Automatic Loudness Control System for Surround Sound Speaker System Using Ultrasonic Sensor

Alwary Suhaimy bin Johari
Faculty of Electrical Engineering
Universiti Teknologi MARA Malaysia
alwary84@yahoo.com

Abstract *– This project deals with designing equal loudness perception of a listener when surrounded by surround sound system. The loudness of the speaker is controlled to be inversely proportional to their distance between the speaker and the listener. Sensors, microcontroller and digital volume controller is used to achieve a perception of equal loudness from the speakers*

Keywords – Ultrasonic Sensor, Surround Sound System Amplifier, Digital Potentiometer (DS1669), PIC16F873

1.0 INTRODUCTION

The objective of this project is to design an equal loudness perception by a listener sitting anywhere inside a surround sound speaker system. This circuit is designed for Shinkawa Amplifier (AC-3) model for prototyping purposes. Other system may require different modification.

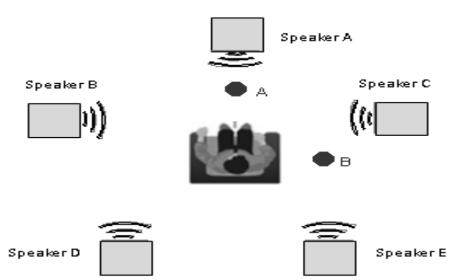


Figure 1.0: Concept of surround sound system

Concept of surround sound system is to provide a real sound situation as seen on television. The speakers are placed at minimum five different places to produce this reality situation. To hear the balance sound produced by the speaker system, the person need to sit at the centre of the hall, and the speaker also need to be arrange at equal distance from the listener as shown in Figure 1.0. The problem is if the person sits at point A as shown in Figure 1.0, speaker A will be louder then the speaker D and E destroying the perception of reality.

2.0 SCOPE OF WORK

In designing the system, several studies were done. Firstly, the analysis about the speaker was to be done to find the suitable point of control. The operation of was studied and understand. On the software side, study and practice of operation of MPLab IDE was conduct in order to program software for the PIC microcontroller. Then the study on PROTEL DXP was done to produce nice and perfect printed circuit board (PCB) hardware for the circuits. After completing the PROTEL artwork, the next step was fabricate the PCB. First, the board was drill by CNC and Milling machine. Then plating process was done for dual layer PCB. After platting process, photoresist was applied to the board, and the photoresist was exposed to UV light. Before that, mask was applied above the photoresist. Then developing process in was done to the board to remove the unexposed photoresist. Lastly was the etching process to remove the unneeded copper.

3.0 METHODOLOGY

In this project, there are three circuits that will be combined together namely the sensing part, volume control part and the controller parts. Figure 3.0 shows the general process in this project. It starts with the sensor detect the distance of the person. Then the microcontroller calculates the distance and the volume were controlled due to the distance of the person.

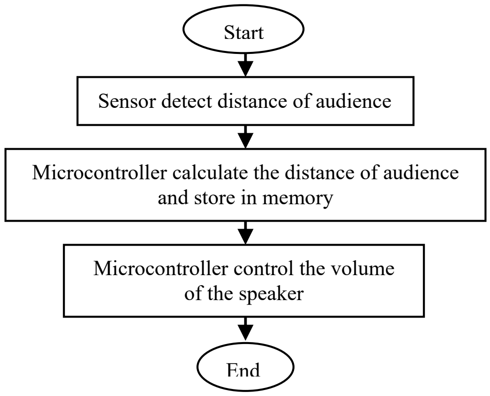


Figure 3.0: Flow chart for general process in this project

3.1 Block Diagram

Figure 3.1 is the block diagram for this circuit. Input output port from speaker was modified by removed the potentiometers and was replaced by jumper wires. The jumper wires are connected to the volume control circuit. The sensor was mounted above the speaker to generate distance between speaker and a person. It was connected at sensor input/output port. Volume control circuit is combined together in controller circuit which contain the PIC microcontroller.

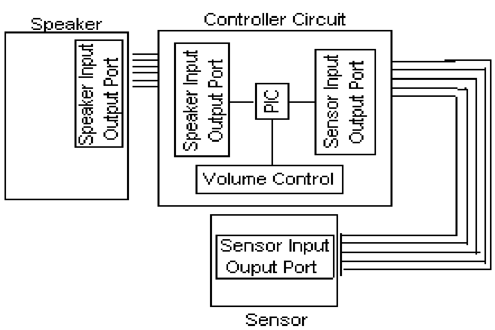


Figure 3.1: Block Diagram For this project

3.2 Sensor

The sensor use is the ultrasonic sensor because this sensor is the most suitable to detect movement and displacement of the person. By calculating the delay between it transmit and receive the wave, the distance of an object can be measured. A sensor which has two important devices which was transmitter and receiver contains several circuits.

3.2.1 <u>Transmitter Circuit.</u> To drive the transmitter, inverter is used. Two inverters are connected in parallel to increase the electrical transmission. The phase with the voltage to apply to the positive terminal and the negative terminal of the sensor was 180 degrees shifted. The output from PIC is +5V, so transistor was used to amplify the voltage to +9V to drive this circuit. CMOS inverters were used to increase the possibilities to do ON/OFF at high speed comparatively.

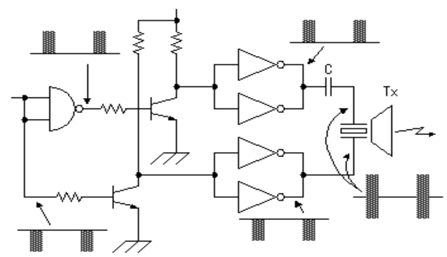


Figure 3.2: Transmitter Circuit

3.2.2 <u>Signal Amplification Circuit.</u> The ultrasonic signal which was received with the reception sensor was amplified by 1000 times (60dB) of voltage with the operational amplifier with two stages. It was 100 times at the first stage (40dB) and 10 times (20dB) at the next stage. The circuits work with the single power supply of +9 V. Then, the positive input of the operational amplifiers will be half of the power supply voltage. Therefore the alternating current signal can be amplified on 4.5V central voltage. When using the operational amplifier with the negative feedback, the voltage of the positive input terminal and the voltage of the negative input terminal become equal approximately. By this bias voltage, the side of the positive and the side of the negative of the alternating current signal was equally amplified [3].

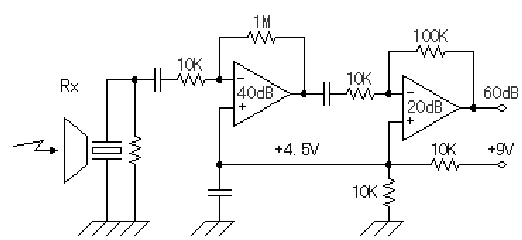


Figure 3.3: Signal Amplification Circuit

3.2.3 Detection Circuit. The detection circuit was detected the received ultrasonic signal. This was the half-wave rectification circuit with Shottky barrier diodes. The Shottky barrier diodes were used because the high frequency characteristic is good.

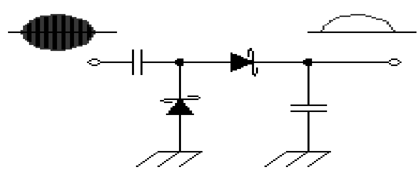


Figure 3.4: Transmitter Circuit

3.2.4 Signal Encoding. This circuit detects the reflected ultrasonic wave which returned from the measurement object. The output of the detection circuit was detected using the comparator. The operational amplifier amplifies and encodes the signal to digital form. Refer to Figure 3.5, when the positive input becomes higher than the negative input, then the output approximately reaches Vcc.

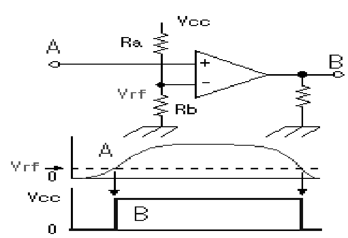


Figure 3.5: Signal Encoding Circuit

When the positive input becomes lower than the negative input, then the output will reach Vrf which is approximately 0V. The output of the detection circuit was connected to the positive input of the signal encoder and the voltage of the negative, Vrf input is made constant [2].

$$Vrf = \frac{Rb \times Vcc}{Ra + Rb} = \frac{47k\Omega \times 9v}{1M\Omega \times 47k\Omega} = 0.4v \qquad \text{Equation (1)}$$

3.2.5 Signal Holding Circuit. Signal holding circuit was used to hold the detected signal using SR flip-flop [1]. Other function of this circuit was to prevent wrong detection of the signal. Once the transmitters send the pulse, the receiver will capture the wave, but it not recognizes whether the wave is reflected wave or the wave that is directly from the transmitter. The detector was designed for receiver to not operate about the first 1.5 ms. This operation was programmed in PIC.

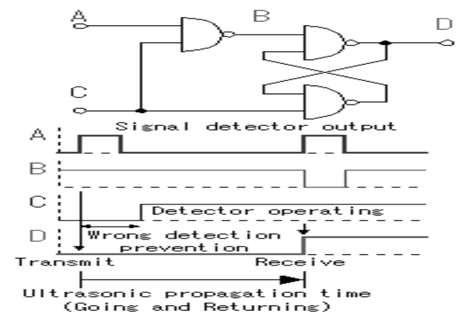


Figure 3.6: Signal holding circuit

3.3 Volume Control

The output and input from the PIC microcontroller was in digital, so the volume of the speakers needs something that can be control digitally. To control the volume of the speaker, some analogue potentiometer needs to be replaced by digital potentiometer. DS 1669 with 8 pins integrated circuit was the answer. This 8-pin IC known as digital potentiometer will replace the analogue potentiometer and the volume was controlled digitally by microcontroller. To decrease or increase the resistance of the digital potentiometer, 0V or ground pulse was send to UC or DC terminal respectively [9].

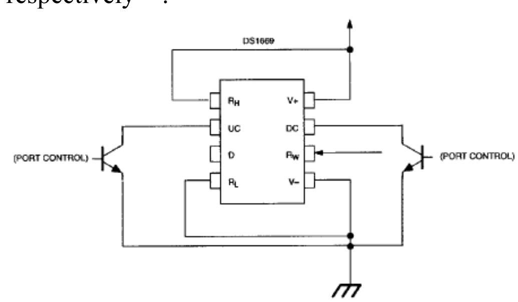


Figure 3.7: Digital Volume Control Circuit [9]

3.4 Controller Circuit

PIC16F873 was used because of the number of input/output port fulfil the requirements. DS 1669 need two inputs for each IC, so for five speakers, it needs ten inputs from microcontroller. Microcontroller also needs five output ports for selecting actives speaker. So the circuit needs at least 15 pins input/output port at microcontroller.

3.4.1 PIC16F873 Operations. Figure 3.8 shows the sequences that were programmed in the PIC. This flowchart is just the basic flow and not the detail of programming that will be programmed in the PIC.

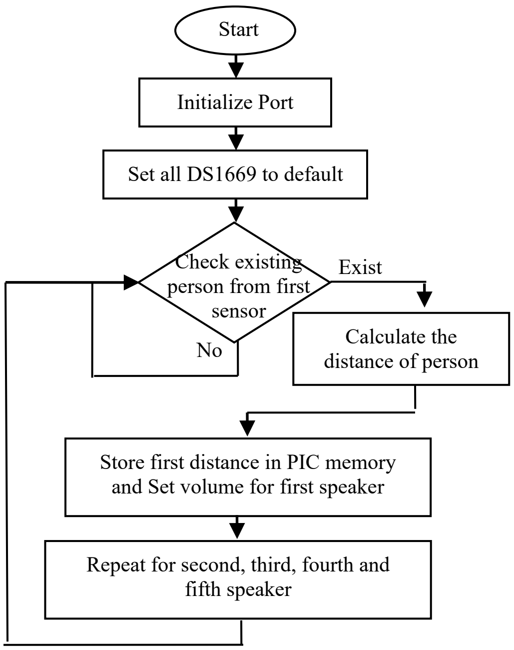
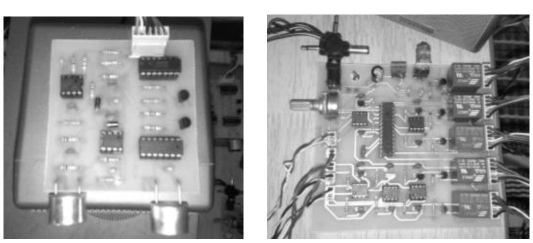


Figure 3.8: Flow chart for Basic PIC process

3.5 Hardware Design

Figure 3.9(a) is a sensor circuit. It was placed above the speaker, so that it can calculate the distance from the speaker to the person. Figure 3.9(b) is controller circuit and volume controller circuit. There were 12 outputs to control the volume and 30 output for activate five sensors.

Figure 3.10(a) shows the amplifier with five speakers mounted with sensor and figure 3.10(b) was close up view which sensor was mounted above the speakers.



(a) Sensor Circuit **(b) Controller Circuit**

Figure 3.9: Circuit for sensor, controller and volume control

(a) Surround Sound speaker system with sensors **(b) Ultrasonic sensor mounted above speaker**

Figure 3.10: Surround sound speaker system with sensor

4.0 RESULT

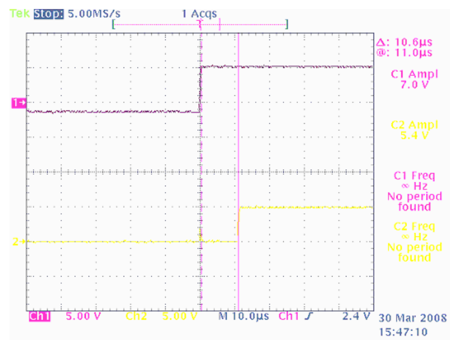


Figure 4.0(a): Ultrasonic sample at distance of 10cm

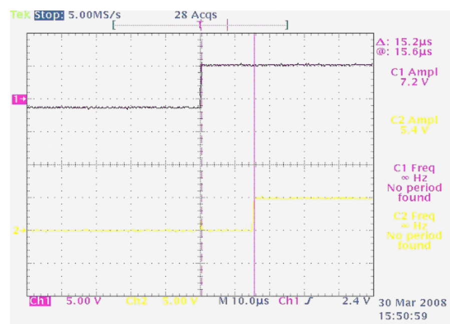


Figure 4.0(b): Ultrasonic sample at distance of 20cm

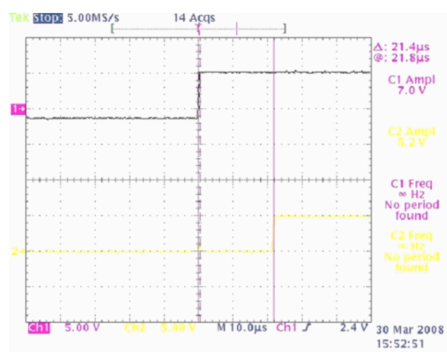


Figure 4.0(c): Ultrasonic sample at distance at 50cm

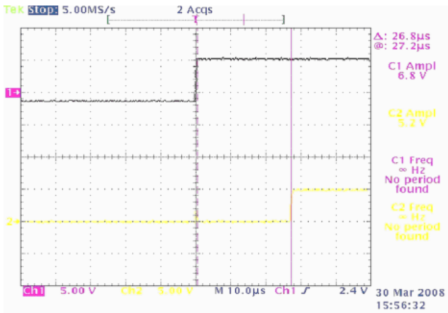


Figure 4.0(d): Ultrasonic sample at distance of 100cm

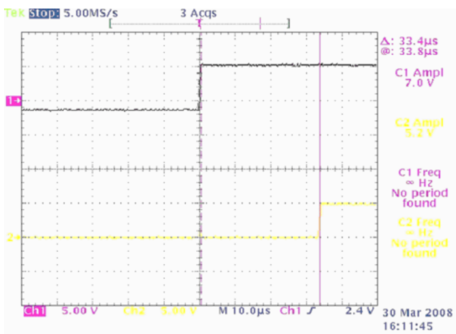


Figure 4.0(e): Ultrasonic sample at distance of 200cm

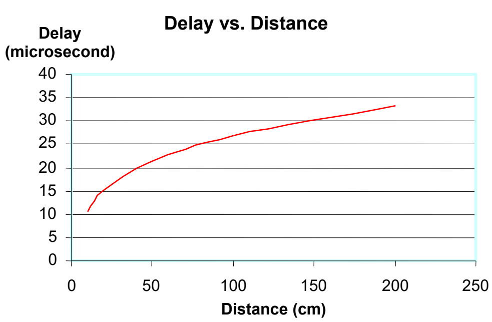


Figure 4.1: Graph Delay vs. Distance

As the result from this project, figure 4.0(a), 4.0(b), 4.0(c), 4.0(d) and 4.0(e) shows a delay that was from ultrasonic for different sample of distance. Figure 4.1 is a plotting graph between delay and distance from the sample taken.

5.0 DISCUSSION

From figure 4.1, it shows that the delay from transmitter transmits and receiver receives reflected wave was not proportional to the distance, so there was a difficulty to implement the calculation in the PIC microcontroller. Base on this problem, it was aspect that the volume of the speaker will not correctly control because of the imperfect calculation.

The digital potentiometer worked by sending 5V pulse to base terminal of transistor as shown in figure 3.7. If longer the pulse performed, the resistance will decrease or increase gradually. Even though the microcontroller send same period of pulse, other digital potentiometers were not worked with same range with each other. In other words, each five digital potentiometers having different period of pulse to control the resistance thus making the volume of the speaker become unbalance with each other. It was aspect that a speaker itself having different consumption powers while it was manufactured. For example, power consumption value for center speaker was not same as power consumption for right left speaker because center speaker having one speaker only but front speaker having two speakers which was right and left. So, the prototype amplifier circuit for center and front speaker having different design, giving different output with each other. The pulse sent was produced different number of step for the digital potentiometer so it will produce different value of resistance.

In addition, it was complicated to control the digital potentiometer because of the limitation on the device. The device has no limit to the number of input. Even though the digital potentiometer reached to the maximum or minimum resistance, there was still an input from the microcontroller. For example, when the digital potentiometer was set to the highest resistance, the resistance was saturated and the resistance cannot reach higher anymore. But there was still an input from the microcontroller if the sensor detects the person moving far away from the speaker. But because of the digital potentiometer was reached their maximum, the input after that was ignored while microcontroller was still writing the distance in the memory. The distance was store in the memory of microcontroller for reference. After that if the person moving near to the speaker, the microcontroller send the input to decrease the volume, thus making the speaker slowing down the volume. As the result, if the person moving nearer and nearer to the speaker, it was slowing down the volume before the person reaches to the specified place because of the ignored input before. Lastly the volume will be shut down. In what ever cases, suppose the volume should not be turn off and just slowing down the volume.

6.0 CONCLUSION

The digital potentiometer was achieved best functional output because it controlled the volume digitally. It presently requires more precise input from PIC that should be accurately programmed to obtain better output.

Ultrasonic sensor was good for detecting the displacement. At this phase, the sensor generates good feedback as the reflectance wave because the circuit for the sensor was accurately design and nicely programming from PIC.

Before the controller circuit was constructed, the availability of the hardware should be known whether it is compatible with PIC and software. If not, the controller cannot produce the output as inspected. Many modifications made on the hardware before to suit this project making the controller circuit was 80% working in good condition because of the track for dual layer was imperfect.

As a conclusion, this project was not ideal. Many aspects should be considered and further study and analysis should be done to ensure the accuracy and reliability of this project. Better planning should be done to ensure the systematic and proper design in this project.

The proportionality between distances and delay was not proportional so another method that suitable should be explored to carry out this mission. Otherwise, more sample of distance is needed so a reference table can be construct and the programming can be more precise. Furthermore the microcontroller need more precisely program to make sure the perfect and accurate function.

7.0 FUTURE DEVELOPMENT

For a future development, hoping that this project will have better efficient output than before and less miscalculation produced. Further study on ultrasonic and PIC also should be done to minimize the error and accurately program. Furthermore, it is more fantastic if this project can work with existing for many audiences for example in a concert or cinema.

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