Journal of Emerging Technologies and Industrial Applications
Vol. 4 No. 1 (2025) pp. 1-5
e-ISSN: 2948-507X
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Journal homepage: https://jetia.mbot.org.my/index.php/jetia/index

Exploring Vehicle Cabin Noise Patterns Using an Arduino-Integrated Sound Level Meter

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Abstract: Noise engendered attributable to vibrations distresses the comfort besides performance of drivers and passengers in vehicles. This study evaluates the noise levels within the cabin of a Perodua Viva Elite 1.0cc under stationary and dynamic conditions. An Arduino-based low-cost coding and a professional sound level meter were used for data collection. The findings reveal that noise levels correlate with engine RPM and vehicle speed as well as the Arduino can be used as a instrument measurement. The Arduino system demonstrated its utility as a viable alternative for dynamic noise measurement. This research emphasizes the need for enhanced cabin noise control measures to improve user comfort and safety.

Received 10 February 2025; Accepted 20 May 2025; Available online 30 June 2025

Keywords: vehicle cabin noise, Arduino data logger, sound level meter, noise measurement, dynamic conditions

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1. Introduction (Section 1)

The interior noise of vehicles plays a pivotal role in determining driver and passenger comfort. Noise, Vibration, and Harshness (NVH) encompass the sensory impact of auditory and tactile disturbances in vehicles, where undesirable noise levels can disrupt communication, reduce driver focus, and cause fatigue. Specifically, this study investigates the noise characteristics within the cabin of a Perodua Viva Elite 1.0cc, employing an Arduino-based data logger integrated with advanced sound sensors monitoring capabilities. By evaluating noise behavior across varying engine RPMs and vehicle speeds, the research aims to know the practicality of Arduino as a cost-effective, energy-efficient alternative to professional sound level meters for noise monitoring and analysis. Noise in vehicle cabins, caused by structural vibrations, airborne noise, and external factors, significantly affects passenger comfort and safety. Traditional noise monitoring solutions are often expensive, less accessible, and not integrated into real-time feedback systems. This research proposes an innovative Arduino-based system that overcomes these challenges while providing comparable accuracy and versatility.

The main objectives of this research are:

1. To measure the noise levels in the cabin of a Perodua Viva Elite 1.0cc.
2. To integrate sound sensors for enhanced noise detection.

2. Literature Review (Section 2)

2.1 Fundamentals of Vehicle Cabin Noise

Vehicle cabin noise arises from various sources such as engine vibrations, tire-road interactions, and aerodynamic effects. According to Genuit (2003), noise is an audible and often undesirable sound that disrupts passenger comfort. Studies by Junoh et al. (2011)

demonstrate that engine speed directly impacts the noise intensity inside vehicle cabins, with higher RPMs correlating with greater noise levels.

2.2 Major Sources of Interior Cabin Noise

Engine Noise: Engine components such as pistons and valves contribute significantly to cabin noise. Cerrato (2009) highlights that diesel engines produce distinct noise characteristics at idle and high speeds.
Tire-Road Interaction: Vibrations from tire-road contact are a major contributor. Research by Aldhahebi et al. (2016) shows that road surface texture influences noise levels.
Airborne and Structure-Borne Noise: Noise transmitted via air and structural components, such as the exhaust system, adds to the overall cabin noise (Schevenels et al., 2007).

2.3 Use of Arduino in Noise Measurement

Arduino microcontrollers are increasingly used for noise measurement due to their affordability and versatility. Hjort (2015) demonstrated the integration of Arduino with sensors to monitor mechanical vibrations effectively. Additionally, a sound level meter design using a MAX4466 sound sensor and Arduino UNO microcontroller has demonstrated accuracy comparable to traditional SLM tools, further validating Arduino's reliability for noise measurement applications L. Lapono & R. Pingak, (2018).

2.4 Human Comfort and Noise Standards

Noise levels exceeding 50 dB significantly affect passenger comfort (Putra et al., 2011). WHO guidelines recommend noise exposure limits to prevent hearing loss and discomfort. Vehicles with high noise levels require enhanced NVH treatments to meet these standards.

3. Methodology (Section 3)

3.1.1 Flowchart

Below is the flowchart of Parcel Delivery Alert System as shown on Figure 8.

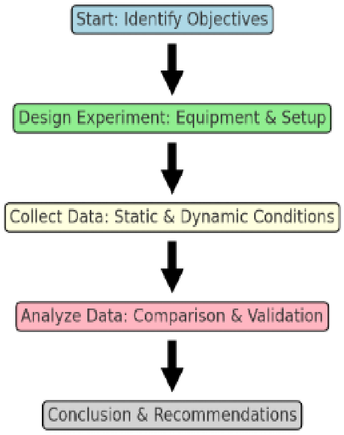

Figure 1. Project flowchart

Start: Identify Objectives – Clarify the research goals and define the problem statement.

Design Experiment: Equipment & Setup – Plan the experiment, selecting tools like Arduino with sound sensors and professional sound level meters.

Collect Data: Static & Dynamic Conditions – Gather noise data under different operating conditions.

Analyze Data: Comparison & Validation – Process and compare results from Arduino and sound level meter for validation.

Conclusion & Recommendations – Summarize findings and propose improvements or future work.

Calibration	Average Sound level meter (dB) in 1 minute	Average Arduino (dB) in 1 minute	Different of data (dB)	Percentage of different (%)
Before	47.4	70.7	23.3	39.5%
After	47.4	44.9	2.5	5.4%

Figure 2. The calibration result

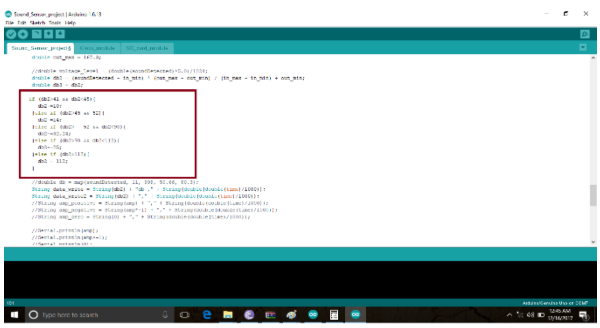

Figure 3. Calibration code IDE software

3.2 Equipment and Setup

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An Arduino-based data logger equipped with sound sensors and a micro-SD card module was utilized for data collection. A professional 3M Sound Level Meter (SLM) served as a benchmark. Noise levels were recorded under static and dynamic conditions at varying RPMs and vehicle speeds. Each Average Data recorded at least 1 minutes stored inside the SD card and processing in excel software. Integration with process allowed for noise visualization.

Figure 4. Outlining assembly of an Arduino, SLM 3M Pro type II, Microcontroller

Figure 5. Location of an Arduino to detect noise

Figure 6. Location of sound level meter (SLM)

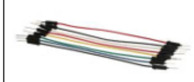
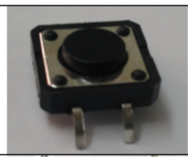
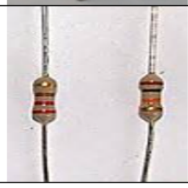
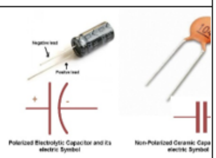
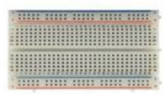
Name	Specifications	Sample
Hook-up wire	Solderless flexible jumper wires that can be used over and over again at breadboard 16pcs at 4 types of different length Male to Male pin at both ends Random with mixed colours	
Push button	dimension: 0.5cmx 0.5cm	
resistor	1Ω,10Ω,100Ω,1k,10k	
Microphone / sound sensor	Supply Voltage: 2.7v 3mA current Output 2Vpp on 1.25V bias Frequency Response: 20Hz – 20KHz Programmable attack and release ratio Automatic gain, selectable max from 40db, 50 dB or 60 dB	
Polarized and non-polarized capacitors	Non-Polarized (ceramic) Capacitor 50V 0.1uf Type: Polarized (Low ESR) High Frequency & Long Life Rated Voltage: 25V Capacitance: 100uF	
breadboard	Dimension: 16.5cm x 5.4cm	
Arduino UNO compatible with USB cable	System voltage: 5V Clock speed: 16 MHz Digital I/O: 14 Analog Inputs: 6 PWM: 6 UART: 1 Programming Interface: USB Via ATMega16U2	
LED	5mm led bulb- red, green, yellow, white, blue	
Micro SD card	Input Voltage: 3.3V/5V 4 mounting holes with 2.2mm diameter Only use 4 I/O pins on the Arduino	

Figure 5. Selection equipment

Experimental Conditions:

1. **Static Tests**: Conducted at 2000–4000 RPM.
2. **Dynamic Tests**: Performed on a highway at speeds of 60–100 km/h under varying road surface conditions.

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Data Collection:
Data from the Arduino logger were recorded in text format and processed using Microsoft Excel. Calibration was performed to minimize discrepancies between the Arduino system and the SLM.

4. Result and Discussion (Section 4)

4.1 Noise Levels and Observations

Noise levels increased with RPM and speed in both static and dynamic conditions. Dynamic conditions exhibited higher noise levels due to additional factors such as tire-road interaction, aerodynamic effects, and external environmental noise.

4.2 Comparison Between Instruments

The Arduino data logger demonstrated a 0–2.5% deviation from the SLM measurements, affirming its reliability. Sound sensors provided improved sensitivity and accuracy over traditional sensors. Factors affecting discrepancies included sensor placement and calibration precision including the sensitivity of sensor.

4.3 Innovation in Noise Behavior Analysis

Graph monitoring revealed noise patterns that aligned with theoretical expectations, providing actionable insights for cabin noise reduction strategies. Noise levels consistently exceeded the passenger comfort threshold of 50 dB, particularly at higher RPMs and speeds, emphasizing the need for advanced NVH treatments.

Condition	Rpm	Average SLM (dB)	Average Arduino (dB)	Percentage of different %
Static	2000	55.2	54.0	2.2
	2500	57.7	57.1	1.0
	3000	58.9	57.6	2.2
	3500	69.7	68.0	2.5
	4000	71.2	70.9	0.4

Figure 6. Static condition data Arduino data logger and Sound Level Meter

Condition	Speed (km/h)	Average Arduino (dB)
Dynamic	60	64.8
	70	68.4
	80	70.2
	90	74.8
	100	75.0

Figure 7. Dynamic condition data only Arduino data logger

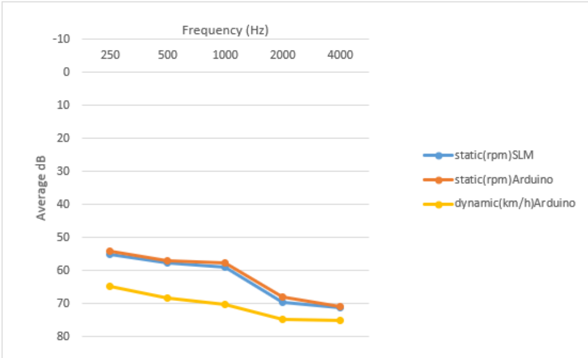

Figure 8. Noise (dB) vs frequency

3. Conclusion

This study successfully demonstrated the enhanced capabilities of an Arduino-based data logger integrated with sound sensors for vehicle cabin noise measurement. The system's monitoring feature, cost-effectiveness, and portability make it a competitive alternative to conventional solutions and can be used for educational tools for related program or subject in automotive technology. The findings highlight opportunities for its application in modern vehicles, including autonomous and electric models, for improved passenger comfort and safety.

4. Recommendations for Future Work

Develop a fully wireless IoT-based system for noise monitoring in fleets. Incorporate vibration sensors to analyze structural contributions to cabin noise and using of MEMs sensor. Besides that, enhance the smartphone application with predictive analytics for noise trend forecasting and integrate noise reduction algorithms into the system for real-time NVH management.

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