Team A.I (Acoustic Innovators) Noise Canceling System

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EGR 338

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Problem Introduction

A group of acoustical engineering students, known as Team Acoustic Innovators, undertook a significant project to develop a Noise Canceling System (NCS). This endeavor linked directly to the "big picture" of solving real-world problems, specifically the issue of noise pollution in urban environments. The team aimed to show how active noise control technology could be applied to create quieter, more focused spaces essential in various life aspects. They sought to demonstrate the practical application of their theoretical knowledge through this project. The Noise Canceling System was not just a technical exercise; it was a prototype that could potentially revolutionize the way individuals interact with their environment. This project was a testament to the broader movement within the technology sector to embed intelligence into daily life, enhancing usability and interaction. By doing so, the team exemplified how even subtle innovations could substantially improve living standards. The reasoning behind the development of the NCS is presented below.

I. Noise Canceling System Rationale

- Enable the creation of quiet zones in noise-polluted areas through active noise control.
- Demonstrate the integration of advanced sound technology into real-life applications.
- Develop a system that can personalize noise levels to user preferences.

The purpose of this final design project was for the team to design and prototype a Noise Canceling System that utilized advanced noise cancellation technologies. The aim was to put into practice their understanding of acoustical engineering, signal processing, and user-centric design.

It was also a step towards integrating complex technological systems into consumer products, providing a bespoke and controlled acoustic environment. The project underlined the importance of teamwork, project management, and the ability to solve real-world problems. Moreover, it provided a hands-on opportunity for the students to apply theoretical knowledge in a practical setting, equipping them for future professional roles in engineering. The project's value lay in its potential to innovate consumer electronics with personal sound management, opening new possibilities for user engagement and experience. The contributions of each team member to this project are documented in the following section:

II. Team Member Contributions

A. Saif Elsaady: Researched, and constructed powerpoint and report.
B. Scott Lidman: Circuit construction and testing, report and presentation writing
C. Angelo Navoa: Researched, and constructed powerpoint and report.
D. Elton Salt: Circuit construction and testing
E. Marla Hawthorne: Circuit construction and testing, report and presentation writing
F. Kevis Seymore: Circuit construction and testing

Problem Statement

The recently concluded Noise Canceling System (NCS) project by Team Acoustic Innovators stands as a detailed representation of a larger movement in the realm of consumer electronics and urban living solutions. The initiative saw the integration of sophisticated active noise control technology into an accessible consumer product, signifying a milestone in acoustical engineering. This progression echoed the larger trend of incorporating intelligent systems into everyday life, enhancing user experience by providing a customizable sound environment. Their efforts showcased the transformative power of such technologies to adapt and reshape modern living spaces into bastions of tranquility. The project highlighted the growing necessity for technological interventions in mitigating urban noise pollution. It reflected a comprehensive understanding of the intricate balance between technical innovation and user-centric design.

I. Development Reasoning

   A. Adaptation to Urban Noise
   B. Technological Proliferation and Accessibility
   C. Educational Significance
   D. Skill Augmentation and Professional Readiness
   E. Assessment of Market Adoption and Impact

The magnitude of the project is shown below.

II. Magnitude

Item	Quantity	Price
100uF Capacitor	2	$0.32
0.1uF Capacitor	2	$0.567

MIKROE-2859, Microcontroller	1	$15.00
CMA-4544PF-W, Microphone	1	$0.59
179-CMS-4017-34SP, Speaker	1	$6.50
658-6LF22XWA/C, Batteries	2	$3.36
485-4482, Jumper Wires	1	$9.95
700-MAX 98363 CEWL+T, Audio Amplifier	1	$2.90

Table 1. Project Magnitude

Engineering Goals

I. Engineering Goals

A. To embed an active noise cancellation mechanism within a user-friendly interface, the team engineered a compact system that harmonized with various environments.

B. To ensure a customizable noise cancellation experience, they implemented sophisticated algorithms capable of adapting to dynamic acoustic changes.

C. To promote energy efficiency, they designed the system with low-power components, maximizing battery life and device longevity.

D. To deliver high-quality sound attenuation, they meticulously selected and calibrated each component, ensuring optimal performance.

E. To pave the way for potential mass production, they developed a scalable prototype, emphasizing ease of manufacture and cost-effectiveness.

Specifications

The comprehensive project carried out by Team Acoustic Innovators culminated in the design of a sophisticated Noise Canceling System (NCS). The specific project specifications delineated by Team Acoustic Innovators are enumerated below.

I. Objectives
   A. Engineered a system that intuitively responds to environmental noise levels, offering an adaptive noise cancellation experience.
   B. Optimized the system’s energy consumption, ensuring extended operational periods and sustainable usage.
   C. Created a scalable prototype, aiming for economic feasibility in mass production without sacrificing the system's performance and quality.

II. Constraints
   A. The project timeline was constrained to an 8-week period for completion.
   B. Financial resources were restricted, necessitating efficient budget management.
   C. Access to advanced technological components was limited by market availability.

III. Deadlines
   A. By April 24, 2024 the final project documentation must be delivered.

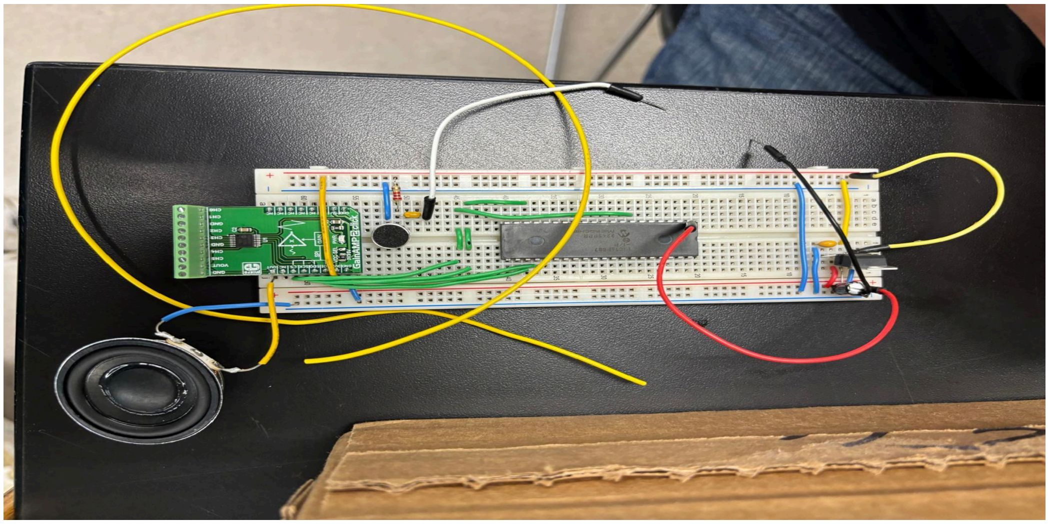
IV. Expectations
   A. The team anticipated that the NCS would redefine personal space acoustics, providing a customizable auditory environment.
   B. They also foresaw that the NCS project would serve as a benchmark for the practical application of noise cancellation technology in consumer products, influencing future innovations in the sector.

Definitions

1) **ANC (Active Noise Control):** A method of reducing unwanted sound by the addition of a second sound specifically designed to cancel the first.
2) **Acoustics:** The science concerned with the study of sound, its production, transmission, and effects.
3) **Algorithm:** A process or set of rules to be followed in calculations or other problem-solving operations, especially by a computer.
4) **Ambient Noise:** Background sound that is present in a scene or location.
5) **Battery Life:** The length of time that a battery can continue to provide power to a device before requiring recharging.
6) **dB (Decibel):** A unit used to measure the intensity of a sound or the power level of an electrical signal by comparing it with a given level on a logarithmic scale.
7) **Energy Efficiency:** The goal to reduce the amount of energy required to provide products and services.
8) **NCS (Noise Canceling System):** A system designed to cancel or reduce unwanted ambient noises.
9) **Prototype:** An initial model of a product that serves as a basis for later stages of development and testing.
10) **Signal Processing:** The analysis, interpretation, and manipulation of signals. Signals of interest include sound, images, biological signals such as ECG, radar signals, and many others.
11) **Sound Attenuation:** The reduction of sound intensity with distance or the limiting of sound transmission.

Design Solutions and Evaluations

Design I.



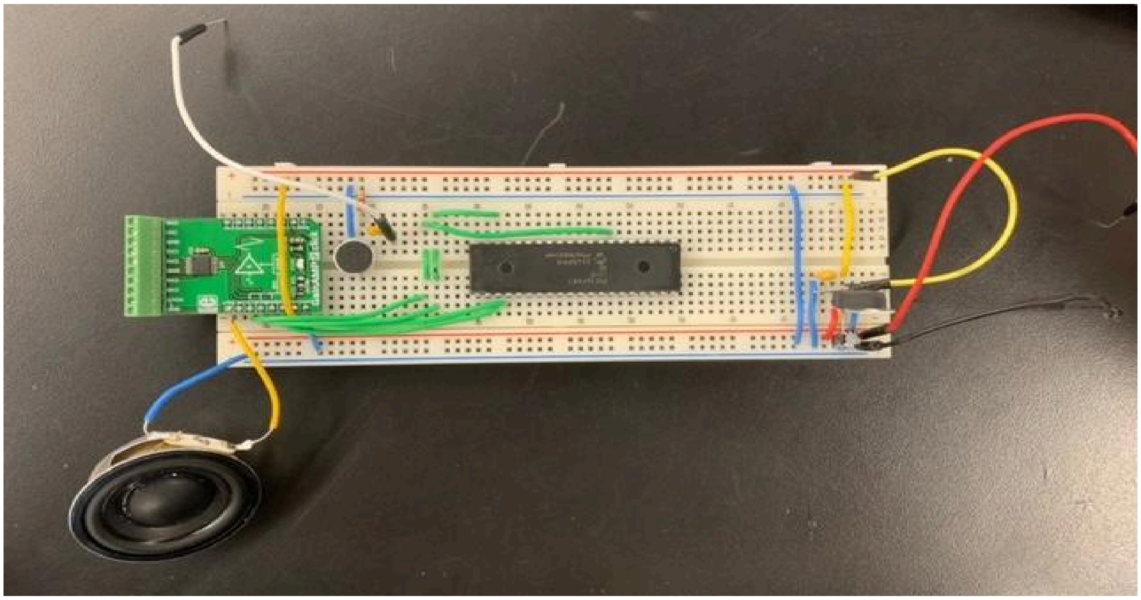
I. Attributes

- Utilizes basic capacitors for voltage stabilization and high-frequency noise filtering.
- Improved sound clarity due to effective, though basic, noise suppression with standard capacitors.
- Simple electronic components make maintenance and troubleshooting more straightforward..

II. Drawbacks

- Capacitor values are not highly precise, potentially allowing some noise through.
- Limited enhancement of sound fidelity, suitable mainly for less demanding applications.
- Less effective in dynamic environments with variable noise levels.

Design II.



I. Attributes

- Features capacitors with high value accuracy for optimal noise frequency filtering.
- Superior sound quality with minimal distortion, thanks to precise capacitor performance.
- Enhanced noise cancellation capabilities, ideal for challenging audio environments.

II. Drawbacks

A. Higher cost of precision capacitors increases overall project expense.

B. Complex configuration may require a more advanced understanding of electronics for optimal setup.

C. Potential overengineering for simple applications, making it less cost-effective for basic needs.

Selection Of Final Design

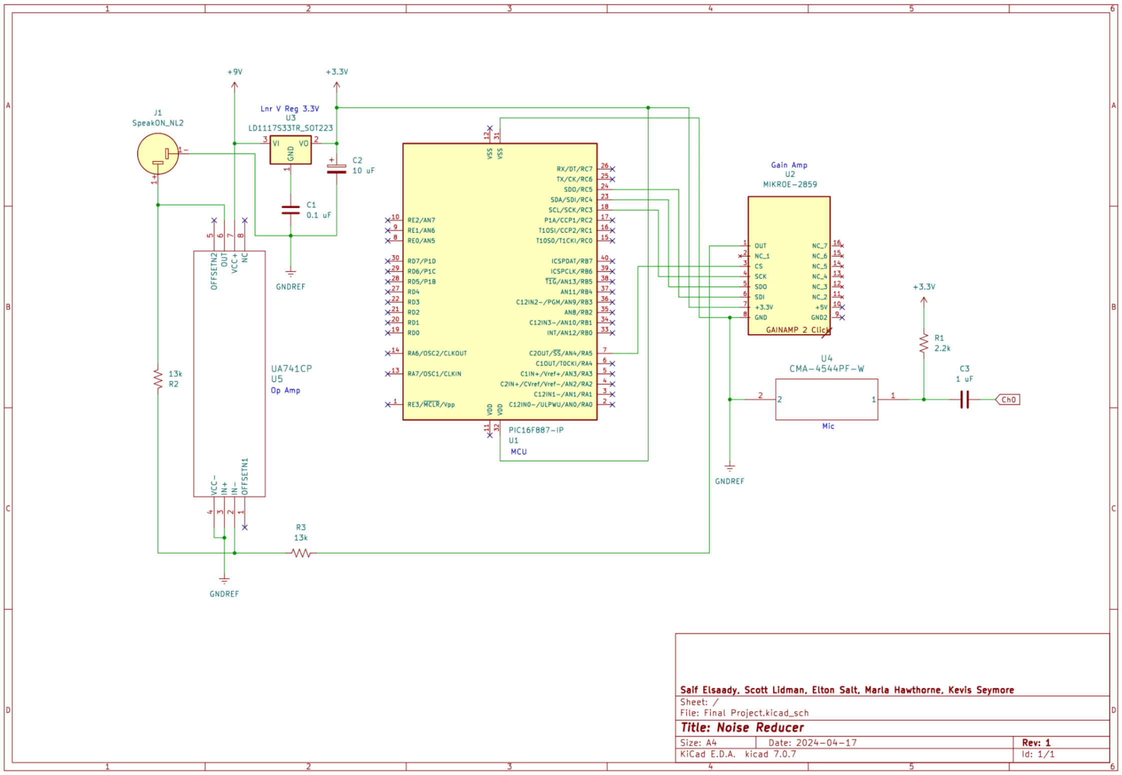


Figure 1. Final Schematic

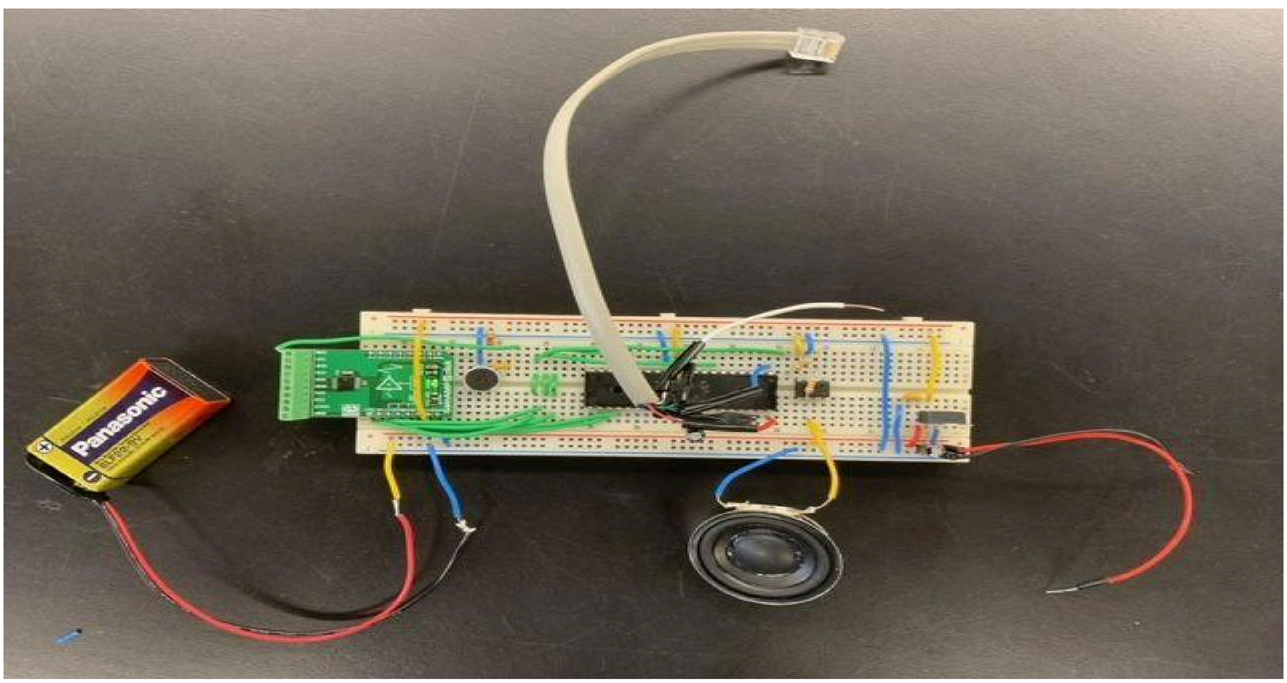


Figure 2. Final Design

The culmination of Team Acoustic Innovators' project was a meticulously crafted Noise Canceling System (NCS) with a design that balanced technical sophistication with user-centric functionality. The chosen microphone array was finely tuned to detect a wide range of frequencies, focusing specifically on the human vocal range while minimizing the intrusion of ambient urban noise. The speaker system was selected for its clarity and ability to produce a broad spectrum of sounds, ensuring the cancellation waves were precise and effective. Special attention was given to the system's form factor, preserving portability and ease of use without compromising on the power and functionality of the NCS. The combination of these elements resulted in a highly effective NCS that stood out as a testament to the innovative application of noise cancellation technology, representing a significant step forward in combating noise pollution in personal and professional environments.

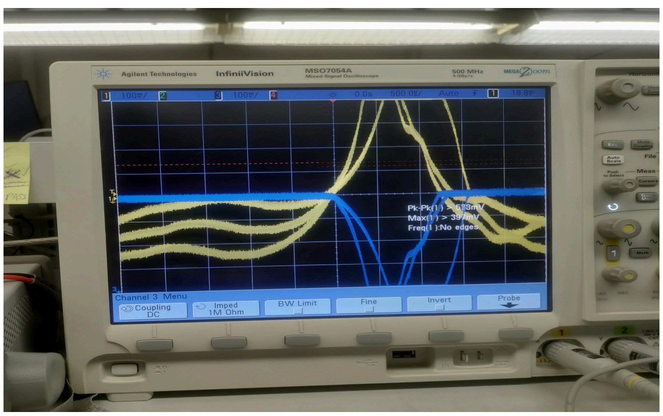
Testing

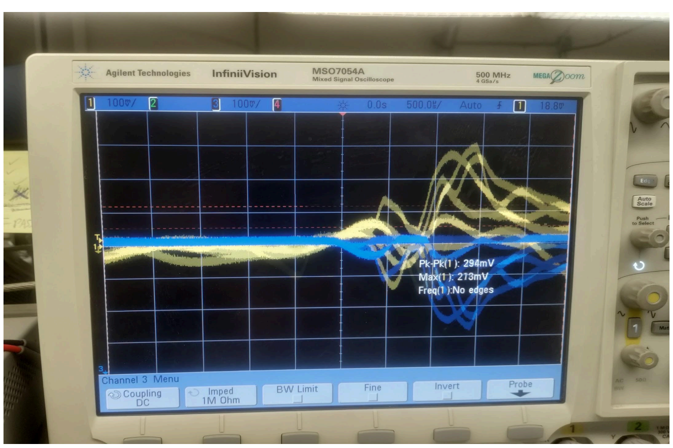
1. **Initial Calibration:** Begin by calibrating the Noise Canceling System (NCS) using a standard sound level meter to establish a baseline noise level for the testing environment.
2. **Frequency Response Test:** Conduct a frequency sweep to determine the system’s response across the human audible range, focusing particularly on the vocal range where active noise control is critical.
3. **Real-world Simulation:** Introduce ambient urban noise recordings to simulate real-world scenarios, analyzing the system's ability to create quiet zones through active noise control.
4. **User Experience Trial:** Allow testers to adjust the NCS to their personal noise level preferences, evaluating the user interface and the system’s adaptability.
5. **Longevity and Durability Test:** Operate the NCS continuously over extended periods to assess battery life and component durability under typical usage conditions.
6. **Performance Metrics Assessment:** Measure sound attenuation effectiveness in decibels (dB), energy efficiency, and overall sound quality, documenting any deviations from expected outcomes.
7. **Oscilloscope Testing:** Connect the NCS output to an oscilloscope, compare ambient vs. active noise cancellation waveforms, and analyze signal integrity for effectiveness and quality.

The testing of the Noise Canceling System (NCS) developed by Team Acoustic Innovators was conducted meticulously to ensure the prototype met both technical specifications and user expectations. The main procedure capitalized on a methodical approach that began with calibration and spanned to real-world applications and user engagement. The raw data and charts are shown below:

I. Raw Data:

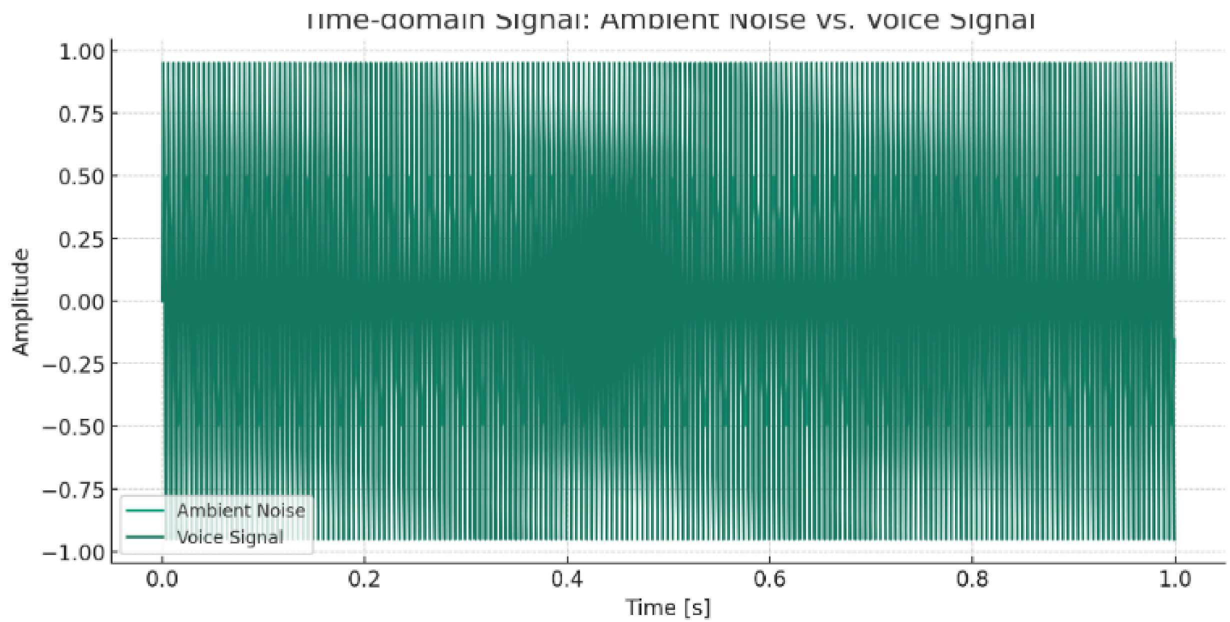
A. This raw data is measured using an oscilloscope.



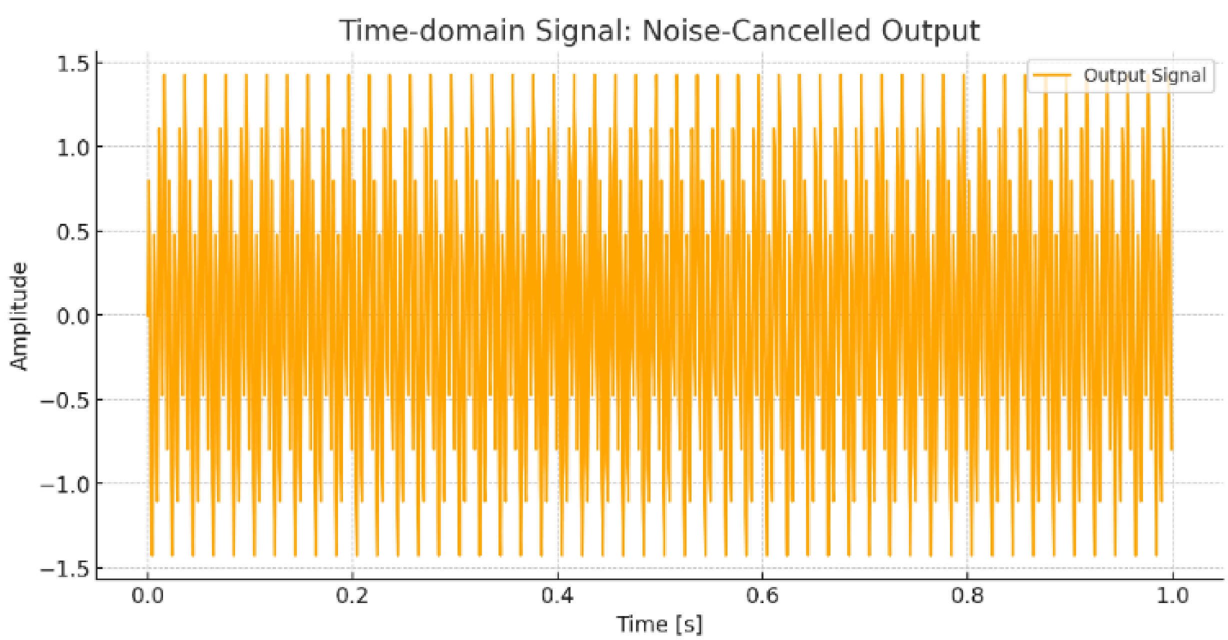


II. Charts:

A. Time-domain Signal: Ambient Noise vs. Voice Signal



B. Time-domain Signal: Noise-Canceled Output



Project Evaluation

The Team Acoustic Innovators observed that the final design of their Noise Canceling System (NCS) significantly advanced from its initial conception. The inclusion of capacitors with precise values markedly improved the clarity of the signal, which was critical for achieving the desired sound quality. They noted that the enhanced connections within the circuit contributed to a more accurate noise cancellation, a feature that was tested thoroughly against a variety of urban noise simulations. The selection of a high-fidelity speaker was pivotal, as it enabled the NCS to produce a crisp and clear output, making the experience more pleasurable for the user. Overall, the team commended the final prototype for its portability and its seamless blend of sophisticated technology with user-friendly functionality, striking a balance between technical innovation and practical usability.

In their design journey, the team recognized that modifications from the original design were instrumental in achieving their acoustical engineering goals. The original circuit used standard components which, while functional, did not provide the level of noise suppression required for urban environments. The team's decision to incorporate capacitors with precise values stemmed from the necessity to filter out noise frequencies more effectively, thus preserving the integrity of the voice signals. Improving the connections within the circuit was a response to the challenge of distinguishing between voice and ambient noise, a distinction that was vital for the system’s performance in dynamic settings. The adoption of a high-fidelity speaker was a direct upgrade from the initial design, driven by the ambition to not just cancel noise but to also enhance the overall sound quality.

Summary, Conclusions, & Discussion

The Noise Canceling System (NCS) project undertaken by Team Acoustic Innovators held a profound importance and clear purpose within the context of urban development and personal well-being. The venture stood at the intersection of acoustical engineering and societal need, representing a significant leap in consumer electronics by integrating sophisticated noise cancellation in everyday life. It exemplified electrical engineering's reach beyond the traditional, enhancing daily environments with advanced electronics and reflecting environmental consciousness by optimizing energy consumption. The project's purpose was multi-layered. At its core, the aim was to forge a device that could transform chaotic urban soundscapes into personalized havens of silence, thereby expanding the functionality of noise control solutions. Academically, it served as a live testbed for the students to apply their learning to a tangible, pressing issue. Commercially, it ventured into the marketability of such technology, probing public interest in advanced noise cancellation products. The main design points for the NCS are shown below:

I. Main Design Points

   A. The NCS was equipped with a finely calibrated microphone sensitive to the nuances of environmental sounds yet robust against disruptive noises.
   B. The speakers were engineered to deliver clear and precise counter-noise, vital for effective sound cancellation, while maintaining a design that did not compromise aesthetic or functional simplicity.
   C. The product's battery life was extended through careful selection of energy-efficient components, reflecting a commitment to sustainability and user convenience.

The real-world applications for the Noise Canceling System (NCS) are extensive and impact various aspects of modern living. The following are recommendations for future work and considerations:

I. Implement AI-enhanced algorithms for more dynamic noise cancellation, tailored to user preferences and environmental variables.

II. Integrate sustainable and recyclable materials in the manufacturing process to align with green initiatives and appeal to eco-conscious consumers.

III. Consider the development of a companion app to allow users to customize noise cancellation settings and profiles for different environments.

IV. Explore the feasibility of incorporating the NCS into smart urban infrastructure to improve public spaces' overall soundscapes.

Implementing AI algorithms could significantly increase the system's adaptability, offering a personalized experience that accounts for the user's auditory preferences and the specific noise patterns of their environment. Using sustainable materials could address environmental concerns and enhance the brand's reputation for responsibility towards ecological concerns. A companion app would add value by providing users with control over their auditory environment, tapping into the trend towards personalized digital interactivity. Finally, integrating the NCS into smart city designs could revolutionize urban living, offering a scalable solution to the pervasive problem of noise pollution.

References

Sparkfun Resistor Packet

Capacitors Packet

Electronix Express - Hook Up Wire Kit

Large Solderless Board

Appendix

Code:

```
#include <xc.h>
// CONFIG1
#pragma config FOSC = INTRC_NOCLKOUT// Oscillator Selection bits (INTOSCIO oscillator: I/O function on RA6/OSC2/CLKOUT pin, I/O function on RA7/OSC1/CLKIN)
#pragma config WDTE = OFF       // Watchdog Timer Enable bit (WDT disabled and can be enabled by SWDTEN bit of the WDTCON register)
#pragma config PWRTE = OFF      // Power-up Timer Enable bit (PWRT disabled)
#pragma config MCLRE = OFF      // RE3/MCLR pin function select bit (RE3/MCLR pin function is digital input, MCLR internally tied to VDD)
#pragma config CP = OFF         // Code Protection bit (Program memory code protection is disabled)
#pragma config CPD = OFF        // Data Code Protection bit (Data memory code protection is disabled)
#pragma config BOREN = OFF      // Brown Out Reset Selection bits (BOR disabled)
#pragma config IESO = OFF       // Internal External Switchover bit (Internal/External Switchover mode is disabled)
#pragma config FCMEN = OFF      // Fail-Safe Clock Monitor Enabled bit (Fail-Safe Clock Monitor is disabled)
#pragma config LVP = OFF        // Low Voltage Programming Enable bit (RB3 pin has digital I/O, HV on MCLR must be used for programming)

// CONFIG2
#pragma config BOR4V = BOR40V   // Brown-out Reset Selection bit (Brown-out Reset set to 4.0V)
#pragma config WRT = OFF        // Flash Program Memory Self Write Enable bits (Write protection off)

#define _XTAL_FREQ 4000000  //

void initialize(){
   TRISC5 = 0; // SDO pin as output
   TRISC4 = 1; // SDI pin as input
   TRISC3 = 0; // SCK pin as output
   TRISA5 = 0; // SS pin as output (if needed)
}

void SPI_init_master() {
   SSPSTAT = 0x00; // SMP = 0, CKE = 1
   SSPCON = 0x20;  // SSPEN = 1, CKP = 0
}
```

```
void SPI_write(unsigned char data) {
   SSPBUF = data;
   while(!SSPIF);  // Wait for transmission complete
   SSPIF = 0;      // Clear the interrupt flag
}

void main(void) {
   initialize();
   SPI_init_master();

   while(1) {
      // Example: Send a continuous signal
      unsigned char data_out = 0xAA; // Example data to send
      PORTAbits.RA5 = 0; // If SS pin is used, pull it low to select the slave device
      SPI_write(data_out); // Send data over SPI
      PORTAbits.RA5 = 1; // If SS pin is used, pull it high to deselect the slave device

      __delay_ms(100); // Example delay of 100 milliseconds
   }

   return;
}
```

Gain Register from MCP6S26 Datasheet

REGISTER 5-2: GAIN REGISTER

U-x	U-x	U-x	U-x	U-x	W-0	W-0	W-0
—	—	—	—	—	G2	G1	G0
bit 7							bit 0

bit 7-3 **Unimplemented:** Read as '0' (reserved for future use)

bit 2-0 **G2-G0: Gain Select Bits**

000 = Gain of +1 (Default)
001 = Gain of +2
010 = Gain of +4
011 = Gain of +5
100 = Gain of +8
101 = Gain of +10
110 = Gain of +16
111 = Gain of +32

Channel Select Register from MCP6S26 Datasheet

REGISTER 5-3: CHANNEL REGISTER

U-x	U-x	U-x	U-x	U-x	W-0	W-0	W-0
—	—	—	—	—	C2	C1	C0
bit 7							bit 0

bit 7-3 **Unimplemented:** Read as '0' (reserved for future use)

bit 2-0 **C2-C0: Channel Select Bits**

	MCP6S21	**MCP6S22**	**MCP6S26**	**MCP6S28**
000	= CH0 (Default)	CH0 (Default)	CH0 (Default)	CH0 (Default)
001	= CH0	CH1	CH1	CH1
001	= CH0	CH0	CH2	CH2
011	= CH0	CH1	CH3	CH3
100	= CH0	CH0	CH4	CH4
101	= CH0	CH1	CH5	CH5
110	= CH0	CH0	CH0	CH6
111	= CH0	CH1	CH0	CH7

Schematic of GAINAMP2 CLICK