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Design and Implementation of a Variable Control Protection Circuit for DC Low Voltage Application

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Abstract: This paper proposes the design and implementation of an overvoltage protection circuit for DC low voltage devices or appliances. The entire setup consists of basic components like 555 timer, diodes, relay, resistors and capacitors. The system can be used to protect devices having any decimal value of operating DC voltage. The maximum voltage over which the supply voltage should be disconnected from the load or the maximum operating voltage can be set by tuning a variable resistor used in the circuit. The system is compact, portable and consumes very low power; it also has remote control option to facilitate the user to control from a distance. The circuit was simulated in Proteus Professional Software before implementing on a Vero board. The experimental results obtained shows that the circuit is able to control the rating of overvoltage protection with high sensitivity.

Keywords: 555 timer, surge protection, infrared sensor, digital control

I. INTRODUCTION

One of the primary requirements of electrical power system is the need for automatic operation, particularly in high-end computer, telecom, medical, and industrial applications, where overvoltage protection is paramount. The device must disengage before its overvoltage condition affects sensitive circuitry. Prior to the implementation of semiconductor devices, electrical transients in the form of voltage surge have always existed in electrical distribution system, they were of minor concern [1-2]

Almost all electrical and electronic devices are damaged by overvoltage due to load dump events or voltage transients [3]. The amount of energy they absorb may vary before such damage occurs. Most modern semiconductor devices, such as low voltage MOSFETs and integrated circuits can be damaged by disturbances that exceed only 10 volts or so, their survivability is poor in unprotected environments [4-6].

As semiconductors have evolved, the trend to produce smaller and faster devices and the spread of MOSFET and gallium arsenide FET technologies has led to an increased vulnerability [7]. The ability of these devices to absorb energy and to conduct large currents is limited by high impedance inputs and small junction sizes. As a result, it has become significantly important to supplement vulnerable electronic components with devices specially designed to cope with these hazards [8].

Selection of the proper protective method should be made based upon a thorough investigation of the potential sources of the overvoltage hazard. Different applications and environments present different sources of overvoltage. The sources may be external, or they may be within the circuit[9-11].

This paper outlines the design considerations of proper protective method with high sensitivity due to overvoltage, and gives recommendations as to how these considerations can be reliably implemented into an automatic overvoltage protection system.

II. SYSTEM DESIGN AND DESCRIPTION

There are two different power supplies V_{CC1} and V_{CC2} to operate the whole circuit as shown in fig 1. Two 9volt 6F22 type portable batteries are used as V_{CC1} and V_{CC2}. A DPDT(Double pole double throw) switch is connected to these different power supplies separately. V_{CC1} goes to the SUPPLY pin-8 of the timer IC NE555 via one pole of the DPDT switch V_{CC2} is connected to a series of red LED D_4 and resistor R_8 via other pole the DPDT switch V_{CC1} and V_{CC2} are connected to the DPDT switch in such way that if the DPDT switch is closed then V_{CC1} will be connected with Ne555 and V_{CC2} are connected with the red LED D_4. The red LED will glow to indicate that power of the circuit is ON.

The RESET pin-4 is connected to pin-8 of the timer IC to avoid false triggering. The TRIGGER pin-2 is connected to V_{CC1} via a resistor R_1. It makes the TRIGGER pin generally high and allow the comparator, COMP2 (fig 1) to work and a chance to make change in output. Pin-2 is also connected to a push button S_3 which goes to ground. The push button is added to make the TRIGGER pin “low” when it is needed.

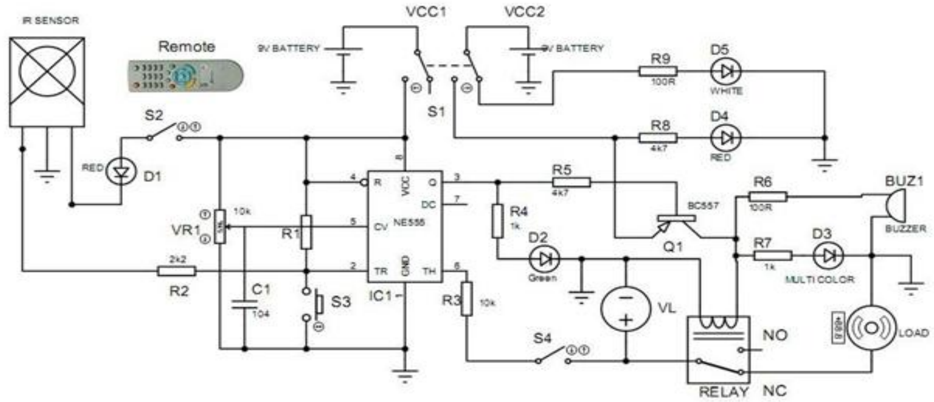

Figure 1 - Overvoltage Protection Circuit Design

A variable resistor VR1 is placed to the CONTROL VOLTAGE pin-5 and also connected with the power supply V_{CC1} and the ground to vary the voltage level by tuning it. The variable resistor is needed to tune to set a certain voltage over which the load voltage V_L should be separated from the load. A ceramic capacitor C_1 is connected between pin-5 and ground to filter the control voltage. The IR (Infra-red) sensor (TSOP1738) is used to make the TRIGGER pin "low" by pressing any key of an IR remote from a distance. However this is optional part of this protection circuit and it provides an opportunity to control the device from particular distance. The positive input pin of the IR sensor is connected to the positive voltage rail of NE555 through a series LED D_1 and a switch S_2. The negative input pin of the IR sensor is connected to ground and the output terminal of the IR sensor goes to the TRIGGER pin of NE555 through the resistor R_2.

The GROUND pin-1 of NE555 is directly connected to ground. The THRESHOLD pin-6 of NE555 is connected to a terminal of the resistor R_3 and the other terminal of this resistor is connected to a SPST (Single pole single throw) switch S_4 and the load voltage V_L which should be protected from the load during over-voltage condition. In other word, the load voltage V_L is applied to the THRESHOLD pin through the resistor R_3 and switch S_4. In the OUTPUT pin (pin-3) a green LED D_2 along with a resistor R_4 is connected so that, when the output goes "high", then the green LED glows and indicates that the load voltage V_L is in normal condition.

In the case of over-voltage condition, the load voltage V_L should be disconnected from the load and it is handy to aware the user about the circumstance with an audio and visual indicator. To do the task a SPDT (Single pole double throw) relay, buzzer and a multi color LED D_3 are used. They all are connected in parallel to work simultaneously. Now to operate them a pnp transistor Q_1 is used; where the emitter is connected to the positive supply V_{CC2} via a switch S_1, the base is connected to the OUTPUT pin through a resistor R_5 and these three components (relay, buzzer and multi color LED) are added to the collector.

There is a powerful white LED D_5 connected with a series resistor R_9 and the DPDT switch S_1 to the positive supply line of V_{CC2}. Here the DPDT switch S_1 is connected in different orientation than described before. Now, while the DPDT switch is thrown in other direction, the whole circuit will be powered off except the white LED D_5. With this throw the LED D_5 will glow. This powerful LED D_5 is used to indicate the battery (connected in V_{CC2}) charge condition to the user. However, it is also an optional part of the circuit and can be removed if not needed. The COM(Common) terminal is connected with positive point of the load voltage V_L. The NC (Normally closed) terminal of the relay is connected to the positive terminal of the load and the negative terminal of the load is directly connected to ground.

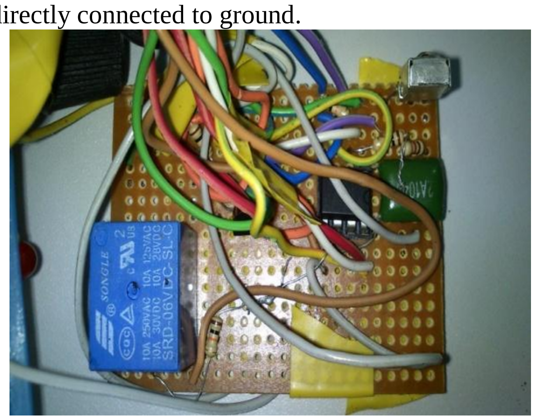

Figure 2 - Implementing the system on veroboard

Fig. 2 shows the overvoltage circuit is being implemented on a veroboard. The overall size of the circuit is compact and can easily be installed in a small box.

III. WORKING PRINCIPLE

First of all the switch S_4 should be opened to disconnect the load voltage V_L from the load. Then to power on the whole circuit the switch S_1 should be closed in such way that the power indicating LED D_4 glows. Since the TRIGGER pin is "high", the output goes low and operates the pnp transistor Q1 which activates the relay, buzzer and the multi color LED D_3 . So during start-up the buzzer will sound and the multi color LED will glow and also the relay coil is energized. To stop them simply press the push button S_3 for once. It will set the output to "high". Now the pnp transistor is in cut off region, hence the relay, buzzer and multi color LED becomes inactive. The green LED D_2 will glow and indicate that the circuit is in normal condition. Any IR remote key can be used instead of pressing the push button S_3. To enable the IR sensor the SPST switch S_2 must be closed. When the switch S_2 is closed the red LED D_1 will glow to indicate that the IR sensor is active now. Any IR remote/Transmitter around us (TV, DVD player or any IR remote) can be used with this circuit. The IR sensor normally outputs "high" and when an IP signal is given to it then the output of the IR sensor goes "low". Press any of the keys available in the IR remote to make the TRIGGER pin "low" and stop the buzzer, relay and LED D_3.

Now place a voltmeter between pin-5 and ground and tune the variable resistor to set the control voltage. The control voltage (voltage on pin-5) is the voltage over which the relay will be operated and separate the load from the load voltage in this circuit.

Now set the control voltage by varying the variable resistor V_{R1}. After setting the control voltage close the switch S_4 to connect the load voltage V_L with the load. If the load voltage V_L is less than the control voltage, then the output will remain "high" on pin-3 and the relay will not be energized. In that condition the COM (Common) and NC (Normally closed) terminals of the relay will be short circuited. Thus the load will run with the load voltage V_L and the green LED will keep glowing to indicate that everything is fine and normal.

Figure 3- The overvoltage protection circuit in ON mode

When the load voltage V_L becomes greater than the control voltage, then the output of the COMP2 (Comparator-2) inside the NE555 (in Fig-2) will become "high" and hence the external OUTPUT terminal (pin-3) will become "low". This is the over-voltage condition. At that moment the transistor Q1 will operate and switch on the relay, buzzer and the multi color LED. As a result the COM and NC terminals will be opened and COM and NO (Normally opened) terminals will be closed. So the load will be disconnected from the load voltage. Also the buzzer will sound and the multi color LED will glow to inform the user that the load voltage V_L has become greater and the load has been disconnected from the load voltage.

Once the over-voltage condition takes place, output will remain the same until the TRIGGER pin (pin-2) gets a low pulse. This can be done by pressing the push button S_3 or any one of the remote keys for once. Right this moment if the load voltage V_L remains greater than the control voltage, then everything will remain the same to indicate the over-voltage condition. But if the load voltage V_L becomes less than the control voltage, then the output will go "high" and the relay will become inactive and so will be the buzzer and the LED D_3 also. The load will again be connected with the load voltage V_L and the normal condition indicating green LED D_2 will glow.

The battery connected in the power supply V_{CC2} will fade earlier than that of V_{CC1}. It is because V_{CC2} has to drive more loads than V_{CC1}. However, to check the battery status closes the switch S_1 in the other direction so that only the White LED D_5 may get the power. The intensity of the LED D_5 indicates the condition of the battery charge.

Figure 4- The overvoltage protection circuit in OFF mode

IV. RESULTS AND DISCUSSION

There is a wide range to set the control voltage. The maximum performance can be achieved when the control voltage will be set to any value between 1volt to a maximum value of [V_{CC1}-1] volt. For example, in this circuit with a 9volt supply, the maximum performance or efficiency of the device can be achieved if the control voltage will be selected between 1volt to (9-1) volt or 8volt. However, according to the capacity of NE555, maximum 15volt of DC can be used as the supply V_{CC1}. Then the control voltage can be in between 1volt to 14volt. The device only works for DC load voltage V_L.

Figure 5- Control Voltage Setting.

Fig. 5 shows the setting of control voltage using a millimeter. In this case, a control voltage of 5.01 is setting and the device worked perfectly indicating a high level of sensitivity.

V. CONCLUSION

The overvoltage protection circuit is implemented using 555 timer, diode, relay, resistors and capacitors. It is portable in size and reliable. The system is very sensitive to respond any rise in voltage that can be set in the device. The system is simulated in Proteus Professional Software and experimentally tested after implementing it on veroboard. It is found that the system works satisfactorily and the experimental results are almost same.

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