DESIGN AND CONSTRUCTION OF AN INVISIBLE BROKEN WIRE DETECTOR

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OCTOBER, 2006

DEDICATION

This thesis is dedicated to the entire Aliyu family.

ATTESTATION

I, Aliyu Suleiman, 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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ABSTRACT

Portable loads such as video cameras, halogen floodlights, electrical irons, hand drillers, grinders, electric heaters, cookers, adapters etc are powered by connecting long 2- or 3- core cables to the mains supply. Due to prolonged usage, ageing, overheating and some other environmental factors like corrosion, the power wires are subjected to mechanical stress, which can lead to internal fracture of wires at any point. In such a case, most people go for replacing the core/cable, as finding the exact location of a breakage is difficult (almost impossible).

The gadget here can satisfactorily detect a broken wire and its breakage point in 1-core, 2-core and 3-core cables without disturbing wires. [1]

It operates on the principle of electromagnetic induction; a metal pad picks up the field created by the flow of current through a conductor in a cable. When there is current flow continuity in the cable, under test, the output indicator is high; otherwise the indicator output is low implying the prevalence of an open circuit.

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CHAPTER ONE

INTRODUCTION

1.1 PROJECT OVERVIEW

The demand for electric energy is drastically rising day by day, as more and more devices, including those hitherto run mechanically/ thermally are currently being continually developed and made electricity –driven, for greater efficiencies.

So far, the most widely known means of conveying this vital form of energy, from source to sink, is with electric cables. Although these cables are being designed and manufactured by most competent engineers, using the best of materials; all in a bit to perfect the cables, they inevitably depreciate with time and, in many cases, fail.

In an attempt to minimize the expenses incurred by cables users in renewing cables, which are repairable, there then arises the need to curtail the menace of incessant cables failure.

Meanwhile, the commonest instrument that comes to mind, when a cable indicates a sign of failure is the so-called continuity tester- which basically seeks to establish whether or not there is continuity of flow of signals in the conductors. In the event of discontinuity, most people simply resort to throwing away the whole lot of the cable in question, as tracing the exact point of breakage in the conducting wires is almost impossible.

The gadget "invisible broken wire detector" seeks to go extra mile to trace the precise location of the breakage in a conducting wire hidden under the insulation cover of an electric cable.

1.2 PROJECT OBJECTIVES

The objectives of the project are to design, implement and test a device capable of:

i. Detecting the precise point of breakage in a faulty/broken conductor in a cable.

ii. Checking wires, fuses and appliances to see if they are energized.

iii. Remotely check high voltage/tension lines whether they are excited.

1.3 SCOPE OF THE PROJECT

The project seeks to design and implement a portable device aimed at detecting faults in cables.

However, since it's operating principle centers around sensing the alternating current mains field generated by the current flowing through the cables conductors, the device area of application is broadened to encompass some other applications like determining if a cable is excited or a fuse blown. Also, the gadget is primarily meant to detect open circuit faults.

1.4 PROJECT OUTLINE

The project write up is composed of chapters arranged in a logical sequence. Chapter one entails the introductory aspect of the project work, which highlights the project background, objectives and scope of the project application. Other items embedded in it are methodology and sources of materials used in the design and construction.

Chapter two presents a literature review of devices and techniques linked to detection/tracing of faults in cables. It also seeks to have a general review of cables including the concept, types and sizes of cables as well as various faults and faults causes of cables.

Chapter three, tagged circuit design and implementation, gives an in-depth analysis of the major units of the circuit, description of values of components used as well as calculations and selection of components suitable for the design. It also goes further to analyze the construction of the circuit and casing.

Chapter four presents, in a nutshell, the steps taken to test the gadget, results and discussion of the results. The constraints encountered, photographs of the circuit and the casing are also embedded in this chapter.

Chapter five concludes the whole work. Recommendations for improvements of the project are also given. Others are references and BEME (Bill of engineering measurement and evaluation).

1.5 METHODOLOGY

For the ease of design and implementation, the circuit is subdivided into five (5) units, as depicted by figure 1.1; namely:

I. Power supply unit.
II. Input switching unit.
III. Variable gain linear amplifier unit.
IV. AC-to Dc converter unit
V. Output indicator.

The power supply unit is the source of energy to the system, and its indispensability can be attested to from the fact that without it, the circuit cannot perform its fundamental role. As illustrated in figure 1.1, the unit is fixed in the circuit in such a way as to directly supply the operational amplifiers and the AC-to-DC converter with one direct voltage with a common ground.

The input switching unit comprises of two sensors or pick-up components - the metal pad and the coil linked by a switch to facilitate switching over between the two components as desired. The sensors are directly connected to the variable gain linear amplifier input, so that the signal picked up from the cable under test goes straight into the amplifier for magnification.

The AC-to - DC converter is composed of IN4148 with its positive terminal coupled directly to the output terminal of the operational amplifier. It serves to rectify the output amplified a.c signal from the amplifier.

The output indicator is connected directly to the output of the converter, to give an indication of either low or high output as the case may be. Two indicating components are used- the meter deflector and the piezo- electric buzzer. Both are connected via a switch, so that only either of the two is enabled at a time. However, the meter deflector is more appropriate for the detection of breakages, since it is able to discriminate against stray fields.

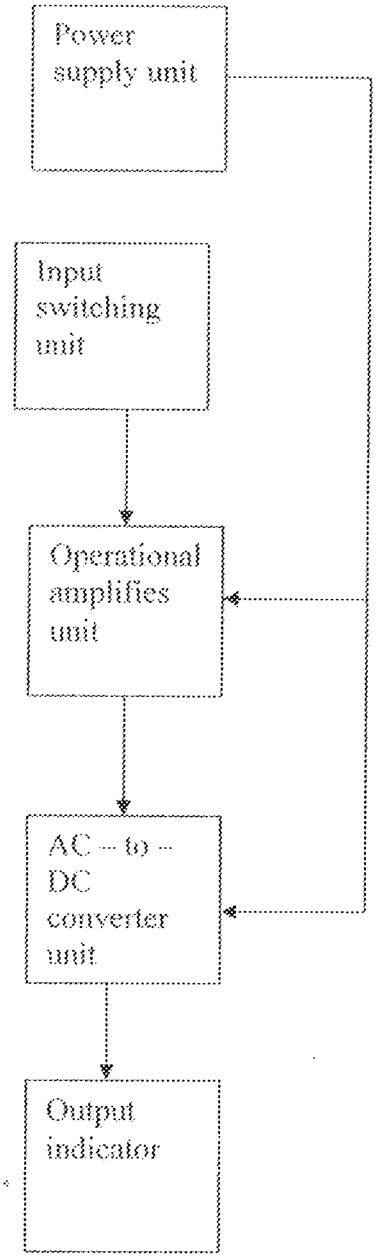

Fig 1.1: Block diagram of an invisible broken wire detector

1.6 SOURCE OF MATERIAL

When building electronic projects, the hardest thing can sometimes be finding parts. This is especially true if one lives in a relatively small town with little or no specialty electronic stores. Sometime, there is a local surplus shop, but they might not have what one needs. The use of data book comes into play, when sourcing for the materials to use. Data book provides an alternative component to adequately substitute a particular component of a circuit, which is not available at a point in time, to facilitate interchangeability of components. It was partly on this basis that the materials for this project were sourced. The materials were then purchased locally at electronic stores.

CHAPTER TWO

LITERATURE REVIEW/THEORETICAL BACKGROUND

2.1 TYPES OF CABLES/WIRES FAULTS DETECTORS

Any amount of emphasis made on the significance of electric cables cannot but only constitute an under-statement, considering the unparalleled role they have come to play in our modern society. The application scope of electric cables in electrical engineering is so broad that the profession itself is increasingly becoming synonymous with electric cables or wires.

Thus, no meaningful task or fit can be accomplished in branches such as power systems, analog control, instrumentations, communications and computer systems without making use of wires in one way or the other.

It is against this backdrop that there has been rising concern to retrench the incessant cables faults/failure to the barest minimum. The concerted efforts in this regard have given rise to, among others, gadgets such as standard continuity tester, latching continuity tester, time domain reflectometer(TDR), thumper machine, cable sniffer, polarity tester, extended volt stick and cable fritter.

2.1.1 STANDARD CONTINUITY TESTER

This is an item of electrical test equipment used to determine if an electrical path can be established between two points; that is if an electrical circuit can be made. The circuit under test is completely de-energized, prior to connecting the apparatus.

The tester consists of an indicator in series with a source of electrical power-normally a battery terminating in two test leads. If a complete circuit is established between this test-lead, the indicator is achieved [2].

2.1.2 LATCHING CONTINUITY TESTER

There are times when a simple continuity tester does not tell the whole story. For example, vibration-induced problems in automobile wiring can be extremely difficult to detect, because a short or open is not maintained long enough for a standard tester to respond.

In these applications, a latching continuity tester is used. A more complex device, it detects intermittent opens and shorts as well as steady state conditions. The device contains a fast acting electronic switch (generally a Schmitt trigger) forming a gated astable oscillator which detects and locks (latches) the indicator on an intermittent condition with duration of less than a milliseconds [2].

2.1.3. SMART CONTINUITY TESTER

Occasionally, one needs a continuity test between two points in an electronic circuit. Unfortunately most continuity tester are prone to "lie". They do not do that deliberately, but if they see a small resistance, they still tell one that one has continuity. They just do not know any better. This unit is different. If you have continuity, it will tell you so. And if you are reaching even a low resistance through a component, the unit will tell you that as well. The unit uses two 741 op-amps. It offers a short circuit test current of less than 200μA. It detects resistance values of less than 10Ω. [1].

2.1.4 TIME DOMAIN REFLECTOMETER (TDR)

This is also known as "cable radar". It uses the pulse echo process to provide visual indications of cable faults by sending periodic pulses in the cable. As the pulses travel along the cable, a fraction of the pulse energy is reflected from the fault to the test set. All reflections are displayed on the liquid crystal display (LCD).Any reflecting surfaces, cable start, joint transformers, fault, changes in cable type, as well as cable end are shown in time sequence [11].

2.1.5 THUMPER MACHINE

This employs a capacitive discharge method used in conjunction with acoustical detection instruments. In this method, an electrical impulse of sufficient voltage is transmitted along the cable to arc over a break in the cable insulation. The arc can then be detected by site or sound. [3].

2.1.6 CABLE SNIFFER

This is a light weight handheld portable detector that locates underground cable faults by detecting specific gases produced by burning insulation from all common types of cables, an essential tool in faults location .[4]

2.1.7 POLARITY TESTER

A pen-sized device designed to detect the presence of an electric field surrounding a live low voltage insulated wire. The instrument is calibrated to illuminate when within 3mm of a live core of a standard cable allowing identification of live wires when bundled with others [4]

2.1.8 EXTENDED VOLT STICK

This is designed to address the problem of damaged underground cables during highway maintenance and repairs, ensuring the correct cable has being isolated. With the aid of a hot stick, the extended volt stick can be brought into the proximity of the conductors yet keeping personnel at a safe distance. [4]

2.1.9 FRITTER

Developed by EA technology, utilizes the principle of β frit welding to reduce the resistance of a low voltage mechanical cable joint to that of a newly made one; rejuvenates old cable joints, rectifies intermittent cable fault and can extend cable life when used within a maintenance plan (4).

2.2 LIMITATIONS

A fundamental limitation of continuity testers is their inability to trace the precise location of the point of breakage of a broken wire.

Devices like the time domain reflectometer(TDR) and Thumper machines are very cumbersome and not portable, and more importantly are used on high voltage cables.

Most of the equipment explained above also cost a fortune and thus, not accessible by the ordinary man hence, the need to devise a simpler, cheaper and more potable gadget like the "invisible broken wire detector".

2.3 THEORY OF CABLES

Since the project revolves around determination of faults – breakage points in cables, as highlighted under the project objectives, then there arises the need to review the concept of cables, their types, the color coding, various faults associated with the cables as well as their causes of faults/failure.

2.3.1 CABLES CONCEPT

A cable is a single solid or stranded conductor insulated from one another helically laid or twisted together and enclosed in a concealed sheath, which may or may not have an outer protective covering in which the cable is to operate. [5]

Originally, a cable was referred to as a cordage of great length or heavy metal chain used for hauling, towing supporting the roadway of a suspension bridge or securing a large ship to its anchor or mooring. Today, a cable often refers to a line used for the transmission of electric signals. [6]

One type of electric cable consists of a core protected by a twisted wire stands and suitably insulated, especially when it is used to cross oceans undersea; a message transmitted by cable is known as a cablegram.[6]

France and England were first successfully connected by submarines telegraphic cable in 1845. The first permanent transatlantic cable was laid in 1886 by Cyrus West Field, although demonstration of its possibility had been made in 1858. The first telephone massage was transmitted from New York to Philadelphia in 1936; the first transatlantic cable was laid in 1956. [6]

2.3.2 CLASSES OF CABLES

By purpose, cables fall into two classes, namely: power cables and pilot (control) cables. Power cables serve to transmit and distribute electric power to devices and various types of switchgears. Pilot cables carry comparatively low currents for apparatus and devices employed in control, signaling and other automatic systems. [5]

By the kind of insulation and sheathing used, cables fall into one of the following groups: impregnated paper insulated metal-sheathed cables, non-draining compoundsheathed cables; plastic insulated plastic-covered cables with plastic, sub-bear or meal sheath jackets. [5]

Each group includes cables differentiated by the voltage rating, cores sections, number of conductors, conductor material and types of protective covering.

For voltages up to 35kv, cables are available in voltage ratings of 0.66,1,3,6,10,20 and 35kv with cores sections of current carrying conductors ranging from 1 to 1000mm^2

2.3.3 CONTITUENT ELEMENTS OF CABLES

Current carrying conductors: - these are made up of a few types of wire: copper wire of soft-, medium hard-, hard-, and extra hard-drawn grades, and wires produced from special low-resistance high strength steel stock. Conductors are available in both solid and stranded construction. The solid conductor is a single solid wire. Stranded conductor is a conductor composed of a group of wires . The strand is one of the wires or group of wires and the wires in a stranded conductor are usually twisted or branded together. The wire twisted into strand or the strands twisted together must be in intimate contact with one another. Besides, the wire or strands in the same bay must not cross over. [5]

Insulators: - These are used on cables to confine electrical current to the conductor and not to allow electricity to leak to adjacent conductors in order to prevent short circuits and electrical shocks. Some common conducting materials are vulcanized Indian robber (VIR), polyvinylchloride (PVC), mineral insulation (e.g. magnesia) and paper. [8]

Meanwhile, plasticized PVC is the single largest volume electrical insulating material in use today. It has good electrical properties, excellent abrasion and moisture resistance and may be formulated to meet specific physical requirements. [5]

Most wire and cable insulation is comprised of three layers, namely:

— Primary insulator: material applied directly to the electrical conductor

— Jacketing: an outer coating covering multiple insulated conductors to form a cable

— sheathing; a tight fitting wrap, generally nylon, that covers the outer surface.[7]

2.3.4 CABLE SIZES/THICKNESS

The sizes of cable, by convention, are determined by the cross sectional areas of the core conductors of the cables.

Cables normally used in electrical installations work have conductor cross sectional areas, for example, $1.5mm^2$ for socket outlets and $6mm^2$ for cookers and other heavy equipment. [8]

Usually, the greater the cross-sectional area of the cable, the higher its current rating, as shown in the table2.1 below:

Table 2.1:various cable sizes, current ratings and voltages at 240V.[9]

Core size(mm^2)	Current(A)	Wattage(kW)
1.0	14	3.25
1.5	18	4.25
2.5	24	5.75
4.0	32	7.75
6.0	40	9.75

2.3.5 CABLE COLOR CODING

Wire color coding is used to indicate wire function or the voltages the wire carries. For multi-core cables, e.g. 3-core cables, the conductors are designated live, neutral and earth.

I. Live wire: This is the wire that carries electrical energy to an outlet or other devices in contrast to a neutral, which carries the current away again. It is normally the brown wire. [10].

II. Neutral wire: This carries the current from an outlet or other devices in contrast to a live that carries the current to the outlet or other devices. It is normally the blue wire [11].

III. Earth wire: This carries the current if the neutral wire is interrupted, thus preventing electric shock. By convention, it is assigned yellow/green color. [2]

The following table shows a typical commercial coding for AC wiring for United States (US) and Europe, as well as the United Kingdom (UK).

Table2.2:commercial coding for AC wiring[13]

Service	US	Europe	UK
115v/240v60Hz	Black	Brown	Brown
common	White	Blue	Blue
ground	Green	Green/yellow	Green/yellow

2.3.6 FAULTS ASSOCIATED WITH CABLES

Some of the faults linked to electric cables include short circuits, low resistance shunt faults, open circuits, high resistance series faults, wet sections, splices, cable transitions and concentric neutral corrosion. [3]

Some of these are discussed below:

I.. Shunt faults: These are faults when one or more of the phases are short-circuited (possibly to earth). They are in general, severe.

II. Series fault: An IEC standard has the following definition of a series fault "A fault for which the impedances of each of the three phases are not equal, usually caused by the interruption of one or two phases".

III. Open circuit faults: these are faults arising mainly as a result of breakages in the cables current carrying conductors thereby creating paths of infinitely large resistances. [3]

It is worth nothing, at this juncture, that this project is restricted, in application, to the open circuit faults.

2.3.7 CAUSES OF CABLE FAULTS FAILURE

The continuity of power supply to various loads calls for the reliable operation of cable lines which in the final analysis, depends on the quality of work done in manufacturing the cables, joining the cable lengths and maintaining the serviceability of cable lines.

Cable faults may arise from manufacturing defects such as creases on paper tapes, cuts and slits on coverings, breaks of insulating tapes interlayer, imperfect conductors and lead sheaths e.g. some in-process insulation defects unrevealed in the cause of high D.C voltage testing leads to a heavy short circuit in the cable put into use.

Mechanical injuries done to cables during wiring operations, such as fractures, breaks in PVC hoses, dents and scores may be responsible for the failure of the cable in Service. Old cables that have operated for a long time may fail as a result of the collision of the metal sheath.

Lead connections fail for a number of reasons: incomplete soldered joints between leads and cables sheaths, voids formed in hand-applied tape insulations, short run molding, poor control over the temperature of the impregnating or potting compounds e.t.c.

Meanwhile, even properly installed cables are subjected to conditions such as overheating, excessive moisture, corrosive environment and ageing. [5]

CHAPTER THREE

CIRCUIT DESIGN AND IMPLEMENTATION

3.1 DESIGN OVERVIEW

In circuit design, just as in many aspects of life, simplicity is often the order of the day. Towards this end, the saying that the simplest option is usually the best is not new in analog circuits either.

Thus, this project is built on a minimal number of components, as depicted by the circuit diagram (3.6).

3.2 CIRCUIT OPERATION

Oersted, a. Danish scientist, discovered in 1819 during an experiment that there was a close relationship between electricity and magnetism. He observed that a magnetic needle was deflected in a certain direction if it was placed under and parallel to a current carrying conductor. This implies that the current carrying conductor had a magnetic field around it. Oersted further added that the flux so setup around the conductor was in the shape of concentric circles around the conductors. [4]

A reciprocal of the above principle was postulated by Michael Faraday who discovered that when a conductor moved in a magnetic field, such that the conductor cut the magnetic field, then an electromotive force (and hence, electric current) was induced in the conductors; the value of which was directly proportional to the rate of change (or cutting) of flux. [4]

The operation principles of this project fundamentally revolves around the two reciprocal laws stated above. The input switching (made up of a metal pad and a coil of wire-inductor) picks up the alternating current (a.c) field radiated from a cable by the current flowing through the cable live conductor. This field gets transformed into a small current signal, which is amplified (magnified) by the operational amplifier (UA741) and subsequently rectified by the ac to dc converter. The resulting signal triggers a moving coil meter or an electric buzzer (depending on which is enabled at a point in time). The gadget is slid along the cable so that in the event of a fault (or breakage) along a conductor length; giving raise to discontinuity of current flow, the input switching picks up nothing and hence the output is low.

3.3 FUNCTIONAL UNITS.

From the foregoing, it is evidenced that various units are coupled to yield the single entity "invisible broken wire detector" circuit. These units are the power supply, the input switching, the operational amplifier (variable gain linear type) the ac-to-dc converter, the output indicator (comprising of a meter driver and a buzzer).

3.3.1 POWER SUPPLY

Most of the electronic devices and circuits require a direct current (d.c) source for their operation. This is primarily because it has the advantage of being portable and ripple free.

Thus, it is for this purpose that a 9v dc battery is used for this project. The circuit is run off a 9v dry cell battery with a large value capacitor to stabilize the dc supply as shown in figure 3.1 below.

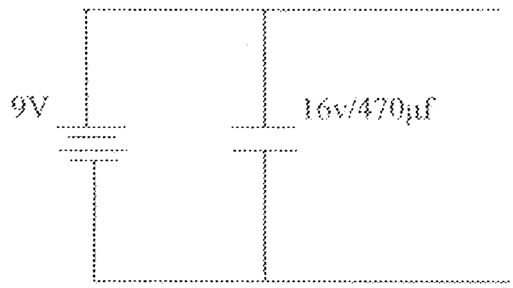

Fig 3.1 Power supply unit for the project

3.3.2 INPUT SWITCHING UNIT

The sensor or input switching unit comprises of a metal pad and an inductive coil (a hundred turns of enameled gauge wire wound around an air former). The two are linked via a push-button switch, to facilitate switching over between the two sensors depending on which is being used at a time.

Although the two sensors could be used interchangeably, on some occasions, it is preferred to enable the metal pad when trying to trace an exact fault location on a cable. The reason being that it is more sensitive to the ac field than the coil and, besides, by virtue of the design and construction of the casing, the metal pad is placed outside the casing and the wire coil is from within. Thus, the metal pad is more exposed to the cable to be examined than the coil.

The coil comes into play in a bit to widen the gadget scope of application to detect electromagnetic field, with frequency range of 50Hz to 100kHz from electromagnetic field sources. The input switching stage is coupled to the circuit as shown below:

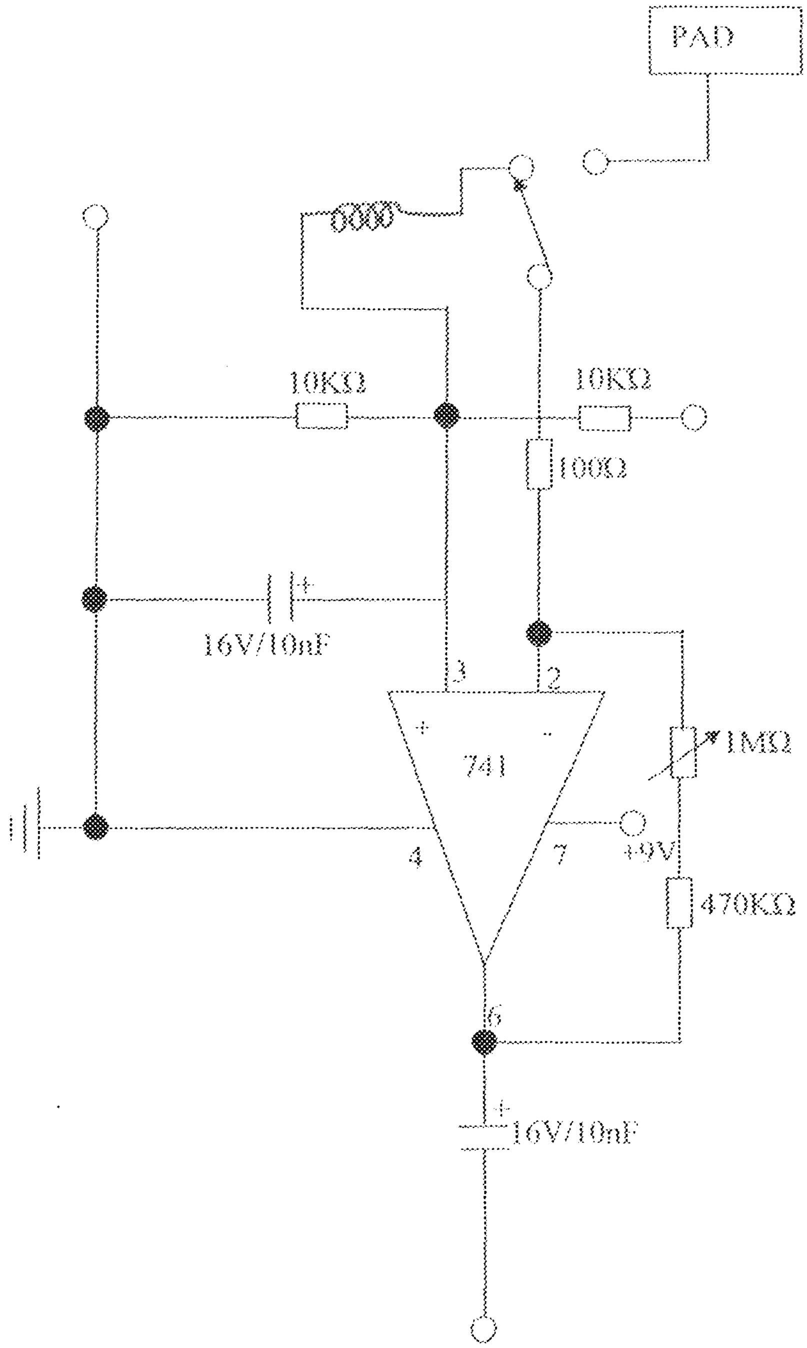

Fig 3.2 Input switching coupling to the circuit

3.3.3 THE VARIABLE GAIN AMPLIFIER UNIT

This is designed around a 741 operational amplifier configured in the inverting mode (fig. 3.3). A 1MΩ adjustable resistance is incorporated in the feedback loop to provide a variable gain setting for the system. This is the positive adjust potentiometer.

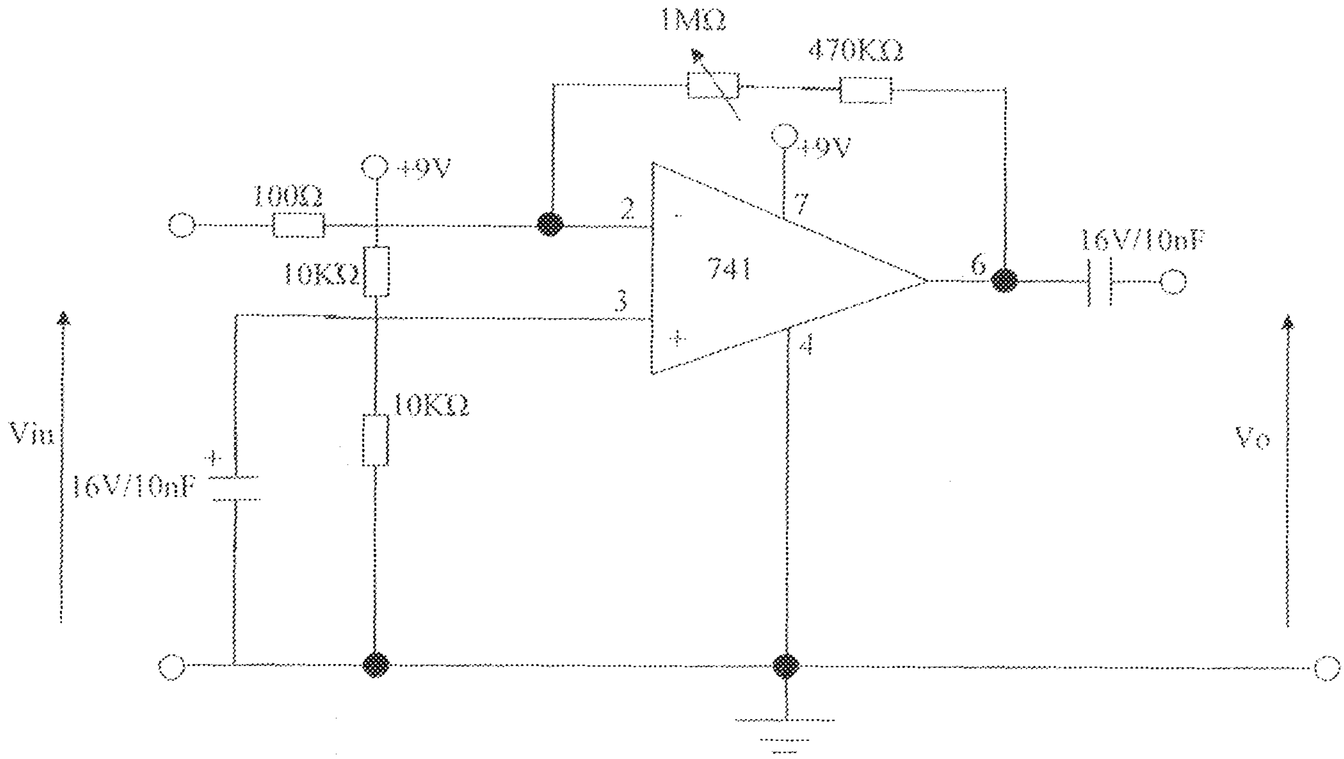

Fig.3.3: The inverting mode configuration of the 741 operational amplifier

For the inverting mode configuration shown in fig. 3.3, the gain is given by :

G = - 470,000/100 to -(470,000 + 1,000,000) / 100

Thus, a minimum gain of 4700 and a maximum of 14,700 is achieved.

As most operational amplifiers are designed to run off a split supply of +Vcc, using an operational amplifier designed for split supply operation on a suitable polarity supply demands that the amplifier be biased appropriately. This biasing is effected by setting the quiescent d.c output voltage(in most cases to Vcc/2) for equal undistorted voltage swing.

An inverting amplifier is always biased in a single supply operation by having a voltage 0.5Vcc connected to its positive non-inverting input, as illustrated below.

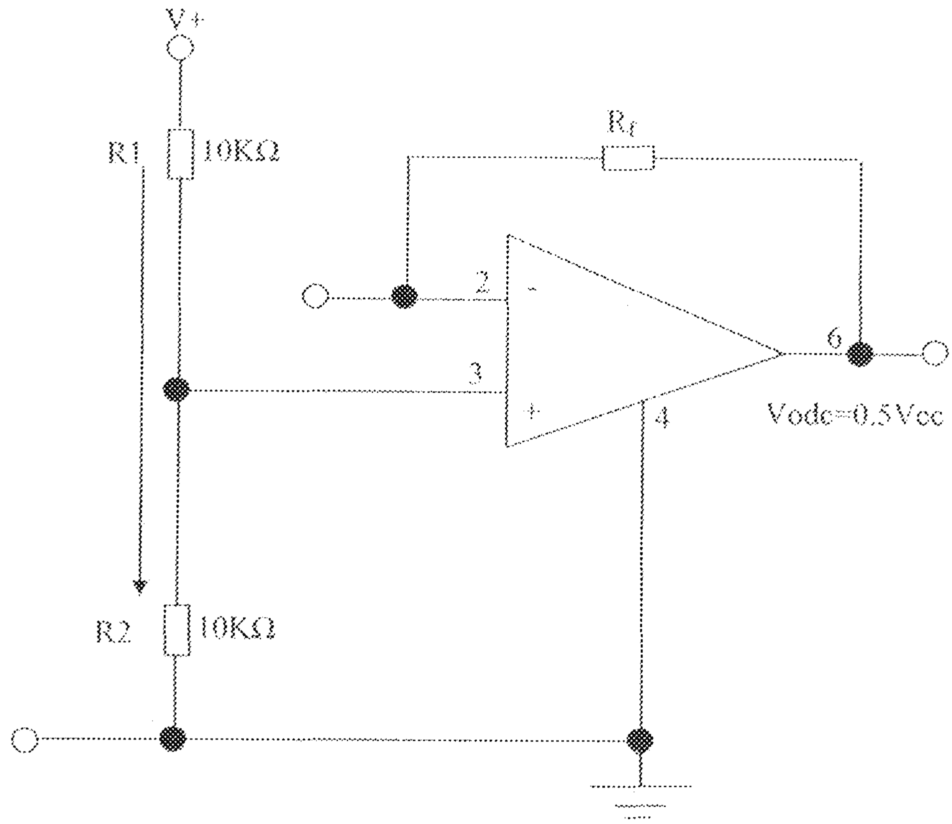

Fig. 3.4: Biasing the operational amplifier in a single supply operation

Using the current divider theorem, the current flowing through the series resistances $R_1$and R_2 is given by :

$I = +Vcc / (R_1 + R_2)$

But $R_1 = R_2$, which implies that $2R_1 = 2R_2$

Therefore, $I = +Vcc/2R_1 = +Vcc/2R_2$

The voltage V_{R2} developed across R_2 is calculated using:

$V_{R2} = IR_2 = IR_1$

Therefore, V_{R2}, the voltage at pin3 of the operational amplifier is calculated by deducing that:

$I = +Vcc/2R_1 = +9/40{,}000 = 0.45mA$

$V_{R2} = IR_2 = 0.45mA * 10{,}000 = 4.5V$

Since this voltage is applied to the non-inverting input, the 741 amplifier appears like 100% negative feedback voltage follower. Thus, it's output is at 0.5Vcc. This is the quiescent d.c output voltage around which an amplifier voltage swings. V_{R2} is held stabilized by a 16V/10μF capacitor against fluctuation.

3.3.4 A.C – D.C CONVERTER

This simple rectifier is a modification of the standard half- wave peak rectifier: the only difference being the application of a little forward- bias voltage so that the diode forward voltage drop is cancelled out and hence does not subtract from the incoming A.C voltage. This enhances sensitivity allowing the circuit to respond to low level input signals.

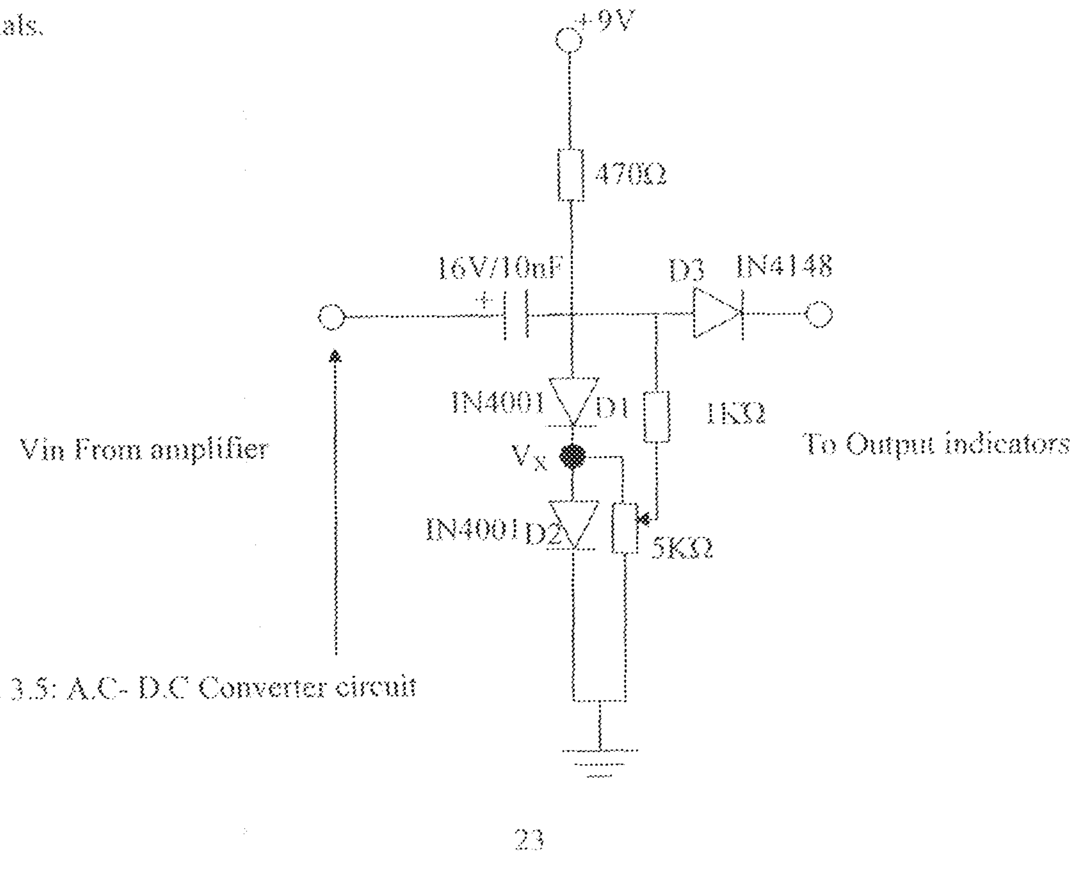

Fig. 3.5: A.C- D.C Converter circuit

From Fig. 3.5 above, D1 and D2 hold V_X at two diode forward voltage drop; i.e V_X is approximately 1.2V. Measured value was 0.94V. The 5KΩ resistance is adjusted to place D3 at the threshold of conduction so that the smallest voltage can pass rectified without the normal diode forward voltage drop.

3.3.5 OUTPUT INDICATOR

Two output components are provided: a moving coil meter visual indicator and an audible note buzzer. Only either of the two is enabled at a point in time, depending on the prevailing circumstances. For this design, the moving coil meter is strongly recommended when a precise point of breakage in the cable is the current area of interest. This is sequel to it's sensitivity to extraneous fields other than the mains A.C field. This serves to avoid false impression of continuity existence at points where partial discontinuity due to a minute breakage exists.

Thus, the output moving coil meter indicator rises with increasing A.C field around a metal pad pick-up, reflecting easily on the deflecting pointer of the meter.

When the piezo-electric part is enabled the output is a note of varying pitch. The note rises in pitch with increasing A.C field, and falls in pitch with decreasing A.C field in contact with the pick-up.

The complete circuit diagram is depicted by fig. 3.6 below;

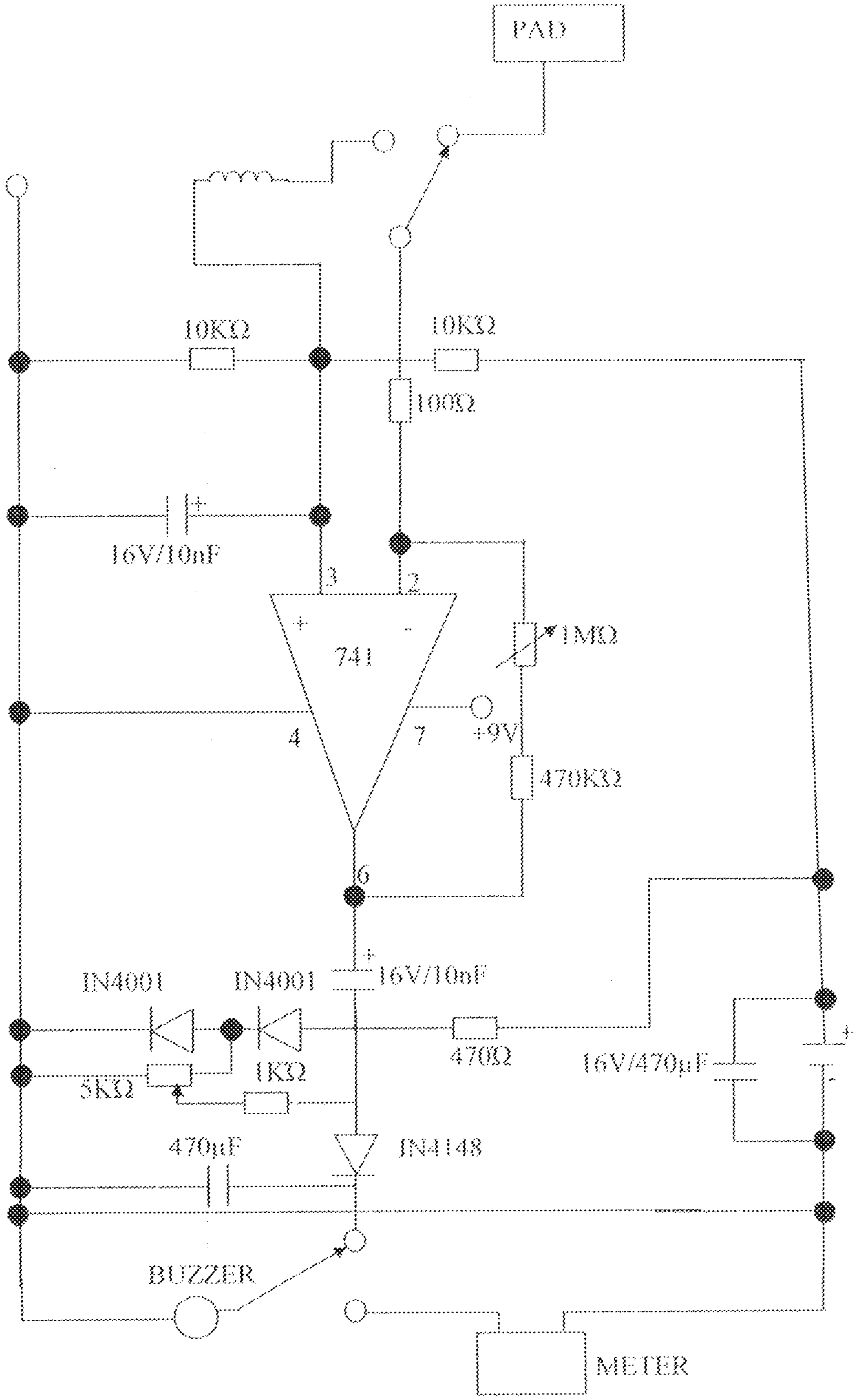

Fig. 3.6: Circuit diagram of an invisible broken wire detector

3.4 CONSTRUCTION

The circuit diagram was first analyzed on paper and all design analysis was done to determine the values of the components required. After the thorough analysis and determination of appropriate components values, via calculations, the components were purchased.

The hardware design was done in modules. In order to facilitate construction, the project was first connected on a breadboard. This helps to facilitate easy troubleshooting of the circuit. It also ensures that all faults detected are corrected before the components are finally soldered together on the Vero board. This is very important to prevent multiple soldering and de-soldering of circuit components on the Vero board in the event of fault detection as well as protect the components from damage.

Having tested and certified the circuit okay on the breadboard, the components were transferred to the Vero board. On the opposite side to copper strips of the Vero board, the layout plan was made and the components were placed in accordance. The discrete components-capacitors, diodes, resistors where soldered accordingly. Also, the IC sockets were soldered to the Vero board. This is so, because of easy removal and replacement and to avoid breakage of the IC pins. Where continuity was not required or desired, the copper strips were cut using a sharp razor blade. Connecting wires were soldered firmly in place.

A digital multimeter was used to test the continuity between interconnected points as well as check possible short circuits, which may occur accidentally during soldering.

The IC was then plugged into the socket and troubleshooting was done to rid the circuit of all flaws.

Care was exercised in handling components particularly the IC and the diode, to avoid damage. Components such as the battery, diodes and the IC were connected properly with respect to their polarities, to avoid damage or non-functionality. The components were also adequately spaced during connection for easy access to faulty components in addition to providing ease in fault tracing. Proper spacing also helps to check capacitive build up between components when they are connected in close proximity. At least 15 – 20 seconds was allowed between joints in order to prevent the building up of heat which may destroy the components.

After soldering, the leads were trimmed with a sniper. Also, during deflecting (desoldering), a small brush was used to dislodge stubborn globes of flux.

The Vero boarded circuit was now made ready for casing. Casing is done to protect electronic devices from the outside environment (heat, moisture, touching e.t.c) and for the purpose of insulation (i.e. electrical insulation), most cases are made either of metals or plastic. The casing for this detector circuitry was constructed using a plastic sheet; 5mm thick. It was shaped in such a way as to fit the constructed circuit.

CHAPTER FOUR

TESTS, RESULTS AND DISCUSSION

4.1 TESTS

After construction, tests were carried out at various points and joints of the circuit to ensure the gadget operates as designed. The main test is that conducted to trace faults in cables.

Before detecting broken faulty wires, any connected load is disconnected first from the cable and the faulty wire found out by continuity method using any multimeter or continuity tester. Then 240v AC mains live wire is connected at one end of the faulty wire, leaving the other end free. Neutral terminal of the mains AC is connected to the remaining wires at one end. However, if any of the remaining wires is also found to be faulty, then both ends of the wires are connected to the neutral. For single wire testing, connecting neutral terminal at one end of the live wire is sufficient to detect the breakage point.

Having plugged the cable in the mains a.c supply socket, in accordance with the foregoing methodology, the detector is then powered and the input switching set to either the metal pad or the coil (internally fixed in the casing) via the p/c (an acronym for pad or coil) switch. The output indicator switch is equally set to either the deflector or the buzzer.

The detector is now brought very close to the cable under test, to make contacts with the pick-up pad. The detector is then slid along the cable, having excited it (the cable).

As long as there is continuity of current flow, the output responds. If the output indicator was preset to the deflector, the response manifests in the deflection of the meter pointer to a value high up the calibration .In the absence of coninuity (meaning presence of a breakage), the pointer deflects low. If the deflection of the pointer goes low at a point, the detector is slid again past that point, to ensure there really exists a breakage so as to avoid false conclusions.

4.2 RESULTS / DISCUSSION

The results obtained during testing at prototyping were satisfactory. In the final testing of the detector, test signals of electric cables and some sources of electromagnetic field were obtained. The detector was particularly tested on cables of various conductors cross sectional areas especially on $1.5mm^2$ and $2.5mm^2$ wires and the results were satisfactory.

However, as the detector is slid along the cable further away from the point of cable excitation, because of the voltage drop, the detector sensitivity decreases owing to decrease in field strength. The sensitivity level also varie with variation in the cross sectional area of the cables conductors, due to reduced amounts of flux; being high for large area conductors and vice- versa;

$B = \Phi/A$,

$H = NI/L$

Where B =flux density, Φ=total magnetic flux, A=cross sectional area H=magnetic field intensity and I=current

Meanwhile, the detector works satisfactorily with even the ever-fluctuating low voltages (sometime as low as 100 – 150v) in our locality; though with decreasing sensitivity .

4.3 CONSTRAINTS

A fundamental problem encountered was non-functionality of the circuit at the early stage of the construction. Time, energy and resources were expended in designing, redesigning and modifying, before it eventually became a reality.

The choice of a pick-up item appropriate for the fundamental goal of the project - detection of opens or breakages also posed a problem. Several kinds of probe were tried to no avail, before finally arriving at the zinc metal pad.

Given the aim of the project, a very high amplification gain was required, which is obtainable by using as large a resistance value as possible in the feedback path of the operational amplifier. About 10MΩ was required, but 1MΩ variable was the one ultimately obtained.

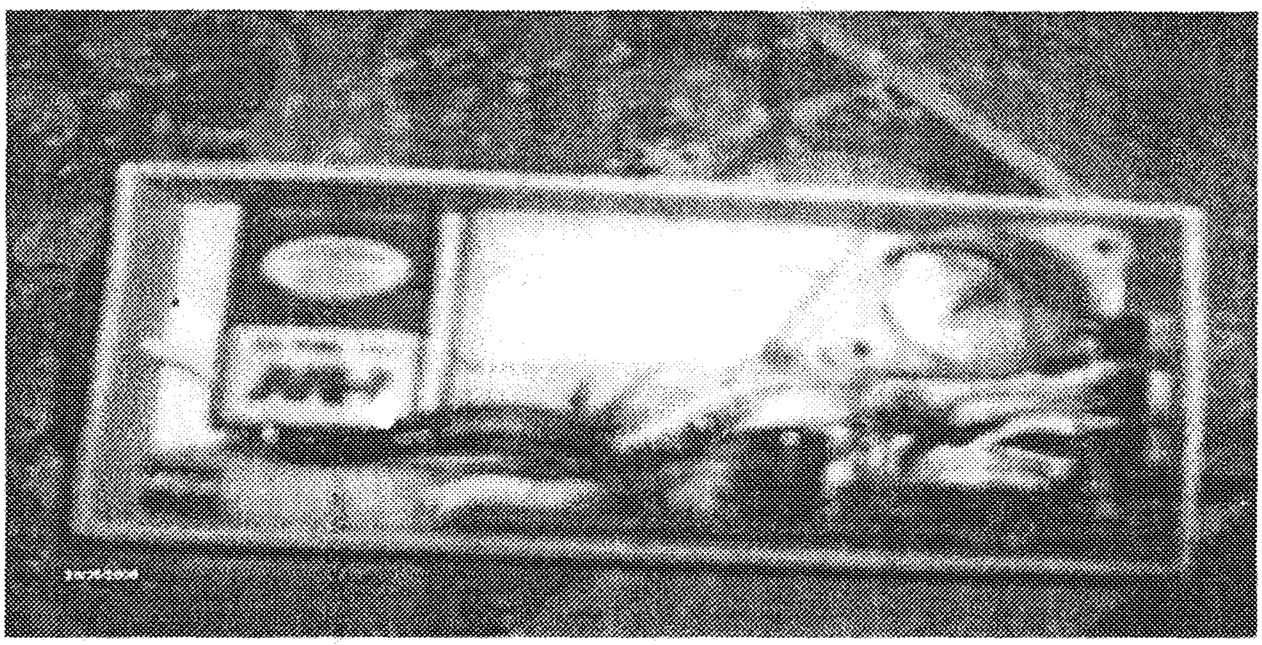

fig. 4.1: constructed circuit of the invisible broken wire detector

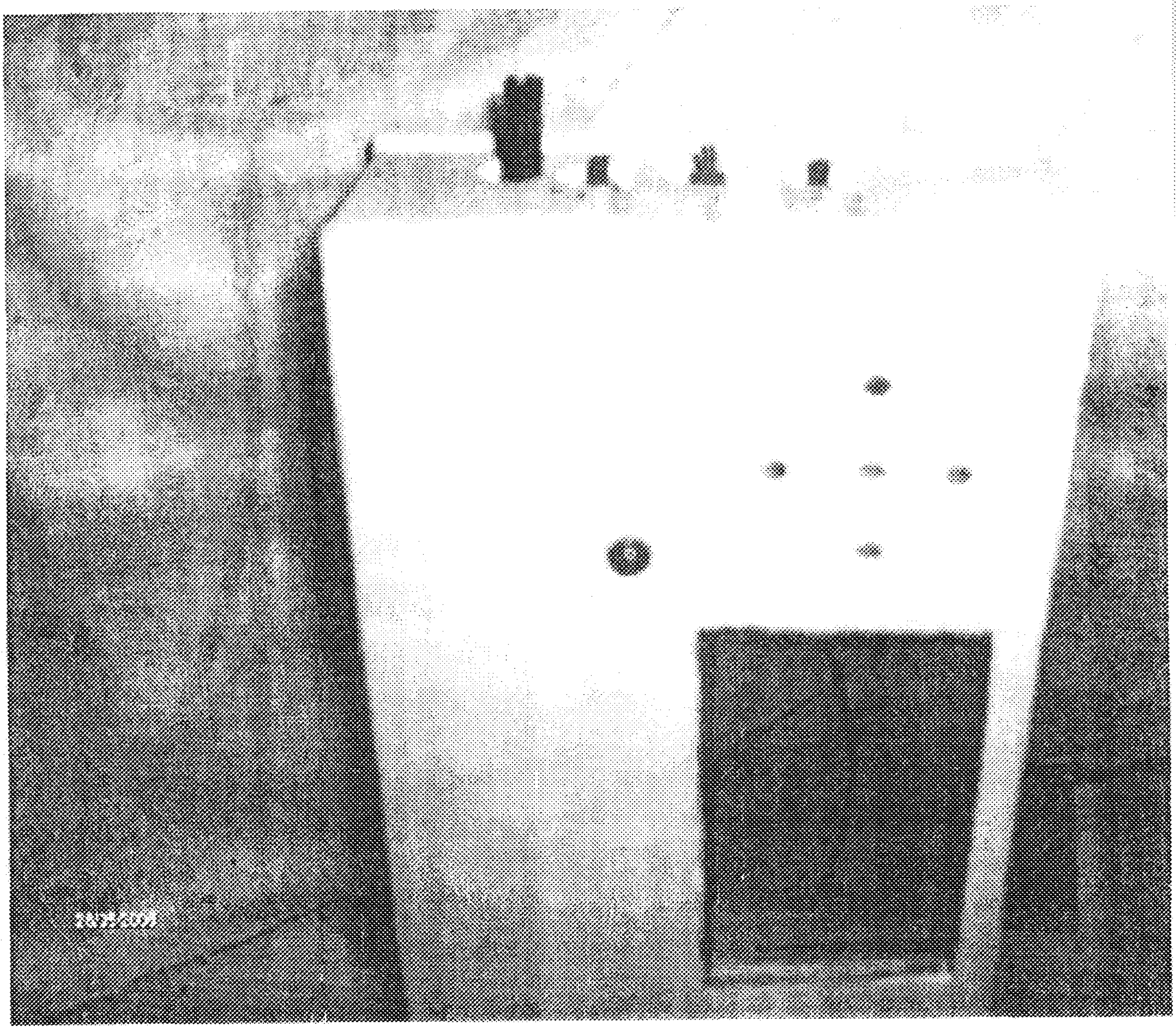

Fig. 4.2 : casing of the invisible broken wire detector

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Design and construction of invisible broken wire detector was the aim of the project. The principle of the project earlier stated has been actualized. The device detects satisfactorily breakages or opens in conductors hidden under the insulation cover of cables.

The project has brought to the fore a simple technique of building a cheap, reliable and flexible means of detecting cable faults- mainly opens; thus a considerably big success.

5.2 RECOMMENDATION

As discussed earlier, the working principle of the gadget "invisible broken wire detector" is based on sensing the AC field generated by the current flowing through an AC – excited cable. This limits its applicability to only power cables; it is thus not applicable to pilot (or control) cables found mostly in electronics and telecommunications. The use of a.c mains supply to excite the faulty cable also tends to give false detections, due to prevalence of the 50Hz frequency virtually everywhere, unless the gadget is as much as possible isolated from ac mains carriers.

To tackle these drawbacks, it is recommended that any future work on the project implores the aid of a tone decoder to generate a test frequency much higher than the 50Hz AC mains and inject into the cable wire under test; instead of the ac mains supply. This way, the influence of extraneous fields is minimized, and the applications scope of the gadget broadened to include pilot cables.

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APPENDIX

Bill of Engineering measurement and Evaluation

(BEME)

Materials	Unit	Unit cost(naira)	Total cost (naira)
Vero board	1	100	100
Coil	1	25	25
Switch buttons	3	20	60
Resistor	7	20	140
Variable resistor	1	50	50
Operational amplifier	1	50	50
Capacitors	4	20	80
Diodes	3	30	90
Buzzer	1	400	400
Meter deflector	1	500	500