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Low Cost Screening Audiometer

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Abstract

Screening audiometer is used for the preliminary evaluation of the hearing function. Basically, an audiometer is a machine which is used to determine the hearing loss in an individual. An audiometer must be able to make all measurements quickly, precisely, and with no discomfort to the patient. It gives sinusoidal output at one of the test frequencies, calibrated in dB HL. A low cost reliable version is immensely useful for a primary health care center. The different frequencies and levels can be selected digitally using switches and the output can be obtained on a speaker. In India, 70% population is rural and the doctors have to travel long distances for attending to these masses. So, keeping this in mind it has been designed to be a light portable device.

1. Introduction

The main objective of the project was to design a low cost screening audiometer, which could give sinusoidal output at different frequencies, calibrated in dB HL and it should also display the frequency and level selected on LEDs. The design involves an 89C52 micro-controller, ICL8038 waveform generator and TDA8551 volume controller chips. ICL8038 has been chosen for generating a sinusoidal output as it gives better output than other oscillatory circuits with easy option of selecting frequencies by changing the input voltage.

2. Main Design

The audiometer has been designed to make it a low cost product. It produces different frequencies and levels of output, calibrated in dB HL, which can be selected using switches.

2.1. User Interface

The core of this module is based on AT89C52 micro-controller. This constitutes the digital part of the circuit. This is used for selecting different frequencies and different levels of attenuation. The selection made, is also displayed on LEDs and the effect of de-bouncing has been taken care of by an efficient coding. The coding has been done in assembly language. AT89C52 micro-controller has been used instead of AT29C51 micro-controller as the requirement of the I/O pins is more. So, it would have required a decoder with AT29C51, which would have increased the cost of production and also the current requirement of the circuit.

Figure 1: Screening Audiometer

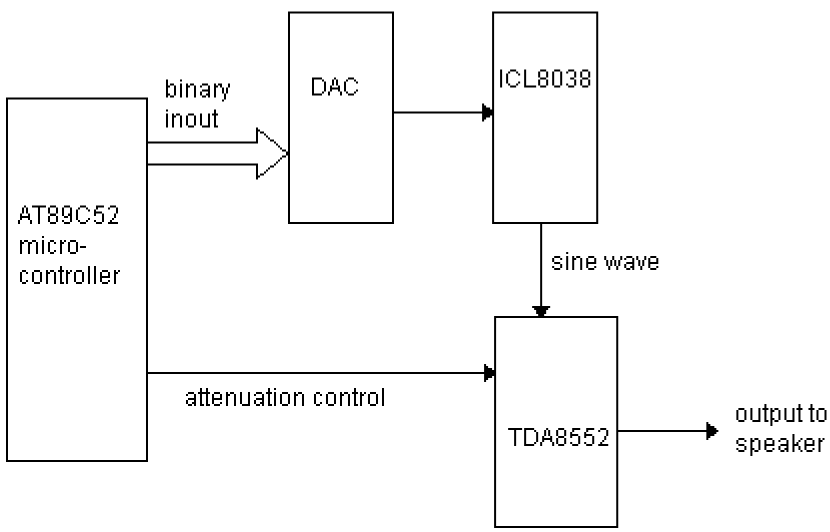

Figure 2: Block Diagram of Screening Audiometer

2.1.1.Circuit Details

AT89C52 micro-controller has been used for the digital part of the circuit as shown in Figure 3. This works on 5 V input supply and consumes 1 mA of current with a crystal oscillator of 12 MHz frequency. Port 1 has been used for giving the input to the micro-controller. The two switches on this port are capable of selecting frequency and attenuation level. Port 0 has been used for providing the input pulses to the TDA8551 volume controller and the attenuation level selected is displayed on LEDs at port 3. The port 0 has also been used to show the frequency selected by glowing a particular LED. Although, LEDs have been used in the circuit but they consume around 2 mA of current each and there are 2 LEDs simultaneously glowing. The other option was to use LCD in place of them which consumed very less current but it would have increased the cost of the product.

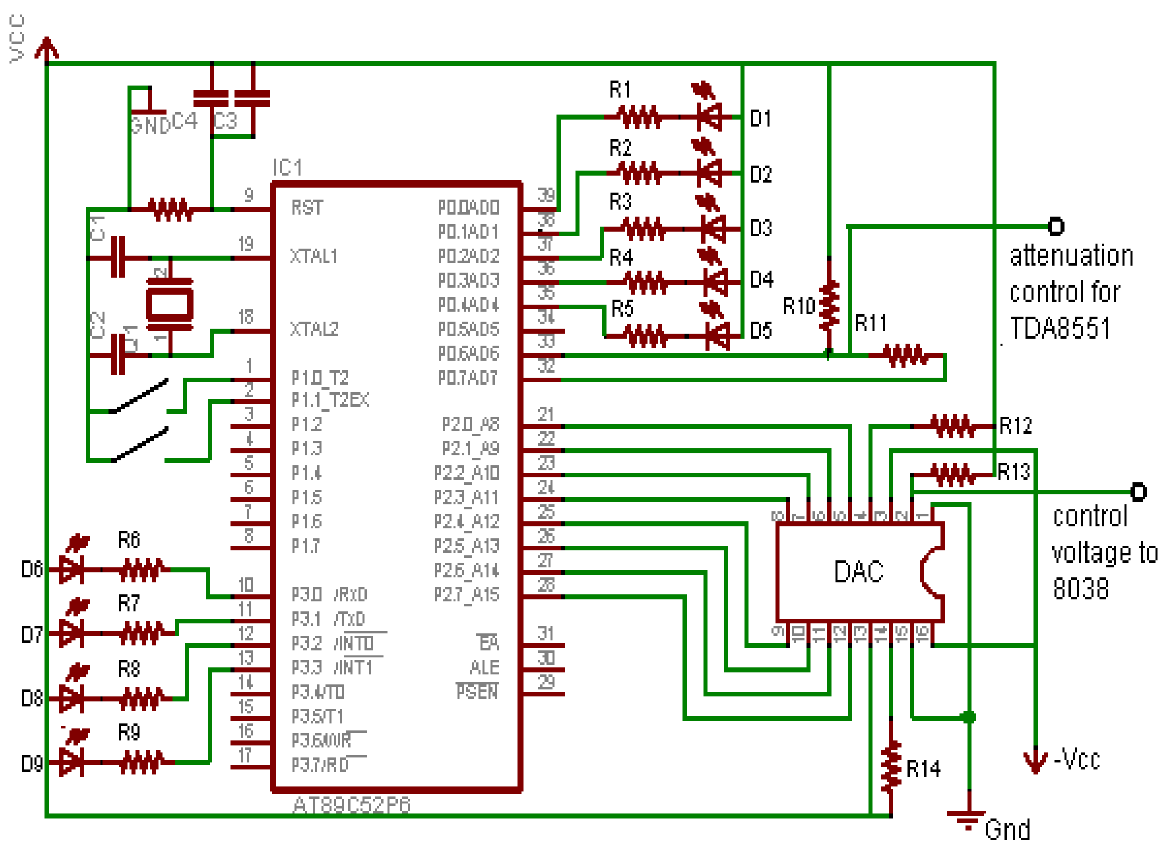

Figure 3: Schematic of the Digital Module

2.2. Waveform Generator

The ICL8038 function generator is used for sine wave generation of different frequency. It works on the principle of variable voltage input which is controlled by DAC0800, whose input is coming from the micro-controller. This chip has been selected instead of using other oscillatory circuits as it gives better waveform output. The other options are chips like MAX038 and XR8038 but they both are very costly. The circuit designed, works for frequencies between 250 Hz to 4 kHz. The frequency selection has been made discrete by providing different voltages as input to the IC to generate 250 Hz, 500 Hz, 1 kHz, 2 kHz and 4 kHz, which lie in the human audible range. A resistor network had also been tried for providing the variable input voltages but that was very sensitive to voltage supply variation.

2.2.1. Details of ICL8038

The ICL8038 waveform generator is a monolithic integrated circuit capable of producing high accuracy sine, square, triangular, saw-tooth and pulse waveforms with a minimum of external components. The frequency can be selected externally from 0.001 Hz to more than 300 kHz by providing a variable voltage input.

2.2.1.1 Features of ICL8038

The frequency of the waveform is a direct function of the DC voltage at pin no.8 (measured from pin no.6). The symmetry of the waveform can be adjusted with the external timing resistors and a variable duty cycle from 2% to 98% can be achieved. The output obtained from ICL8038 shows high linearity of 0.1% for triangle output and low distortion of 1% for sinusoidal output. The supply voltage range varies from ±5 V to ±18 V. The typical current consumes by this chip is 15 mA. One of the advantages of this chip is that it shows less drift in frequency with temperature variation.

2.2.2. Circuit Details

The ICL8038 waveform generator is capable of producing high accuracy sine, square and triangular waveforms with a minimum of external components. The oscillator is the standard ICL8038-based oscillator circuit as shown in Figure 4, taken from the ICL8038 data sheet. The timing resistor R16 has been chosen to be rather small, to give a wide range of frequencies. The duty cycle is decided by the two resistors R15 and R16 on pin no.4 and pin no.5, as shown in the circuit and the resistor R17 on pin no.12 is used for distortion control of the output waveform. The input to the chip has been given at the pin no.8 and the difference of voltages between pin no.8 and power supply at pin no.6 gives the particular frequency. As the difference between the voltages between these two pins increases, the frequency also starts increasing. The circuit has been designed to work for 250 Hz to 4 kHz and the frequencies can be digitally selected by choosing the respective voltage, which is govern by the DAC0800 connected to the micro-controller. The main problem with this IC is that it consumes a supply current of 15 mA which is not good for battery operated devices.

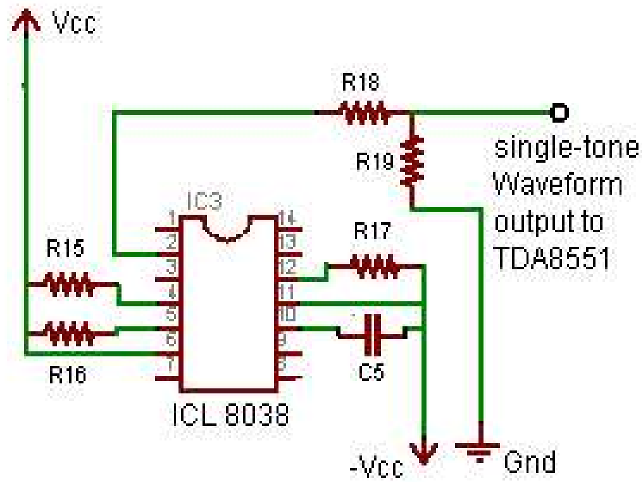

Figure 4: Schematic of Waveform Generator

2.3. Attenuation Level

This module is based on the chip TDA8551, which has a digital volume control and also contains an inbuilt power amplifier and gave 1 W output power to 8 Ω load. The chip is being used in operating mode and the input to the chip comes from ICL8038. The volume is controlled by up-down going pulses, which in turn, is controlled by the micro-controller. The circuit is shown in Figure 5, which has been taken from its data sheet. This chip reduces the cost of the circuit as a separate power amplifier is not required. Also, the attenuation levels are generated with great precision. Although, as per need, only 4 levels of attenuation are required, this chip is capable of giving gain from 20 dB to -60 dB in 64 steps of 1.25 dB. CD4066 analog switch had also been tried for generating the pulses but that was adding to the cost of the product. Earlier, instead of using TDA8551, a resistive network was also tried to act as potential divider and the input from a CD4066 was fed to the power amplifier circuit. But, to obtain the precision using that was difficult. This chip reduces the need of all these and gives a better precision.

2.3.1 Details of TDA8551

The TDA8551 is a one channel audio power amplifier capable of delivering 1 W output power to an 8 Ω load using a 5 V supply voltage. This chip contains a digital volume control and standby/mute logic. The volume can be set by UP/DOWN pulses at Terminal 1. Using the MODE pin the device can be switched to standby condition, the mute condition and the normal operating condition. Basically, the volume control operated as a digital controlled attenuator between the audio input pin and power amplifier.

2.3.1.1 Volume Control

The volume control operates as a digital controlled attenuator between the audio input pin and the power amplifier. In the maximum volume control setting the attenuation is 0 dB and in the minimum volume control setting the typical attenuation is 80 dB. The attenuation can be set in 64 steps by the UP/DOWN pin. If the UP/DOWN pin is floating it means volume will remains unchanged and the negative pulses starts setting volume towards minimum. Similarly, positive pulses lead to increase in the volume. Each pulse on the UP/DOWN pin results in a change in gain of 80/64 = 1.25 dB (typical value). In the basic application the UP/DOWN pin is switched to ground or supply voltage by a double push-button. When the supply voltage is initially connected, after a complete removal of the supply, the initial state of the volume control is an attenuation of 40 dB (low volume), so the gain of the total amplifier is -20 dB. After powering-up, some positive pulses have to be applied to the UP/DOWN pin for turning up to listening volume. When the device is switched with the MODE select pin to the mute or the standby condition, the volume control attenuation setting remains on its value, assumed that the voltage on pin does not fall below the minimum supply voltage. After switching the device back to the operation mode, the previous volume setting is maintained.

2.3.1.2 Mode Selection

The device is in the standby mode (with a very low current consumption) if the voltage at the MODE pin is between 5 V and 4.5 V. At a mode select voltage level of less than 0.5 V the amplifier is fully operational. In the range between 1 V and 3.6 V, the amplifier is in the mute condition. The mute condition is useful for using it as a ‘fast mute’; in this mode output signal is suppressed, while the volume setting remains at its value. Using the MODE pin the device can be switched to standby condition, the mute condition and the normal operating condition.

2.3.2 Circuit Details

The circuit used for this module is the standard circuit given in the data sheet of TDA8551 as shown in Figure 5. The sinusoidal input to the pin no.4 is coming from the waveform generated by ICL8038 which gets attenuated by the pulses supplied by the micro-controller at the pin no.8. The up going pulses are from 2.5 V to 5 V and down going pulses are from 2.5 V to 0 V. The micro-controller is providing these pulses from port 0 to generate required attenuation level.

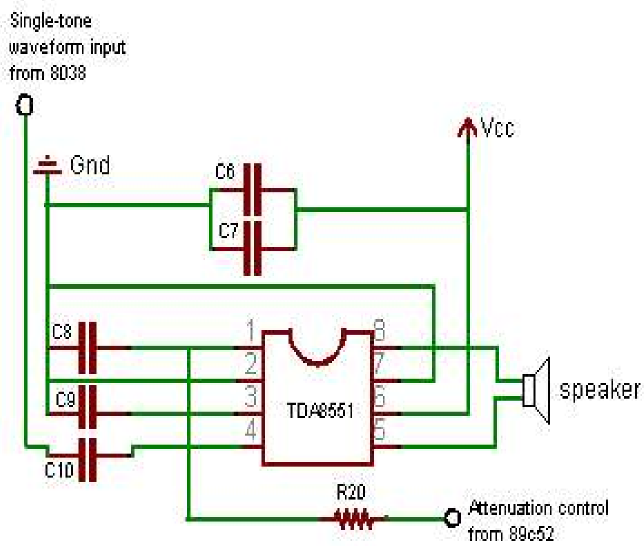

Figure 5: Schematic of Attenuation Control

2.4 Power Supply

Since, the current requirement of the circuit is high, the audiometer has been operated on main power supply of 220 V.

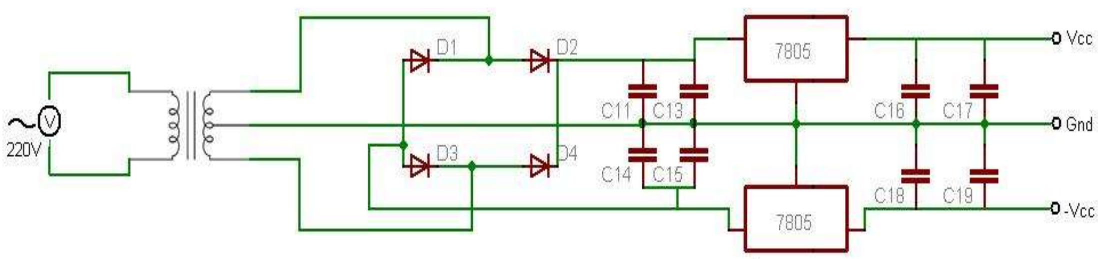

Figure 6: Schematic of the power supply circuit

2.4.1 Circuit Details

This part comprises of a 9-0-9 center tap transformer. After rectification the output is passed through the two regulators 7805 and 7905 which give +5 V and -5 V, respectively.

This also fulfills the current requirement of the circuit. IN4001 diodes have been used for the rectification. The other option to supply power to the circuit was using battery but the battery was unable to fulfill the current requirement of the circuit.

3. Component List of the Circuit Design

IC requirement

1. AT89C52 micro-controller
2. TDA8551 having digital volume control
3. ICL8038 Waveform Generator
4. DAC0800

Table 1 Resistor Values

Serial no.	Resistor	Values
1	R1, R2, R3, R4, R5	470 Ω
2	R6, R7, R8, R9	330 Ω
4	R10, R11, R12, R13, R14	5.5 kΩ
5	R15,R16	5.5 kΩ
6	R17	82 kΩ
7	R18, R19	22 kΩ

Table 2 Capacitor Values

Serial no.	Capacitor	Values
1	C1, C2	0.3 pF
2	C3	10 uF
3	C4	10 nF
4	C5	330 nF
5	C6	220 uF
6	C7	100 nF
7	C8	100 nF
8	C9, C10	3300 pF
9	C11,C14	2200 uF
10	C13,C15	0.1 uF
11	C16,C18	10 uF
12	C17.C19	0.1 uF

4. Observations

Table 3 Output Voltage Level after Attenuations

Serial No.	Level of output calibrated in dB HL	Output Voltage
1	100	2 V
2	80	0.2 V
3	60	15 mV
4	40	Could not be measured

Table 4 Voltage Input to ICL8038 for Frequency Generation

Serial No.	Frequency	Input Voltage
1	4 kHz	4.1 V
2	2 kHz	4.4 V
3	1 kHz	4.8 V
4	500 Hz	4.85 V
5	250 Hz	4.9 V

4.1.Current Requirements

1. ICL8038 waveform generator : 15 mA
2. DAC0800 : 4 mA
3. TDA8551 : 6 mA

There are two LEDS which glows simultaneously during the operation. So, the total current requirement of the circuit is approximately 30 mA.

5. Conclusion

Early detection and intervention can dramatically improve the lives of hearing-impaired children. The doctors can use the screening audiometer for testing the hearing ability of an individual. The audiometer designed, is a portable device, used for measuring hearing function. It is a low cost product and can be operated with the main power supply of 230 V. The device is a digitally operated product, which makes it easier to handle. There are five frequencies in audible range and four attenuation levels which are available in the product. The product obtained is a good example of trade off between cost and operation.

6. Future Scope

There can be lot of improvements which can be made in designing audiometers. Some of them are listed below

1. LCD can be used instead of LED for displaying the selection of frequency and

attenuation level because the requirement of current is less for LCD. Although, this will increase the cost of the device.

2. XR8038A can be used instead of ICL8038 because it' s output waveforms are more accurate than ICL8038. Moreover, the input supply current requirement of ICL8038 is 15 mA which is not good for a battery operated product. The other option is to design oscillator using op-amps but they are not capable of producing highly accurate waveforms, though will reduce the cost of the product.

3. Some improvements can be made for reducing the frequency change due to supply voltage variation as the supply voltage decides the frequency of waveform generated by ICL8038 which is very frequency sensitive.

4. Memory feature can also be added to the design for storing the last results performed.

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