SMART MUFFLER FOR PREVENTION OF NIHL

A MINOR PROJECT PHASE - I

Submitted by

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in partial fulfilment for the award of the degree

of

B.Tech.

in

ELECTRONICS AND COMMUNICATION ENGINEERING

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

RAMAPURAM

November - 2019

SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

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BONAFIDE CERTIFICATE

Certified that this minor project "SMART MUFFLER FOR PREVENTION OF NIHL" is the bonafide work of "DHINESH.R (RA1711004020198), JINU.S (RA1711004020193), VISHAL.K.C (RA1711004020200), MOHAMED NIHAL.B.S (RA1711004020203)" who carried out the project work under my supervision.

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INTERNAL EXAMINER - I

INTERNAL EXAMINER – II

ACKNOWLEDGEMENT

We are place on regard our deep sense of gratitude to our beloved Chancellor to **Dr.T.R. PACHAMUTHU,** for providing us with the requisite infrastructure throughout the course.

We take the opportunity to extend our hearty thanks to our Chairman, **Dr .R. SHIVAKUMAR** for his constant encouragement.

We take the opportunity to extend our hearty thanks to our Director E&T, **Dr. V. SUBBIAH BHARATHI** for his constant encouragement.

We take the opportunity to extend our hearty thanks to our Dean, **Dr. G.Selva Kumar** for his constant encouragement.

We convey our sincere thanks to our Vice Principal (Academic), **Dr**. **K.N. SRINIVAS** for his interest and support throughout this project.

We take the privilege to extend our hearty thanks to the Head of the Department **Dr. PHANI KUMAR POLASI,** for his suggestions, support and encouragement towards the completion of the project with perfection.

We express our heartfelt thanks to our faculty coordinator G. VINOTH KUMAR. Assistant professor Department of Electronics and Communication Engineering for his sustained encouragement, consecutive criticisms and Support throughout this project work.

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ABSTRACT

Using MATLAB, we designed an algorithm for analysing real time signal and calculate its pressure level in dB. It uses the muffler's built in-mic to listen to real time audio environment and captures the noise for processing. The sample recorded will be passed through a Butterworth low pass filter which can be implemented through the 'filter' command in MATLAB. The processed signal is converted to pascal's scale for measurement of sound pressure level (SPL) of the signal. When the SPL is greater than a certain threshold limit which is 85dB predicted through various medical research the signal be de-amplified or it's amplitude will be reduced automatically. Depending on the sensitivity of the hearing equipment, the SPL of the signal will be reduced below 80dB safer for the human ear. The background noise which are reduced to safer limits will be sent to the muffler's built-in speakers. Whenever there's a loud sound in the environment of a person wearing this smart muffler, he/she will be prevented from the adverse effects of NIHL. Unlike traditional mufflers they don't completely block the entire sound and depriving the person of situational awareness which is very crucial in industry, mining and military related applications. The ear muffler will be designed with a high NRR (Noise Reduction Rate) around 31 to 33 which can block sounds up to 120dB. The muffler will have a comfortable fit and variable size ear cups for wide compatibility and continued long hrs usage. Traditional mufflers can also be retro fitted with mic, speakers and controlling unit by using bone conduction technology. In existing system, the Muffler will block the entire external noise. In this system it blocks all the sound from the surrounding which is essential for situational awareness like military combat situations. Disadvantage of the muffler is voice of nearest person cannot be heard. The device is temporarily used to overcome high noise. But the devices are safe and secure. The ear protection that is used by soldiers is not comparable to the ear protection that

you will find in use in most of the civilian sector. While ear muffs and ear plugs that are used in civilian jobs tend to block out noise, military ear protection has to accomplish something slightly different. When in combat, situational awareness is one of the most essential things in the world, if you don't know what's going on around you, you will likely end up dead. How can ear protectors allow you to hear your surroundings without allowing gunshots and explosions to deafen you. In practice, you will find that military ear protectors use a simple system of noise filtration instead of pure noise isolation like standard models. This makes it so the ear protectors amplify that quieter, ambient noises but sounds which are past a certain threshold are diminished significantly. This system ensures that you do not end up going deaf because your ear protectors weren't working but it also allows you to hear an insurgent rising out of cover, ready to open fire. While these ear protectors may be more advanced, they are not unattainable for a civilian; there simply isn't much use for them.

LIST OF FIGURES

1. INTRODUCTION

1.1 NIHL:

Every day, we experience sound in our environment, such as the sounds from television and radio, household appliances, and traffic. Generally, these sounds are at safe levels that don't damage our hearing. But sounds can be harmful when they are too loud, even for a brief time, or when they are both loud and long-lasting. These sounds can damage sensitive structures in the inner ear and cause noise-induced hearing loss (NIHL).

NIHL can be immediate or it can take a long time to be noticeable. It can be temporary or permanent, and it can affect one ear or both ears. Even if you can't tell that you are damaging your hearing, you could have trouble hearing in the future, such as not being able to understand other people when they talk, especially on the phone or in a noisy room. Regardless of how it might affect you, one thing is certain: noise-induced hearing loss is something you can prevent.

In simple terms, noise-induced hearing loss (NIHL) is permanent damage to the tiny hair cells in your ears, which are responsible for sending sounds to the brain. Loud sounds produce vibrations in the hair cells which causes permanent damage to the hair cells. Hair cells are not replaceable structures. Damaged hair cells are unable to trigger electrical signals to the brain, impeding hearing. Both intense but short noises such as a nearby gunshot and repeated or continuous exposure to loud noises such as operating construction equipment can damage the hair cells.

Exposure to harmful noise can happen at any age. People of all ages, including children, teens, young adults, and older people, can develop NIHL. Based on a 2011-2012 CDC study involving hearing tests and interviews with participants, at least 10 million adults (6 percent) in the U.S. under the age of 70 and perhaps as many as 40 million adults (24 percent) have features of their hearing test that suggest hearing loss in one or both ears from exposure to loud noise. Researchers have also estimated that as many as 17 percent of teens (age 12 to 19) have features of their hearing test suggestive of NIHL in one or both ears (Pediatrics 2011), based on data from 2005-2006.

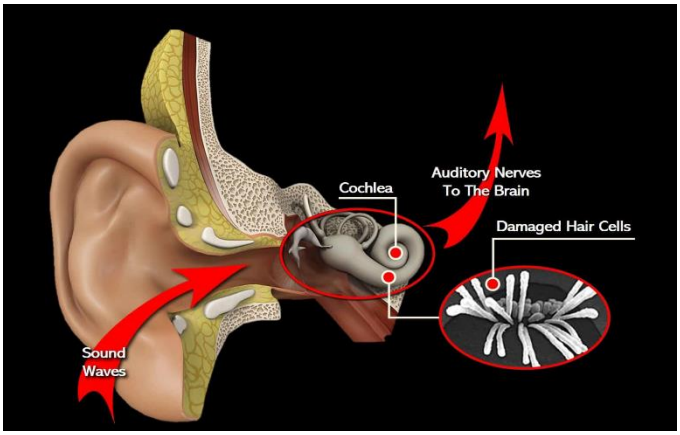


FIG 1 - VIEW OF INNER EAR

1.2 CAUSE OF NIHL:

NIHL can be caused by a one-time exposure to an intense “impulse” sound, such as an explosion, or by continuous exposure to loud sounds over an extended period of time, such as noise generated in a woodworking shop.

Sound is measured in units called decibels. Sounds at or below 70 A-weighted decibels (dBA), even after long exposure, are unlikely to cause hearing loss. However, long or repeated exposure to sounds at or above 85 dBA can cause hearing loss. The louder the sound, the shorter the amount of time it takes for NIHL to happen.

1.2.1Workplace exposure:

The most common origin of NIHL Jobs with the highest risk of noise exposure include:

- **Agriculture:** Tractors, combines, grain dryers, crop-dusting aircraft and orchard sprayers can register between 80 and 115 decibels (dB). Even pig squeals can be dangerous, measuring between 85 and 115 dB.

FIG 2 - FARMING TRACTOR

- **Construction and carpentry**: According to the Centre for Disease and Control (CDC), 44 percent of carpenters and 48 percent of plumbers report being hard of hearing.

FIG 3 – CARPENTERY WORK

FIG 4 - DEMOLITION HAMMER – CONSTRCUTION NOISE

- **Mining**: According to the CDC, nearly 50 percent of miners will have hearing loss by age 50, compared to only 9 percent of the general population. Additionally, 70 percent of miners will have hearing loss by age 60.

FIG 5 - MINING

- **Military**: Combat is loud, especially blast sounds like those from improvised explosive devices. But even just working around military equipment and even chemicals that impact hearing health, such as jet fuel can damage hearing.

FIG 6 - GATLING GUN OPERATION

TYPES OF NOISE	DECIBEL VALUE
Normal Conversation	60 – 70 dB
Movie Theatre	74 – 104 dB
Motorcycles and dirt bikes	80 – 110 dB
Music through headphones at maximum volume, sporting events, and concerts	94 – 110 dB
City Traffic	90– 129 dB
Ambulance Siren	110 – 140 dB
Fireworks show	140 – 160 dB

Table 1.1 (types of sound in decibels)

When the ear is exposed to excessive sound levels or loud sounds over time, the overstimulation of the hair cells leads to heavy production of reactive oxygen species, leading to oxidative cell death. In animal experiments, antioxidant vitamins have been found to reduce hearing loss even when administered the day after noise exposure. They were not able to fully prevent it. Damage ranges from exhaustion of the hair (hearing) cells in the ear to loss of those cells. NIHL is therefore the consequence of overstimulation of the hair cells and supporting structures. Structural damage to hair cells (primarily the outer hair cells) will result in hearing loss that can be characterized by an attenuation and distortion of incoming auditory stimuli.

1.3 EFFECT & SIGNS OF NIHL:

When you are exposed to loud noise over a long period of time, you may slowly start to lose your hearing. Because the damage from noise exposure is usually gradual, you might not notice it, or you might ignore the signs of hearing loss until they become more pronounced. Over time, sounds may become distorted or muffled, and you might find it difficult to understand other people when they talk or have to turn up the volume on the television. The damage from NIHL, combined with aging, can lead to hearing loss severe enough that you need hearing aids to magnify the sounds around you to help you hear, communicate, and participate more fully in daily activities.

NIHL can also be caused by extremely loud bursts of sound, such as gunshots or explosions, which can rupture the eardrum or damage the bones in the middle ear. This kind of NIHL can be immediate and permanent.

Loud noise exposure can also cause tinnitus-a ringing, buzzing, or roaring in the ears or head. Tinnitus may subside over time, but can sometimes continue constantly or occasionally throughout a person's life. Hearing loss and tinnitus can occur in one or both ears.

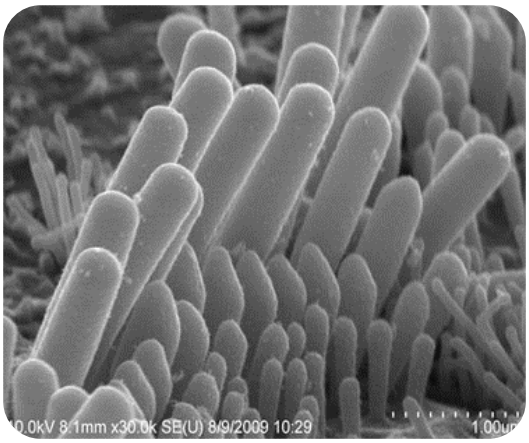


FIG 7 - INNER HAIR CELL

Sometimes exposure to impulse or continuous loud noise causes a temporary hearing loss that disappears 16 to 48 hours later. Recent research suggests, however, that although the loss of hearing seems to disappear, there may be residual long-term damage to your hearing.

Aside from damaging the hearing, loud noise exposure and NIHL can lead to:

- Stress
- Anxiety
- Insomnia, even after noise stops
- High blood pressure
- Increased heart rate
- Isolation due to hearing loss
- Depression due to hearing loss

1.4 MATLAB:

1.4.1 INTODUCTION:

MATLAB (*matrix laboratory*) is a multi-paradigm numerical computing environment and proprietary programming language developed by MathWorks. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran and Python.

Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems.

By using MATLAB software we can simulate a code that will reduce the high decibel noise and amplifies the low noise to the hearing level so that it can eliminate the high level noise from workspace so that we can hear only the normal conversation.

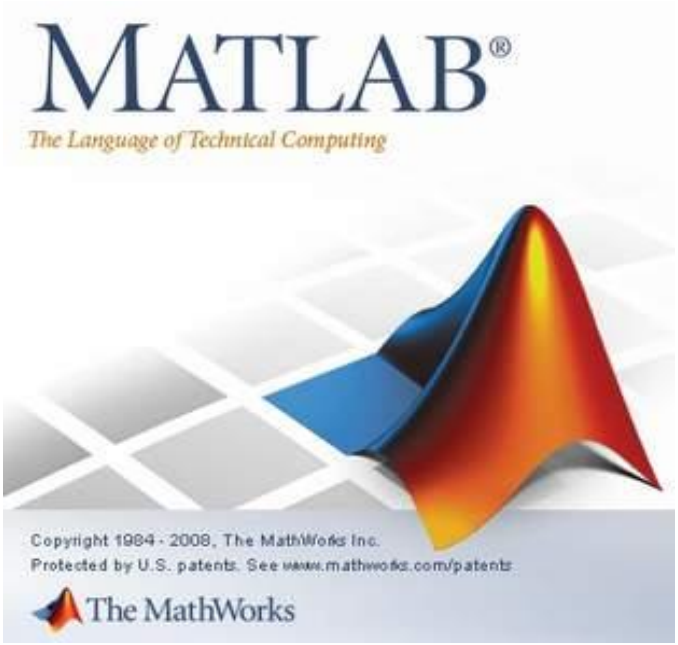


FIG 8 - MATLAB LOGO

2. LITERATURE REVIEW

2.1 EXISTING SYSTEM:

2.1.1 Noise-induced hearing loss:

Peter M Rabinowitz

American family physician 61 (9), 2759-2760, 2000

Hearing loss caused by exposure to recreational and occupational noise results in devastating disability that is virtually 100 percent preventable. Noise-induced hearing loss is the second most common form of sensorineural hearing deficit, after presbycusis (age-related hearing loss). Shearing forces caused by any sound have an impact on the stereocilia of the hair cells of the basilar membrane of the cochlea; when excessive, these forces can cause cell death. Avoiding noise exposure stops further progression of the damage. Noise-induced hearing loss can be prevented by avoiding excessive noise and using hearing protection such as earplugs and earmuffs. Patients who have been exposed to excessive noise should be screened. When hearing loss is suspected, a thorough history, physical examination and audiometry should be performed. If these examinations disclose evidence of hearing loss, referral for full audiologic evaluation is recommended. (Am Fam Physician 2000; 61: 2749-56, 2759-60.)

Noise-induced hearing loss is a sensorineural hearing deficit that begins at the higher frequencies (3.000 to 6.000 Hz) and develops gradually as a result of chronic exposure to excessive sound levels. Although the loss is typically symmetric, noise from such sources as firearms or sirens may produce an asymmetric loss. Acoustic trauma, a related condition, results from an acute exposure to short-term impulsive noise.

2.1.2 Centers for Disease Control and prevention efforts to increase awareness and prevention of noise-induced hearing loss:

Yulia Carroll, John Eichwald

The Journal of the Acoustical Society of America 145 (3), 1866-1866, 2019

For 45 years, the Centers for Disease Control and Prevention (CDC) has researched noise induced hearing loss (NIHL) in the workplace and disseminated its research to prevent occupational hearing loss. Additionally, CDC has made research and educational materials available on hearing loss in children. In 2015,

CDC received inquiries from the public and medical community about NIHL in non-workplace settings. In response, CDC began efforts to raise public awareness of NIHL and awareness about how to prevent its health effects. A CDC intra-agency working group collaborated with the World Health Organization, the National Institute on Deafness and Other Communication Disorders and the Dangerous Decibels® program for the promotion of the materials including (1) MMWR Vital Signs: Noise-Induced Hearing Loss Among Adults—United States 2011–2012; (2) CDC Public Health Grand Rounds: Promoting Hearing Health Across the Lifespan; (3) World Hearing Day educational materials; and (4) MMWR: Use of Personal Hearing Protection Devices at Loud Athletic or Entertainment Events Among Adults — United States, 2018. Additionally, CDC scientists and communicators continue to leverage internal and external channels for developing materials and spreading the word about the prevention of NIHL at work, at home and in communities. For 45 years, the Centers for Disease Control and Prevention (CDC) has researched noise induced hearing loss (NIHL) in the workplace and disseminated its research to prevent occupational hearing loss. Additionally, CDC has made research and educational materials available on hearing loss in children. In 2015, CDC received inquiries from the public and medical community about NIHL in non-workplace settings. In response, CDC began efforts to raise public awareness of NIHL and awareness about how to prevent its health effects. A CDC intra-agency working group collaborated with the World Health Organization, the National Institute on Deafness and Other Communication Disorders and the Dangerous Decibels® program for the promotion of the materials including (1) MMWR Vital Signs: Noise-Induced Hearing Loss Among Adults—United States 2011–2012; (2) CDC Public Health Grand Rounds: Promoting Hearing Health Across the Lifespan; (3) World Hearing Day educational materials; and (4) MMWR: Use of Personal Hearing Protec.

2.1.3 Listening To Music While Exercising Increases The Risk For Noise-Induced Hearing Loss:

Gabriella Messina, Alicja Stannard, Jamie Marotto

Medicine & Science in Sports & Exercise 51 (6), 838, 2019

PURPOSE: The purpose of this study was to assess the risk of NIHL among students utilizing campus recreational facilities and examine whether music used as a motivator was associated with increased risk for NIHL.

METHODS: One hundred and nineteen students were recruited from the main fitness center on college campus. Physical activity level was recalled using a modified short version of the International Physical Activity Questionnaire. Music intensity levels were assessed by a sound pressure level mannequin with a built-in microphone.

2.1.4 Assessment of occupational noise-induced hearing loss for ACC: A practical guide for otolaryngologists:

Suzanne Purdy, David McBride, Zhi-ling Zhang, Amanda Bowens, Patricia Niland

The guideline includes summaries of ACC-commissioned systematic literature reviews on key aspects of ONIHL, and references to resources to assist you to provide robust, evidence- based reports. Background information on relevant legislation and specific details of the New Zealand context, including useful guidance on carrying out assessments for third parties, are also included. See Appendix A for the 2018 Otolaryngologist Report (ACC723).

2.1.5 Prevalence of Noise-Induced Hearing Loss Among Tanzanian Iron and Steel Workers: A Cross-Sectional Study:

Israel P Nyarubeli, Alexander M Tungu, Bente E Moen, Magne Bråtveit

International journal of environmental research and public health 16 (8), 1367, 2019

Iron and steel factory workers in Tanzania are likely to develop noise-induced hearing loss (NIHL) due to exposure to high sound levels. Studies on hearing status in this population are lacking. The aims of this study were to determine prevalence of NIHL among iron and steel workers and compare hearing thresholds at different frequencies with a control group. We conducted a cross-sectional study among 221 iron and steel workers exposed to average noise level of 92 dB (A), compared with 107 primary school teachers recruited as controls and exposed to average noise level of 79.7 dB (A). We used a questionnaire-based interview to collect information on socio demographic characteristics and other confounding variables. Hearing loss was defined as hearing threshold levels≥ 25 dB hearing loss in either ear at 3000, 4000 or 6000 Hz. The prevalence of hearing loss was significantly higher among the exposed group than among the controls, ie 48% and 31%, respectively. There were significant differences in hearing thresholds between the exposed and control groups at 3000, 4000, 6000, and 8000 Hz.

2.1.6 Military grade ear mufflers and other ordinary mufflers:

- In existing system, the Muffler will block the entire external noise.
- In this system it blocks all the sound from the surrounding which is essential for situational awareness like military combat situations.
- Disadvantage of the muffler is voice of nearest person cannot be heard.
- The device is temporarily used to overcome high noise. But the devices are safe and secure.
- The ear protection that is used by soldiers is not comparable to the ear protection that you will find in use in most of the civilian sector. While ear muffs and ear plugs that are used in civilian jobs tend to block out noise, military ear protection has to accomplish something slightly different.
- When in combat, situational awareness is one of the most essential things in the world, if you don't know what's going on around you, you will likely end up dead. How can ear protectors allow you to hear your surroundings without allowing gunshots and explosions to deafen you.
- In practice, you will find that military ear protectors use a simple system of noise filtration instead of pure noise isolation like standard models. This makes it so the ear protectors amplify that quieter, ambient noises but sounds which are past a certain threshold are diminished significantly.
- This system ensures that you do not end up going deaf because your ear protectors weren't working but it also allows you to hear an insurgent rising out of cover, ready to open fire. While these ear protectors may be more advanced, they are not unattainable for a civilian; there simply isn't much use for them.

FIG 9 - MILITARY GRADE EAR MUFFLER

2.2 PROPOSED TECHNIQUE:

- Using MATLAB, we designed an algorithm for analysing real time signal and calculate its pressure level in dB.
- It uses the muffler's built in-mic to listen to real time audio environment and captures the noise for processing.
- The sample recorded will be passed through a Butterworth low pass filter which can be implemented through the 'filter' command in MATLAB.
- The processed signal is converted to pascal's scale for measurement of sound pressure level (SPL) of the signal.
- When the SPL is greater than a certain threshold limit which is 85dB predicted through various medical research the signal be de-amplified or it's amplitude will be reduced automatically.
- Depending on the sensitivity of the hearing equipment, the SPL of the signal will be reduced below 80dB safer for the human ear. The background noise which are reduced to safer limits will be sent to the muffler's built-in speakers.

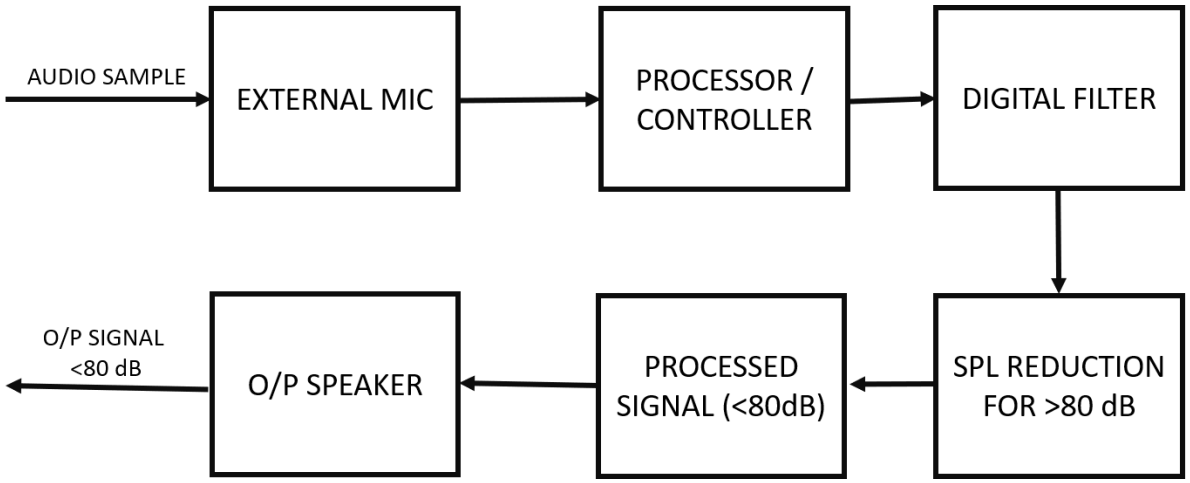
- Whenever there’s a loud sound in the environment of a person wearing this smart muffler, he/she will be prevented from the adverse effects of NIHL.
- Unlike traditional mufflers they don’t completely block the entire sound and depriving the person of situational awareness which is very crucial in industry, mining and military related applications.
- The ear muffler will be designed with a high NRR (Noise Reduction Rate) around 31 to 33 which can block sounds up to 120dB.
- The muffler will have a comfortable fit and variable size ear cups for wide compatibility and continued long hrs usage.
- Traditional mufflers can also be retro fitted with mic, speakers and controlling unit by using bone conduction technology.

3. METHODOLOGY

3.1 OPERATION:

Using MATLAB, we designed an algorithm for analysing real time signal and calculate its pressure level in dB. It uses the muffler's built in-mic to listen to real time audio environment and captures the noise for processing. The sample recorded will be passed through a Butterworth low pass filter which can be implemented through the 'filter' command in MATLAB. The processed signal is converted to pascal's scale for measurement of sound pressure level (SPL) of the signal. When the SPL is greater than a certain threshold limit which is 85dB predicted through various medical research the signal be de-amplified or it's amplitude will be reduced automatically. Depending on the sensitivity of the hearing equipment, the SPL of the signal will be reduced below 80dB safer for the human ear. The background noise which are reduced to safer limits will be sent to the muffler's built-in speakers. Whenever there's a loud sound in the environment of a person wearing this smart muffler, he/she will be prevented from the adverse effects of NIHL. Unlike traditional mufflers they don't completely block the entire sound and depriving the person of situational awareness which is very crucial in industry, mining and military related applications. The ear muffler will be designed with a high NRR (Noise Reduction Rate) around 31 to 33 which can block sounds up to 120dB. The muffler will have a comfortable fit and variable size ear cups for wide compatibility and continued long hrs usage. Traditional mufflers can also be retro fitted with mic, speakers and controlling unit by using bone conduction technology.

3.2 BLOCK DIAGRAM:



3.3 CODE:

```
rec = audiorecorder(44100, 16, 1);

disp('start speaking');

recordblocking(rec, 5);

disp('stop speaking');

wav = getaudiodata(rec);

fs_Hz = 44100;

my_cal_factor = 1.0;

wav_Pa = wav * my_cal_factor;

smooth_sec = 0.125;

smooth_Hz = 1/smooth_sec;

[b,a]=butter(1,smooth_Hz/(fs_Hz/2),'low');

wav_env_Pa = sqrt(filter(b,a,wav_Pa.^2));

Pa_ref = 20e-6;

SPL_dB = 10.0*log10( (wav_env_Pa ./ Pa_ref).^2 );
```

```
figure;
subplot(3,1,1);
t_sec = ([1:size(wav_Pa)]-1)/fs_Hz;
plot(t_sec,wav_Pa);
xlabel('Time (sec)');
ylabel('Pressure (Pa)');
subplot(3,1,2);
plot(t_sec,SPL_dB);
xlabel('Time (sec)');
ylabel('SPL (dB)');
yl=ylim;ylim(yl(2)+[-80 0]);
z = SPL_dB > 80;
d = length (z);
j=0;
for i=1:d
   if(z(i,2) == 1)
      j = 1;
   end
end
if(j == 1)
   wav_1 = wav * 0.1;
   filename = 'MKBHD1.wav';
   audiowrite(filename,wav_1,fs_Hz);
   [wav_2,fs_Hz] = audioread(filename);
```

```
    sound(wav,fs_Hz);
    pause(25);
    sound(wav_2,fs_Hz);
    wav_Pa_1 = wav_1 * my_cal_factor;
    wav_env_Pa_1 = sqrt(filter(b,a,wav_Pa_1.^2));
    SPL_dB_1 = 10.0*log10( (wav_env_Pa_1 ./      Pa_ref).^2 );
    subplot(3,1,3);
    SPL_dB_1(SPL_dB_1 > 80) = NaN;
    plot(t_sec,SPL_dB_1);
    xlabel('Time (sec)');
    ylabel('SPL_1 (dB)');
    yl=ylim;ylim(yl(2)+[-80 0]);
else
    sound(wav,fs_Hz);
end
```

4. EXPERIMENTAL WORK

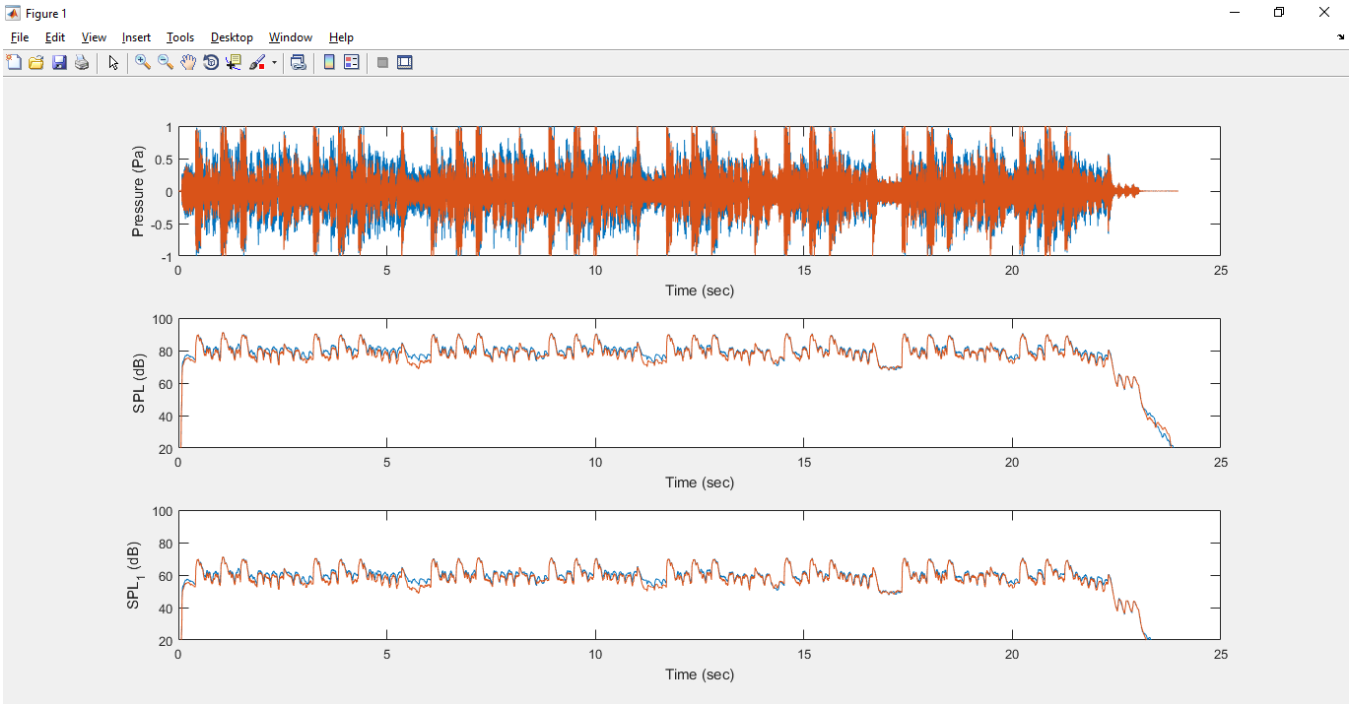


FIG 10 - SIMULATION GRAPH

- Graph 1:
  - It represents the input signal or audio sample given to the MATLAB algorithm in pascals scale.
  - X-Axis represents Time in sec and Y-Axis represents Amplitude in Pascals (Pa).

- Graph 2:
  - It represents the digitally filtered input signal or audio sample given to the MATLAB algorithm in decibel scale.
  - X-Axis represents Time in sec and Y-Axis represents Amplitude in SPL (dB).

- Graph 3:
    - It represents the output signal with decibel levels below 80 dB for NIHL prevention.
    - X-Axis represents Time in sec and Y-Axis represents Amplitude in SPL (dB).

5. CONCLUSION & FUTURE WORK

- As we were gathering the information from different sources, we had an idea to create a project for those who are working in industry, factory & military fields. Hence, we came with the conclusion of making the software part of the research idea during the current semester and expanding it to practical and real time simulations and scenarios.

- In future we planned to create a working prototype model that is cost effective and has high accuracy useful in preventing NIHL across different domains.

  .

6. REFERENCES

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2. Targeting dysregulation of redox homeostasis in noise-induced hearing loss: Oxidative stress and ROS signalling

3. Risk Assessment of Recreational Noise–Induced Hearing Loss from Exposure through a Personal Audio System

4. Use of Hearing Protection to Discriminate Between Different and Identify Individual Noise Sources to Control and Reduce Risk of Noise Induced Hearing Loss

5. Screening of noise-induced hearing loss (NIHL)-associated SNPs and the assessment of its genetic susceptibility

6. Noise induced hearing loss (NIHL) in wasit corporation textile industries

7. Conventional audiometry, extended high-frequency audiometry, and DPOAE for early diagnosis of NIHL

8. Noise-Induced Hearing Loss (NIHL): literature review with a focus on occupational medicine

9. Reducing noise-induced hearing loss (NIHL) to achieve US Healthy People 2010 goals

10. Vital signs: noise-induced hearing loss among adults—United States 2011–2012

11. Occupational noise-induced hearing loss: ACOEM task force on occupational hearing loss

12. Combined effect of smoking and occupational exposure to noise on hearing loss in steel factory workers