Preliminary Studies Comparing Heart Rate Measurement Using Optical Sensor Based on Self Mixing Interferometry and Photoplethysmography (PPG)

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Abstract. Heart Rate is important information about the physiological and psychological condition of human. The pulse rate is directly related to the heart activity because of the impact of the volume changing of blood correlated to the heart which pumps blood throughout the body periodically. Heart rate measurement is used generally ECG (Electrocardiogram) or Blood Pressure Measurement in the medical world. In this paper the ratio of the heart rate is analyzed by using a technique photoplethysmography and optical sensor based on self-mixing interferometry. A typical self-mixing configuration consist of a laser diode as a light source (LD, 785 nm) and the photodetector which integrated in the package. Photoplethysmography consist of infrared (IR, 940 nm) acts as source of light, photodiode as a photo-detector, PPG circuit, arduino and PC. Photoplethysmography is non-invasive optical technique that can used to detect blood volume changes in the microvascular bed of tissue. The result show that human heart rate signals can be detected using the SMI method with a frequency of 100 kHz and input current 50 mA, but using PPG method the human heart signal was detected in the amplitude range of 2,070 to 2,080 mV.

1. Introduction
The heart is the most important organ in the human circulatory system because it functions to pump oxygenated blood throughout the body. Heart rate is the most significant physical sign related to human health. Prevention of heart disease can be done by monitoring heart rate. At present the methods used in cardiac examinations related to the human body's cardiovascular system are electrocardiogram (ECG) and photoplethysmography (PPG). PPG is a method that used to measure the changing of blood volume in the body by capturing the signals that are formed at optical sensors when a light source is transmitted to the skin tissue. In addition to PPG, another method that is currently being developed to determine the human heart signal is a vibration sensor based on self-mixing interferometry (SMI). The SMI method is based on light sources and detectors which integrated in the package. SMI have some advantages because its structure is simple, easily aligned, easily integrated and contactless [1].

Self-Mixing Interferometry (SMI) is a measurement method using optical technology. The SMI sensor utilizes reflected light from a light source that hits an object. The self-mixing effect occurs from the coherent back-coupling of the reflected or scattered lights from a target surface into the laser cavity where it mixes with the original light of the laser [2].
In the SMI scheme, the laser diode is integrated with the photodiode. A high-efficiency laser must be formed from a resonator that has an ability not only to amplify electromagnetic waves but also for feedback. A laser resonator generally consists of two parallel mirrors toward perpendicular to the optical axis. This structure is called the Fabry Perot resonator. Both mirrors have different levels of reflectivity [4].

Photoplethysmography is a simple, low cost, non-invasive optical technique that can used to detect blood volume changes in the microvascular bed of tissue. PPG is a method used to measure changes in blood volume in an organ or body by capturing the signals that form when light sources are transmitted to the skin tissue using optical sensors. The pulse can be detected non-invasively using PPG system [5]. The measurement of blood volumetric changes in the skin perfusion by means of PPG depends on the fact that blood absorbs ultrared or infrared light more strongly than skin, tissues and fluids. The change in blood volume caused by the pressure pulse can be detected by illuminating the skin from a light source and measuring the amount of light transmitted to a photodetector. The signal obtained from the photodetector is related to pulsatile arterial blood volume changes and the signal is called as PPG [6].
Figure 3. PPG signal pattern that show differences in systolic and diastolic pressure

Figure 4. Probe sensor finger for heart rate measurement

In this paper the ratio of the heart rate is analyzed by using a technique photoplethysmography and optical sensor based on self-mixing interferometry.

2. Experimental Setup

Figure 5. Human heart signal testing scheme using vibration sensors based on Self-Mixing Interferometry.
Basic scheme of Self-Mixing Interferometry for analyzing human heart rate signals as in Figure 5. This system consists of a laser diode and photodiode integrated in one device, a reflective mirror surface inserted in the speaker, a laser driver as an input current source and a PC that can display signals with the help of Parallax data acquisition (PLX-DAQ). Signal electro cardiogram artificial produced by an ECG generator. This is to simulate the heart rate signal with frequency variations. The signal is amplified by the audio amplifier and sent to the speaker to vibrate the mirror. While the laser diode is still given an input voltage by the power supply. The measured output voltage can be seen and analyzed with an oscilloscope for variations in heart rate frequency and amplitude. Where the amplitude of the heart rate is changed by varying the voltage of the audio amplifier. After that it can be known the value of the frequency and amplitude of the heart rate signal.

The Laser diode as light source with a wavelength of 785 nm. Laser light that hits the vibrating target is reflected and captured by photodiode the integrated in the diode laser. Then the captured light is passed on to the laser driver. Then the output is connected to Arduino Uno as data acquisition through the CTL-OUT probe contained in the laser driver.

The block diagram of the PPG system consists of an infrared as a light source, a photodiode as a light detector, a PPG circuit, Arduino uno, PLX-DAQ, and PC. Arduino uno is used to convert analog signals into digital signals so they can be displayed on a PC. PLX-DAQ is a software to display data from Arduino. The PPG circuit consists of 3 parts namely the signal amplifier, comparator and mono-stable circuits.

Infrared are used as a light source to illuminate the fingers. The light produced by Infrared can penetrate skin tissue around 1 mm-100 mm. Irradiation of skin tissue in this range can capture the pattern of changes in blood flow that follows the rhythm of the human heartbeat and is part of the cardiovascular system in the human body. This pattern of changes in blood flow is accepted by the photodiode which then forms PPG signals as a representation of changes in blood flow in the cardiovascular system in the human body.

The signal produced by the photodiode is a natural signal from the body with a small frequency mixed with noise. So the signal must be processed using a signal conditioning circuit. Part of the signal conditioning circuit used is the high pass filter circuit to filter signals that can interfere with PPG signals at low frequencies. The output signal from the circuit is a PPG signal which is an analog signal.

3. Results

Before testing the human heart signal, first testing the vibration sensor based on self-mixing interferometry with a frequency set of 50 Hz on the function generator and the results are obtained in figure 7.

Figure 7 shows the SMI signal pattern formed when the speaker as a vibrating object is given a frequency of 50 Hz from the function generator. The SMI signal pattern forms an irregular pattern and show feedback. The presence of this feedback is characteristic of the SMI signal. Feedback on the SMI signal repeats due to vibrations given to the target of 50 Hz. In Figure 7 above the time required for data collection is around 0-1000 ms and the voltage captured by the detector is 3.53 - 3.59 mV.
Figure 7. SMI signal with a vibration frequency of 50 Hz from function generator

Figure 8. Human heart signal based on SMI with 100 kHz frequency and 50 mA input current.

Figure 9. PPG signal on human finger amplitude range of 2,070 to 2,080 mV

Figure 10. PPG reference signal display on computer screen [6]

Figure 8 shows a human heart signal using an ECG generator and an SMI-based vibration sensor. Testing is done by simulation using a programming language that is entered into the arduino due. Heart signal testing is performed at a frequency of 100 kHz, where the input voltage supplied by the power supply to the audio amplifier is 14 volts.

The graph of the human heart signal shown in Figure 8 shows that the pattern of the human heart signal is well formed at a frequency of 100 kHz. The PQRST point on the human heart signal graph using an ECG generator and an SMI-based vibration sensor can be seen clearly like a normal electrocardiogram (ECG) graph. Heart signals can be seen clearly at a frequency of 100 kHz. So it can be said that a large frequency is needed to be able for display a graph of a simulated heart signal using an SMI based vibration sensor.
Figure 9 shows the pattern of PPG signals detected on the fingers with amplitude range of 2,070 to 2,080 mV. The results of the PPG signal indicate that the PPG signal obtained does not match the PPG signal from the reference. PPG signal mismatch which is obtained with the reference PPG signal because the PPG signal output from the sensor probe on the fingers contains a lot of noise in the initial signal that enters the PPG circuit, so that when forwarded to the PPG signal amplifier circuit it cannot display PPG signals correctly. So the PPG signal results displayed on the PC still look like in figure 9.

Based on two measurement methods used to display heartbeat signals namely self-mixing interferometry and photoplethysmography (PPG), it is seen that human heart rate signals can be detected using the SMI method with a frequency of 100 kHz and input current 50 mA, but using PPG method the human heart signal was detected in the amplitude range of 2,070 to 2,080 mV.

4. Conclusion
Based on the research that has been done, it can be concluded that human heart rate signals can be detected using the SMI method with a frequency of 100 kHz and input current 50 mA, but using PPG method the human heart signal was detected in the amplitude range of 2,070 to 2,080 mV.

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