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Design and Realization of Microcontroller-based Sound Level Meter Calibration Devices

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Abstract. *A noise measurement device is a sound level meter. A measurement device, like the sound level meter is best calibrated first, so the user knows how precise the device is. In association to the usage of the measuring device, several cases of different measurement results have occured. Those cases can be resolved by calibrating the device. Calibration is a set of actions that form a relation between the value displayed by the measuring device or system, or a value represented by measuring material, with known values related to values measured in certain condition. The design and realisation of the sound level meter is done automatically without moving the measuring point's selector. This device utilises processing modules, Wi-Fi modules, a dashboard on a laptop and a Band Pass Filter (BPF) module. The BPF module on this device will function as a filter that releases certain frequencies at certain ranges and atenuate the signals with frequency outside the range. The BPF module will wilter sound sources coming from the software, DAQARTA, which has already been installed to the laptop. The sound source is an input for this calibration device. The sound that has been filtered by the BPF module is passed on to a speaker, which is an output from the designed device and measured by the sound level meter that has received a calibration certificate by LIPI. The device can fulfil the standards of ISO/IEC 61672-1 : 2017 "Electroacoustic-Sound Level Meters" at a frequency point of 125 Hz – 8000 Hz, with a value difference from the standard as much as 4,39% - 4,89%, accuracy level intensity A-weighted and C-weighted with a range of 98,28% - 100% at a point of 125 Hz - 8000 Hz and precision value of 100%.*
Keywords: *Measuring device, Sound Level Meter, Calibration, Band Pass Filter(BPF)*

1. Introduction

Noise is the occurrence of unwanted sound which can be disturbing and harmful for the health [1]. The noise brings many deceases such as physiological, psychological, and communication disorders, including deafness. Psychological disorders include discomfort, lack of concentration, insomnia, and irritability [2]. The noise can be measured using a sound level meter. The meter such as sound level meter should be calibrated regularly to provide precise and accurate measurement results. Many cases have been found related to the use of measurement devices with unbalanced results. The noise is introduced by several factors, such as improper function of the measurement device which cause false measurement results. The issue of inaccurate measurement results can be overcome by conducting the re-calibration process to the device. Calibration is a set of actions that form a relation between the

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value displayed by the measuring device or system, or a value represented by measuring material, with known values related to values measured in certain condition [3]. PT. KALIMAN utilizes a device named multifunction acoustic calibrator to calibrate the sound level meter. This device is used as a filter to avoid the noise produce by the sound source while the measurement process is conducted. A Band Pass Filter is used to pass a certain range of band frequencies and attenuate signals outside the selected range [4]. The filter utilizes a frequency selector according to the point of measurement manually. Based on the existing condition, an innovation to design an automatic filter selection for the existing calibration instrument is initiated using an application in a laptop through wireless network a.k.a. Wireless Fidelity (Wi-Fi). The sound level meter belongs to PT. KALIMAN has been certificated by Lembaga Ilmu Pengetahuan Indonesia (LIPI). The purpose of the design and realization of the microcontroller-based sound level meter (SLM) calibration device is to expand the existing SLM calibration device of PT. KALIMAN.

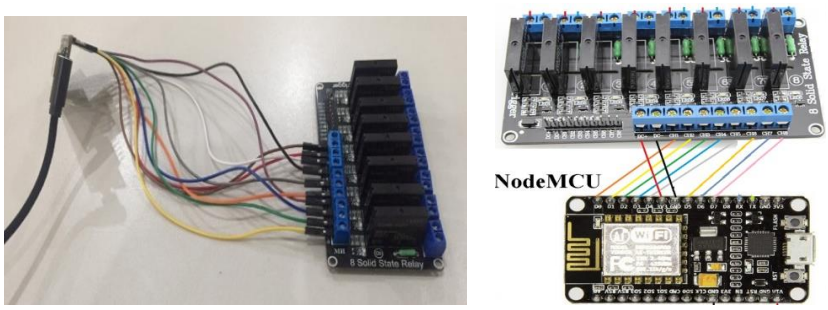
2. Methods and Realization

2.1 The Dashboard Module

The dashboard provides the information system for the users to present the performance of the company or organization [5]. The realization of the dashboard in the laptop serves as the interfacing for the users which is displayed as 3 buttons for automatic modes and 8 buttons for manual modes. The button on the dashboard will be selected using a mouse. The user points the mouse to select the appropriate button and then press the left button of the mouse. The buttons are presented with different colours to differentiate each other. The automatic mode comes with 3 button functions: start, stop and pause. The start button will start the calibration measurement according to the chosen point of measurement. The stop button will end the calibration process, while the pause button uses to hold the calibration process. If the pause button is pressed, it will change to a resume button. If the user presses the resume button the calibration will be continued. The manual mode consists of 8 buttons which have the remark for the frequency values according to the calibration point of measurement which are 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz dan 8000 Hz. The manual button is an addition to the first design with the purpose that if the automatic mode is not functioning the calibration process can still be executed.

2.2 The NodeMCU ESP8266 Module

The NodeMCU ESP8266 development board comes with the ESP-12E module containing ESP8266 chip having Tensilica Xtensa 32-bit LX106 RISC microprocessor. This microprocessor supports RTOS and operates at 80MHz to 160 MHz adjustable clock frequency [6].



(a) (b)

Figure 1. The realization and schematic diagram of NodeMCU ESP8266 module
(a) Realization (b) Schematic diagram

The NodeMCU ESP8266 module is realized to present the dashboard and adjust the movement of the selector in the SSR module. The NodeMCU ESP8266 is connected to the designed system and is programmed with Arduino IDE software. The NodeMCU ESP8266 module becomes the processor of the designed system which is connected to SSR and LCD modules as the display. The SSR module consists of 8 channels from CH1 to CH8. The realization and schematic diagram of the NodeMCU ESP8266 module is shown in Figure 1.

2.3 The BPF Module

The BPF module has the function to select the BPF channel from the sound source. The sound produces by the source will enter the BPF module and will be attenuate to remove unwanted frequency by determining the value of the cut-off frequency according to the point of measurement which are 63 Hz, 125 Hz, 250 Hz, 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz dan 8000 Hz. The point of measurement is selected based on the rule defined by ISO/IEC 61672-3 2006 which regulates the measurement for the class 2 sound level meter. The NodeMCU module will detect and read the command selected by the user and display it to the LCD. The cut-off value will be accommodated and passed to the speaker. The movement of one channel to another channel of BPF is arranged with a delay from NodeMCU in SSR. The realization of the BPF module is shown in Figure 2.

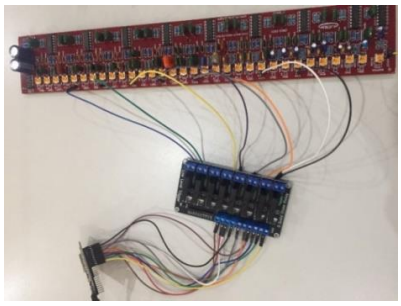


Figure 2. Realization of BPF module

2.4 The Sound Level Meter

Sound Level Meter (SLM) is a noise level measurement device. This device is capable to measure noise between 30 – 130 dB with a frequency range of 20 – 20,000 Hz [7]. The sound level meter consists of a microphone, amplifier, weighting network, and layer in the decibel (dB) unit. The level of SLM usually is symbolized with letter L and followed by a subscript letter on the right side to show the symbolized quantity level. The weighting is an electronic circuit that has a sensitivity similar to the audible frequency range of the human ear. There are 4 types of weighting that is: A, B, C, and D. The A is similar to low noise, while B is medium noise, C is high noise, and D is the response of human ear to an airplane noise [8.9.10].

In a subjective measurement to the response of the human ear, it is often found that the B and C weighting is not correct. It happens because the reference tends to measure sounds with one suppression, while in daily lives, the human ear hears many sounds with various suppression at the same time. In the contrary, A-weighting is very accurate to the human hearing level. Therefore, the A-weighting is frequently used as the guidance for measurement [9]. B and D weighting is not commonly utilized since IEC 61672 in 2003. There are two classifications of SLM they are: class 1 (type 1) and class 2 (type 2). The classification built upon the usage and need of the users. Type 1 is accommodated for the measurement with good precision especially in research and calibration in the laboratory. Type 2 fits for the measurement or survey of environmental noise and industry [11]. SLM type 1 able to measure the weighting level of A, C, dan linear (Z), while SLM type 2 only able to measure the weighting level of A and C.

3 Results and Discussions

The examination was conducted by connecting all the realized modules which are: processor module, BPF module, the dashboard in the laptop, and other modules. Furthermore, the SLM was used as the measurement device to identify the value generated by the SLM calibrator. The LSM was placed to the speaker and the system was operated to the determined point of measurement. The experiment was conducted 5 times for each frequency, which is at the frequency of 63 Hz to 8,000 Hz. The measurement results of the weighing with SLM output for the noise level of A-weighting (L_{AF}) and C-weighting (L_{CF}) are presented in Table 1. The measurement results of the LSM output for L_{AF} and L_{CF} of the calibration device of PT. KALIMAN is displayed in Table 2.

Table 1. The measurement results of the weighing with SLM output for the noise level of A-weighting (L_{AF}) and C-weighting (L_{CF})

Frequency (Hz)	Measurement									
	1		2		3		4		5	
	L_{AF} (dB)	L_{CF} (dB)	L_{AF} (dB)	L_{CF} (dB)	L_{AF} (dB)	L_{CF} (dB)	L_{AF} (dB)	L_{CF} (dB)	L_{AF} (dB)	L_{CF} (dB)
63	64,5	89,1	64,5	89,1	64,5	89,1	64,5	89,1	64,5	89,1
125	77,9	93	77,9	93,0	77,9	93	77,9	93,0	77,9	93,0
250	85,4	94,0	85,4	94,0	85,4	94,0	85,4	94,0	85,4	94,0
500	90,8	94,0	90,8	94,0	90,8	94,0	90,8	94,0	90,8	94,0
1000	94,0	94,0	94,0	94,0	94,0	94,0	94,0	94,0	94,0	94,0
2000	94,5	93,4	94,5	93,4	94,5	93,4	94,5	93,4	94,5	93,4
4000	93,4	91,6	93,4	91,6	93,4	91,6	93,4	91,6	93,4	91,6
8000	91,7	89,4	91,7	89,4	91,7	89,4	91,7	89,4	91,7	89,4

Table 2. The measurement results of the LSM output for L_{AF} and L_{CF} of the calibration device of PT. KALIMAN

Frequency (Hz)	Measurement									
	1		2		3		4		5	
	L_{AF} (dB)	L_{CF} (dB)	L_{AF} (dB)	L_{CF} (dB)	L_{AF} (dB)	L_{CF} (dB)	L_{AF} (dB)	L_{CF} (dB)	L_{AF} (dB)	L_{CF} (dB)
63	67,8	93,2	67,8	93,2	67,8	93,2	67,8	93,2	67,8	93,2
125	77,8	93,9	77,8	93,9	77,8	93,9	77,8	93,9	77,8	93,9
250	85,4	94,1	85,4	94,1	85,4	94,1	85,4	94,1	85,4	94,1
500	90,8	94,0	90,8	94,0	90,8	94,0	90,8	94,0	90,8	94,0
1000	94,0	94,0	94,0	94,0	94,0	94,0	94,0	94,0	94,0	94,0
2000	95,3	94,0	95,3	94,0	95,3	94,0	95,3	94,0	95,3	94,0
4000	95,0	93,2	95,0	93,2	95,0	93,2	95,0	93,2	95,0	93,2
8000	92,9	90,6	92,9	90,6	92,9	90,6	92,9	90,6	92,9	90,6

Table 2 shows that from the 5 measurements the LAF and LCF value in all frequencies obtain the same results which also means that the device has 100% precision. According to Table 1 and Table 2 the measurement of the designed equipment and PT. KALIMAN's device has different measurement results for the 63 Hz frequency. However, the results for 250 to 1,000 Hz frequency are the same. The value of L_{AF} and L_{CF} cannot give a close result to the standard because the BPF module at the appropriate point of measurement has a restriction in the variable resistor. The accuracy of the designed equipment can be discovered by comparing the L_{AF} and L_{CF} of Table 1 and Table 2. The result of Table 2 is used as the comparison value / standard value and Equation (1) can be used to calculate the comparative value.

$$\text{Comparative Value (\%)} = \frac{\text{Standard Value - Value on Designed Tool}}{\text{Standard Value}} \times 100\% \quad (1)$$

The accuracy can then be calculated based on the result of comparative value using Equation (2) below.

$$\text{Accuracy} = 100\% - \text{Comparative value } (\%) \quad (2)$$

The computation of the comparative value and Accuracy of L_{AF} and L_{CF} was conducted for all frequency, the calculation at the frequency of 63 Hz is calculated as follow:

$$\text{Comparative Value } L_{AF}\,(\%) = \frac{\text{Standard Value - Value on Designed Tool}}{\text{Standard Value}} \times 100\%$$

$$= \frac{67.8\text{ dB} - 64{,}5\text{ dB}}{67{,}8\text{ dB}} \times 100\%$$

$$\text{Comparative Value } (\%) = 4{,}86\%$$

$$\text{Level accuracy of } L_{AF}\,(\%) = 100\% - 4{,}86\% = 95{,}14\%$$

Using the same method, the comparative value of L_{AF} and L_{CF} for other frequencies can be calculated with the results presented in Table 3. The same thing with the accuracy and the results of the accuracy for L_{AF} and L_{CF} for other frequencies are shown in Table 4.

Table 3 The comparative value of L_{AF} and L_{CF} between the designed sound level meter calibrators and sound level meter calibrator of PT. KALIMAN

Frequency (Hz)	Percentage	
	L_{AF} (%)	L_{CF} (%)
63	4,86	4,39
125	0,13	0,95
250	0	0
500	0	0
1000	0	0
2000	0,84	0,64
4000	1,68	1,72
8000	1,3	1,32

Table 4 The accuracy of the designed microcontroller-based Sound Level Meter calibration device

Frequency (Hz)	Accuracy	
	L_{AF} (%)	L_{CF} (%)
63	95,14	95,61
125	99,87	99,05
250	100	100
500	100	100
1000	100	100
2000	99,16	99,36
4000	98,32	98,28
8000	98,7	98,68

Table 3 shows that the highest comparative value of LAF is 4.86% and LCF is 4.39% for 63 Hz. In Table 4, the accuracy of LAF and LCF at 63 Hz is low which is 95.14% for LAF and 95.61% for LCF. While in other frequencies between 250 to 8,000 Hz, the accuracy quite high which is between

98.28% to 100%, which can be concluded that the accuracy of the designed microcontroller-based Sound Level Meter calibration device has the accuracy close to 100% except for 63 Hz. However, according to ISO 61672-1:2017, the standard for class 2 sound level meter calibration device, the deviation frequency allowed for SLM calibration device is 125 Hz – 8,000 Hz.

4. Conclusions

- The microcontroller-based Sound Level Meter calibration device has met the ISO/IEC 61672-1: 2017 standard at the point of measurement frequency between 125 Hz to 8,000 Hz, except for the 63 Hz.
- The comparative value between the designed microcontroller-based Sound Level Meter calibration device and the calibrator of PT. KALIMAN is 4.39% to 4.89%.
- The accuracy of the designed equipment for the level of sound intensity with A-weighting and C-weighting has the range of 98.28% to 100% at the point of measurement frequency between 125 Hz to 8,000 Hz, except for the 63 Hz, which means that the device has an accuracy of 100%.
- The designed microcontroller-based Sound Level Meter calibration device has an accuracy and precision of 100%. Therefore, the designed equipment has fulfilled the purpose to expand the calibration device of PT. KALIMAN.

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