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Design of modulated infrared laser as a radiation source of portable photoacoustic spectroscopy

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Abstract. Photoacoustic spectroscopy can appl in various fields including in the fields of biology (measuring trachea volume and observing insect breathing patterns), medicine (a measurement of internal disease biomarkers through respiratory gases), environment (measuring NO_2 gas in the environment near roads), and agriculture (measurement ethylene gas in postharvest fruit). The existing photoacoustic spectroscopy still has a large size and high operating costs, so it is necessary to design photoacoustic spectroscopy that is portable and low operating costs. In this research, designing an infrared diode laser that can be modulated using software using Visual Studio. There are two tests to see the characteristics of the devices made in this study, namely Arduino testing and testing of the software programs created. Arduino testing resulted in a calibration factor of $f_o = 0.9068f_i + 109.33$. Meanwhile, software testing resulted in a calibration factor of $f_o = 0.7343f_i + 462.74$. The two tests that have been carried out have different output results. The software output that is created has a smaller calibration factor than the direct output of the Arduino program.

1. Introduction

The detection and diagnosis of disease is often done in an invasive manner that can be expensive or require time-consuming biological (culture), microscopic (cell or tissue biopsy), or complex analytical (chemical) examinations. Some of the conventional methods used in clinical diagnosis include many invasive and potentially dangerous biopsy procedures, such as endoscopy, computed tomography, magnetic resonance imaging (MRI), mammography, serological blood tests, ultrasound or x-ray imaging of other organs. Many of these methods not only present some risk of serious negative side effects, but are often painful enough that the patient often does not participate in the procedure to detect the disease early. These human sentiment factors continue to point to an increasing need for improvements in diagnostic methods towards more noninvasive and painless procedures in disease screening for early diagnosis and for examination and examination of patients in routine clinical practice [1].

One of the disease detection methods being developed is the analysis of exhaled gas. Breath analysis is a promising field with great potential for the non-invasive diagnosis of a number of diseases by analyzing the concentration of volatile organic compounds (VOC) in breath [2]. The breath that is exhaled contains more than 3,500 components, most of which are organic compounds that are volatile in very small amounts. Many of these organic compounds characterize the function of the organism as a whole (systemic biomarkers), but some are related to processes that occur in the respiratory system and airways in particular (lung biomarkers) [3]. The concentration of volatile organic compounds in the exhaled gas is in units of ppm and even ppb so it requires a high sensitivity detection device.

The photoacoustic spectrometer is a highly sensitive tool that can be used to detect gas concentrations [4] so that it can be used to measure the concentration of volatile organic compounds in exhaled gas which is in the ppm to ppb range [5]. Another major advantage of photoacoustic spectroscopy is its ability to provide a direct spectrum of any type of solid crystal, powder, gel, or biological tissue-spectra that are impossible to obtain by other techniques [6]. Photoacoustic detection provides not only the high sensitivity but also the selectivity required to analyze multicomponent mixtures using an adjustable infrared laser, such as a CO laser or a CO2 laser [5].

The CO2 laser is very interesting, because it has a high output power in the wavelength region (9-11 μm) where more than 250 molecular gases / vapors exhibit strong absorption, so it has become a concern of environmental, industrial, or medical research [5]. Research using a CO2 laser photoacoustic spectrometer has been carried out by Mitrayana et al. [7] measured the concentration of acetone in breath of Lung Cancer patients, Tyas et al. [8] measured the concentration of acetone in exhaled gas in type 2 diabetes mellitus patients, Oktafiani et al. [9] measured the concentration of ethylene gas in people around the dumpsite and research by Darmawan et al. [10] tested the performance of a CO2 laser photoacoustic spectrometer to measure the concentrations of ethylene, acetone and ammonia gas in smoker's blown gas. However, the use of a CO2 laser photoacoustic spectrometer is relatively expensive. In addition, the large shape of the CO2 laser photoacoustic spectrometer does not allow it to be carried at any time, so a photoacoustic spectrometer with a radiation source in the infrared spectrum is needed which is more portable and does not require expensive costs to operate. Therefore, this research designed an infrared diode laser that can be modulated for radiation sources in portable photoacoustic spectroscopy.

2. Research method

The modulation method used is laser power amplitude modulation with a duty cycle of 50%. Diode laser modulation settings in this study using the help of Arduino. This research produces hardware and software that control the magnitude of the laser diode modulation frequency. Controlling the frequency of the diode laser modulation using the Arduino Mega 2560 hardware, Arduino IDE software to create programs that are included in the Arduino, Visual Studio as a display interface in providing the desired modulation frequency value and a calibrated digital oscilloscope to test the modulation signal output from Arduino. The test is carried out in two steps, namely Arduino testing and software testing in producing the modulation frequency.

2.1 Arduino's characterization

Arduino testing is carried out to determine the characterization of Arduino in making square wave signals by assembling the tools as shown in Figure 1. The Arduino output pins are connected to the digital oscilloscope to see the compatibility between the frequency of the square signal issued by the Arduino and the desired frequency. The output frequency varies from 100 Hz to 20,000 Hz. The amount of frequency read on the oscilloscope will be compared with the input frequency on the Arduino to determine the linearity of the Arduino output from the program being made.

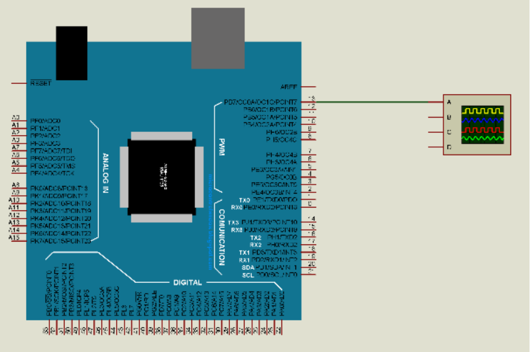


Figure 1. circuit for testing Arduino's output.

2.2 Software's calibration

Software's calibration is made by calibrating the frequency given to the software with the output on the Arduino which is connected to a digital oscilloscope. The circuit for software testing is shown in **Figure 2**. The frequency set for the Arduino via the software varies from 100 Hz to 20,000 Hz. The amount of frequency read on the oscilloscope will be compared with the frequency on the Arduino.

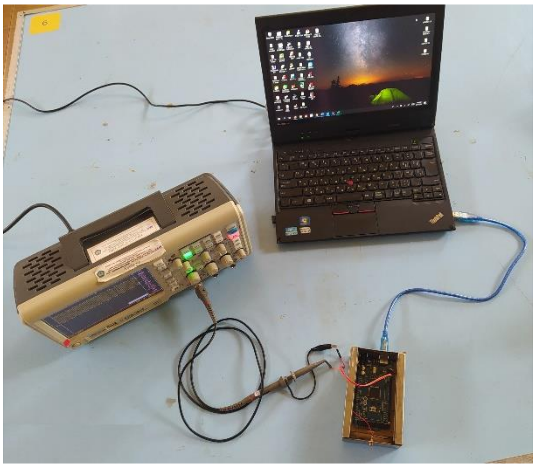
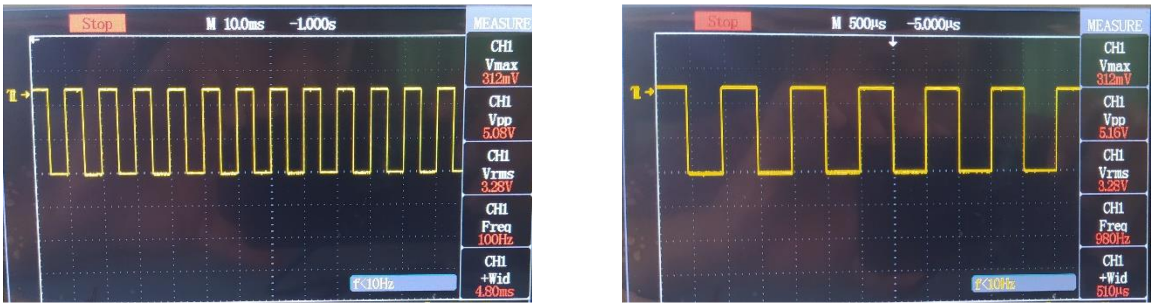


Figure 2. Circuit to test the software's output.

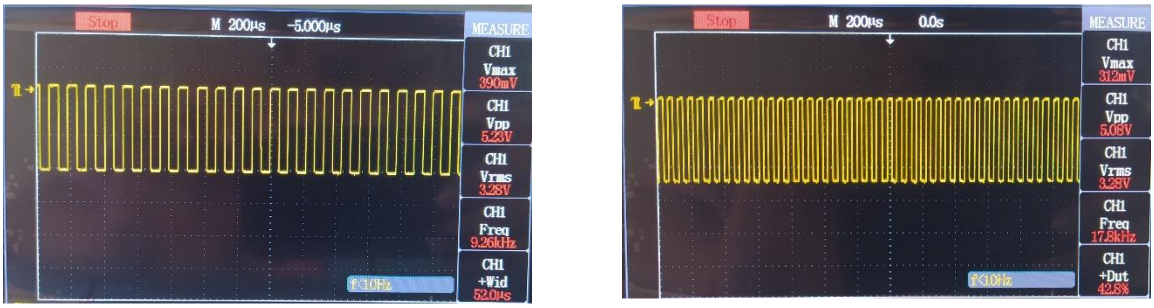
3. Results and discusion

3.1 Arduino's characterization

The results of the square waves from the Arduino output are given in **Figure 3**. From this figure, we can see that the Arduino output always produces square signals with different frequencies according to the program input uploaded to the Arduino.



(a) (b)



(c) (d)

Figure 3. Arduino's output signal. (a) Output signal at 100 Hz (b) Output signal at 1 kHz (c) Output signal at 10 kHz (d) Output signal at 20 kHz

The characterization between the input program made and the Arduino output used produces a graph that is still linear as shown in **Figure 4** with the calibration factor in Eq. (1).

$$f_o = 0.9068 f_i + 109.33 \tag{1}$$

The results on the graph show that the frequency issued at the output pin has shifted by ± 0.0932. This shift is due to Arduino's delay in reading the commands in the program that is made each line.

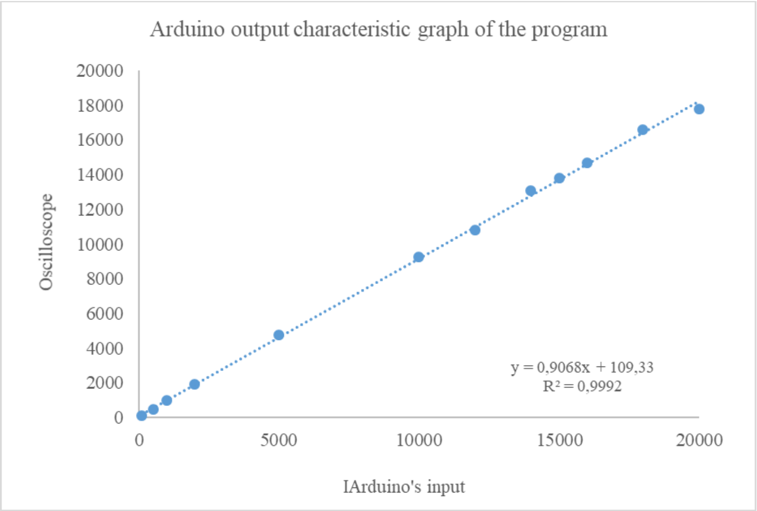
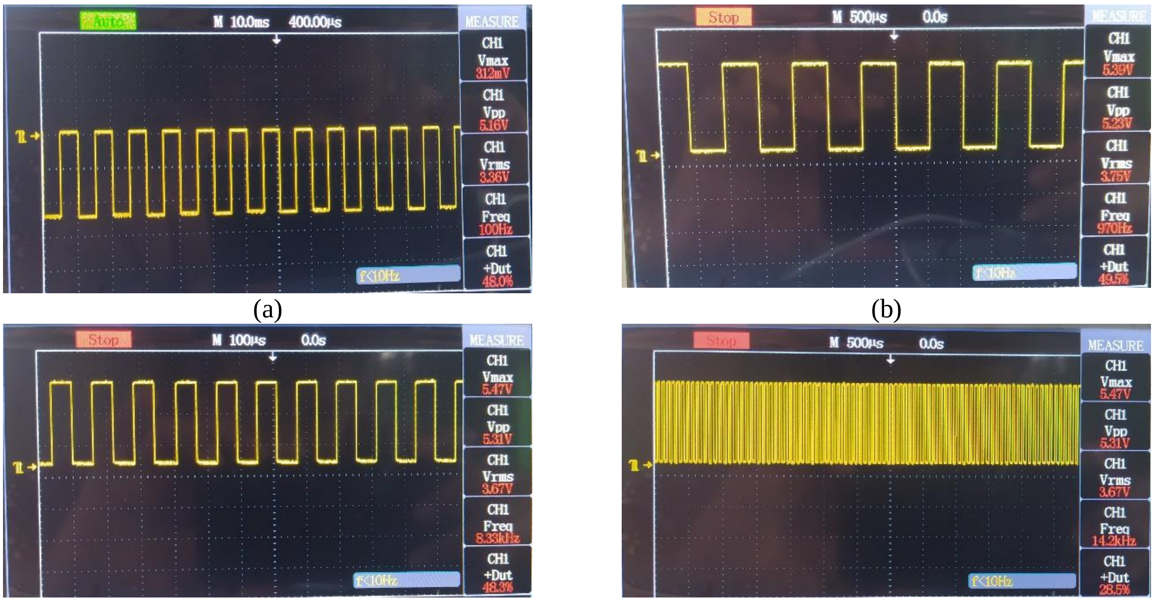


Figure 4. Arduino output characteristic graph of the program.

3.2 *Software's calibration*

The results of the square wave from the program output are given in **Figure 5.** From this figure, we can see that the Arduino output produces square signals with different frequencies according to the input of the software program created.



(a) (b)

(c) (d)

Figure 5. Software's output signal. (a) Output signal at 100 Hz (b) Output signal at 1 kHz (c) Output signal at 10 kHz (d) Output signal at 20 kHz

Characterization between the input program made and the Arduino output used produces a graph that is still linear as shown in ***Figure 6*** with the calibration factor in Eq. (2).

$$f_o = 0{,}7343 f_i + 462{,}74 \quad (2)$$

The results on the graph show that the frequency issued at the output pin has shifted by ± 0.2657.

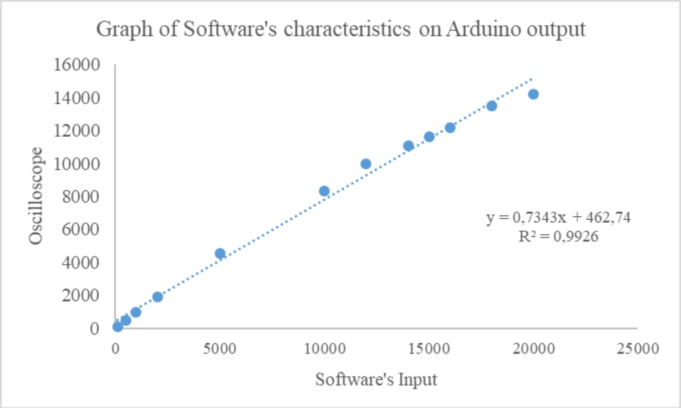


Figure 6. Graph of Software's characteristics on Arduino's output

The two tests that have been carried out have different output results. The software output that is created has a smaller calibration factor than the direct output of the Arduino program. However, this is still acceptable considering the error value in the software calibration factor of 0.9926. This smaller calibration factor is due to the program first reading the serial connection between the Arduino and the PC to get the frequency inputted on the Arduino. The software that is made will be more efficient and will not reduce the service life of the Arduino because we don't need to always upload the program every time we change the desired modulation frequency.

To anticipate the modulation output to match what it should be, we can increase the input frequency in the software by applying Eq. (2). For example, if we want a modulation output of 20 kHz, the software input frequency is 26.6 kHz.

4. References

[1] Wilson A D, 2015 Advances in electronic-nose technologies for the detection of volatile biomarker metabolites in the human breath *Metabolites* **5**, 1 p. 140–163.
[2] Lourenço C and Turner C, 2014 Breath Analysis in Disease Diagnosis: Methodological Considerations and Applications *Metabolites*.
[3] Popov T A, 2011, Human exhaled breath analysis, *Annals of Allergy, Asthma and Immunology*. .
[4] Harren F J M Cotti G Oomens J and Hekkert S te L, 2000 Photoacoustic Spectroscopy in Trace Gas Monitoring *Encycl. Anal. Chem.* p. 2203–2226.
[5] Dumitras D C Bratu A M and Popa C, 2012, CO 2 Laser Photoacoustic Spectroscopy : 1. Principle, in *CO2 Laser - Optimisation and Application*, (InTech).
[6] Karasek F W, 1977 Photoacoustic spectroscopy *Research-Development*.
[7] Mitrayana Apriyanto D K and Satriawan M, 2020 CO2 Laser Photoacoustic Spectrometer for Measuring Acetone in the Breath of Lung Cancer Patients *Biosensors* **2020**, 10 p. 55.
[8] Tyas F H, Nikita J G, Apriyanto D K, Mitrayana and Amin M N, 2018 The Performance of CO2 Laser Photoacoustic Spectrometer in Concentration Acetone Detection As Biomarker for Diabetes Mellitus Type 2 in *Journal of Physics: Conference Series*.
[9] Oktafiani F, Stiyabudi R, Amin M N and Mitrayana, 2016 Detection of ethylene gas in exhaled breath of people living in landfill using CO2 laser photoacoustic spectroscopy with multicomponent analysis *AIP Conf. Proc.* **1746**.
[10] Darmawan Yoga M Mitrayana and Ali Joko Wasono M, 2015 Kinerja Spektroskopi Fotoakustik Laser CO2 untuk Deteksi Gas Etilen (C2H4) , Aseton (C3HO), Amonia (NH3) pada Gas Hembus Perokok *J. Fis. Indones.* **19**, 57 p. 35–42.

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