Application of Micro Electro-Mechanical Sensors (MEMS) Devices with Wifi Connectivity and Cloud Data Solution for Industrial Noise and Vibration Measurements

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Abstract. This paper introduces the application of Microelectromechanical Systems (MEMS) for industrial noise and vibration measurements. Sound measurement was done using a compact sound level meter with type 1 Micro-Electro-Mechanical Systems (MEMS) microphone while the vibration measurement used a compact vibration measuring device with 3-axial accelerometer, which is also a MEMS type sensor. The MEMS Sensors being used in both measuring devices provide advantages in terms of features and specifications such as weight reduction, compact in size and economically affordable for various applications. Besides MEMS Sensors, the devices are equipped with wireless connectivity to a local server via a WIFI router. This eliminates the usage of wired connection in data handling. Furthermore, Cloud connectivity is an add-on feature to the wireless capabilities of both devices. Using the Cloud features enable threshold alert alarm, data monitoring and collection to be done regardless of time and location of devices, provided that the internet connectivity is available to the user and the devices.

1. Introduction
A typical sound level meter is a hand-held instrument with a microphone used for acoustic measurement (in decibels dB SPL) especially in industrial and environmental applications. The microphone of this sound level meter consists of a diaphragm which moves corresponding to changes in air pressure caused by sound waves and the movement is converted into electrical signal [1-4]. The problem with this type of sound level meter is that its size, weight and design is not suitable to leave it stand alone for measurement and required to be hand-held. Furthermore, these sound level meters usually have high power consumption as such they are not suitable for long term continuous measurement.

In present work, we used a sound level meter that consists of Microelectromechanical systems (MEMS) microphone as in Figure 1:
As could be seen in Figure 1, physical appearance and design of MEMS sound level meter is totally distinct from typical sound level meters. It is compact in terms of size, weight and design due to the adoption of MEMS microphone instead of typical diaphragm microphone. MEMS are made up of components that are microscopic in size, thus it is known as a technology of microscopic devices. These components include a microprocessor and microsensors that interact with surroundings. MEMS has a lot of application ranging from our daily devices such as smartphones to autopilot and navigation of an airplane [5-7].

MEMS can be used as an accelerometer [7], which is why it can be used for navigation as mentioned above. Therefore, in addition to measure sound using MEMS sound level meter, we also conducted vibration measurement using a vibration meter that is made up of MEMS accelerometer which was as Figure 2:

Typical vibration measurement set up and configuration using external data acquisition system connected to sensors and computer are time consuming and inconvenient. MEMS vibration meter being used in this work does not require external data acquisition system and comes with standalone built-in storage for continuous measurement. Like the MEMS sound level meter, the vibration meter also has a lower power consumption compared to typical vibration meter, thus can also be used for long term measurement and monitoring (number of hours). Both sound and vibration devices being used in this work are also equipped with WIFI connectivity and Clouds storage capability using the Clouds webpage as illustrated in Figure 3.
Figure 3 Clouds page of one of MEMS-equipped sound and vibration measuring devices.

It eliminates wired connection and allows data handling to be done anytime and anywhere. These features ease the measurement and data handling works, thus is convenient for industrial applications.

2. Measurement Set Up
The device used for sound and measurement was known as Convergence Instruments NSRTW_mk2 and Convergence Instruments VSEW_mk2 respectively. The measurements were carried out at a Mass Rapid Transit (MRT) station for 1 hour and the train platform that the devices were placed was the platform where the train bound for Sungai Buloh. The level of sound and vibration at the station every time a train arrived were observed in this project. The MEMS sound level meter was connected to a PC and configured a computer software named Instrument_Manager which was installed on the PC. The instrument set up instructions can be obtained from the user manual which is available at (https://convergenceinstruments.com/pdf/NSRTW_mk2_UserManual.pdf). The following figure shows sound measurement parameters set-up using the software for this project:

Figure 4. Sound level measurement parameter set up using Instrument_Manager software.
Meanwhile, a MEMS vibration sensor was configured using similar method and the measurement parameters for vibration were as following figure:

![Figure 5](image)

**Figure 5.** Vibration measurement parameter set up using Instrument_Manager software.

Both sensors were configured to automatically begin measurement at 11.25AM. Then, the sensors were placed on the glass barrier that separate the platform with the train track as can be seen in the following figure:

![Figure 6](image)

**Figure 6.** Sound and vibration measurement devices placement on the glass barrier. (a) Device in top circle is the sound measurement device while device in the bottom red circle is the vibration measurement device; (b) Sound measurement device in closer look; (c) vibration measurement device in closer look.
From Figure 6, we could see that the compact size eased the placement and set up of both devices such that no additional mounting support accessories such as tripod stand was required as typical sound level meter. As the measurement automatically started at 11.25AM indicated by flashing red LED light on the sensors, time for each train arrival for both train direction was recorded throughout the 1-hour measurement duration. After 1-hour measurement, the measurement by the sensors were stopped and the data was collected and saved to the PC using the software mentioned above.

3. Results and Discussion
The following table shows recorded train movement time at the for both directions.

| Time     | Bound       |
|----------|-------------|
|          | Sungai Buloh |
| Kajang   |              |
| 11.29AM  | 11.31AM     |
| 11.36AM  | 11.38AM     |
| 11.43AM  | 11.45AM     |
| 11.50AM  | 11.51AM     |
| 11.57AM  | 11.59AM     |
| 12.04PM  | 12.06PM     |
| 12.11PM  | 12.13PM     |
| 12.18PM  | 12.20PM     |
| 12.25PM  |              |

From the table, we could observe that the train movement direction alternates with another at every single time. The measurement was carried out at the platform where the train bound for Sungai Buloh which was a factor that contribute to sound and vibration level of each train movement.

3.1. Sound Level
Measurement data from both devices were collected after 1 hour measuring duration. Sound level measurement result was as Figure 6 (a), (b) and (c).
Max sound level, $L_{\text{max}}$ (dB-Z)

Min sound level, $L_{\text{min}}$ (dB-Z)

Figure 7 Sound level data collected. (a) $L_{\text{EQ}}$; (b) $L_{\text{MAX}}$; (c) $L_{\text{MIN}}$.

Data presented in Figure 6 (a), (b) and (c) are Z-weighted Sound Levels in $L_{\text{MAX}}$, $L_{\text{MIN}}$, and $L_{\text{EQ}}$ in decibels (dB-Z) against measurement time respectively. From the data, one could see that the sound level will be highest at times when there was train movement close to the platform that the device is placed, in other words train that was bound for Sungai Buloh. This was followed by times when there was train movement in the opposite direction where the track is further from the platform.

3.2 Vibration Level
Velocity data collected from vibration measuring device were presented in the following Figure.
Figure 8 Vibration data collected in velocity. (a) x-axis vibration; (b) y-axis vibration; (c) z-axis vibration.
The vibration measuring device consists of 3-axial sensors. Therefore, three measurement data, one for each axis were collected and presented where Figure 7 (a), (b) and (c) represent vibration data in for x-, y- and z-axis respectively.

4. Conclusion
In this paper, the technology of MEMS was introduced and applied in sound and vibration measurement. Sound and vibration measuring devices used in this project were compact in size, lightweight, wireless and easy to use without the need of other extra support equipment or accessories.

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