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Wireless Data Logger Instrument for Indoor Acoustic Quality Measurement Based on Noise Background, Sound Distribution and Reverberation Time

Ayu Afifah Al-Farzaq[1], Harmadi Harmadi[1*], Elvaswer Elvaswer[1]

[1] Department of Physics, Universitas Andalas, Limau Manis, Padang 25163, Indonesia.

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Corresponding Author:

Harmadi Harmadi
Email: harmadi@sci.unand.ac.id

ABSTRACT

A wireless data logger system measuring indoor acoustic quality was developed using a NodeMCU ESP8266 and microphone sensor KY-037. The acoustic quality is based on parameters of sound pressure level and reverberation time. The system consists of a transmitter unit and a receiver unit. The transmitter unit is equipped with a Microphone KY-037 sensor as a sound detector and NodeMCU ESP8266 as a microcontroller and serial communication with the database. The transmitter unit of this measuring instrument is set at predetermined position points in a room. The results of testing the sound pressure level have an error percentage of 2.09% compared to the Digital Sound Level Meter GM1356 tool. Comprehensive testing of the tool has sent and processed sensor measurement data wirelessly into the database. The processed data is displayed through a GUI web server in the form of a background noise average, an average of the reverberation time value, and a graph of the sound pressure level in the room.

1. INTRODUCTION

Acoustic design in a room is essential to be noticed. The room's acoustic design will allow room users to obtain ideal listening conditions. The perfect acoustic quality is when the sound at a certain distance does not experience a decrease in the level of intensity and clarity of the sound. Acoustic quality in a room is often neglected, except for specific spaces such as theater rooms, recording studios, cinemas, and concert halls. For people whose hearing senses are sensitive, about 2% of the Indonesian population, being in a room with poor acoustic design will affect their health and psychology (Zahorik & Brandewie, 2016).

Room conditions will affect the acoustic quality, where the acoustic quality in an open space will be different from that in a closed area. Acoustics in closed spaces are more complex than in open spaces. Sound waves propagating in a closed space will interact with the material in the room with forms of interaction, including reflection, absorption, diffusion, and transmission (Kencanawati, 2017). The behavior of these sound waves will affect the value of the acoustic parameters in a closed room. Parameters used to measure acoustic quality include sound pressure level and reverberation time. Sound pressure level can represent the noise level and sound distribution in the room (Inacio, 2014).

Noise level is an essential parameter in acoustic quality. Noise is unwanted sound from a business or activity at a certain level and time that can cause disturbances to human health and environmental comfort. The average hearing level of humans when talking in daily life is 60 dB, while the noise exposure threshold or standard human hearing threshold is 120 dB (Fraden, 2016). Noise exposure at this threshold can impact hearing loss, psychological disorders, and high blood pressure (hypertension) (Nuristian et al., 2015).

Another critical parameter in designing the acoustic quality of a room is the sound distribution (Flaga, 2015). When a sound source with a normal sound pressure level can reach the farthest listener, it is ensured that sound pressure levels in the room are evenly distributed (Neubauer, 2000). Good sound distribution is when the sound pressure level is spread evenly in the room so that listeners in different positions can capture the same information. The condition for listeners to capture the same information even in different positions is that the difference between the closest and furthest sound pressure levels from the sound source in the room is not more than 6 dB (Kencanawati, 2017).

The following parameter used to determine a closed room's acoustic quality is reverberation time (RT). Reverberation (echo/echo) is a buildup of sound in space, produced by repeated reflections of sound waves from the entire surface of the area to distort the clarity of speech in the room. The RT value is obtained from the time it takes for the sound to decay by 60 dB. A long RT is needed in the music room to give and add an elegant impression to the resulting tone, while a short RT is required in the seminar room so that the sound does not distort the clarity of speech in the seminar (Karnefi, 2006). The wider the sound-absorbing material used, the shorter the reverberation value is (Istiadji, 2007).

Several companies have developed modern equipment for measuring indoor acoustic parameters. The company-made measuring instrument widely used in measuring acoustic parameters is the XL2 model sound level meter produced by NTi Audio. The sound level meter can measure several acoustic parameters such as sound pressure level, RT, and delay time. One of the studies using the XL2 model sound level meter is by Puglisi et al. (2015) regarding acoustic comfort for students and teachers in high school classrooms. The study was conducted by evaluating the acoustic quality of classrooms in two high school buildings in different locations. Acoustic parameters measured using this sound level meter include background noise and RT values. This study also uses DIRAC and SPSS 21 software as signal processors and data processing of measurement results. The company's design of acoustic parameter measuring instruments has several limitations, such as the relatively high price and the need for support from some software for data processing.

Research using wireless technology for acoustic quality parameters measurement has been carried out by Tu'u et al. (2019), designing a wireless indoor sound distribution measuring instrument. The design uses four sound sensor units, the nRF24L01 module and the Arduino Pro Mini microcontroller. The interface software design to the PC is made using the Python 2.7 programming language. The limitation of this research is that it only measures the sound distribution parameters.

Based on the problems and research results described previously, an indoor acoustic quality measuring instrument based on sound pressure levels and reverberation time wirelessly based on NodeMCU ESP8266 has been developed. The design of instrument is made in a portable form so that it can be easily moved when measuring test points in a room. The measurement data is directly processed and displayed on a PC using a localhost web server without using other software. The data is recorded in a database server, a computer (server) intended to run database programs (Fadhilah et al., 2018). A measuring instrument was developed using a microphone sensor KY-037 as a sound pressure level detector and NodeMCU ESP8266 as a microcontroller and serial communication. The advantage of using the KY-037 microphone sensor is that apart from its relatively low price, its sensitivity is also high in detecting sound pressure levels because it is a condenser microphone that utilizes a sound-sensitive capacitor (Gusti & Subandi, 2017). The sound pressure level value generated by the sensor is processed on the NodeMCU ESP8266. The use of the ESP82666 NodeMCU has the advantage that it has features like a microcontroller with access to wifi capabilities. Thus, the value from the sensor can be directly sent and displayed on the webserver (Priyono, 2017).

2. METHOD

Block diagram design of acoustic quality measuring instrument can be seen in Figure 1. The hardware system consists of two main parts: the transmitter and receiver units. The transmitter unit consists of a microphone sensor KY-037, NodeMCU ESP8266, and a push-button, while the receiver consists of a PC connected to the network.

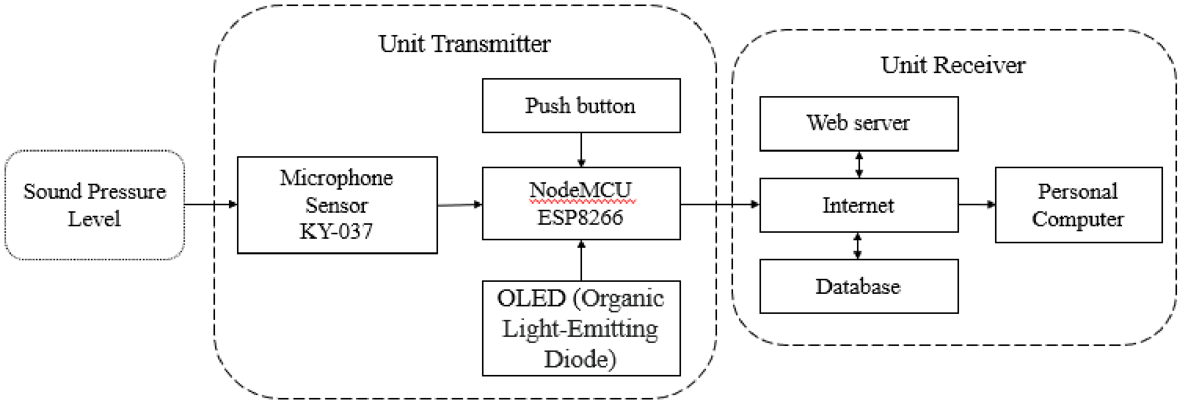

Figure 1. Block diagram design of wireless data logger unit transmitter and unit receiver.

The working principle of the hardware system for measuring sound quality in the transmitter unit is that when there is a change in sound pressure level in the room, it will affect the value of the output voltage on the microphone sensor KY-037. The sensor output voltage value will be processed at NodeMCU ESP8266 and represented as sound pressure level. The sound pressure level value is received again by calculating the time it takes for the sound to decay by 60 dB to get the reverberation time value. The push-button is used when sending the sensor value to the database so that the sensor value is sent to the unit's receiver.

The working principle of the receiver unit is that when the sensor readings are entered into the database, the values will be compared with the standard values for room acoustics. The room standards in question are the standard values for the acoustic level, sound distribution, and reverberation time that have been previously entered into the database. The results of comparing sensor values and standard room acoustic values in the database will then be added to the webserver. The web server will automatically display the results of the data placed through the database in the form of average values, sound distribution graphs, graphs, and the average value of the echo time in the room to be measured. The web server can be accessed via a personal computer connected to the same network as NodeMCU ESP8266.

The system software design uses Visual Studio Code Software for data display and Arduino IDE for ESP8266 NodeMCU programming. The design of this view uses HTML (Hypertext Markup Language) to create and arrange paragraph sections, headings, and other views on web pages. The web display will display the average background noise value, sound distribution graph, average reverberation time, and acoustic quality results based on these three parameters.

The system's accuracy can be determined from the percentage error between the actual value and the visible value. The percentage of error in testing the scale of a measuring instrument can be determined by Equation (1).

$$\varepsilon = \left| \frac{Y_n - X_n}{Y_n} \right| \times 100\% \tag{1}$$

where ε indicates the percentage error value, Y_n is the actual value on the comparison tool, and X_n is the value read on the measuring instrument (Deswilan & Harmadi, 2019).

3. RESULTS AND DISCUSSION

A wireless data logger system for indoor acoustic quality measurement has been developed in various stages, accompanied by testing each part of the tool. Tests are carried out on both hardware and software. Testing aims to determine whether the designed system can work and function properly.

The portable system will make it easier to measure the acoustic quality in a room. Figure 2 shows the physical form of the sensor system consisting of the box for the sensor system used, having dimensions of 14.5 x 9.5 x 4.5 cm. There is an OLED, push button, and KY-037 microphone sensor visible on the box's surface.

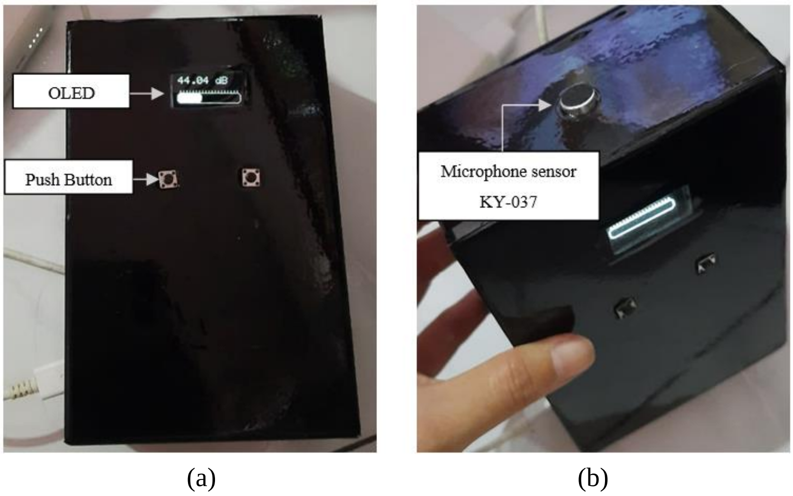

Figure 2. The physical form of the tool (a) front view (b) top view.

3.1 Microphone Sensor KY-037 Characterization

Figure 3 shows sound pressure level versus the output voltage of the KY-037 microphone sensor. The output voltage value of the microphone sensor KY-037 is directly proportional to the sound pressure level detected by the Digital Sound Level Meter GM1356, with the transfer function $y = 0.0372x + 0.9356$. Variable y is the output voltage, and variable x is the sound pressure level. The value of 0.0372 V/dB is a sensitivity value, states that every change in the sound pressure level of 1 dB results in a change in the output voltage value of 0.0372 V. The value of 0.9356 V is an offset value, which states that the initial output voltage value of the microphone sensor KY-037 when the sound pressure level is zero is 0.9356 V. Coefficient of determination of linear regression obtained is 0.8964, which is close to 1, indicating that the measurements are in good agreement with the standard sound level meter. The output voltage increases with increasing sound pressure level.

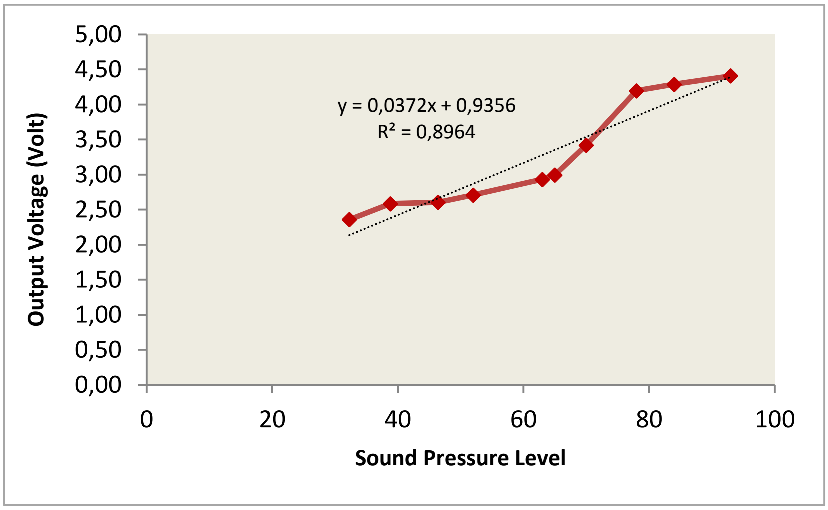

Figure 3. Output voltage against sound pressure level.

3.2 Testing of Measuring Instruments with Digital Sound Level Meter GM1356

Figure 4 compares the sound pressure level measured by the developed acoustic quality measurement tool and Digital Sound Level Meter GM1356. The developed instrument has an error percentage of 2.09% for sound pressure levels from 40 dB to 120 dB. The error percentage increase and become unstable when the volume of the sound source is greater than 110 dB. According to research conducted by Nurjannah et al. (2017) using the KY-037 microphone sensor, the sensor capability ranges from 31-110 dB, which is consistent with our study. Hidayat et al. (2019) used a condenser microphone sensor to measure sound pressure levels in a minimum range of 41 dB and a maximum of 69 dB with an average error value of 1.0%. Although the error percentage of our instrument is larger than Hidayat et al. (2019), the measurement range of ours is more comprehensive than that of Hidayat et al. (2019).

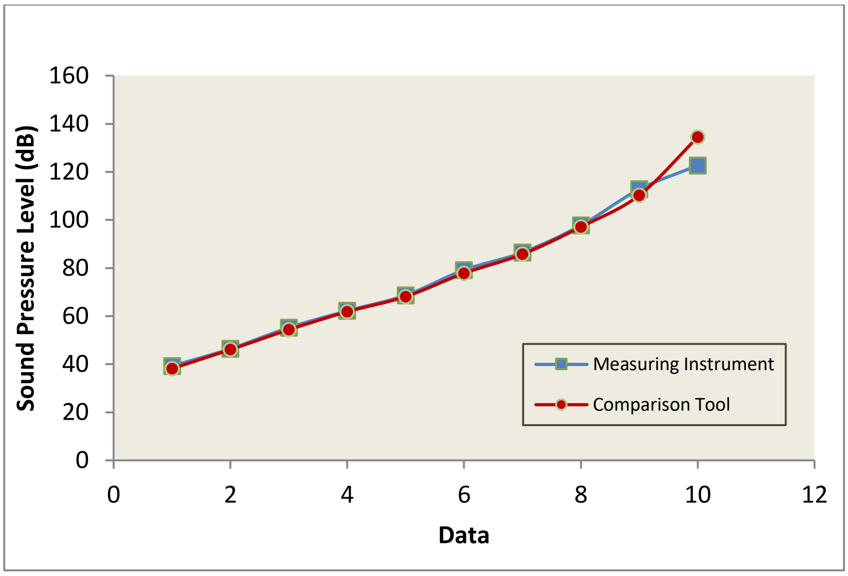

Figure 4. Sound pressure level from our instrument with the Digital Sound Level Meter GM1356.

3.3 Testing Data Transmission to Localhost Webserver

Data transmission testing is done by adjusting the data sent to the webserver with the received data (Figure 5). The display data from the embedded system is displayed through a serial monitor, and the data received by the webserver can be viewed in the database. The data on the serial monitor is the same as the data received by the webserver database (Figure 5). Wicaksono (2017) also proved that NodeMCU ESP8266 could receive the output of the sensor and send the sensor data to the server.

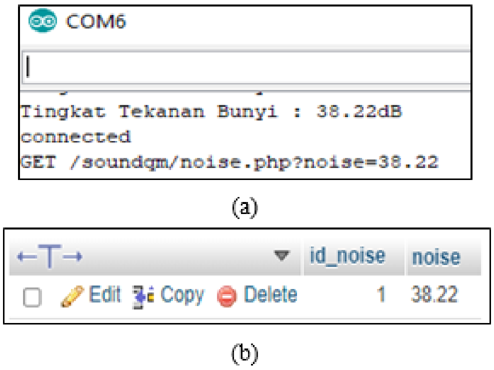

Figure 5. Data on the serial monitor (a) and on the webserver database (b).

3.4 Overall Tool Testing

Overall system testing aims to determine the working ability of each part of the tool when it is used simultaneously. The tool system uses the KY-037 microphone sensor as a sound pressure level detector and the NodeMCU ESP8266 as serial communication and a microcontroller. The sound pressure level and RT values detected by the sensor will be sent to the webserver database when the push button is pressed. Sensor values sent to the database will be processed and compared with standard values for noise level, indoor sound distribution, and RT parameters. The standard value of the comparison has previously been embedded in the database program. The standard value refers to the regulations of the Ministry of Environment of the Republic of Indonesia (Menteri Negara Lingkungan Hidup, 1996).

Table 1 Data recording in the database

Number	Noise Background	Sound Distribution	Reverberation Time
1	55.58	80.31	2.29
2	54.49	87.64	2.27
3	53.12	86.39	2.27
4	47.31	84.76	2.59
5	48.94	84.37	2.51
6	54.76	82.74	2.31
7	49.94	83.85	2.28
8	48.84	87.11	2.30
9	45.63	87.21	2.27
10	44.71	89.66	2.27

The data received in the database is then processed to obtain the average background noise level, sound distribution graph, and the average RT value in the room. The results of data processing will appear on the GUI (Graphical User Interface) webserver after filling in the data for the measured room. The test location is in the Mushalla Yayasan Darul Makmur room, which has a length of 6 m, a width of 7 m, and a height of 4 m. The test was carried out at 64 points with a height of ±0.6 m, and the distance of a measurement with the next measurement was 1 m.

Figure 8 shows the sound distribution and reverberation mapping pattern in the mushalla room. The background noise average value during the test is 53.73 dB. This value is in the safe category because the threshold value for noise background for places of worship such as prayer rooms is 55 dB (Menteri Negara Lingkungan Hidup, 1996). Furthermore, the RT value for the room is 2.91 seconds, indicating that the RT of the Mushalla room exceeds the recommended standard for places of worship. The standard reverberation value for the worship room is 0.9 – 1.2 seconds (Gumelar et al., 2018). The sound distribution value of the Mushalla Darul Makmur is also in the good category because the difference between the maximum and minimum sound pressure levels in the room is less than 6 dB. The highest sound pressure level is is 89 dB, while the lowest value is 85 dB. The longest reverberation time is at point [4,0] with a value of RT 3.00 seconds and the lowest reverberation is at point [4,6] with a value of 2.78 seconds. Overall reverberation time pattern in the Darul Makmur Foundation Mushalla spread evenly. However, the longest reverberation time value is located close to the sound source. Based on the three variables measured, there is only one RT variable which does not match the standard for the prayer room, according to Gumelar et al. (2018). Therefore, the acoustic quality of Mushalla Yayasan Darul Makmur's room can be categorized as "Good." The acoustic quality can be improved if sound-absorbing materials are added in the room to reduce the RT value (Binti & Rohmah, 2012).

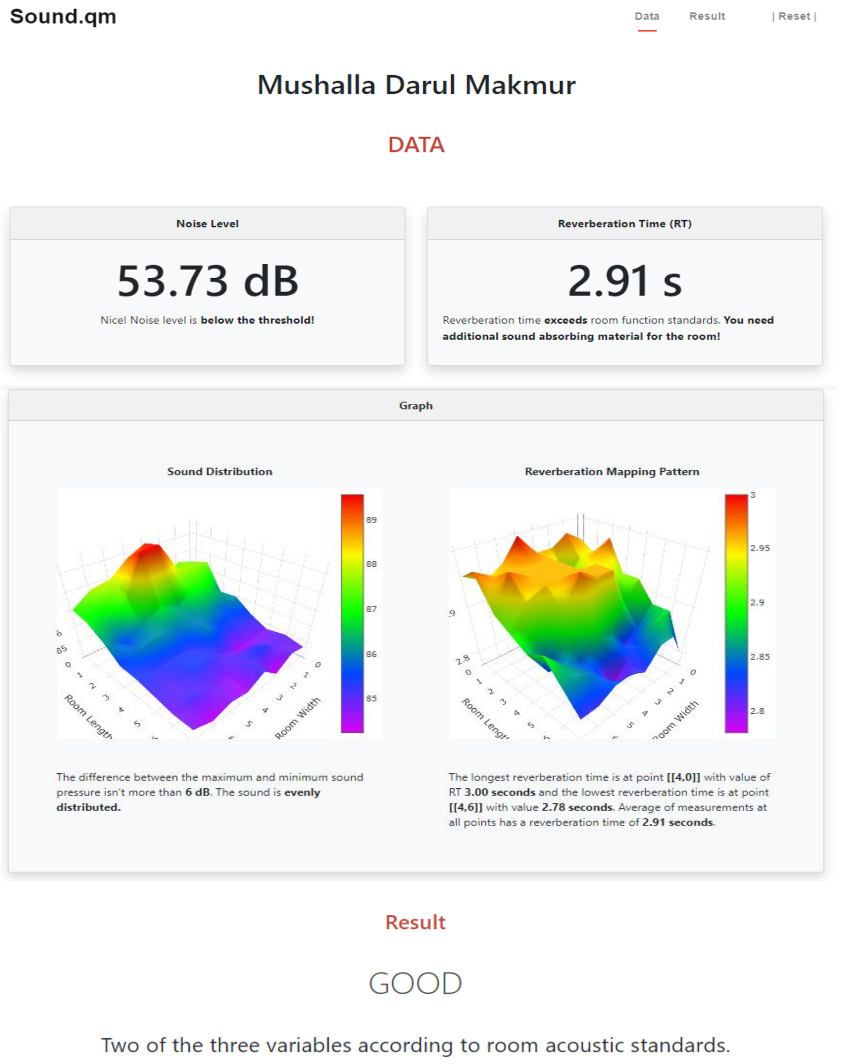

Figure 8. Testing result in Mushalla Yayasan Darul Makmur Agam District.

4. CONCLUSION

This research has successfully developed a wireless data logger instrument for indoor acoustic quality measurement based on noise background, sound distribution, and reverberation time. The KY-037 microphone sensor and NodeMCU ESP8266 can be used as a wireless data logger for indoor acoustic quality measurement. The percentage error between our instrument and the Digital Sound Level Meter GM1356 is 2.09%. The instrument can send and process sensor measurement data wirelessly into the database. The processed data can be displayed via a web server GUI in the form of average background noise, RT level, a graph of sound pressure, and acoustic quality level in the room. Thus, the instrument can be used for indoor acoustic quality measurement.

REFERENCE

Binti, O., & Rohmah, M. (2012). Analisis Waktu Dengung (Reverberation Time) Pada Ruang Kuliah B III . 01 A Fmipa UNS, *skripsi*, Jurusan Fisika, UNS.

Deswilan, S., & Harmadi. (2019). Rancang Bangun Alat Pendeteksi Kebisingan Berbasis Sensor Serat Optik. *Jurnal Fisika Unand*, *8*(3), 245–251.

Fadhilah, M. R., Tulloh, R., & Novianto, H. (2018). Perancangan dan Implementasi Database Server dengan

MariaDB dan Linux CentOS (Studi Kasus PT. Infomedia Nusantara). *E-Proceeding of Applied Science*, *4*(3), 2601–2611.

Flaga, A. (2015). An acoustic study of the auditorium hall to be located in the proposed building of the Applied Acoustics Laboratory of Cracow University of Technology. *Czasopismo Techniczne*, *2015*(Budownictwo Zeszyt 2-B (12) 2015), 343–357. https://doi.org/10.4467/2353737XCT.15.142.4179

Fraden, J. (2016). Handbook of Modern Sensors. In *Handbook of Modern Sensors*. Spinger. https://doi.org/10.1007/978-3-319-19303-8

Gumelar, A. (2018). *Perancangan Instrumentasi Pengukuran Dan Pola Kualitas Kustik Ruangan Berdasarkan Tingkat Tekanan Bunyi Dan …*. *06*(01), 123–132.

Gusti, D. R., & Subandi, A. (2017). Alat Pendeteksi Birahi pada Domba Betina berbasis Android dan mikrokontroler. In *Sistem Komputer Unikom*.

Hidayat, A. D., Sudibya, B., & Waluyo, C. B. (2019). Pendeteksi Tingkat Kebisingan berbasis Internet of Things sebagai Media Kontrol Kenyamanan Ruangan Perpustakaan. *Avitec*, *1*(1), 99–109. https://doi.org/10.28989/avitec.v1i1.497

Inacio, O. (2014). *Fundamentals of room acoustics*. *August 2002*. https://doi.org/10.1007/978-3-540-92723-5

Istiadji, A. D. (2007). Studi Simulasi Ecotect Sebagai Pendekatan Redesain. *Dimensi Teknik Arsitektur*, *35*(2), 107–116.

Karnefi, V. S. (2006). Uji Kualitas Akustik Auditorium. *Jurnal Gradien*, *2*(1), 113–115.

Kencanawati, C. I. P. K. (2017). Akustik dan Material Penyerap Suara. In *Bahan Ajar Universitas Udayana*.

Menteri Negara Lingkungan Hidup. (1996). *Keputusan Menteri Lingkungan Hidup No. 48 Tahun 1996 Tentang Baku Mutu Kebisingan*. *48*, 7. https://toolsfortransformation.net/wp-content/uploads/2017/05/48-Tahun-1996-Kepmen-LH-Baku-Tingkat-Kebisingan.pdf

Neubauer, R. O. (2000). Estimation of Reverberation Time in Rectangular Rooms with Non-Uniformly Distributed Absorbtion Using a Modified Fitzroy Equation,. *ICSV*, *3*, 1709–1716.

Nuristian, K., Warsito, Pauzidan Ahmad, G., & Supriyatno, A. (2015). Analisis Tingkat Kebisingan Suara di Lingkungan Univeristas Lampung. *Jurnal Teori Dan Aplikasi Fisika*, *03*(01), 69–73.

Nurjannah, I., Harijanto, A., & Supriadi, B. (2017). Sound Intensity Measuring Instrument Based on Arduino Board with Data Logger System. *International Journal of Advanced Engineering Research and Science*, *4*(9), 27–35. https://doi.org/10.22161/ijaers.4.9.7

Priyono, N. . (2017). *Sistem Peringatan Dini Banjir Berbasis Protocol MQTT Menggunakan NodeMCU ESP8266*.

Puglisi, G. E., Cantor Cutiva, L. C., Pavese, L., Castellana, A., Bona, M., Fasolis, S., Lorenzatti, V., Carullo, A., Burdor, A., Bronuzzi, F., & Astolfi, A. (2015). Acoustic comfort in high-school classrooms for students and teachers. *Energy Procedia*, *78*, 3096–3101. https://doi.org/10.1016/j.egypro.2015.11.763

Tu'u, D. H., Sugriwan, I., & Fahrudin, A. E. (2019). Pembuatan Alat Ukur Distribusi Bunyi dalam Ruang, secara Nirkabel Berbasis Mikrokontroler. *Jurnal Fisika FLUX*, *1*(1), 99. https://doi.org/10.20527/flux.v1i1.6152

Wicaksono, M. F. (2017). IMPLEMENTASI MODUL WIFI NODEMCU ESP8266 UNTUK SMART HOME. *Jurnal Teknik Komputer Unikom*, *6*(1), 1–6. https://doi.org/10.33751/komputasi.v16i2.1622

Zahorik, P., & Brandewie, E. J. (2016). Speech intelligibility in rooms: Effect of prior listening exposure interacts with room acoustics. *The Journal of the Acoustical Society of America*, *140*(1), 74–86. https://doi.org/10.1121/1.4954723