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Design and Simulation of a Microcontroller Based Loudspeaker Protection System Against Amplifier Direct Current (D.C) Offsets

[1]Abiodun. A. Ogunseye and [2]Olamide O. Olusanya
[1,2]Department of Electrical/Electronics & Computer Engineering
Bells University of Technology,
Sango-Otta, Nigeria
[1]abbey_ogunseye@yahoo.com, [2]olamide4jc@yahoo.com

***Abstract*—A number of failure mechanisms can result in the damage of loudspeakers that are directly connected to an audio power amplifier system. One of such failure modes occurs when the amplifier circuit develops an output d.c voltage, in which case, the loudspeaker coil will be damaged by overheating. D.c offset detection circuits, usually based on simple transistor circuits are normally used to protect the loudspeaker against this failure mode. However, as effective as they are, these circuits can fail in ways that can result in loudspeaker damage. In this work, a microcontroller based circuit that monitors the critical components of a loudspeaker d.c detection circuit, namely the switching transistor and the isolating relay circuit was developed. The hardware of the developed circuit was modelled with Proteus® software and its firmware was written using MikroC® software. The modelled circuit successfully detects the presence of d.c signals and also reports the states of the isolating relay and the switching transistors when these components fail.**

Keywords—* *Microcontroller, Loudspeaker, d.c Offset, Protection, Relay

I. Introduction

Public address systems are useful in disseminating audible information to a group of people. Most public address systems consist of microphones(s), audio power amplifier(s) and loudspeaker subsystems. The public address (P. A) system, like similar electronic products, is usually designed for a high level of reliability. However, the failure of the audio power amplifiers and loudspeakers will affect the operation of the entire P. A. system. Common causes of loudspeaker failure are voice coil overheating and excessive cone displacement [1]. The voice coil of a loudspeaker can develop overheating problems if it is overdriven by applying excessive audio or d.c signals for an appreciable period. Audio power amplifiers can fail in many ways, one of which is the development of large offset d.c signals at their output.

Loudspeaker systems are easily damaged when they are powered from d.c sources for an appreciable time. This can happen when the loudspeaker is directly coupled to an amplifier that has developed output d.c errors. In some amplifiers, a network that has the ability to isolate d.c signal-usually a single coupling capacitor-is used in coupling the amplifier output to the loudspeaker. However, some authors [2, 6] are of the opinion that such capacitors can introduce distortions into the signal chain. Direct coupling of the amplifier to the loudspeaker has been touted as capable of producing good sound quality. Thus, a large number of audio power amplifiers are operated on the split supply philosophy to ensure direct coupling to the loudspeaker unit [5]. As simple as this concept is, there are problems associated with it. Such problems include amplifier turn-on and turn-off transients and the possible production of an output d.c offset voltage by the amplifier.

Several circuits have been proposed to solve this d.c offset problem. Most of these circuits are based on simple transistor circuits that detect the presence of d.c signals and isolate the loudspeakers from the output of the audio power amplifier with the use of mechanical relays or electronic switches [4]. These circuits are mostly adequate, but they can fail in ways that can render them ineffective, thereby endangering the life of the connected loudspeaker system.

Fig. 1 shows the schematic diagram of the output stage of a typical d.c offset protection circuit. In this circuit, if the transistor Q3 fails or the relay coils are open circuited or the relay contacts are shorted together, the loudspeaker unit will not be adequately protected. This may go unnoticed for a long time because the output of the amplifier may be connected permanently to the loudspeaker by such faults. In the event of an output offset voltage in the audio power amplifier, there is a risk of damage to the loudspeaker unit(s), which most times, are more expensive than the cost of the protection circuit. A way of solving this problem is to monitor the states of the critical components of the protection circuit and indicating to the user whenever any of them is faulty.

In this work, a microcontroller based loudspeaker d.c offset protection circuit that also monitors the states of the transistor switch and the connecting relay was designed. The circuit has a liquid crystal display unit that displays the states of the key components whenever the circuit is powered on. There is also a provision for the user to test the circuit by pressing a single push button switch.

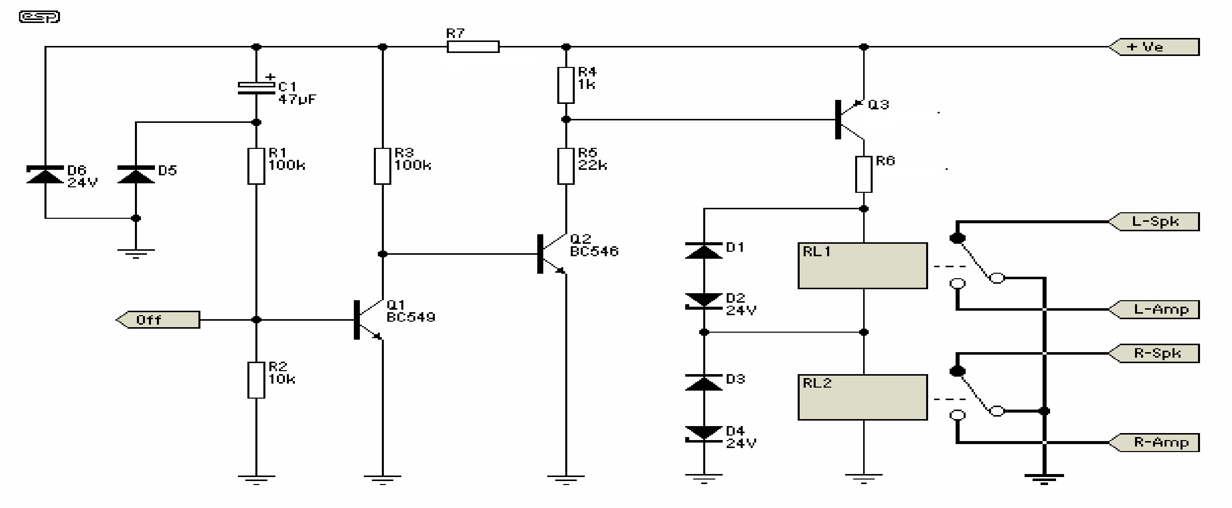

Fig.1. The output stage of an offset protection circuit [4].

The designed circuit offers a higher level of protection in comparison to conventional d.c offset detection circuits used in protecting loudspeakers. This circuit displays a message on the LCD screen and also light an LED when there are problems with the switching transitor and relay. In conventional loudspeaker protection circuits, such failures can go unnoticed until they result in the damage of the protected loudspeaker unit.

II. METHODS

A. The Hardware

The circuit of the loudspeaker circuit proposed in this work, like other loudspeaker protection circuits [3,4,6], essentially extracts the d.c offset voltage from the output signal of the audio power amplifier and isolates the loudspeaker from the output terminals of the audio power amplifier if this d.c voltage is too high. This circuit however differs from conventional circuits in its ability to detect if there are problems with the switching relay and transistor. To achieve this, the circuit is based on a simple microcontroller unit.

The d.c offset protection circuit, designed around a PIC16F877A microcontroller unit, is shown in Fig. 2. The circuit essentially monitors the output of the amplifier circuit for possible d.c offset voltage. When such fault is detected, the loudspeaker unit is disconnected from the amplifier through an electromechanical relay (RL 1).

The audio signal from the audio power amplifier is low pass filtered, attenuated and then d.c level shifted by the network formed by resistors R16, R17,R18 and R21 and capacitor C6. A 4.7 volts zener diode is used to limit the maximum output voltage of this network to 4.7 volts to protect the microcontroller's analogue input against overload condition. Under normal quiescent condition, the values of the resistors are selected such that the output voltage of the network is 2.5 volts to ensure good dynamic range. This network was designed to reduce the amplitude of the input d.c offset voltage by a factor of three. Capacitor C6 and resistors R16,R17, R18 and R19 form a simple single pole low pass filter with a cut-off frequency of 0.145 Hz. This filtering operation is required to extract the d.c offset signal from the composite audio output signal of the audio power amplifier. Such a low filter cut-off frequency ensures that high frequency audio signals are sufficiently attenuated by the simple first order filter.

To test the contacts of the relay for short circuit conditions, it was necessary to pass a small current through the loudspeaker unit under software control. The microcontroller pin RD6 is used to generate a logic signal which is then buffered by the class B emitter follower circuit, formed by transistor Q2 and Q3. The buffer circuit ensures that the current drawn from pin RD6 is sufficiently low to prevent damage to that pin and the microcontroller chip. The test current is limited by resistor R5 to 5 mA with a 5 volts supply voltage.

The drain voltage of the switching transistor Q1 is sampled by the microcontroller through resistors R2, R20 and zener diode D2. The actual output voltage of the buffer network and the voltage at the normally closed contacts of the relay are also sampled by the microcontroller through component R9, D4 and R6, D3 respectively. Diodes D2 and D4 are used in protecting the respective microcontroller input/output pins against possible damaging overvoltages.

A liquid crystal display unit (LCD) is used to display error messages. LED (D14) glows whenever a d.c offset voltage is detected or when any of the critical components (RL1 and Q1) is faulty. A pushbutton switch allows the tests to be carried out by the user anytime.

B. Mode Of Operation

When the circuit is powered on, it switches off Mosfet switch (Q1) and reads the voltage at the drain of the MOSFET.

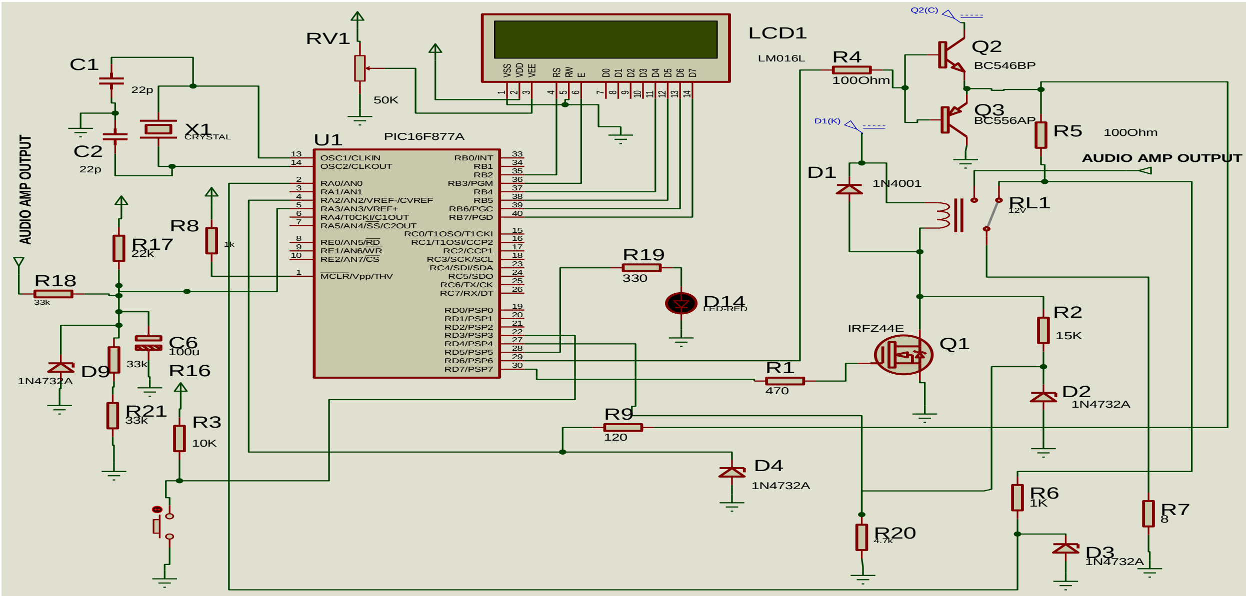

Fig. 2. The circuit diagram of the offset protection circuit

If this voltage is close to the power supply voltage, then it implies that the relay coil is continuous. If this voltage is close to ground, then the relay coils are either open circuited or the MOSFET's drain-source terminals are shorted together.

The circuit then turns on the MOSFET and reads the drain voltage of the MOSFET. This voltage is expected to be close to zero volts if the MOSFET switch is working properly and the relay coil is continuous. In this test, the duration of the pulse is about 100us which is not long enough to result in the activation of the relay. The states of the MOSFET switch and that of the relay coil are inferred from these procedures.

If the tests show that the MOSFET switch and the relay coils are working properly, the relay contacts are the tested. The circuit measures the resistances of the loudspeaker when the relay is energised and de-energised. The state of the relay contact is determined by comparing the relative values of the measured loudspeaker resistances. It is assumed that a loudspeaker unit with finite resistance value is already connected to the circuit.

The circuit continuously samples the output voltage of the connected audio power amplifier for the presence of d.c error voltage every millisecond. If the d.c error voltage exceeds 200 mV continuously for more than a second, the loudspeaker is disconnected from the amplifier output to prevent loudspeaker damage.

C. Tests

The developed circuit is tested for the detection of transistor drain-source short-circuit, relay contact short-circuit and amplifier output offset. The normally open contact of the relay was actually short-circuited to the moving contact of the relay to simulate a shorted relay contact condition. To simulate a short circuit MOSFET condition, the drain and the source terminals of the transistor were short-circuited. A 10 volts sinewave signal with a frequency of 100 Hz and a d.c offset of 2.5 volts was applied to the input of the circuit to test the circuit's response to the presence of d.c offset signal.

III. Results

Fig. 3 shows the message displayed on the LCD screen whenever the output switch Q1 is short circuited. Fig. 4 shows the message on the LCD unit when the relay contact are shorted together. As seen in Fig.5, the circuit displays a 'DC detected' message on the LCD unit, lights a warning LED and disconnects the loudspeaker from the amplifier output when a d.c offset is detected in the output amplifier signal.

IV. Conclusion

A d.c offset detection circuit for loudspeaker protection that can monitor the states of the output relays and the MOSFET switch was developed. The developed circuit isolates the loudspeaker from the output terminal of the audio power amplifier when a d.c offset signal is detected at the amplifier's output terminal. The circuit also monitors the states of these devices and reports the same to the user through a liquid crystal display unit.

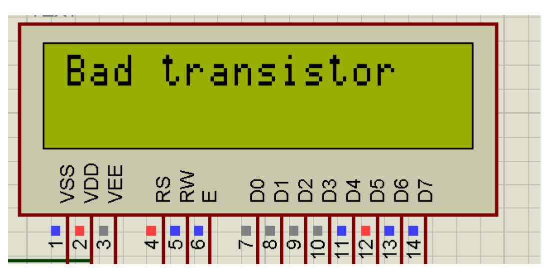

Fig. 3: The LCD message with the drain-source terminal of the switching transistor shorted

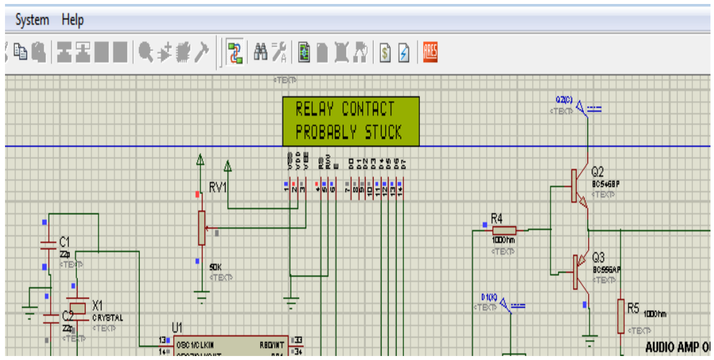

Fig. 4: The LCD message of the circuit with shorted relay contacts

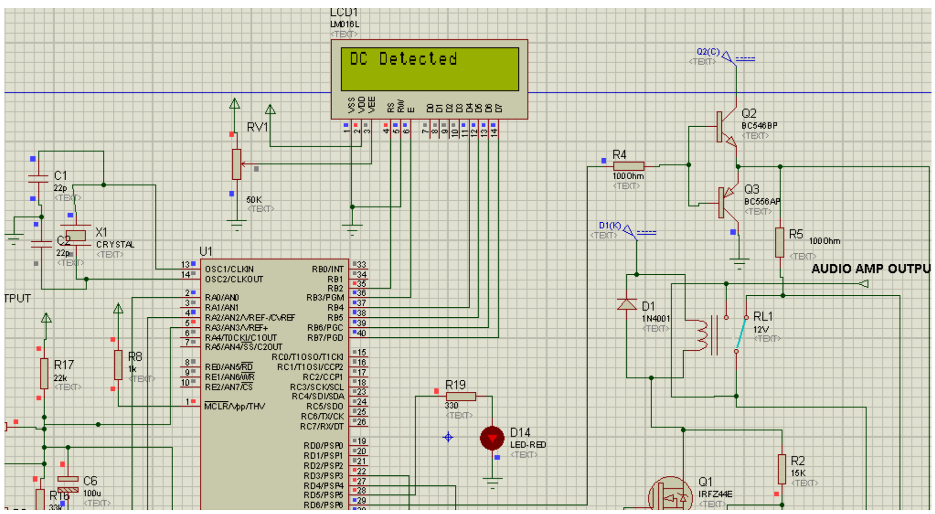

Fig. 5: The LCD message of the circuit when a direct current signal is detected.

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