DOI: https://doi.org/10.4038/jrm.v2i1.14

# AUTOMATED DIGITAL WIND INSTRUMENT USING ARDUINO UNO MICROCONTROLLER

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JOURNAL OF RESEARCH IN MUSIC
VOLUME 02 | ISSUE 01 | 2024

**Abstract**

Recently, Blackstar Amplification Ltd. has introduced a Compact Carry-On Digital Wind Instrument (CDWI), mirroring the design of traditional recorder instruments in their size and shape. This CDWI can be played as a traditional wind instrument by blowing into the mouthpiece and simultaneously manipulating finger holes, enabling the production of desired musical notes. The main aim of this research work is the development of a prototype model to automate the CDWI, by utilizing the Arduino UNO microcontroller board and introducing the Automated Digital Wind Instrument (ADWI). The CDWI has a mouthpiece, nine finger holes, and one thumb hole, and the blowing mechanism can be automated by using a 12 Volts DC air blower and a servo valve. The author ingeniously develops a new servo valve using a plastic syringe, a ball, and a 5 Volts DC micro servo motor to regulate the air pressure blown into the mouthpiece. The ADWI fingers are meticulously crafted using plastic pen barrels, thrust tubes, and metallic springs to simulate the actions of a human music player's fingers. Positioned to maintain all finger holes in an open state by default, the selective closing of specific holes is achieved by ten micro servo motors to produce a specific musical note. In a preliminary test, the ADWI prototype is programmed to perform the Nursery Rhyme "Twinkle, Twinkle, Little Star." While evaluating the sound output by hearing, it is evident that the proposed ADWI effectively generates all the necessary musical notes. However, the noise generated by the air blower and micro servo motors introduces interference, impacting the clarity of the produced musical notes. Consequently, it is planned to integrate a noise reduction mechanism as part of future work.

**Keywords**

Arduino, Automation, Music, Noise, Wind instrument

## Introduction

Robotics technology has significantly influenced the field of music, leading to innovative developments and new creative possibilities. This fusion of technology and music has given rise to a wide range of applications such as (i) *Musical Performance*: Robots equipped with sophisticated sensors and actuators can play musical instruments with incredible precision and consistency. They can replicate complex compositions with a level of accuracy that human musicians may find challenging. (ii) *Live Music Shows*: Robotic performers are increasingly making appearances in live music shows and concerts. They can dance, interact with the audience, and provide a unique visual element to the performance. (iii) *Music Production*: Automation and robotics have revolutionized

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music production. Automated systems can arrange, mix, and master music, making the production process more efficient and accessible to a wider range of artists. (iv) *Instrument Augmentation*: Musicians are exploring the use of robotic technology to augment their traditional instruments. This can result in novel sounds and capabilities that expand the possibilities of musical expression. (v) *Experimental Music*: Robotics has led to the emergence of a new genre of experimental music that incorporates mechanical sounds and interactions. Artists are using robots to create avant-garde compositions that challenge traditional musical norms. (vi) *Accessible Instruments*: Robotics technology has enabled the development of musical instruments that are more accessible to people with physical disabilities. Adaptive instruments and interfaces can be customized to individual needs, allowing a wider range of people to engage with music. (vii) *Teaching and Learning*: Robots can serve as educational tools for teaching music. They can provide interactive lessons, assist in practicing, and offer real-time feedback to help students improve their musical skills. (viii) *Music Therapy*: Robotic devices are used in music therapy to assist individuals with special needs. They can help in rehabilitation, emotional expression, and cognitive development through music. (ix) *Artificial Intelligence (AI)-Generated Music*: AI-powered algorithms and robots can generate music autonomously. They can compose music based on predefined parameters or even learn from existing compositions to create entirely new pieces. (x) *Collaborative Performances*: Musicians are collaborating with robotic systems to create unique performances that blend human creativity with machine precision. This interdisciplinary approach can result in captivating and thought-provoking experiences.

The integration of robotics technology and music continues to evolve, pushing the boundaries of what is possible in the world of musical expression and performance. This convergence offers exciting opportunities for artists, musicians, and technologists to explore new horizons in sound and creativity. Developed by Blackstar Amplification Ltd. (Carry-on, 2022) the compact carry-on digital wind instrument (CDWI) offers a unique blend of tradition and technology. The CDWI closely resembles a conventional recorder, featuring a mouthpiece and ten holes, which is a combination of nine finger holes and one thumb hole. The instrument can be automated to control air blowing into the mouthpiece and simultaneous manipulating of finger holes to produce different musical notes. The primary aim of this work is to create a prototype model using an Arduino UNO microcontroller (Arduino, 2023), thereby introducing an automated digital wind instrument (ADWI) to mimic the functionality of a traditional recorder wind instrument. To automate the process of blowing air into the mouthpiece, the model employs a 12 Volt DC air blower in tandem with a servo-actuated ball valve. Notably, the author ingeniously constructs a new servo valve from basic materials, including a plastic syringe, a ball, and a 5-volt DC micro servo motor, which regulates the air pressure directed into the mouthpiece. To replicate the manual control of the instrument, this work uses plastic pen barrels, thrust tubes, and springs to create artificial "fingers" that simulate the actions of a human player. These finger components are arranged to maintain all holes in an open position by default. The closure of specific holes to produce desired musical notes is achieved through the use of ten distinct micro-servo motors, each dedicated to controlling an individual hole. In an initial test, the ADWI prototype was programmed to play the classic Nursery Rhyme "Twinkle, Twinkle, Little Star." Impressively, it was able to produce all the necessary musical notes to perform the song. However, a significant challenge has emerged: the noise generated by the air blower and the micro servo motors interferes with the production of the intended musical notes. This issue highlights the need for future work, which will focus on incorporating a mechanism to mitigate the noise and enhance the instrument's overall performance.

## Literature Review

Numerous research studies have focused on automating conventional wind instruments, specifically addressing the automation of both the blowing mechanism and fingering mechanism. This automation has proven to be particularly valuable when it comes to the testing of multiple wind instruments, streamlining the evaluation process. In (Haidar et al, 2018), an artificial mouth model was created to accurately regulate the input pressure and output flow of a wind instrument's resonator, specifically in the context of a flute. This precise control is essential for producing exact musical notes. In the work of (Chand et al, 2018), a cost-effective prototype of a robotic pan flute was designed, allowing a non-expert musician to play a traditional wind instrument. This innovation opens up opportunities for individuals without extensive musical expertise to engage with the instrument. In (Li et al, 2019), a Chinese bamboo flute robot with intricate wooden carving was developed. This robotic system employs six pneumatic fingers to play the flute, showcasing the fusion of traditional craftsmanship and modern technology. (Kumar et al, 2015) introduced an automated pan flute player designed specifically to play the Solomon Islands' Pan Flute. This innovation facilitates musical expression even for individuals lacking advanced musical skills. For recorders without finger holes, [d'Andrea-Novel et al, 2008] presented a more sophisticated automated control model. This recorder is equipped with a piston mechanism for adjusting the resonator's length, enhancing the instrument's playability and versatility. The development of a Thai flute (Khlui) playing robot mechanism is described in (Kato et al, 2018). This robotic system combines blown airflow control and fingering force control, allowing for the creation of tremolo and vibrato effects, enriching the musical performance. Similarly, (Abhilash, 2018) detailed an Arduino-based flute playing machine specifically designed for polyvinyl chloride (PVC) flutes. This machine utilizes a plastic blowing tube connected to a low-noise 12 Volt fan blower for air supply. The position of the blowing tube is adjusted using two micro servo motors, and the entire system is mounted on a sponge base to absorb vibrations and minimize noise.

These research works demonstrate the fusion of traditional wind instruments with automation technology, enabling a wider range of musicians to explore and enjoy playing these instruments. To the best of author's knowledge, no works were reported on the automation of digital wind instrument (DWI). Hence, this motivated the author to focus on automating both the blowing control and fingering control of CDWI.

## Overview of CDWI

The CDWI, innovatively introduced by Blackstar Amplification Ltd (Carry-on, 2022), closely resembles a traditional recorder wind instrument in both design and size, comparable to a soprano recorder. With a built-in speaker and a convenient headphone jack, this musical device offers a harmonious fusion of classical and contemporary elements. Mimicking the mechanics of a traditional wind instrument, the CDWI features a mouthpiece, nine finger holes, and a thumb hole, as illustrated in Figure 1. Functioning much like its conventional counterparts, musicians can play the CDWI by blowing into the mouthpiece while skillfully manipulating the finger holes to produce a range of musical notes.

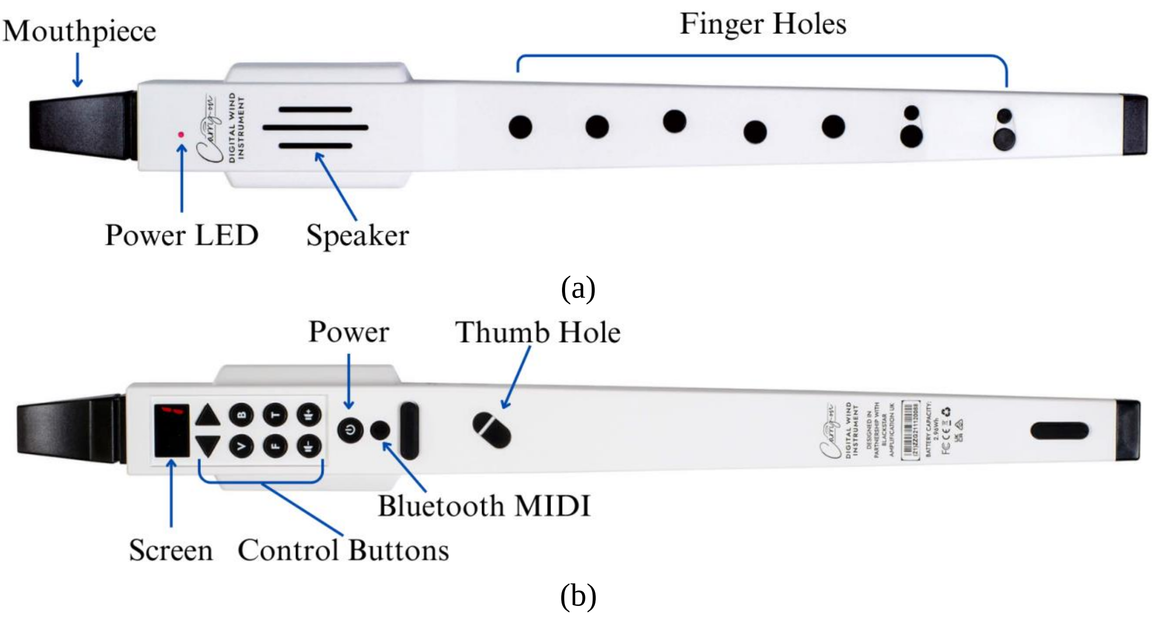


Figure 1. Parts of CDWI (a) Front side (b) Back side (https://carryonplaying.com/product/carry-on-digital-wind-instrument/)

## System Overview of ADWI

Figure 2 illustrates the block diagram of the ADWI, where the automation of both the blowing and fingering mechanisms of the CDWI is done by the Arduino UNO microcontroller board. To achieve automated blowing, a 12 Volt DC air blower serves as the air source, to produce the musical notes. The finger movements are controlled by servo motors S1 to S10, while S11 takes charge of the valve control. All servo motors receive a 5 V DC power supply. The Arduino UNO microcontroller seamlessly coordinates the operation of these servo motors, with each assigned to specific pins detailed in Table 1. To capture the output of the CDWI, a microphone is used.

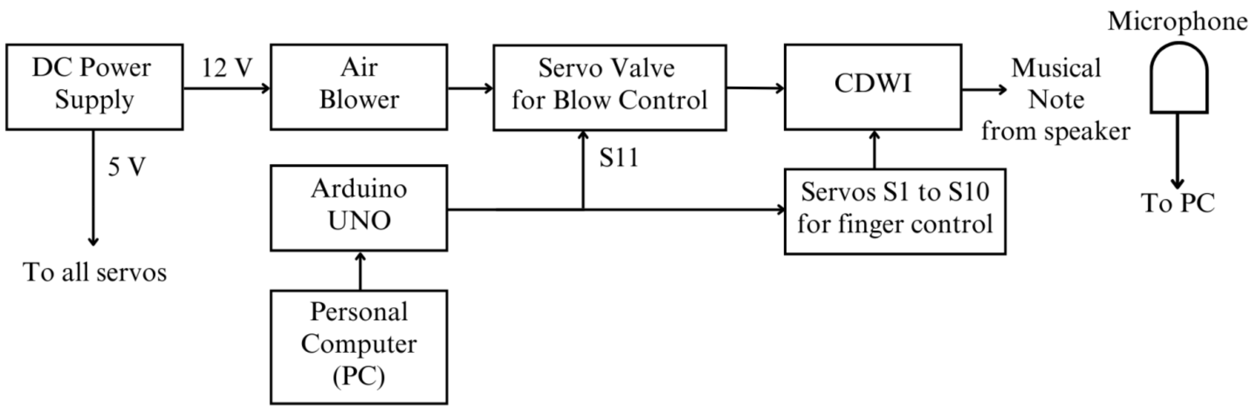


Figure 2. Overall block diagram of the ADWI System

Table 1. Usage of Arduino UNO pins

| **Pin Number** | **Pin Type** | **Servo Motor Number** | **Corresponding** | | **Pin Number** | **Pin Type** | **Servo Motor Number** | **Corresponding** | |
|---|---|---|---|---|---|---|---|---|---|
| | | | **Finger Number** | **Finger Hole Number** | | | | **Finger Number** | **Finger Hole Number** |
| 5 | PWM or Digital I/O | S1 | F1 | H1 | 4 | Digital I/O | S7 | F7 | H7 |
| 9 | PWM or Digital I/O | S2 | F2 | H2 | 2 | Digital I/O | S8 | F8 | H8 |
| 11 | PWM or Digital I/O | S3 | F3 | H3 | 13 | Digital I/O | S9 | F9 | H9 |
| 10 | PWM or Digital I/O | S4 | F4 | H4 | 7 | Digital I/O | S10 | F10 | H10 (Thumb Hole) |
| 6 | PWM or Digital I/O | S5 | F5 | H5 | 8 | Digital I/O | S11 | For the Servo Valve | |
| 3 | PWM or Digital I/O | S6 | F6 | H6 | | | | | |

### *Blowing Mechanism of ADWI*

To regulate the airflow for the CDWI, a 12 Volt DC air blower serves as the air source, continuously operational when connected to the DC power supply. However, for precise control of the air stream directed towards the instrument, a new ball valve has been ingeniously crafted by the author using plastic syringes, as presented in Figure 2. The choice of plastic syringes, beyond their cost-effectiveness, is attributed to their nozzle's adeptness in producing a well-directed air stream. This newly devised ball valve is seamlessly integrated with a micro servo motor, illustrated in Figure 3, facilitating dynamic control over the airflow. The valve's opening percentage ranges from 0 to 100, where 0 indicates complete closure, blocking the air stream, and 100 represents full openness, allowing unrestricted airflow. This servo-actuated valve, linked to the Arduino UNO, automates the CDWI's blowing mechanism in synchronization with the musical notes to be played. The nozzle-end of the servo valve is connected to the CDWI's mouthpiece, while the opposite end interfaces with the air blower through a tubular connection, as depicted in Figure 3. A piece of thermocol (see Figure 4) is used to firmly hold the nozzle near the mouthpiece of the instrument.

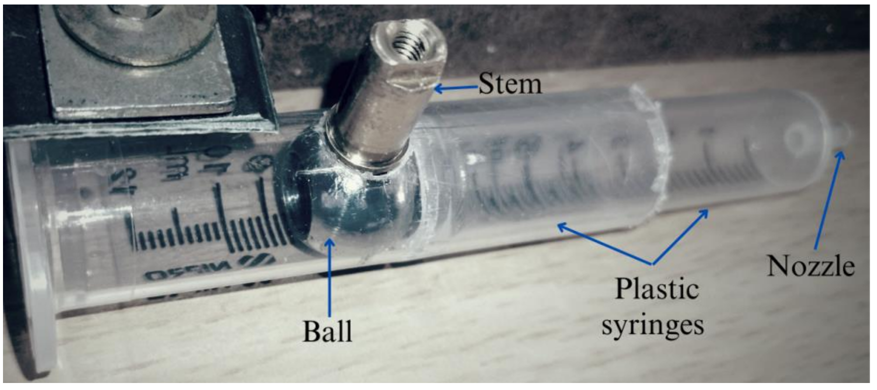


Figure 3. A ball valve using plastic syringes

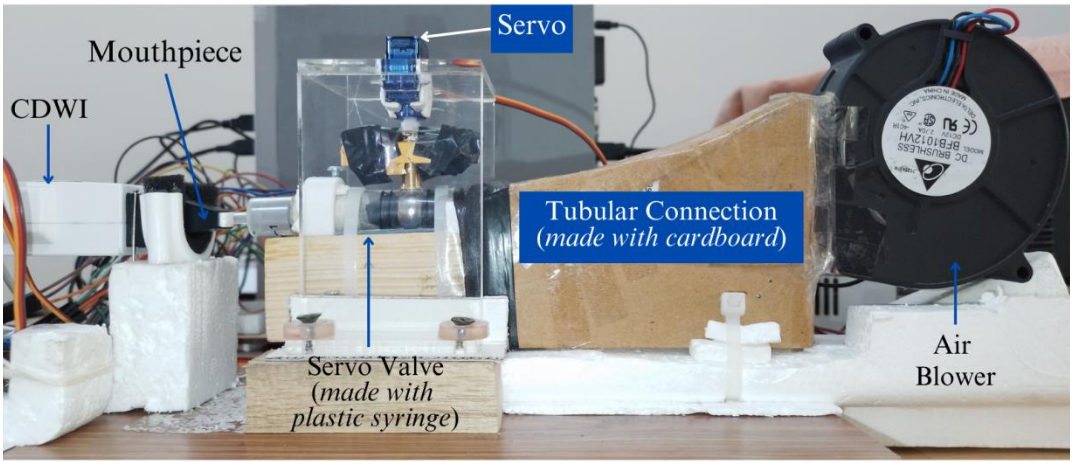


Figure 4. Air blowing mechanism

### *Fingering Mechanism of ADWI*

The finger holes depicted in Figure 1 on the CDWI are not traditional openings but rather electronic touch buttons. When a player's real finger makes contact, the corresponding touch button is activated, simulating the closure of a hole. This project introduces an innovative approach to automate the fingering mechanism by replacing the electronic touch buttons with plastic fingers, which are incapable of triggering the touch buttons. Consequently, the touch buttons on the CDWI, as illustrated in Figure 4, are removed. Plastic fingers equipped with metallic springs, as depicted in Figure 5, are employed to activate the finger holes designated as H1 to H10. In this setup, when the metallic spring makes contact with the metallic touch plate, the respective hole is considered closed, replicating the traditional manual fingering action.

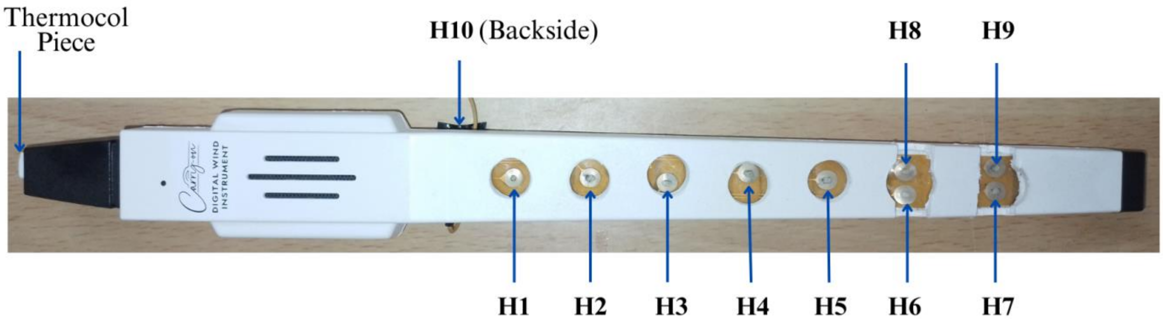


Figure 5. Front side of CDWI after removing touch buttons

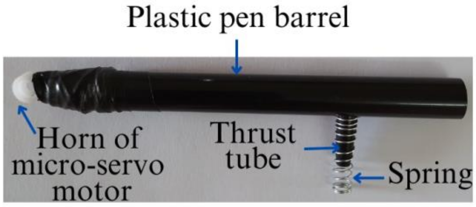


Figure 6. Plastic Finger to mimic the actual finger of a player

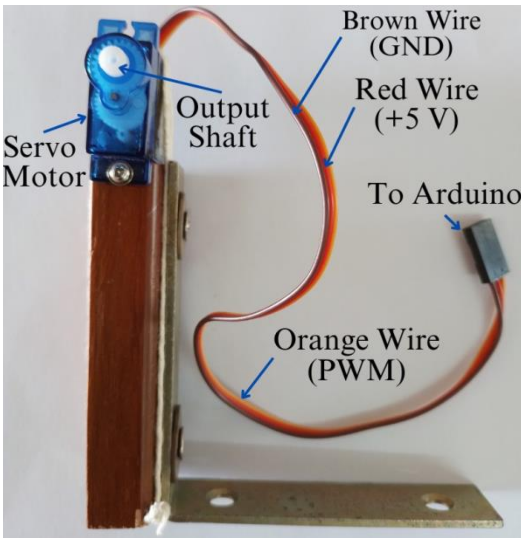


Figure 7. Stand to hold the plastic finger

A stand, depicted in Figure 6, is crafted using a wooden piece and an L-clamp.  At the top of this stand, a servo motor is securely affixed, and each plastic finger is connected to it, as illustrated in both Figure 6 and Figure 7.  The arrangement ensures that all plastic fingers are positioned to activate the designated finger holes H1 to H10, facilitating automated control of the CDWI's fingering mechanism.

Figure 8 displays the functional model of the proposed ADWI system. The blowing mechanism encompasses (i) a DC air blower, (ii) a tubular connection crafted from cardboard material, and (iii) the servo valve.  Similarly, the fingering mechanism involves plastic fingers affixed to servos.  The control of all servo motors is governed through Arduino programming.  Due to space constraints, plastic pen barrels are not utilized for fingers F6, F7, and F10; instead, thrust tubes and springs are employed.

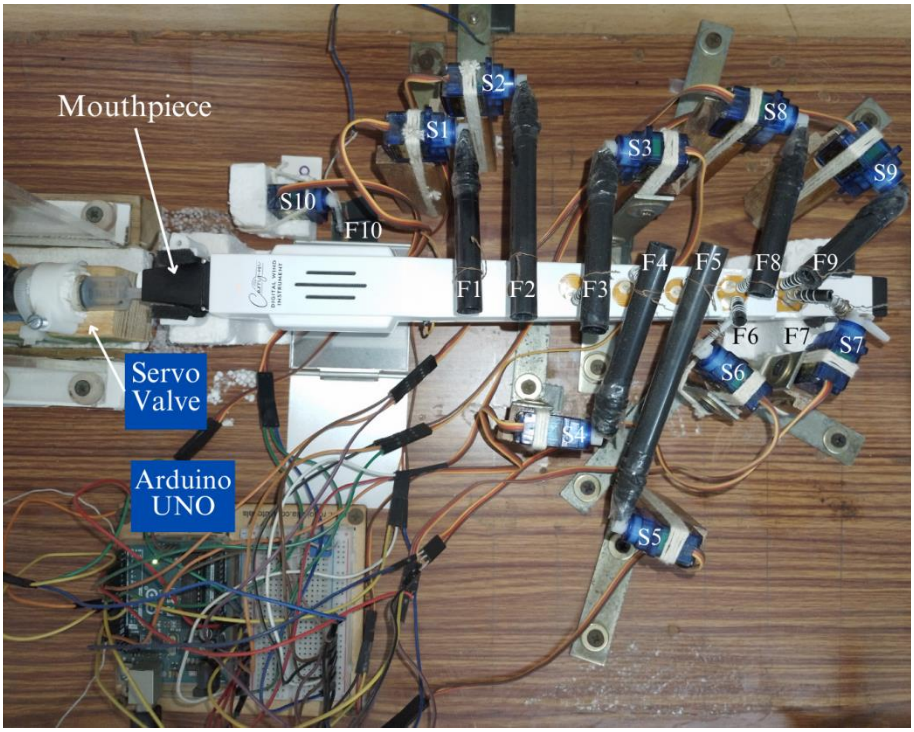


Figure 8.    Fingering mechanism

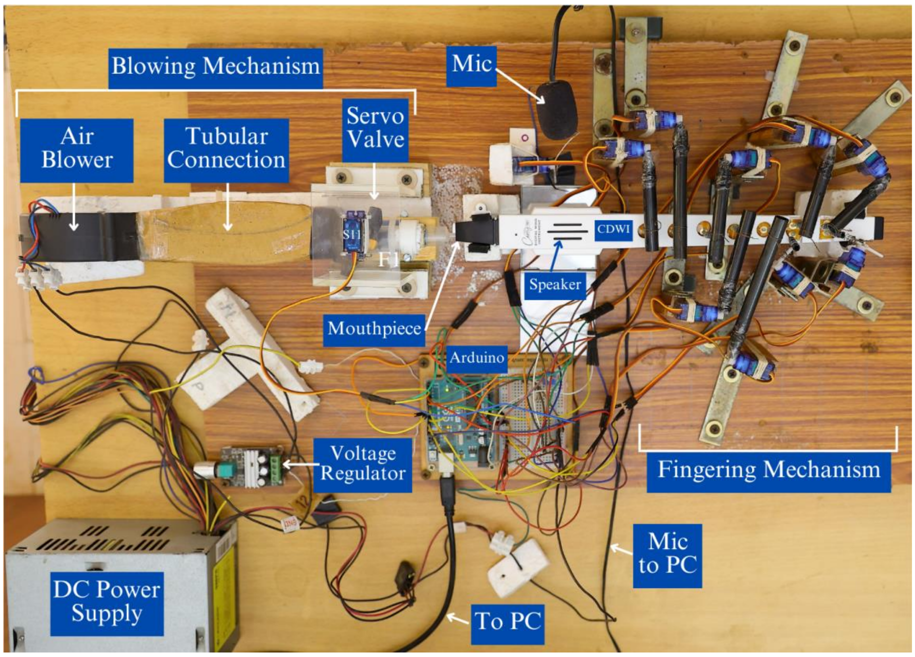

Figure 9. Prototype of ADWI System

After assembling the hardware components for the blowing mechanism and fingering mechanism, and establishing all the required electrical connections to the Arduino microcontroller board as illustrated in Figure 8, the subsequent step involves verifying the functionality of each mechanism.

***Blowing Mechanism Functionality Check***

With the air blower operating continuously, it generates a consistent airflow at a rate of 38 CFM, achieved with a maximum voltage of 12 and a fan speed of 4800 rpm. To regulate the blower fan speed and consequently control the airflow rate, a voltage regulator is employed as depicted in Figure 8. The airflow rate is dynamically managed by adjusting the angle of the servo (S11), thereby modulating the opening and closing of the valve. A servo shaft angle of 0 degrees corresponds to a 0% open valve (i.e., OFF mode), resulting in no airflow and, consequently, no sound production from the instrument. As the servo angle increases to 80 degrees, indicating a 100% open valve (i.e., ON mode), a proportional increase in the magnitude of sound produced by the instrument is observed. The ability to vary the sound intensity by adjusting the angle between 0-80 confirms the proper functionality of the blowing mechanism.

***Fingering Mechanism Functionality Check***

After confirming the instrument's proper sound production by regulating the airflow through the blowing mechanism, the subsequent phase involves assessing the functionality of the fingering mechanism. To achieve this, the angles of servos S1 to S10 are adjusted according to Table 2, enabling the production of the musical notes: C, D, E, F, G, A, B, Ċ.

Table 2. Status of finger holes for different musical notes

| Finger Hole Number | | Musical Note | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **C** | **D** | **E** | **F** | **G** | **A** | **B** | **Ċ** |
| H1 | Angle of Servo S1 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 0 |
| | Status | ● | ● | ● | ● | ● | ● | ● | ○ |
| H2 | Angle of Servo S2 | 20 | 20 | 20 | 20 | 20 | 20 | 0 | 20 |
| | Status | ● | ● | ● | ● | ● | ● | ○ | ● |
| H3 | Angle of Servo S3 | 0 | 0 | 0 | 0 | 0 | 20 | 20 | 20 |
| | Status | ● | ● | ● | ● | ● | ○ | ● | ○ |
| H4 | Angle of Servo S4 | 0 | 0 | 0 | 0 | 10 | 10 | 10 | 10 |
| | Status | ● | ● | ● | ● | ○ | ● | ● | ○ |
| H5 | Angle of Servo S5 | 20 | 20 | 20 | 0 | 0 | 0 | 0 | 0 |
| | Status | ● | ● | ● | ○ | ● | ● | ● | ○ |
| H6 | Angle of Servo S6 | 10 | 10 | 0 | 10 | 0 | 0 | 0 | 0 |
| | Status | ● | ● | ○ | ● | ● | ● | ● | ○ |
| H7 | Angle of Servo S7 | 30 | 0 | 0 | 30 | 0 | 0 | 0 | 0 |
| | Status | ● | ○ | ○ | ● | ● | ● | ● | ○ |
| H8 | Angle of Servo S8 | 20 | 20 | 0 | 20 | 0 | 0 | 0 | 0 |
| | Status | ● | ● | ○ | ● | ● | ● | ● | ○ |
| H9 | Angle of Servo S9 | 0 | 10 | 10 | 0 | 10 | 10 | 10 | 10 |
| | Status | ● | ○ | ○ | ● | ○ | ○ | ○ | ○ |
| H10 | Angle of Servo S10 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| | Status | ● | ● | ● | ● | ● | ● | ● | ● |
| ● Closed Hole | | ○ Open Hole | | | | | | | |

## Results and Discussion

Conducting an initial assessment, the prototype of the ADWI was programmed to perform the Nursery Rhyme "Twinkle, Twinkle, Little Star" with the following musical note sequence: CC GG AA G | FF EE DD C | GG FF EE D | GG FF EE D | CC GG AA G | FF EE DD C. Musical notes produced through manual play on CDWI by the author and by the ADWI system are recorded using a microphone and saved in .*wav* format. The resulting .*wav* file, encompassing notes CC, DD, EE, FF, GG, AA, is then imported into the MATLAB® software workspace for subsequent analysis. The time-domain waveforms and corresponding power spectral density (PSD) of the musical notes are presented in Figure 9. In Figure 9(a), the CC notes, played by the author manually using CDWI, and $CC_{noisy}$, played by the ADWI, are depicted. The PSD analysis of CC and $CC_{noisy}$ reveals a significant amount of noise generated by the air blower and micro servo motors. Moving to Figure 9(b) for the DD notes, the noise magnitude is notably more dominant. A similar observation is made for the EE notes, as illustrated in Figure 9(c). For the FF notes in Figure 9(d), the noise level is prominent, particularly when played by ADWI system. Examining Figure 9(e) for the GG notes, the noise level completely dominates the notes played by ADWI. Furthermore, the detrimental impact of noise is evident for the AA notes, as portrayed in Figure 9(f).

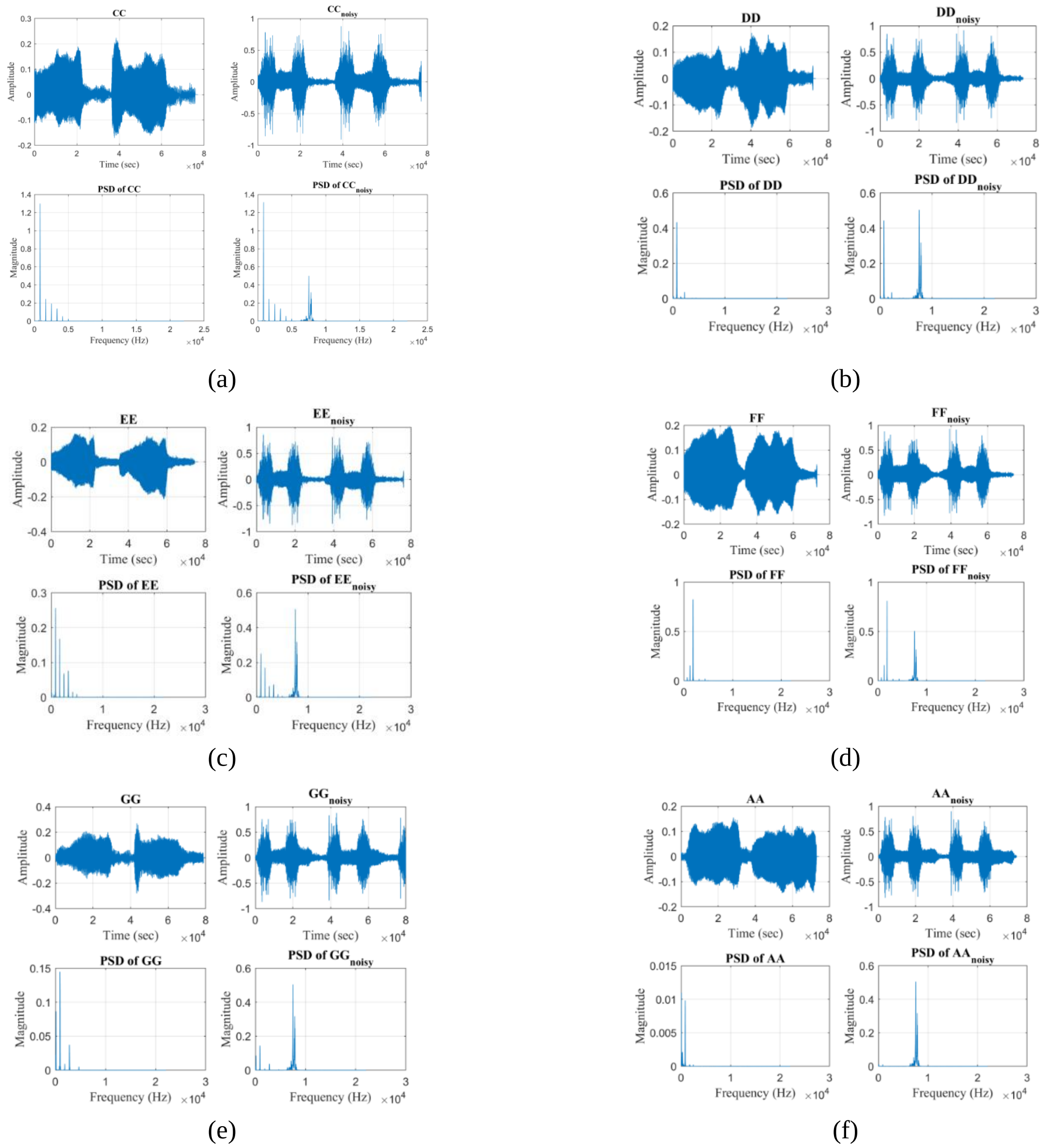


Figure 10. Waveforms and corresponding PSDs of musical notes

Finally, upon auditory evaluation, it was observed that the proposed ADWI successfully produced all the required musical notes. However, the presence of noise generated by the air blower and micro servo motors reduces the clarity of the actual musical notes.

## Conclusion

The development of the Automated Digital Wind Instrument (ADWI) prototype using an Arduino UNO microcontroller presents a significant step towards automating the Carry-On Digital Wind Instrument (CDWI). The integration of various components, such as a 12 Volts DC air blower, a servo actuated ball valve, and microservo motors for finger control, demonstrates the feasibility of automating the CDWI's blowing and fingering mechanisms. In a preliminary test featuring the Nursery Rhyme "Twinkle, Twinkle, Little Star," the ADWI prototype successfully produced the desired musical notes. However, the audible noise generated by the air blower and micro servo motors posed a challenge, interfering with the purity of the musical notes. To address the issue of noise interference and enhance the overall performance of the ADWI, future work will focus on incorporating mechanisms to mitigate and minimize unwanted sounds. Strategies may include optimizing the design of the air blower and implementing noise reduction techniques for the microservo motors. Further refinements in the automation process, such as fine-tuning the servo mechanisms for precise control and exploring alternative materials for constructing the fingers, will be pursued. The aim in future is to achieve a seamless integration of automation while maintaining the authenticity of the musical output.

## Acknowledgement

The abstract of this study is presented at ICFM2023, hosted by the Faculty of Music at the University of the Visual and Performing Arts in Colombo 07, Sri Lanka. The author wishes to express sincere gratitude to the organizing committee of ICFM2023 for furnishing a valuable platform to showcase this research. Additionally, the author extends heartfelt thanks to the authorities of Jawaharlal Nehru Technological University Kakinada, Kakinada, India, for their generous financial support, enabling participation in ICFM2023.

## References

Abhilash, A. (2018, October 22). *Arduino Based Flute Player Machine*. Instructables. https://www.instructables.com/Arduino-Based-Flute-Player-Machine/

*Arduino Uno Rev3*. (n.d.). Arduino Official Store. Retrieved November 10, 2023, from https://store.arduino.cc/products/arduino-uno-rev3

Chand, P., Kumar, K., & Kumar, K. (2018). Development of a low-cost robotic pan flute. *International Journal of Intelligent Machines and Robotics*, *1*(2), 153. https://doi.org/10.1504/IJIMR.2018.094917

d'Andrea-Novel, B., Fabre, B., & Coron, J.-M. (2008). Modeling and automatic control of a slide-flute. *2008 16th Mediterranean Conference on Control and Automation*.doi: 10.1109/MED.2008.4602061

Haidar, G. A., Daou, R. A. Z., & Moreau, X. (2018). Modelling and control of an artificial mouth of a flute wind musical instrument. *2018 IEEE International Multidisciplinary Conference on Engineering Technology (IMCET)*.doi: 10.1109/IMCET.2018.8603053

Kato, T., Shimazaki, K., Higashijima, K., Tokunaga, R., Na Ayuthaya, P. T., &Thumwarin, P. (2018). Refinement of a Thai flute-playing robot in Thai style. *2018 International Conference on Engineering, Applied Sciences, and Technology (ICEAST)*.doi: 10.1109/ICEAST.2018.8434466

Kumar, K., Chand, P., Kumar, K., & Carnegie, D. A. (2015). Towards an automated Pan Flute player. *2015 6th International Conference on Automation, Robotics and Applications (ICARA)*.doi: 10.1109/ICARA.2015.7081146

Li, J., Hu, T., Zhang, S., & Mi, H. (2019). Designing a musical robot for Chinese bamboo flute performance. *Proceedings of the Seventh International Symposium of Chinese CHI*.https://doi.org/10.1145/3332169.3332264

Carry-on Piano.*Small digital wind musical instruments*. (2022, April 8). https://carryonplaying.com/product/carry-on-digital-wind-instrument/