Portable Multifunction Tester Design to Check the Continuity of Wires and to Measure the Electrical Parameters

A. Kunaraj, J. Joy Mathavan, and K. G. D. R. Jayasekara

Abstract The objective of this paper is to design a single device for checking the continuity of single wire and multiwired cables with ease, measurement of current and voltage in an electrical circuit and providing light to the experimentation area by a single device. The device is named as portable multifunction tester. The status of the errors found by this device appears on the LCD display for visual observation. Buzzers are also provided to indicate the errors by making identical sounds. This is a non-destructive testing mechanism because no need to unmount or break any circuit or structures to troubleshoot and rectify the error.

Keywords Continuity checking of wires · VGA cable · RJ45 cable · Portable multifunction tester

1 Introduction

Electrical and electronic equipment used in various applications is prone to faults and defects. There are different testing methods and equipments available to troubleshoot and fix the problems in electrical and electronic-related applications. But they all are individual testers for faults. The design of research work presented here is the combination of four troubleshooting related operations. They are

1. Continuity testing in a single wire.
2. Continuity testing in multiple wires.
3. Check the continuity of current carrying conductor without breaking slab.
4. Voltage and amphere testing.

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5. Providing light to the testing space.

Usually, the defects associated with electrical and electronic appliances are minor and are in the form of broken wires. Single and multiwire continuity tester are subunits in this device, which is used to check the errors in VGA and network cables. There are incidents where the fault in one individual cable in a network cable or VGA cable causes mulfunctioning of the entire cable. In such situation, this device can check the number of cables and the error associated with the exact cable. There are individual LED indicators in main controller module which can indicate which wire is broken in between. In industrial point of view, time is very important and equivalent to money. If the fault detected quickly, it can be fixed quickly and the process can be started immediately once the fault is fixed. Since most of the current equipment consists of bunch of wires, the fault finding has become pretty tough and difficult to diagnose. The small, inexpensive portable multifunction tester can be used to detect such defects. Uninstalling the entire machinery inorder to find the error in a wire is prevented by this equipment. The probes of the continuity tester can be connected to both the ends of the wire and can be tested for its continuity. If the wire is continuous without any break in between, the circuit makes a sound and that is the indication. In addition to that, when the electrical components are fixed on the printed circuit board or on the breadboard, there is a possibility that the components get attached to the printed circuit board or breadboard due to the mistakes committed while assembling the circuit. The continuity tester helps to debug the circuit with ease under such situation. 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 the test-leads, the indicator will be activated. The indicator is a light and a buzzer, which would be the output of continuity test. Usually, audible buzzers or beepers are built into some models of multimeter, and the continuity testing is normally annexed with the ohmmeter setting. Continuity tester is divided into two circuits, namely transmitter circuit and receiver circuit. There are two terminal probes on the transmitter circuit for the continuity testing purpose while the receiver circuit has LCD for visual indication and buzzer for sound indication of the result.

Wirless conductor checking is used to identify the errors in conductor wires without damaging the slab area. Electricity carrying wires are installed through wall or slab in a house wiring. In case of any irregularity, the fault finding in the conductor is very difficult without breaking the wall or conductor. But with the help of wireless conductor checking function available in multifunction tester, the fault finding is easy. When the antenna of the tester is kept near the conductor wire, the LED in the tester blings and buzzer makes sound if there is no fault.

The multifunction tester can check the voltage and give the output ranging between 5 and 40 V and the relavant current measurement will also be displayed. The device can also provide light to the area under inspection in case of poor lighting condition.

The organization of this paper is as follows: Sect. 1 depicts the introduction, Sect. 2 depicts the literature review, Sect. 3 depicts the subsystems, namely single wire continuity testing, mutiwire continuity testing, wireless conductor testing, current and amphere testing and providing light to the testing area along with circuit diagrams

and working principle. The results are presented and discussed in Sect. 4 followed by conclusion and future scopes in Sect. 5.

2 Literature Review

John E.Fletcher and john O'Reilly [1] explained about short circuit and ground fault analysis. Also they explained about troubleshooting the underground cables based on voltage source converter method (VSC). This proposed method was based on simulation results with the range of fault resistances, distances and operational conditions considered. Kedia et al. [2] explained about underground cable fault detection and distance measurement using AT mega 328 microcontroller. This design used for the three-phase supply and it can individually measure the resistance of the cables and find the broken cable. The resistance and distances were measured based on current sensing data values. According to current sensing data, ATmega328 processor processes the sensor data, and the output will be supplied according to program. Kesim [3] explained about automated continuity testing using a continuity tester. Military computers have been widely used by ASELSANT has flexible cable, which has number of wires (nearly 100–160). Since this cable is used to connect processor unit with computer, large number of cables are going through this electrical component. This design was designed to check all the wires at the same time and quickly. Roy et al. [4] designed an electronics circuit to measure the polarity and check for the continuity. Nandhini et al. [5] used Arduino technology to find the fault and the exact location of the fault in the underground cable. Padmanaban et al. [6] designed a circuit using Arduino technology and Ohm's law to identify the fault and abnormality occurs in the underground cables. Choi et al. [7] used microcontroller techniques to find the fault and the distance of the fault from any end and LCD to display the finding. Chandra et al. [8] also found short-circuit fault in underground cables using advanced microcontroller techniques. Tarlochan et al. [9] used two different type of algoritham to identify fault in the underground cable. One algoritham is used to identify the fault induced-transient and the other algoritham is used to identify the single-line-to-ground fault. Sampathraja et al. [10] used PIC16F877A controller to identifiy the distance of fault of the cable from the base station in km. Pal et al. [11] found the fault in the underground cable based on the ohms law principle. Apisit et al. [12], in their research, find the fault and identify the phase using a decision algorithm.

It can be noticed that most of these researches were targeted on designing a device for checking the continuity of an underground cable. Some worked on single wire continuity testing and some worked on multiwire continuity testing. The difference between the past researches and the current research presented here is the past researches concentrated on finding the solution to a particular problem while the current research intended to address more than one problem by a single device. In other words, the device is designed to answer the problems which have high probability to occur while testing a circuit.

3 Methodology

Technicians currently facing time delay in testing a circuit for any irregularities. This is due to the usage of various equipment for fault finding in the industry, which the technicians are not comfortable with. This paper aims to minimize this problem by providing a single device to check and solve four different problems. The main controller module design consists of testing of four functions which are frequently used in industry. In case if one needs additional measurement or testing, there are several sensors and ports available, which can be connected with the main controller modular. Therefore, the design is not limited to address the above mentioned issues only.

The specifications of ATmega328 microprocessor [13] are shown in Table 1. This microcontroller IC is very small, cheap and have high clocking speed. It has more number of input ports and output ports for external connections as shown in Fig. 1.

The circuit of portable multifunction tester is designed using this particular IC, which is the main controller unit. Different sensor modules are attached here with the main controller unit for controlling and switching. Display module also connected with ATmega328 microprocessor IC to display the processed information as visual based output. The block diagram of multifunction tester is shown in Fig. 2.

3.1 Power Supply

AC to DC converter inside the power supply module is used to convert AC voltage to DC voltage. Power supply module is a separate module which can be connected and disconnected with main module, since the power supply module is not required once the multitester is charged. As shown in Fig. 3., the input voltage is 230 V/50 Hz (120VAC–240VAC), and output voltage is 13.5VAC 1000 mA.

The power supply is used to charge the battery. Since 13.5VAC is not suitable for this circuit, it is converted to DC voltage using center tap transformer, diode bridge and capacitor as shown in Fig. 4. The average input voltage of the circuit is 230v/50 Hz and output voltage is 12 V. Figure 5 shows the graph of signal after passing through diode and Fig. 6 shows the signal after passing through capacitor.

Table 1 Specifications of Atmega328 microcontroler IC

Parameters	Range
Microcontroller	Atmega328
Operating voltage	5 V
Digital I/O pins	14 (of which 6 provide PWM output)
Clock speed	16 MHz
DC current per I/O pin	40 mA
DC current for 3.3 V pin	50 mA

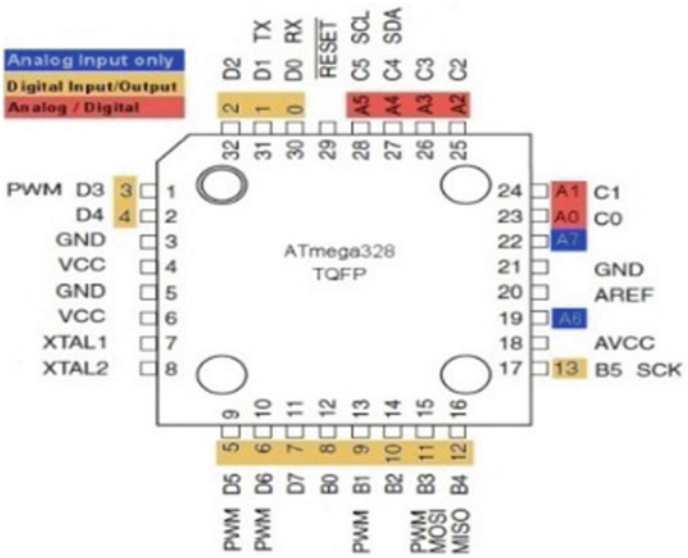


Fig. 1 ATmega328 microprocessor

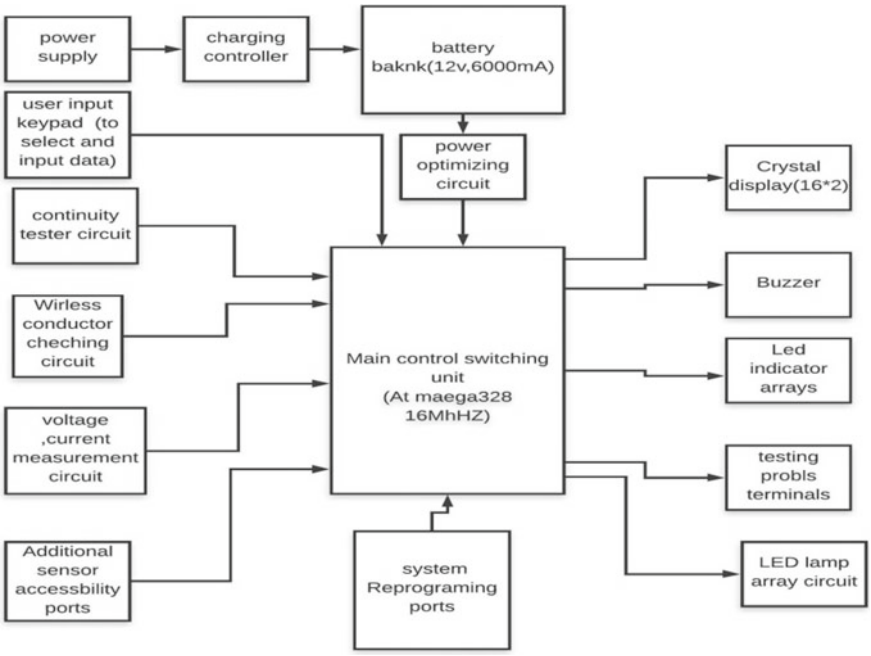


Fig. 2 The block diagram of multifunction tester

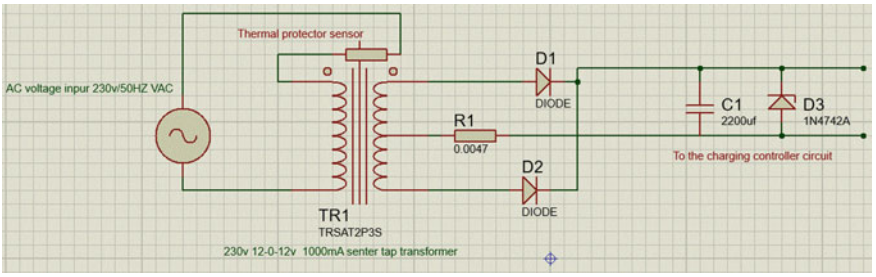


Fig. 3 Power supply circuit consists of AC–DC converter

Fig. 4 Signal generated by AC power source

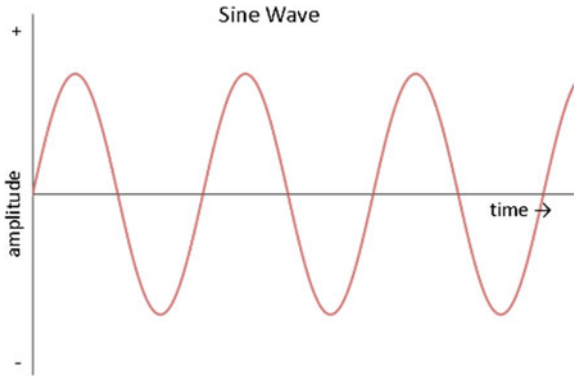


Fig. 5 Signal after passing through diode

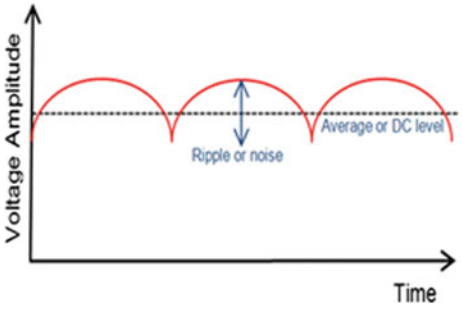
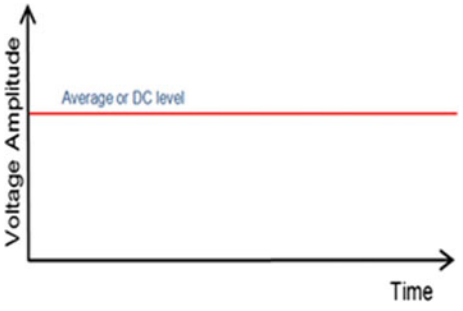


Fig. 6 Signal after passing through capacitor



Due to less initial cost while purchasing and less maintainance cost while operating, center tap transformer is used. Thermal protection sensor is used to cutoff the supply voltage, if the temperature exceeds 40 °C, because there are chances that center tap transformer may be over heated and the copper windings of it get damaged. Primary and secondary coil of center tap transformer is protected by a fusible resistor connected in series with the negative terminal. In case of any short circuit, the fusible resistor breaks the circuit and protects other electrical components. 2200 μf capacitor is used to get smooth DC output voltage and 12 V sensor diode is used to regulate the output voltage.

3.2 Charging Controller

12 V supply voltage is supplied from power supply to battery through charging controller. The charging controller circuit is used to cut off the connection between power supply and battery once the battery is fully charged. Charging controller protects the battery from over charging. BC547 NPN transistor is used in charging controller circuit to sense the voltage level when charging the battery. The emitter terminal is connected with the negative terminal of the battery. The base–emitter (BE) junction of the transistor is forward biased and current flow through the collector–emitter (CE) junction, if the voltage level increases above 12 V while charging the battery. At this point, the relay is on and the battery connection to positive terminal will be cut off. Purpose of D4 diode is to avoid the back EMF of relay and protect the transistor. The green LED indicates fully charged state and red LED indicates the charging state of the charging controller. D7 diode is connected to avoid the discharging of battery once it is fully charged and disconnected from supply. The charging controller circuit is shown in Fig. 7.

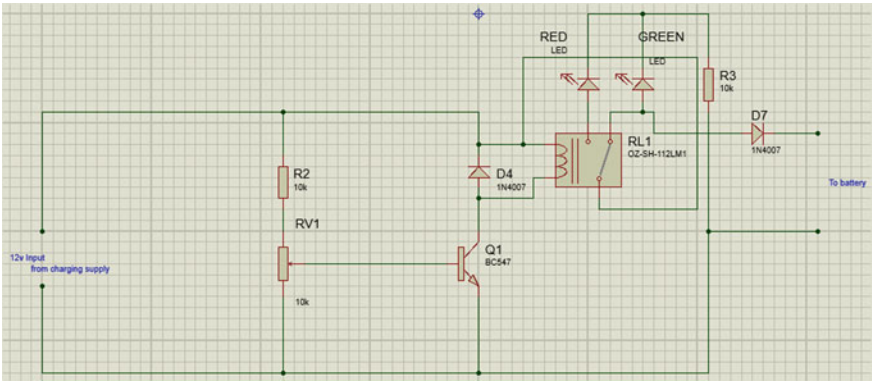


Fig. 7 Auto-cutoff charging controller circuit

Fig. 8 Circuit diagram of battery connection

Battery bank is the power source to store the power and energize the multitester module. Lithium ion battery is used here and one lithium ion battery is of 3.7 V. Since 12 V power is needed as the source, three 3.7 V batteries were connected in series to get the necessary power as shown in Fig. 8.

3.3 User Input Key Pad Array

The key pad is created using three push buttons: an up button, a down button and one select button. 5 V supply is supplied to each button terminal and the last terminal is the signal output terminal. The signal input terminal is connected with 10 kΩ resistor in series. The signal pin is grounded and it is connected with analog pin of the ATmega328 microcontroller. The user input key pad is shown in Fig. 9 The buzzer and LED circuit are used to indicate the output as sound and visual output as shown in Fig. 10.

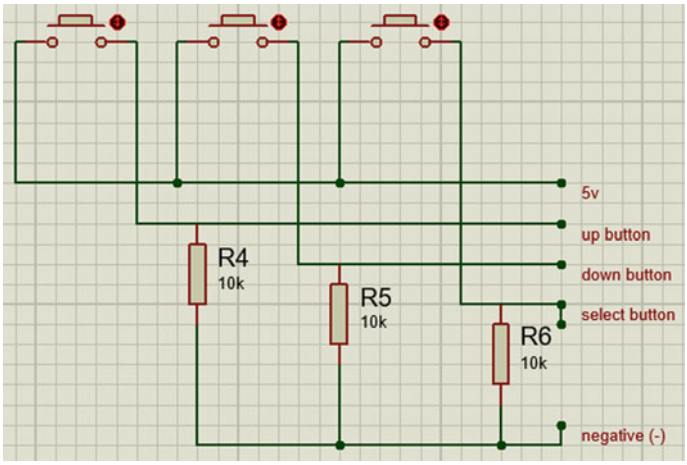


Fig. 9 Keypad array

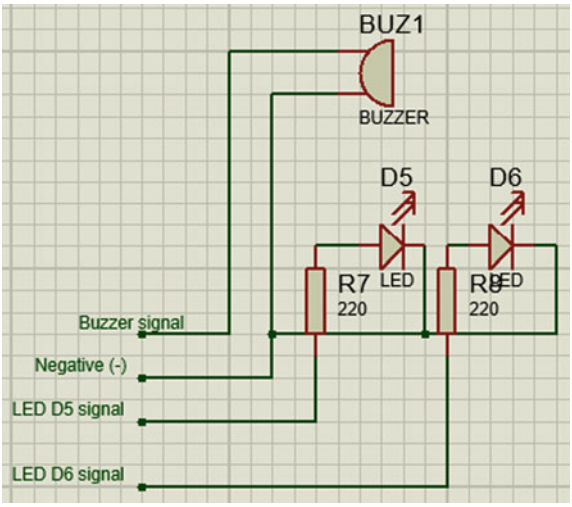


Fig. 10 Buzzer and LED indicators

3.4 Single Wire Continuity Tester

Continuity testing is devided into two major parts: single wire testing and multiwire testing. BC547 NPN transistor switches the single wire tester and voltage supply to the particular circuit. The opperating voltage is 5 V. The output terminal of the IC connected with the positive terminal of the buzzer and the negative terminal of the buzzer is connected with test probe. The output of the IC is connected with one end of the LED through the resistor R2 and the other end of the LED is connected with the tset probe. If the test probe is continueous, the current flows through the circuit without any interuption. Under this condition, buzzer makes sound and LED lit up and this method is used to check and verify the continuity of a single wire. LM7805 regulator IC was used to regulate the voltage. LM7805 IC is one of the best ICs in electrical industry. Maximum output current of LM7805 is 1A and if the IC is overheated due to high current flow through it, the heat sink dissipates the heat and transfers the air very quickly. Any other IC would be burnt out if it is overheated. The circuit diagram of single wire continuity tester is shown in Fig. 11.

3.5 Multiple Wire Continuity Tester

This circuit is designed to check the continuity of multiple cables (VGA or RJ45). There are number of current conducting wires inside VGA and RJ45 cable. Checking each wire one by one is difficult and time-consuming task. The portable multifunction tester circuit is deigned to avoid such delays in trouble shooting. Two type of ICs were used to design the circuit. CD4017 IC is used to count the number of wires and send the output voltage signal. NE555 IC generates chocking pulse, if it encounters

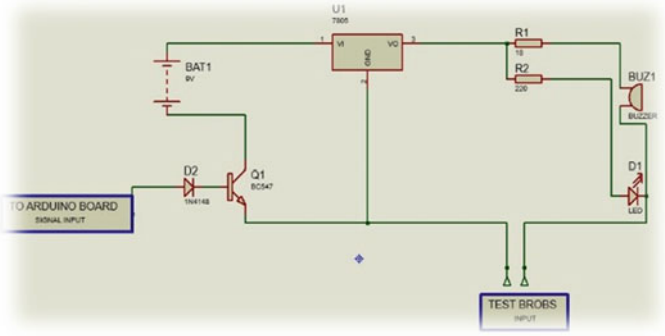


Fig. 11 Single wire tester

any problems. The chocking pulse generated by NE555 IC is given by pin number 3 to clock pin of CD 4017 IC. According to the received pulse signal, CD 4017 IC sends voltage signal to pin 1–12. The circuit diagram of multiple wire tester is shown in Fig. 12.

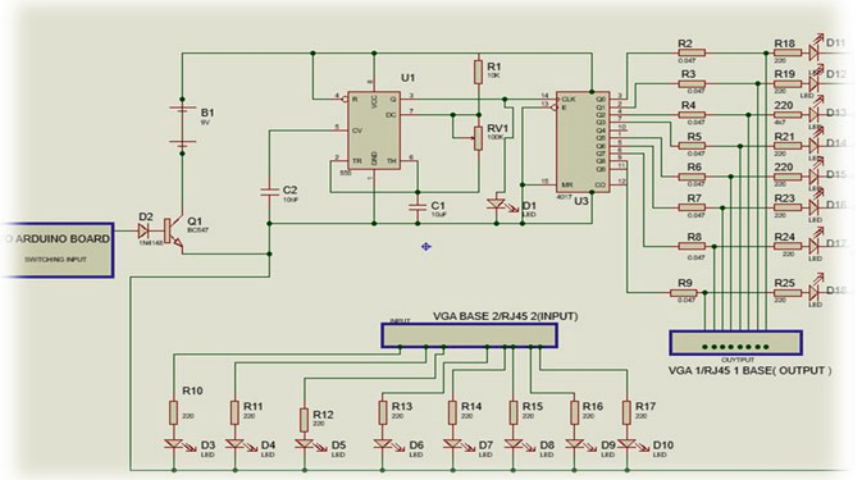


Fig. 12 Multiple wire continuity tester

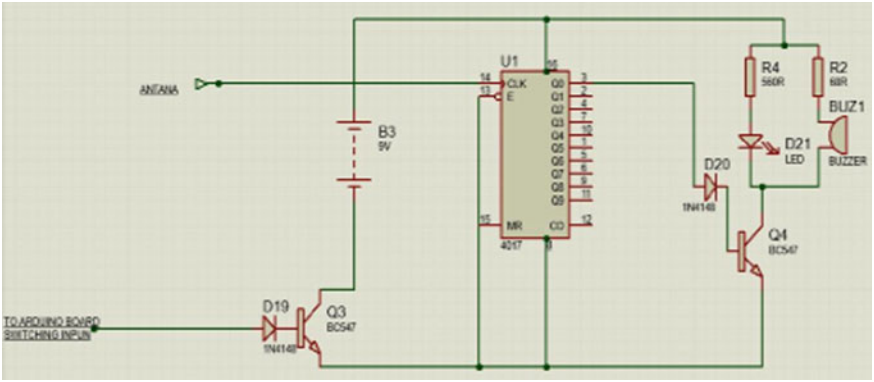


Fig. 13 Circuit diagram for wireless conductor testing

3.6 Wireless Conductor Checking Circuit

The wireless conductor checking circuit is shown in figure. When 9 V power is supplied to the transistor Q3, it switches on the wireless testing circuit. The 4017 IC senses the current carrying conductor through the antenna. The antenna is used to magnify the signal strength. When the conductor kept near to the antenna, a small current is induced in the antenna and it flow to CD4017 IC. This current is detected by the IC and the output signal sends to the transistor Q4 through the diode. When the output signal is high, the Q4 transistor would be biased and it supplies the voltage to the buzzer and LED and they make the indication. The circuit diagram of wireless conductor testing circuit is shown in Fig. 13.

3.7 Voltage and Current Measurement

Various supply voltages are required to work in the industries. There are situations where up to 12 V supply may not be available for most of the test equipment. But this tester can supply up to 40 V with the help of the inverter (5–40 V). The circuit diagram of voltage and amphere tester is shown in Fig. 14. Supply voltage and ampheres are displayed on the liquid crystal display. A 5 V relay is used for switching operation because there would not be any voltage drop through it while using it for switching operation. If a transistor is used for this purpose, there will be some voltage drop across the transistor. A step down transformer also not advisable in this circuit, since it is too big to this situation.

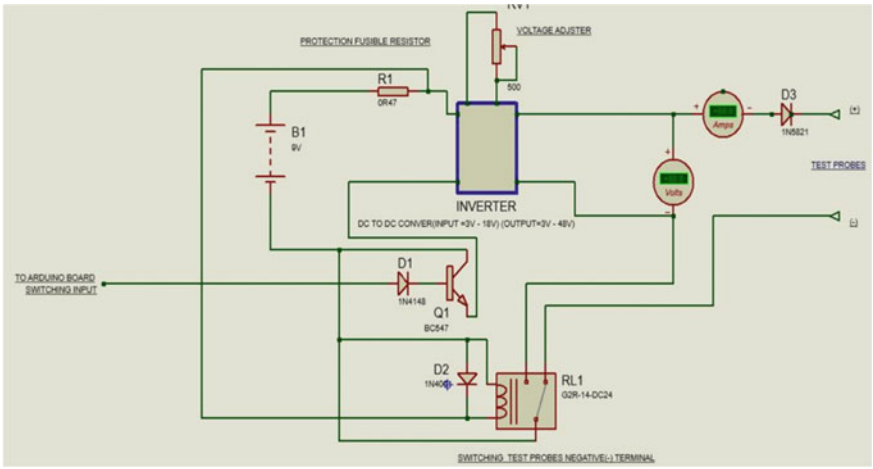


Fig. 14 Circuit tester

3.8 LED Array Circuit

Light emiting diodes are used at troubleshooting time to light up the testing area in case of poor lighting condition. The circuit shown in Fig. 15 switches based on BC547 transistor. The supply voltage is given to the circuit and LEDs lit up. There are two LED arrays and seven LEDs in each array. All the LEDs are connected in parallel to the supply voltage. R2 and R3 resistors are connected in series to control the current for LED array.

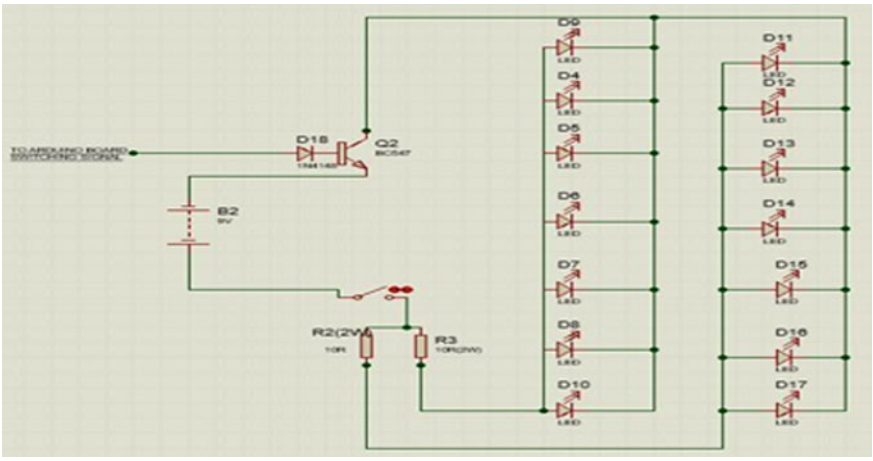


Fig. 15 LED array circuit

In the similar way, more client sensors can be connected with main module through the extra ports provided. Based on the requirement, additional sensors can be connected with the main module and read the information from display fixed on the main module.

4 Results and Discussion

Troubleshooting and fault finding are very important parts in electrical and electronics technology. Proper fault finding device is necessary to finish the troubleshooting process on time and with less labor effort. Eventhough different equipments are used to find and rectify faults in the industry, it would be beneficial if it is possible to compact more number of testing devices in one small portable device. In other words, time and other resources will also be managed in very effective manner. The multifunction tester is designed based on these ideas. There is one main master module. Frequently used functions are already in build with master module. Additional secondary modules can be connected with the master module based on the requirement.

Broken wires passing through slabs or walls could be identified without demolishing the slab or wall. Instead of dismantling the whole system in a machine just to find a broken wire, that particular wire can be identified with ease, if this method is used. The replacement of broken wire can also be achieved by using the lighting provider attached in this device, in case if the broken wire is identified in some highly complexed circuit. Exact broken wire can be identified in the cables like VGA cable and RJ 45 cable which has more than one wire. Since individual LEDs are allocated for each wire, the fault in the exact wire can be identified easily. Through this finding, the broken wire can be changed instead of disposing the whole wire. Voltage and amphere measurement submodule is used to check the voltage and amphere of circuits. In a testing environment, a voltage ranged between 3 and 40 V can be supplied by this device. So the experimentation could be continued without plugging the machinary into an external circuit to obtain the neceaary voltage. The experimentation of each module is shown in Figs. 16, 17, 18, 19, 20 and 21. But it is not limited to only these submodules. Based on user requirements, suitable secondary sensor modules can be connected with the main module.

5 Conclusion and Future Scope

This single device called multifunction tester can be used to

1. Check the continuity of a single wire.
2. Check the continuity of multiple wires in VGA cable, RJ 45 cable, etc.

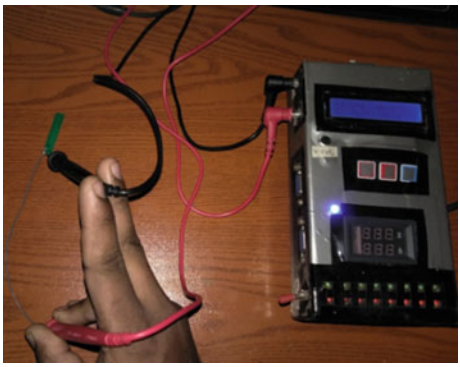


Fig. 16 Continuity testing of single wire

Fig. 17 Continuity testing of multiple wires

Fig. 18 Wireless conductor testing

Fig. 19 Voltage testing

Fig. 20 Amphere testing

Fig. 21 Portable multifunction tester

3. Check the continuity of current carrying conductor without breaking the slab, without connecting any wire when it is in a circuit.
4. Measure and display voltage and amphere of equipment under test.
5. Provide light to the testing space inside a machine where external light finds difficulty to enter in.

It is highly beneficial to people like electrical engineers, electrotechnicians and underground cable operators. Instead of using several devices to troubleshoot various issues in a circuit, a single multifunction tester which can analyze different parameters can be used. The basic unit of the master circuit of the multifunction tester is processing, functioning and controlling based on microcontroller ATmega328. There can be some limitations with input and output pins, frequency, accuracy, speed and storage capacity. To improve the speed, storage, processing delay and multiprocessing, can go for high speed and high accuracy PLC technology. Programmable logical controller unit (PLC) is considered as more efficient than the microcontroller. But the cost should also be taken care if the PLC is used.

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