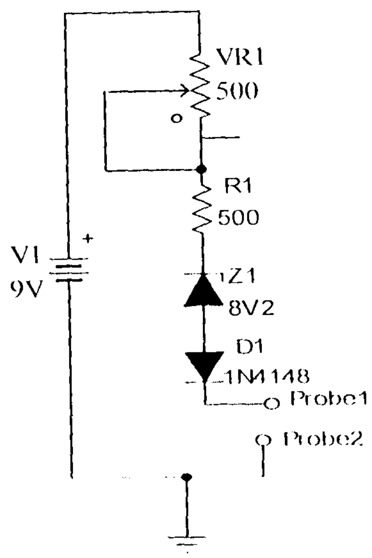

Fig 3.2 circuit diagram of current limiter

The series combination of the variable resistor VR1, R1, zener diode Z1, diode D1 and the probes form a current limiter. This is to ensure that the maximum current flowing through the test circuit is very small (approximately 0.8mA).

<u>Note:</u> the diode D1 wasn't part of the original design. It was added because the voltage drop on Z1 was found not to be 8.2V as expected but rather 7.5V, as such adding a diode which has a forward voltage drop between 0.6 to 0.7V would add up to 8.2Volts

$$\text{Series resistance} R = \frac{(V1 - Vz)}{I}$$

$$= \frac{9 - 8.2}{0.8 \times 10^{-3}}$$

$$= 1000 ohms$$

Note : Vz is the voltage drop across the zener diode Z1 and D1

Series resistance R = VR1 + R1

3.13 Transistor Switch.

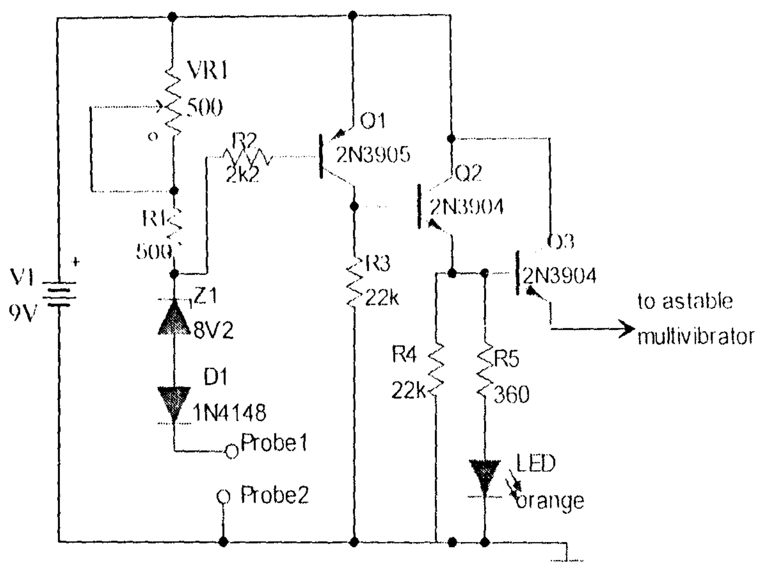

Fig 3.3 circuit diagram of transistor switch

Q1 is a silicon type transistor and the base-emitter voltage will need to be about 0.5 to 0.6 volt to forward-bias the junction and initiated collector current. With a maximum of 0.8 volt (9-8.2) available across VR1 and R1, it is seen that if a semiconductor junction or resistor is included in the outside circuit under test and drops more than 0.3 volt then there will be less than 0.5 volt remaining across VR1 and R1, barely enough to bias Q1 into conduction. But this can also be variable by adjusting the preset variable resistor VR1.

Table 3.1 absolute maximum rating of transistor 2N3906 [9]

Maximum collector current I_{CMAX}	200mA
Collector Emitter breakdown voltage V_{CEO}	40V
Base Emitter breakdown voltage V_{BEO}	5V
DC Current gain h_{FE}	200
Maximum operating frequency f	300MHz

$$Maximum\ base\ current\ I_{BMAX} = \frac{h_{FE}}{I_{CMAX}} = \frac{200}{200m} = 1mA$$

$$Minimum\ base\ resistor R_B = \frac{V_E - V_B - 0.6}{1m}$$

$$= \frac{9 - 8.2 - 0.6}{1m} = 200 \text{ ohms} \leq R_2$$

$$Mininmum\ collector\ resistor R_C = \frac{V_{CC}}{I_{CMAX}}$$

$$= \frac{9}{200m} = 45ohms \leq R_3$$

in order to minimize the current consumption of the circuit, a much higher value were used.

Assuming that the probes are joined by nearly zero resistance, the voltage drop across VR1 and R1 is between 0.7 to 0.8 volt and Q1 turns on. Its collector voltage rises positively to give nearly 9 volt across R3, which biases Q2 a 2N3904 NPN transistor causing its collector to conduct and its emitter thus rises to about 8.4 volt. This lights the LED and also biases the next transistor Q_3.

Table3.2 absolute maximum rating of transistor 2N3904 [9]

Maximum collector current I_{CMAX} Collector Emitter voltage V_{CEO} Emitter base voltage V_{EBO}	200mA 40V 6V
DC Current gain h_{FE}	300
Maximum operating frequency f	300MHz

$$Maximum\ \ base\ \ current\ \ I_{BMAX} = \frac{h_{FE}}{I_{CMAX}}$$

$$= \frac{300}{200m} = 1.5mA$$

$$\text{Minimum resistor } R_5 \quad \frac{V_B \quad 0.6}{1.5m}$$

$$= \frac{9 - 0.6}{1.5m} = 5600 \text{ ohms} < R_4$$

$$\text{Mininmum collector resistor } R_C = \frac{V_{CC}}{I_{CMAX}}$$

$$= \frac{9}{200m} = 45ohms \le R_4$$

$R_4 \ge 5600 0hms \ge 45ohms$, as such a far higher value of 22k was used to minimize power.

$$LED\ \text{Re}sistor\ \ R_5 = \frac{Total\ \ voltage - LED\ \ voltage}{LED\ \ current}$$

$$= \frac{8.4 - 3.0}{15m} = 360ohms$$

Once the base of Q_3 is biased, this causes current to flow from its collector to the emitter and to the astable multivibrator, which starts up a tone.

3.1.4 Astable Multivibrator

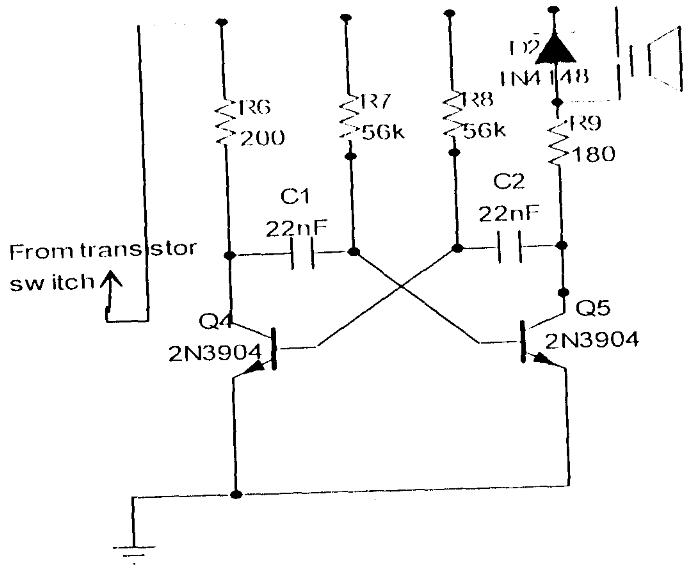

Fig 3.4 circuit diagram of astable multivibrator

The off time for Q_1 is $T_1 = 0.69\ R_7C_1$ and that for Q_2 is $T_2 = 0.69R_8C_2$

hence total time period of the wave is $T = T_1 + T_2$

$$= 0.69(R_7C_1 + R_8C_2)$$

$$if\ R_7 = R_8 = R\ and\ C_1 = C_2 = C,\quad then\ T = 1.38RC$$

Frequency of Oscillation f = reciprocal of time period

$$= \frac{1}{T} = \frac{1}{1.38RC}$$

$$= \frac{0.7}{RC}$$

substituiting the values of R and C into the above equation

$$f = \frac{1}{1.38(56k \times 22n)}$$

$$= \frac{1}{1.70016 \times 10^{-3}} = 588.1799Hz \approx 588.2Hz$$

ensure oscillation the transistor must saturate for which the $h_{FE} = \beta = \frac{R_7}{R_6} = \frac{R_8}{(R_9 + R_{SPK})}$

$$therefore\ R_6 = \frac{R_7}{\beta}$$

$$= \frac{56k}{300} = 186.6\ \Omega \approx 200\ \Omega$$

$$R_9 = R_6 - R_{SPK}$$

$$= 200 - 32 = 168\ \Omega \approx 180\ \Omega$$

The diode D2 is a protective (free wheeling) diode connected across the transducer since fast switching section of the oscillator circuit can produce a high back e.m.f. across the coil and these high voltages might other wise lead to transistor damage of breakdown.

3.2 Cut Point Detector.

The principle behind the operation of the cut point detector has been explained in chapter two (section 2.3.2). It is on this same principle that the transformer operates, with the exception that in this there is high magnetic leakage.

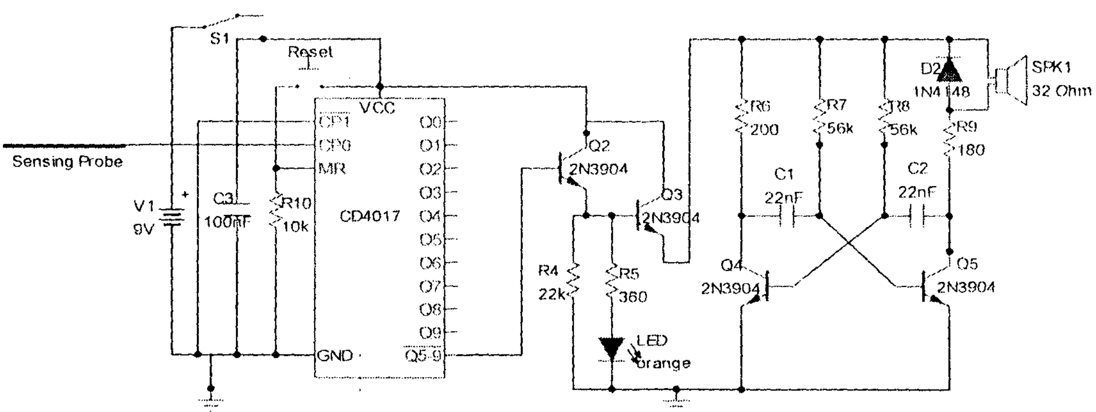

Fig 3.5 circuit diagram of cut point detector

3.2.1 CMOS Decade Counter (1-Of-10) CD4017

The CD4017 is a 5-stage divide-by-ten Johnson counter with 10 decoded outputs and a carry out bit. Its counter is cleared to the zero count by logic 1(high) on its reset line and it advances on the positive edge of the clock signal. Being a Complementary metal oxide semiconductor CMOS IC, it has the following characteristics.

- ✓ Supply voltage is between 3V to 15V
- ✓ Very high input impedance
- ✓ Gate propagation time typically 30ns for a signal to travel through the gate
- ✓ Frequency up to 1MHz
- ✓ Power consumption is very low, a few microwatts.

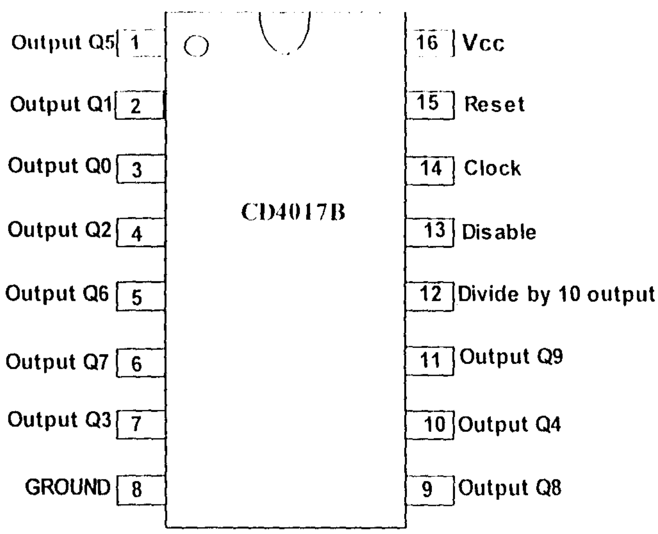

Fig 3.6 pin configuration of CD4017

The disable input should be low (0V) for normal operation. When high it disables counting so that clock pulses are ignored and the count is kept constant. The divide by 10 output is high for counts between 0 and 4 and low for counts between 5 and 9, so it provides an output at one tenth (1/10) of the clock frequency. Due to the very high impedance of the CMOS ICs they do not affect the circuits in which they are part of. However, it also means that the unconnected input pins easily pick up electrical signals and rapidly change between high and low. This characteristic makes the CMOS IC useful in this project.

3.2.2 Quard Two Input Nand Gate CD4011

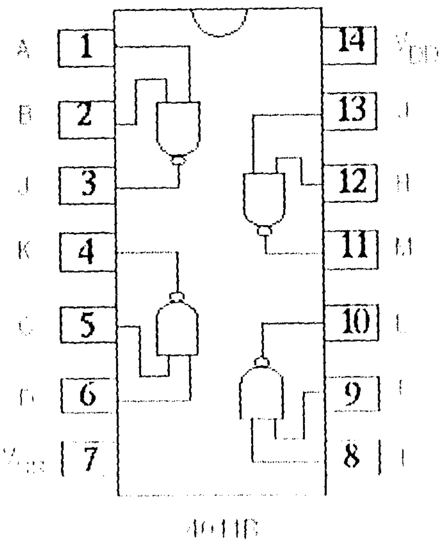

Fig 3.7 IC CD4011 showing its internal connections [10].

The Quard two input NAND gate CD4011 is a CMOS IC and as such has all the characteristics of CMOS ICs as mentioned in above (Section 3.3.1)[10]. It is used in the circuit to keep the output of the counter low at a count of zero. This prevents the beep that would otherwise start when the cut point detector is switched on or when the reset button is pressed since the divide by ten input of the counter (CD4017) is high at counts between 0 to 4.

The faulty cable under test is first powered from the live line of an AC 240V power source. This alternating voltage sets up an alternating magnetic flux around the cable as far as the AC voltage can reach. Beyond the cut point there is no flux because there is no AC voltage. When the probe of the cut point detector is brought very close to the powered cable, a magnetic circuit of very high reluctance is established which induces a very weak alternating voltage in the probe by mutual induction. This induced alternating voltage though weak is sufficient to clock the CMOS counter because of it very high impedance. As the probe is moved along the surface of the powered cable, a point is reached where there is no flux, hence no voltage is induced in the probe. This is the cut point.

Continuity is indicated by the continuous blinking and beeping of the LED (orange in colour) and the astable multivibrator circuit, for a visual and audio indication

frequency of induced voltage f_i = frequency of alternating voltage source

frequency of LED blink $= \frac{f_i}{10}$

since the cable is powered with AC mains voltage of frequency 50Hz,

then frequency of LED blink $= \frac{50}{10}$

$= 5Hz$

frequency of oscillation of astable multivibrator $= \frac{f_i}{10} \times \frac{1}{1.38RC}$

$= \frac{f_i}{10} \times 588.2Hz$

$= 58.8f_i \ Hz$

where f_i = frequency of alternating voltage source

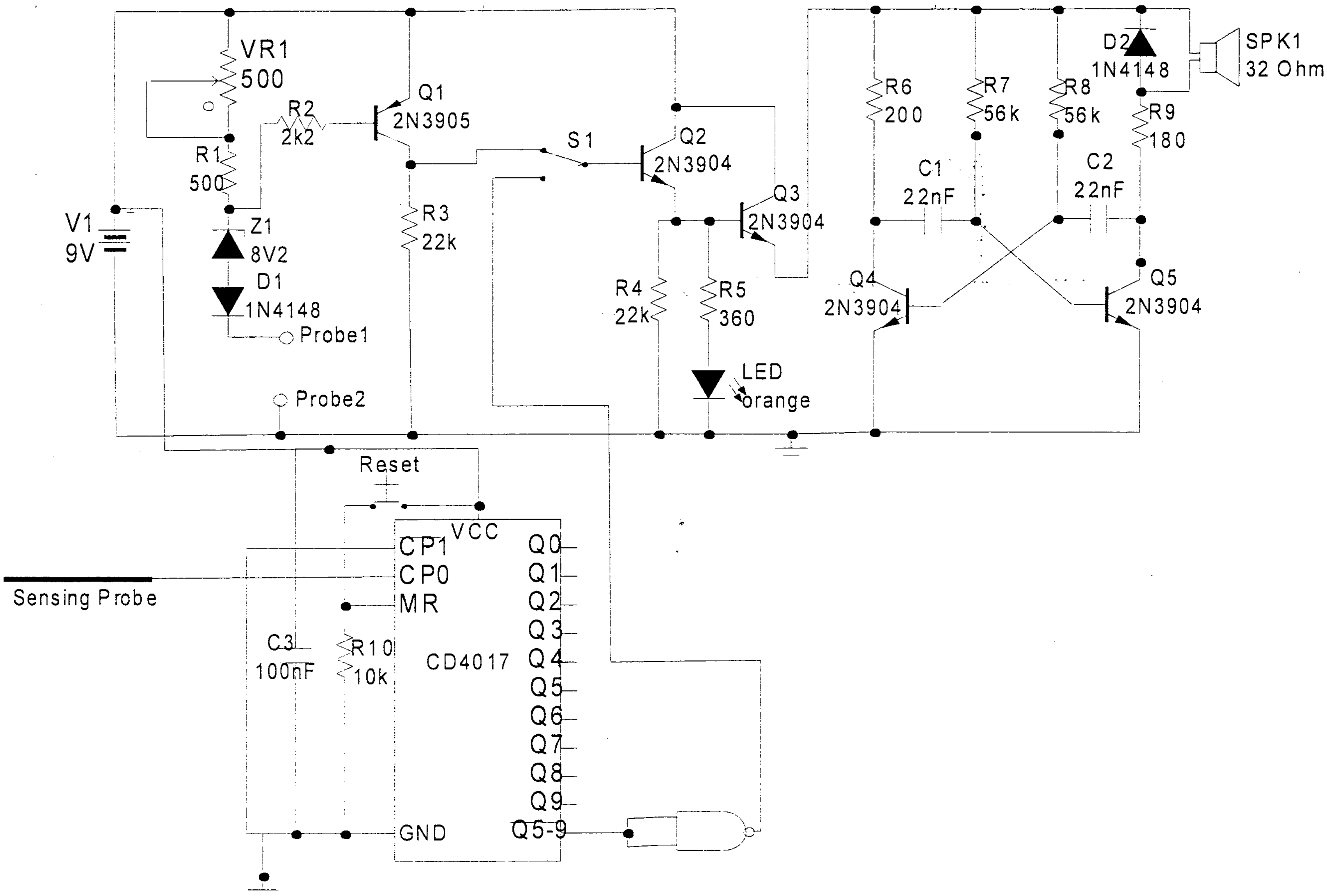

Fig 3.8 complete circuit diagram of continuity tester and cut point detector

Chapter Four

Tests, Results and Discussion

The conception of the project came having experienced some difficulties working with insulated cables, then came the design. As an engineer of the 21st century, computer simulation softwares such as multisim, circuit maker and tina pro were used to ensure the workability of the designed circuit at different levels. Having confirmed it working, progress was made by purchasing the electronic components and implementing the circuit on breadboard, after which the components were placed on vero board and soldering done.

4.1 Testing.

This circuit worked perfect after some adjustments were made. The adjustments were due to some variations in the needed components and available components. This will be discussed later.

Various parts of the circuit were tested, the different inputs and the corresponding outputs. The results gotten were recorded and are shown in the table below.

Table 4.1 test results of various components in the circuit

Item	Input	Output	Discussion
Battery	nil	9.2volts	This is a fixed value which may be a little higher before initial use and reduces with time
Transistor switch	0V to 0.58V base emitter voltage 0.63V and above	Transistor in cutoff region Transistor in saturation region	These are standards with silicon type semiconductor with little or no fluctuations
Zener diode	1.5mA flowing through the zener diode	7.5V voltage drop across the zener diode	This wasn't what was expected, may be due to manufacturing defect. Some adjustments had to be made in the circuit design for proper operation

The preset variable resistor VR1 determines the value of resistance in the test circuit that the tester will regard as continuous and also determines the value or the test current that will flow through the test circuit.

Table 4.2 test result showing current and corresponding resistance

Value Of VR1	Current Flowing In Test Circuit	Resistance Considered As Continuous
Maximum setting	0.8mA	405 Ohms
Center setting	1.04mA	300 Ohms
Minimum setting	1.6mA	202 Ohms

It was also observed that in cut point detection, the kind of metal used as the sensing probe or antenna determines the sensitivity of the cut point detector. Two different materials were used for testing and the results are

Table 4.3 test result showing sensitivity of different metals

Material	Distance From Cable (cm)
Aluminum	0.5
copper	2.0

This also determines the depth in the case of buried cables at which the tester can be useful. The length of the probe was also considered and found to vary proportionally with sensitivity

4.2 Casing

The casing was done with a wooden material. This was used considering cost, availability and originality, which was intended from start to finish. The physical outlook of the project is as shown below

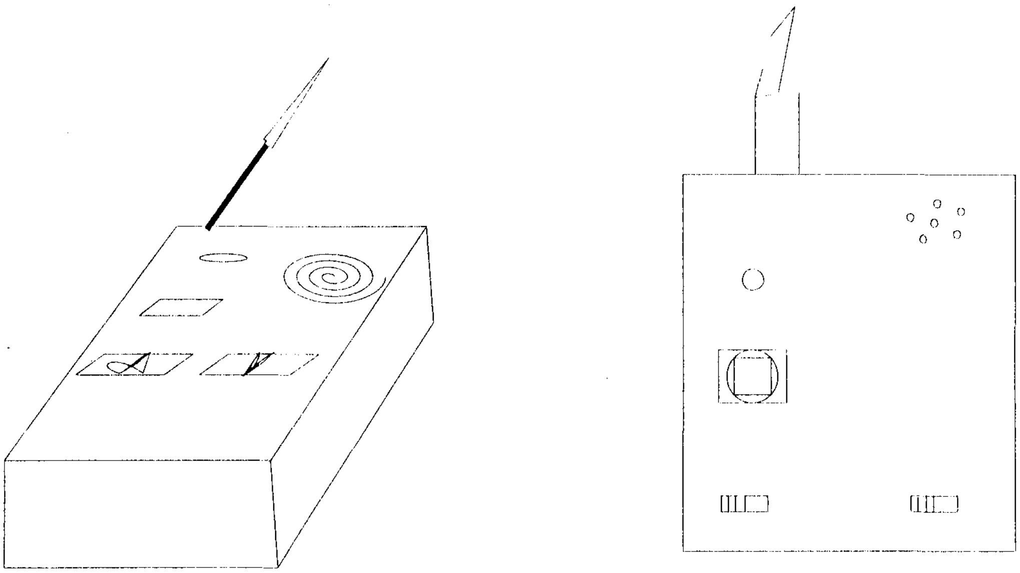

Fig 4.1 isometric and top view of project casing

4.3 Construction Tools Used

Most of the instruments used were personal instrument which have been acquired over time. Others were bought for the purpose of the project, while yet others were borrowed. These are

- Multimeter
- Screw drivers and screws
- Soldering iron, suction tube and soldering lead
- Breadboard, Cutter, blade and connecting wires
- Hammer and saw

Chapter Five

Conclusion

The construction of a continuity tester and cut point detector has been completed, tested and packaged. The aims right from the onset were achieved. The road wasn't easy, but it was all worth the while. Of all that was desired, all was achieved but one and further work could be done on this.

Cut point detection requires that the cable under test be powered with the live line of an AC power supply. This makes the mains power source a very important requirement. With the high fluctuation in availability of mains power supply, an alternative AC power was to be part of this project. This wasn't possible because of time constraint and availability of necessary funds even though the circuit to accomplish this was designed.

5.1 Recommendation

The level of advancement in science and technology is something appreciated by all. The ease and comfort it brings to life cannot be overemphasized. All this came to pass because men worked. "The height which great men attained and are kept was not by sudden flight, but they while men slept toiled" [11]. The long term aim of this project is to provide cheap but effective troubleshooting equipment and as such encourage troubleshooting.

It is thus recommended that:

- When further work is to be done on this project, an alternative AC power source be included to reduce the dependence on the mains power supply which will increase the operational availability of the equipment.

- The students should be introduced to practicals right from their 100 level, and also encouraged to perform practicals on their own.
- The laboratory equipments should be made available to the students not only during class practicals but also during their spare time. This would encourage students to embark on praticals that are beyond the scope of their personal instruments.
- Funds should also be made available to students during their final year project to encourage students whose projects are capital intensive.

Finally, the continuity tester and cut point detector would aid in fault diagnoses and as such should be mass produced and used in the departmental laboratory.

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