DESIGN, CONSTRUCTION AND CHARACTERISATION OF DOMESTIC LIVE-WIRE DETECTOR DEVICE

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Abstract
Domestic Live-wire Detector Device was designed, constructed and characterised in this research work. The device consists of the Detecting Unit, the Oscillator Unit and the Display Unit. The design and construction of the device is centred on 4069UBC inverter chip with fourteen inverter circuits. Detecting unit is implemented with the IC pin1 through an aerial track made of copper conductor, and also comprises pins 2,3,4,5,6,12 and13, resistors R_1, R_2, R_3 and variable resistor VR. The oscillator unit which comprises the pins 8,9,10 and 11 of the chip has resistors R_5 and R_6 and capacitor C_3 as frequency elements and is designed to operate at audible frequency of 50Hz. When a.c. field is detected, the diode incorporated into this unit will now be reverse-biased and allows the oscillator unit to run. It is the output of the oscillator unit that drives the buzzer directly which allows a sound to be heard. The display unit comprises two LEDs; the green LED1 lights when the power switch is turned on, which indicates that the circuit is active while the red LED2 lights through transistor switch TR1-C1914 whenever the device senses an a.c. electromagnetic field. This device is powered by a 9v battery.

Introduction

The Globe has become more comfortable and fascinating due to the presence of electricity. All human activities depend mainly on power supply either directly or indirectly. Electricity is been generated at the generating station and transmitted over long distance by conductors to consumers through a series of processes before being used at our various homes and other places where electricity is needed. The conductor that transmits electricity is a solid with a large number of current carriers. Electrons move easily from one atom to the other in a material, that is to say that they exert very low resistance to the flow of electrons [2].

All metals are good conductors, with silver the best followed by copper, but copper is preferable because it is less expensive than silver. The main purpose of a conductor is to deliver energy from the source to the load with minimum loss, by means of electron flow in the copper wire.

Power supplies used in our various homes are fed by means of a single-phase a.c. supply. Two wires are used; one called the live conductor (usually coloured red) and the other is called the neutral conductor (usually coloured black). It is the live conductor that carries the mains current and the neutral is usually connected via protective gear to earth, the earth wire being coloured green. The standard voltage for a single-phase a.c. supply is 240V [5]. The majority of single-phase supplies are obtained by connection to a three-phase supply. The single-phase supply is used for domestic activities such as cooking, pressing, illumination, communication etc that is to say that in our day to day activities, we come in contact with live wires.

Though life has become easier and comfortable due to the availability of power supply, this supply still has some disadvantages such as electric shock. This is experienced at home or in our places of work. Also we have power outages, outages are the interruptions of supply of electricity. They cause suffering to life, underproduction and unemployment. The effects of power outages on an already depressed economy are devastating. Outages may be the result of a failure or fault in the electrical generation, transmission and distribution system. But the prominent cause of outages in building installation arises while trying to perform our domestic activities within our building. This is most times caused by breakage in the path of live wires, which constitute environmental hazards and danger.

There have being many devices designed and constructed to detect the presence of voltage in a live wire such as the Neon screw drivers, multimeters, etc which requires the user to make contact with live wire via these devices. The user needs special orientation on how to use them and also needs some bravery to overcome fear of shock/electrocution. Ignorance as regards the use of electricity and the fear of receiving electric shock have discouraged many people from using these devices (meters, etc) to test for the presence of voltage in a wire as it requires contact of devices with the wires.

In an attempt to put an end to the fear and anxiety users experience in the process of using multimeters, Neon screw drivers etc (which require contact) and also to ease the detection of a breakage in the path of a live wire concealed in a building, informed the design and construction of the "Domestic Live-wire Detector" which employs the principle of electromagnetic induction in the detection of live wires. The domestic live wire detector is a fascinating and effective device which will detect the presence of mains electricity even if the wires are not connected to anything at one end. It is better than Neon screw drivers or multimeters because you do not have to make contact with the wire. It senses the presence of voltage just about 5cm away from live wire by either a flash or alarm.

It is the kind of device every household should have and can be used by any-one because of its portability and also does not require contact with live wire during usage. Special orientation on its usage is not required and it is very affordable.

Apart from detecting exposed life wire, it could be used to find buried wires in dry plasters or plastic conduit or under floor or ceiling boards by bringing it close to the live wire to about 5cm away.

Design and Construction

The design and construction of Domestic Live-wire Detector device is centred on 4069UBC inverter chip. It consists of fourteen inverter circuits and is manufactured using complementary metal oxide semi-conductor (CMOS) technology to achieve wide power supply operating range, low power consumption, high

noise immunity, and symmetric controlled rise and fall times [6].
Its adaptability permits the fabrication of the device sub circuits- detector, oscillator and display units, around this single chip.

Detector Unit

The detector probe or sensor is an aerial of copper conductor which is connected to pin1 of the chip. The integrated circuit (IC4069UBE) is a digital type and is connected linearly by placing a feedback resistor between pin1 and 2. The need for the high value resistor between these pins 1 and 2 is that since it is an a.c. that flows through the conductor, which is sinusoidal in nature, an increase in strength of the current will increase the strength of the field, but due to the presence of the resistor R_1 and R_2 that keep the characteristics high input impedance so that changes in the surrounding electromagnetic field produce a minimum voltage change across the circuit. Other pins and components used in this unit are pins 3,4,5,6,12 and 13, resistors R_1 R_2 R_3 and VR which is a variable resistor, connected as shown in Fig.1.
The variable resistor VR sets the points at which the output from IC pin4 will trigger the next two stages. This is necessary since the quiescent voltage at pin2 differs from one chip to another. Since the 4069UBE is a digital chip, the quiescent voltage makes no difference. It is significant and the variable has to be present to ensure that every live wire can meet the specification. Capacitors C_1 and C_2 serves to increase sensitivity of the circuit [6].

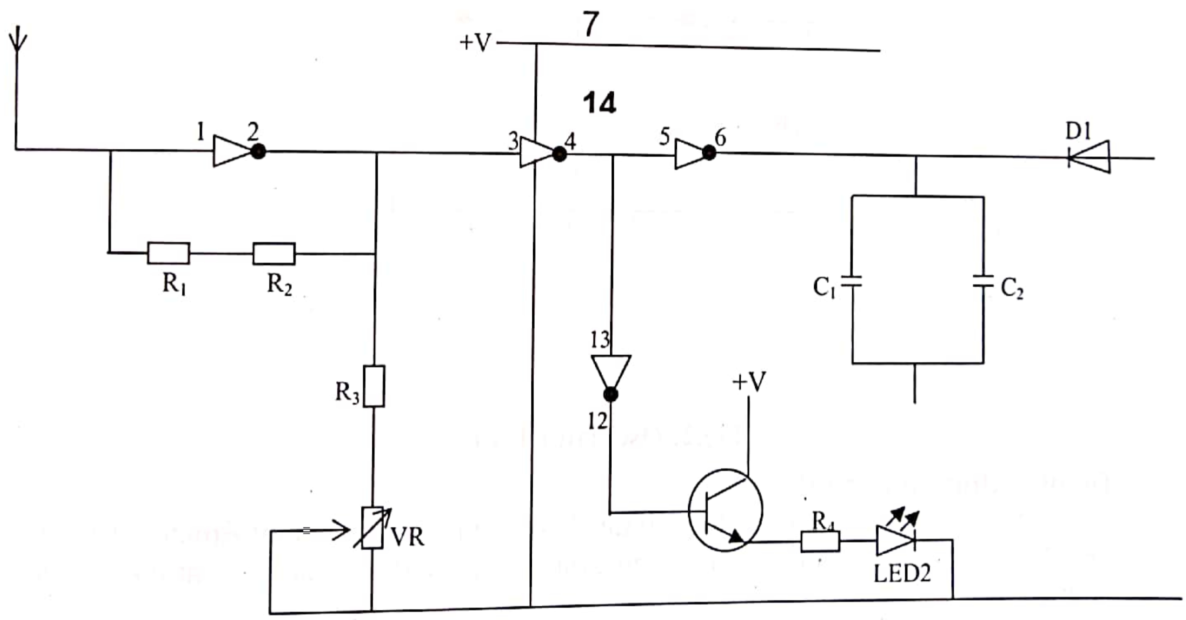


Fig. 1: Detecting Unit

Oscillator Unit

The oscillator unit comprises the final stage of the 4069UBE i.e. IC pin (8, 9, 10 and 11), diode D_1, the resistors R_5 and R_6 and capacitor C_3. R_5 and R_6 and capacitor C_3 are the frequency elements while D_1 maintains the continuous low hold-off condition from pin9 during absence of signals. The need for the high value of resistors R_5 and R_6 across the terminal of the capacitor is to automatically discharge it after the supply is switched off [5][1]. For an astable oscillator, the operating period T, equation is:

$T = 0.693(R_1+2R_2)\, C_T$ [3] 1

Where R_1 and R_2 are timing resistors and C_T is timing capacitor.

Setting $R_1 = R_5 = 4.7K$ and $R_2 = R_6 = 220\Omega$, (see Fig.2).

For audible frequency f of 50 Hz, 2

$T = 1/f$

$= 1/50 = 0.02s = 20\mu s$

From 1,

$20\text{x}10^{-3} = 0.693(4700 + 2\text{x}220)\, C_T$

$20\text{x}10^{-3} \cong 3{,}562.02\, C_T$

$C_T = 20\text{x}10^{-3}/3{,}562.02 = 5.615\text{x}10^{-6}$

$\sim 7\mu F$

It is the output of the oscillator circuit that drives the high impedance buzzer directly.

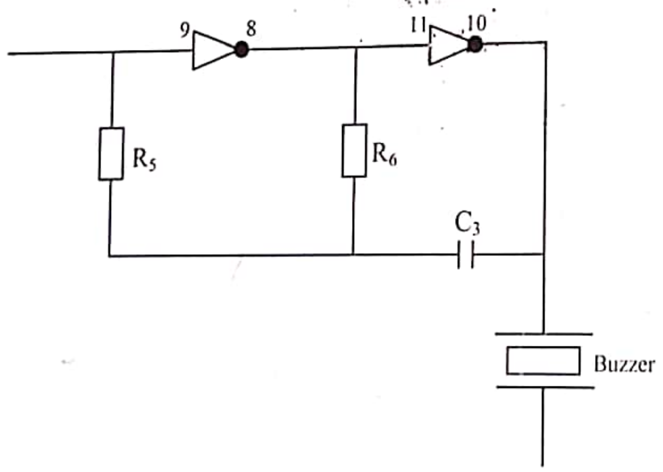


Fig.2: Oscillator Unit

Display Unit (Indicator)

There are two display units in the circuit. The first is a green Light Emitting Diode, LED1 indicator, which glows when the switch is closed to indicate that the power is on.

LEDs glow when current, typically 5mA – 20mA flows through them [3]. For the LED1, the lower limit-5mA is used to calculate its resistor value because being on power line this current is assured so long as there is power. The equation is:

$V = IR$ [4] 3.

Where V = voltage across the resistor, 9V,

I = current through the resistor, 5mA

R = resistor value,

$$R = V/I$$

$$= 9/5\times10^{-3} = 1800\Omega \qquad (4)$$

$$\sim 2K$$

The LED1 is connected in series with a 2kΩ resistor which limits the input current to the desired amount needed to run it as in Fig.3a. When the LED1 glows, it means that the circuit is active.

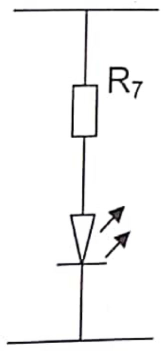
The second display unit is a red LED2 indicator; it glows whenever the detector senses electromagnetic field. This LED2 is on the signal line and so the upper limit-20mA was used in calculating its resistor in order to increase sensitivity. Thus from equation 4:

$$R = 9/20\times10^{-3}$$

$$= 450\Omega$$

$$\sim 470\Omega$$

It is connected to emitter end of NPN transistor in series with a 470Ω resistor to the ground as shown in Fig.3b. The transistor TR1 is designed to act as switch.



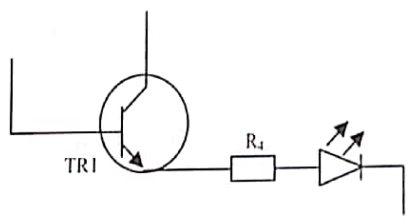


Fig 3: (a) Power Display Indicator (b) Electromagnetic Field Indicator

Power Supply Unit

In the choice of what to use to power the circuit, the range of the power consumption of the circuit was taken into consideration. The CMOS technology has a wide supply voltage range, typically 3-15 volts [3]. The transistor TR1 also fits into this range and so the voltage supply for the detector is from nine volt (9v) battery. .

The complete circuit diagram of domestic live wire detector device is shown below.

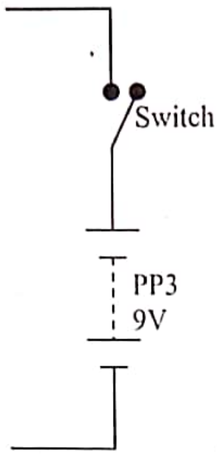


Fig. 4: D.C. Power Supply Unit

System Operation

When the domestic live wire detector is switched on, LED1 lights up indicating that the circuit is on, if no electromagnetic field is detected, the IC pin4 goes high which causes the rest of the circuit to become inactive but when it senses an electromagnetic field, pin4 goes low while pin12 goes high causing the emitter follower transistor to conduct therefore lighting LED2 [7]. At the same time as IC pin12 goes high, IC pin6 goes high also, which reverse biases diode D1 and removes the continuous low hold-off condition from IC pin9 and allows the oscillator to operate. It is the output of the oscillator circuit that drives the high impedance buzzer directly. The buzzer produces an audible sound of about 50Hz and the LED2 also lights up to indicate presence an electromagnetic field which implies the presence of current carrying conductor- Live wire. The magnetic field around the conductor is due to electric current flowing through the live wire.

Conclusion

Domestic Live Wire Detector device using available components is successfully designed, constructed and tested. The technology is simplified and can easily be reproduced for commercial purposes. It is environmental friendly.

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