Gravity: Jurnal Ilmiah Penelitian dan Pembelajaran Fisika

http://jurnal.untirta.ac.id/index.php/Gravity

ISSN: 244-515x; e-ISSN: 2528-1976

Vol. 10, No. 2, Aug 2024, Page 141-150

Characterization of the cough monitoring device for TB patients based on the MAX9814 sound sensor

Masria Musfiana, Aris Widodo*, Muhamad Azwar Annas

Department of Physics, Universitas Muhammdiyah Lamongan, Indonesia

**E-mail:* aris.prof22.@gmail.com

(Received: 19 August 2024; Accepted: 22 August 2024; Published: 30 August 2024)

ABSTRAK

Mycobacterium tuberculosis is the cause of tuberculosis (TB), one of the deadliest diseases in the world that affects the respiratory system as specially in Indonesia. This work aims to characterize MAX9814 as TB's cough monitoring sensor. This device, which has never been used before, detects coughs primarily using the MAX9814 cough sensor. It also employs sound pressure level in addition to audio frequency. It also has Internet of Things (IoT) to remotely operate electronic equipment, transmitting patient cough data, enabling medical professionals to decide medical treatment for patient as monitoring data. Data on the sensor's accuracy and error values, sensitivity, repeatability, precision, and resolution. The instrument was calibrated using an Audiosensor with a 1000Hz audio generator and an SLM (Sound Level Meter) calibrator prior to data collection. The investigation yielded excellent results, with an accuracy rating of 96,14% and an error of 3,86%. This figure is reasonably close to the estimated value of 5% that has been calculated for the Gaussian distribution. The SLM with a sensor has an average value of 0.05, whereas the audiotool has a sensor value of 0.02. 50% is the repeatability value, 0.01% is the precision value, and 0.0125 is the sensor resolution.

Keywords: Characterization, Monitoring, Sensors, Tuberculosis, Sensors.

DOI: 10.30870/gravity.v10i2.28340

INTRODUCTION

Mycobacterium tuberculosis is the cause of acute respiratory infection known as tuberculosis (TB) (Zimmer et al., 2022). Third after China and India in terms of TB cases, Indonesia plays a significant role in the disease. More than 724,000 new TB cases were discovered in 2022, and the number will increase to 809,000 cases in 2023. Phlegm splashes are a common way for germs to enter the air after a patient coughs one cough can result in up to 3000 phlegm splashes (Bhatia et al., 2020). One reason for the rising number of TB patients is the disease's ease and speed of transmission (Otoshi et al., 2021). Nevertheless, the patient only receives direct pharmaceutical administration as part of the existing treatment, which requires a monthly visit to a hospital or health center (Farhana, Nurwahyuni, & Alatas, 2022). Medical personnel only provide medication to patients under close observation (Yellapu et al., 2023). The Internet of Things (IoT) can be utilized to help treat tuberculosis patients because to the advancements in information and communication technology (Syaddad & Abshor, 2019). In this most recent TB case, the Internet of Things (IoT) is being used as a system to help control drug intake for tuberculosis (TB), which needs to be regular in order to boost the cure rate. Internet of Things (IoT) is a service that can be incorporated using specific kinds of sensors. Remotely operated electrical equipment is likewise managed by IoT (Yuhefizar, Nasution, Putra, Asri, & Satria, 2019). A sound sensor can be employed, as it is capable of detecting sound waves produced by coughing (Abdullah, Cholish, & Haq, 2021).

Sound sensors will be employed as a technique for the early identification of COVID-19 through coughing. The MAX9814 sensor was then employed in 2023 as a measuring device to classify coughs according to specific pressures (Widodo & Aisiyah, 2023). The MAX9814 sensor has only been utilized to characterize coughs in numerous earlier investigations; the gadget has not yet been described (Wicaksono, 2017). Hence, characterisation research on the TB cough monitoring instrument was done in 2024 as an addition to earlier studies (Cahyono, Supriyadi, & Rofiq, 2017) . The MAX9814 sensor is used because it is a sound sensor with the benefit of an automated gain controllable sound microphone, which stabilizes the sound pressure level (SPL) in dB. The MAX9814 sensor is a low-cost, high-quality, low-noise sensor (Inayah, 2021). Thus, in addition to managing drug intake, IoT may also regulate the masx9814 sensor, which keeps track of patients' conditions. By doing this, we may learn more about the features of the TB cough monitoring sensor and work toward raising the living conditions of TB patients. Max9814 must be described before being integrated with the Internet of Things system. This will maximize the sensor's performance when used and lower reading and detection errors, which could skew monitoring data and negatively impact medical decisions. The purpose of this study is to evaluate MAX9814 as a cough monitoring sensor for tuberculosis.

RESEARCH METHODS

This experiment begins by preparing tools and materials, including NodeMCU, Adafruit Max9814 sound sensor, OLED display 128 x 64, 9V battery, jumper cables, multimeter, solder, and tin. Then, the circuit design is made using Fritzing software as shown in Figure 1.

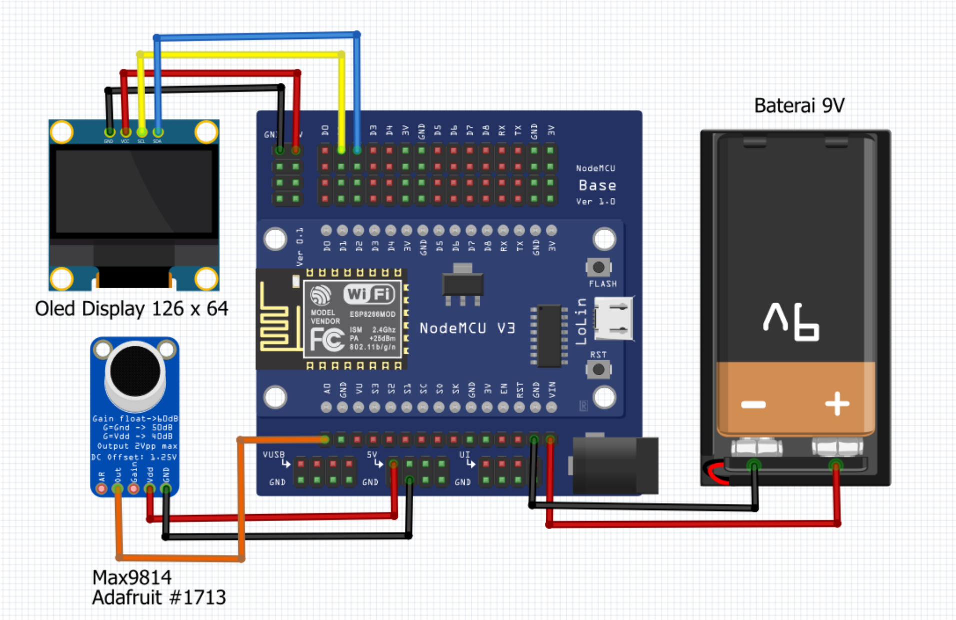


Figure 1. Circuit design

Then, the sensor is assembled likes Figure 1 PCB board. The cough sensor used for this monitoring has the following specifications: it draws 9 watts of power, has a sound frequency of 20–20 kHz, a floating SPL gain of 60 dB, a working SPL of 60–100 dB, and an OLED display for showing SPL data and including IoT server uses Arduino IoT Cloud. In this study, an experimental quantitative method was used to measure the SPL value of cough sounds using the Max9814 sound sensor. Next, audiotool calibration software and SLM (sound level meter) are used to calibrate the MAX9814 sensor. A 1000Hz audio generator is used to generating audio simultaneously for calibration process(Mamahit, 2024). SPL data is acquired from calibration and also combined with secondary audio cough data by using Audacity software (Sudaradjat, 2019). it was used to integrate cough data from TB patients from Coswara dataset in order to characterize the sensor (Bhattacharya et al., 2023). Then, cough combined audio from coswara is played back on speaker while sensor and calibrator measuring its SPL. SPL measurement data is also used to characterize the Max9814 sensor with several criteria, including: Accuracy ,error , sensitivity, repeatability, precision, and resolution for characterize the sensor (Muthmainnah, Tabriawan, & Tazi, 2022).

The following formula is used to get the accuracy and error (Kurniawan, Syaifurrahman, & Jekky, 2021) values:

$$Accuracy = \frac{Measurement\ data}{Callibration\ data} x100\% \tag{1}$$

$$Error = 100\% - Accuracy \tag{2}$$

To determine the sensitivity (Umbu, 2023) value of the sensor:

$$Sensitivity = \frac{Rate\ of\ measurement\ data}{Callibration\ data} \tag{3}$$

To determine the repeatability (Wali, 2019) sensor's value:

$$Repeatibility = \frac{n\ similar\ data}{n\ measurement\ data} \tag{4}$$

The sensor precision (Ulfiati, Purnami, & Karina, 2017) value can be ascertained by:

$$Precision = Average\ of measurement\ data\ \pm \Delta\sigma \tag{5}$$

To ascertain the sensor resolution's (Abdi & Aisyah, 2011) value is:

$$Resolution = \frac{Smallest\ increment\ data}{2} \tag{6}$$

Next, use the standard deviation to compute the sample or population data that was collected. The distribution of data in a sample that is used to determine how much a data value deviates from the average is called the standard deviation (Febriani, 2022). The standard deviation is:

Standard deviation :

$$\boldsymbol{\sigma} = \sqrt{\frac{\sum y^2 - \frac{(\sum y)^2}{n}}{n-1}} \tag{7}$$

Where:

S = standard deviation

n = total number of data

y^2 = square value of the amount of data (I = 1, 2, … n)

y = total data value

Review the sensor's characteristics and then evaluate the outcomes. The outcomes are shown as tables and graphs that include explanations of each equation as well as calculations examples.

RESULTS AND DISCUSSION

In the assembly process, there is hardware and software assembly, namely the Max9814 sound sensor system equipped with Arduino Cloud as an IoT server as shown in the Figure 2.

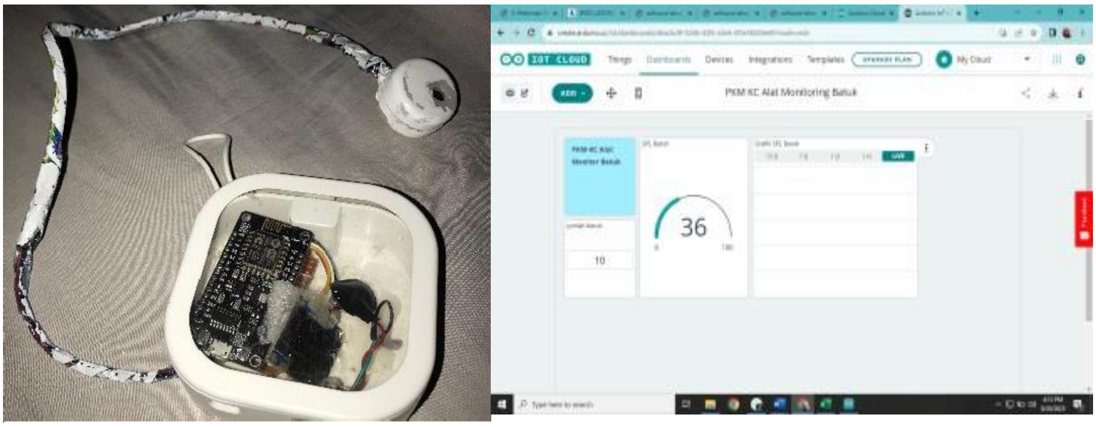


Figure 2. Hardware (left) and arduino cloud IoT (right)

The device connected to the Internet of Things makes advantage of a nearby wifi network. Because the device is small and lightweight, it may be placed next to patients who are frequently on the go and used to look for wifi signals. When the microphone is positioned exactly on the shirt collar, close to the patient's lips, the IoT system shows measured cough SPL data. A 24-hour SPL data plot is another feature of the IoT system that helps track the progression of the patient's cough condition. Data from IoT can also be used to characterize the sensors that produce the following data.

Tables 1 through 4 present the accuracy and error, sensor sensitivity, repeatability resolution, and precision findings from this study. Next, the data is processed with the help of equations accuracy (1) and error (2), the data is collected form sensor and Audiotool callibration software when measuring cough sound

Table 1. Accuracy and error

n - Cough	sensor (dB)	audiotool (dB)	Accuracy %	error %
1	84 ± 2,98	87,7 ± 2,98	95,78%	4,22%
2	85 ± 2,05	87,9 ± 2,64	96,70%	3,30%
3	83,6 ± 3,44	86,6 ± 3,27	96,54%	3,46%
4	85 ± 3,37	88,1 ± 3,48	96,48%	3,52%
5	85 ± 2,87	88,5 ± 3,60	96,05%	3,95%
6	82,5 ± 1,96	86,2 ± 4,02	95,71%	4,29%
7	84,5 ± 2,37	87,5 ± 2,64	96,57%	3,43%
8	84,3 ± 2,67	87,9 ± 2,33	95,90%	4,10%
9	83,3 ± 1,95	86,1 ± 2,08	96,75%	3,25%
10	84,4 ± 2,37	88,9 ± 3,96	94,94%	5,06%
	Average		96,14%	3,86%

It is evident from Table 1's data that the TB cough monitoring sensor has reasonable accuracy and error values. with an average inaccuracy of 3,86% and accuracy of 96,14% on average. The data that follows illustrates why the final error value is still less than the 5% Gaussian distribution (Aeni, Baharuddin, Putera, & Melani, 2024) . Error values can be caused by a number of things, including noise introduction from insufficiently soundproof data gathering procedures, voltage fluctuations in the sensor that lead to unstable readings, and noise-producing circuit connections from jumper cables inside the device (Siagian, 2021).

Table 2. Sensitivity of measurement data

SLM (dB)	**Audiotool (dB)**	**Sensor (dB)**
80,3	82,7	85,2
85,2	88,2	89,9
90,1	92,8	94,3

Table 3. Sensitivity of sensor compares with SLM and Audiotool callibrator

Pair to pair	**1**	**2**	**3**	**average**
sensor - SLM	0,06	0,06	0,05	0,05
sensor - Audiotool	0,03	0,02	0,02	0,02

The sensitivity of the sensor was measured using the data in Table 2, and the result of calculation are displayed in Table 3, which displays the sensor's sensitivity to incoming changes. The sensor has an average sensitivity of 0.05 when used with SLM and 0.02 when used with audiotool. The sensor may adapt to changes indicated by the average value that is obtained, as demonstrated by the sensor's average sensitivity value results (Emrinaldi, Defrianto, Fiddunya, Setiadi, & Umar, 2019). Because human coughs have varying decibel levels, the equipment needs to be simple to adjust in order to distinguish between coughs caused by tuberculosis and non-coughs (Nurfani, 2021).

Next, using equation (4) to magnitude the repeatability and resolution data (6), the outcomes are:

Table 4. Resolution dan repeatability

no	Resolution (dB)	Repeatability (dB)
1	88.57	88
2	89.25	89
3	88.59	88
4	88.72	88
5	89.12	89
6	89.10	89
7	88.79	88
8	88.82	88
9	89.11	89
10	89.13	89

$$Repeatibility = \frac{5}{10} = 0{,}5 = 50\%$$

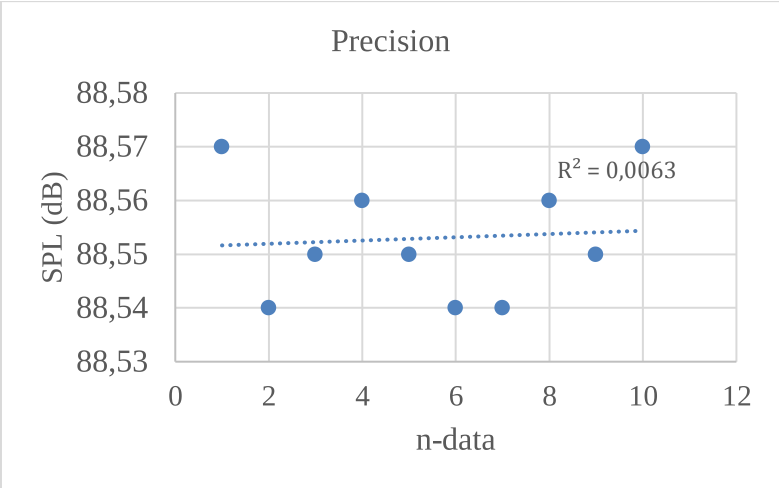
Our goal at this point is to determine whether the data from the sensor is consistent. Table 4 displays the results, which indicate that the sensor's consistency is fairly excellent. where there is a slight variation in the output data (Purnianto, 2020). The first cough data and the other cough data show a slight discrepancy in the acquired results. It is evident that when the data is repeated, the same result yielded has a 50% value for the number of values that are identical. A cough will continue to be noticed as a cough if this technique is used to measure people who have the same cough from the beginning (Hendri & Wildian -, 2013).
Next, about resolution:

$$Resolution = \frac{0{,}25}{2} = 0{,}0125$$

The smallest size that the sensor is able to read is called resolution. The sensor resolution results are rather low, as indicated by the sensor resolution calculation results in Table 4; this number is then utilized as a reference for the sensor resolution. Based on the specifications of the MAX9814 sensor, the sensor's characterisation improves with decreasing resolution (Oktaviani & Johan, 2016). The data shown in the Max9814 sensor data sheet matches the resolution of the sensor.

Next, using equation (5) to calculate the precision of sensor, and the result likes Figure 3.

Figure 3. Precision



$$Precision = 88{,}55 \pm 0{,}01$$

Precision is the closeness of agreement between repeated measurements or the capacity of a sensor to deliver the same reading when all the amounts given are the same and are performed repeatedly (Alfarisi & Syafitri, 2022). If the sensor periodically displays the measurement results regarding the dB value of the cough sound, it is considered to have good precision (Belo, Soares, Lima Filho, Lima, & Adissi, 2023). Figure 3's results demonstrate that data collecting was done ten times, with a data closeness of 0.01. One may say that the sensor's precision is fairly good. Numerous physical parameters, such as the patient's lung health, respiratory muscle strength, respiratory tract size, and body position when coughing, affect the SPL value of the cough sound produced by a tuberculosis patient as detected by the MAX9814 sound sensor. Furthermore, environmental factors like humidity, temperature, and the existence of sound barriers may have an impact on the measurement outcomes. Another crucial element is the frequency of the cough sound, which is determined by the size and tension of the vocal cords. Lastly, the measured SPL value is also determined by the frequency characteristics and sensitivity of the MAX9814 sound sensor.

CONCLUSION

The monitoring sensor in this investigation exhibited accuracy and error rates of 96,14% and 3,86%, respectively. The audiosensor sensor has an average sensitivity of 0.02 while the sensor with SLM has an average sensitivity of 0.05. The sensor resolution is 0.0125 and the repeatability is 50%. Additionally, the sensor's precision has a 0.01 data closeness. The resulting data demonstrates that the monitoring sensor's qualities as a TB cough monitoring sensor are fairly excellent.

REFERENCES

Abdi, N. M., & Aisyah, S. (2011). *Peningkatan Kualitas Citra Digital Menggunakan Metode Super Resolusi Pada Domain Spasial*. *9*(3).

Abdullah, A., Cholish, C., & Haq, M. Z. (2021). Pemanfaatan IoT (Internet of Things) Dalam Monitoring Kadar Kepekatan Asap dan Kendali Camera Tracking. *Circuit: Jurnal Ilmiah Pendidikan Teknik Elektro*, *5*(1), 86–92. https://doi.org/10.22373/crc.v5i1.8497

Aeni, R., Baharuddin, Putera, L. J., & Melani, B. Z. (2024). The ACCURACY OF CHATGPT IN TRANSLATING LINGUISTICS TEXT IN SCIENTIFIC JOURNALS. *Didaktik : Jurnal Ilmiah PGSD STKIP Subang*, *10*(1), 59–68. https://doi.org/10.36989/didaktik.v10i1.2559

Alfarisi, M., & Syafitri, N. (2022). ANALISIS AKURASI DAN PRESISI SENSOR ULTRASONIK HC-SR04 PADA ROBOT KRPAI. *E-Proceeding FTI*. Retrieved from https://eproceeding.itenas.ac.id/index.php/fti/article/view/1552

Belo, F. A., Soares, M. B., Lima Filho, A. C., Lima, T. L. de V., & Adissi, M. O. (2023). Accuracy and Precision Improvement of Temperature Measurement Using Statistical Analysis/Central Limit Theorem. *Sensors*, *23*(6), 3210. https://doi.org/10.3390/s23063210

Bhatia, V., Srivastava, R., Reddy, K. S., Sharma, M., Mandal, P. P., Chhabra, N., … Sarkar, S. (2020). Ending TB in Southeast Asia: Current resources are not enough. *BMJ Global Health*, *5*(3), e002073. https://doi.org/10.1136/bmjgh-2019-002073

Bhattacharya, D., Sharma, N. K., Dutta, D., Chetupalli, S. R., Mote, P., Ganapathy, S., … Alagesan, M. (2023). Coswara: A respiratory sounds and symptoms dataset for remote screening of SARS-CoV-2 infection. *Scientific Data*, *10*(1), 397. https://doi.org/10.1038/s41597-023-02266-0

Cahyono, B. E., Supriyadi, S., & Rofiq, M. A. (2017). Karakteristik Sensor Kapasitif Pelat Sejajar Dalam Aplikasinya Sebagai Instrumen Pengukur Curah Hujan Berbasis Arduino Uno. *INDONESIAN JOURNAL OF APPLIED PHYSICS*, *7*(2), 97–106. https://doi.org/10.13057/ijap.v7i2.14248

Emrinaldi, T., Defrianto, Fiddunya, S. F., Setiadi, R. N., & Umar, L. (2019). PENINGKATAN SENSITIVITAS SENSOR KOIL DATAR MEMPERGUNAKAN SOFT MAGNETIC VITROVAC. *JOURNAL ONLINE OF PHYSICS*, *5*(1), 57–61. https://doi.org/10.22437/jop.v5i1.7986

Farhana, F., Nurwahyuni, A., & Alatas, S. S. (2022). Pemanfaatan Digital Health untuk Meningkatkan Keberhasilan Pengobatan Pasien Tuberkulosis di Negara Berkembang: Literature Review : *Media Publikasi Promosi Kesehatan Indonesia (MPPKI)*, *5*(9), 1043–1053. https://doi.org/10.56338/mppki.v5i9.2542

Febriani, S. (2022). Analisis Deskriptif Standar Deviasi. *Jurnal Pendidikan Tambusai*, *6*(1), 910–913. https://doi.org/10.31004/jptam.v6i1.8194

Hendri, Z., & Wildian -. (2013). PEMBUATAN DAN KARAKTERISASI LVDT SEBAGAI SENSOR JARAK. *Jurnal Fisika Unand*, *2*(3). https://doi.org/10.25077/jfu.2.3.%p.2013

Inayah, I. (2021). Analisis Akurasi Sistem Sensor IR MLX90614 dan Sensor Ultrasonik berbasis Arduino terhadap Termometer Standar. *Jurnal Fisika Unand*, *10*, 428–434. https://doi.org/10.25077/jfu.10.4.428-434.2021

Kurniawan, E., Syaifurrahman, S., & Jekky, B. (2021). Pengujian Tingkat Akurasi dan Error Dimensi Hasil Produk Mesin CNC Lathe Mini Custom. *Jurnal Rekayasa Mesin*, *12*(3), 747–756. https://doi.org/10.21776/ub.jrm.2021.012.03.24

Mamahit, C. (2024). Rumah Pintar dengan Lampu Kontrol Suara Menggunakan Arduino Uno R3. *Electrician : Jurnal Rekayasa Dan Teknologi Elektro*, *18*(2), 144–152. https://doi.org/10.23960/elc.v18n2.2567

Muthmainnah, M., Tabriawan, D. B., & Tazi, I. (2022). Karakterisasi Sensor MAX30102 Sebagai Alat Ukur Detak Jantung dan Suhu Tubuh Berbasis Photoplethysmograph. *JURNAL PENDIDIKAN MIPA*, *12*(3), 726–731. https://doi.org/10.37630/jpm.v12i3.655

Nurfani, M. Y. (2021). EFEK MATERIAL CARBON TERHADAP SENSITIVE SENSOR CONTROL. *Jurnal Teknik Mesin, Elektro Dan Ilmu Komputer*, *1*(3), 1–5. https://doi.org/10.55606/teknik.v1i3.23

Oktaviani, A., & Johan, Y. (2016). PERBANDINGAN RESOLUSI SPASIAL, TEMPORAL DAN RADIOMETRIK SERTA KENDALANYA. *JURNAL ENGGANO*, *1*(2), 74–79. https://doi.org/10.31186/jenggano.1.2.74-79

Otoshi, T., Nagano, T., Izumi, S., Hazama, D., Katsurada, N., Yamamoto, M., … Nishimura, Y. (2021). A novel automatic cough frequency monitoring system combining a triaxial accelerometer and a stretchable strain sensor. *Scientific Reports*, *11*(1), 9973. https://doi.org/10.1038/s41598-021-89457-0

Purnianto, F. I. (2020). Perancangan Sistem Instrumentasi Pada Sistem Monitoring Kualitas Air Berbasis Hybrid Control Dengan Panel Surya. *Setrum : Sistem Kendali-Tenaga-elektronika-telekomunikasi-komputer*, *9*(2). https://doi.org/10.36055/setrum.v9i2.9140

Siagian, N. A. (2021). Comparative Analysis of Accuracy in Identifying Types of Glass. *InfoTekJar : Jurnal Nasional Informatika Dan Teknologi Jaringan*, *5*(2), 378–381. https://doi.org/10.30743/infotekjar.v5i2.3655

Sudaradjat, D. (2019). DIGITALISASI SINYAL SUARA MANUSIA DENGAN ALGORITMA LINEAR PREDICTIVE CODIN. *JITK (Jurnal Ilmu Pengetahuan Dan Teknologi Komputer)*, *4*(2), 177–184.

Syaddad, A. D., & Abshor, A. F. U. (2019). *Sistem Pencegahan Dini dalam Kebisingan Berbasis Arduino*. *18*.

Ulfiati, R., Purnami, T., & Karina, R. M. (2017). FAKTOR YANG MEMPENGARUHI PRESISI DAN AKURASI DATA HASIL UJI DALAM MENENTUKAN KOMPETENSI LABORATORIUM (The Factor that Affect the Precision and Accuracy of Test Result Data within Determine the Laboratory Compentency Level). *Lembaran Publikasi Minyak Dan Gas Bumi*, *51*(1), 49–63. https://doi.org/10.29017/LPMGB.51.1.15

Umbu, A. B. S. (2023). Analisis Grafik Karakteristik Sensitivitas Sensor MQ-135 untuk Menentukan Persamaan Hubungan antara ppm dan Rs/Ro. *Jurnal Teori dan Aplikasi Fisika*, 49–60.

Wali, P. (2019). Analisa Pengujian Repeatability Timbangan Elektronik dengan Metode Syarat

Teknis Timbangan Non Otomatis dan Metode NMI Australia. *Elinvo (Electronics, Informatics, and Vocational Education)*, *4*(2), 176–183. https://doi.org/10.21831/elinvo.v4i2.28356

Wicaksono, M. F. (2017). IMPLEMENTASI MODUL WIFI NODEMCU ESP8266 UNTUK SMART HOME. *Komputika : Jurnal Sistem Komputer*, *6*(1). Retrieved from https://ojs.unikom.ac.id/index.php/komputika/article/view/339

Widodo, A., & Aisiyah, M. C. (2023). Characterization of Cough Sounds Based on Measured Sound Pressure Levels from Arduino-Based MAX9814 Sound Sensor. *Jurnal Fisika Dan Aplikasinya*, *19*(1), 28–33. https://doi.org/10.12962/j24604682.v19i1.14432

Yellapu, G. D., Rudraraju, G., Sripada, N. R., Mamidgi, B., Jalukuru, C., Firmal, P., … Pamarthi, K. (2023). Development and clinical validation of Swaasa AI platform for screening and prioritization of pulmonary TB. *Scientific Reports*, *13*, 4740. https://doi.org/10.1038/s41598-023-31772-9

Yuhefizar, Y., Nasution, A., Putra, R., Asri, E., & Satria, D. (2019). Alat Monitoring Detak Jantung Untuk Pasien Beresiko Berbasis IoT Memanfaatkan Aplikasi OpenSID berbasis Web. *Jurnal RESTI (Rekayasa Sistem Dan Teknologi Informasi)*, *3*(2), 265–270. https://doi.org/10.29207/resti.v3i2.974

Zimmer, A. J., Ugarte-Gil, C., Pathri, R., Dewan, P., Jaganath, D., Cattamanchi, A., … Grandjean Lapierre, S. (2022). Making cough count in tuberculosis care. *Communications Medicine*, *2*, 83. https://doi.org/10.1038/s43856-022-00149-w