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Submission date: 19-Mar-2024 04:08PM (UTC+0700)
Submission ID: 2324628820
File name: 17295_Nugroho_Budi_Wicaksono_nug_866818_163191763.pdf (596.04K)
Word count: 3112
Character count: 16788

Artifact Removal using Passive-Analogue-Filter for Optical Method Heart Rate Data Acquitision

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***Abstract*— Heart rate is defined as number of heart beats per amount of time, usually in a minute; so it is often called as beats per minutes (BPM). Heart rate is an important physiological parameter to determine human's condition. There are several methods to tap human heart rate. Popular method to analyze or count heart beat is using optical sensor. Biosignal is known to be susceptible to noise or artifact. The aim of this study is to show how to use a simple filter configuration as artifact removal of heart rate using optical method. The result shows that artifact removal of heart rate detection can be achieved using simple filter configuration at center frequency 3.5 Hz – High Pass Filter and 16 Hz – Low Pass Filter.**

Keywords—Analoque filter; passive filter; RC filter; heart rate; optical method, artifact removal;

I. INTRODUCTION

Heart rate is defined as number of heart beats per amount of time, usually in a minute; so it is often called as beats per minutes (BPM). Heart rate is an important physiological parameter to determine human's condition. There are several methods to tap human heart rate. Methods that commonly and frequently used are palpation and auscultation. Palpation is an examination method by detect heart beat in the surface of human body, *i.e.*: surface of wrist joint, stomach, and neck. Auscultation is an examination that is performed by medical staff by listening to the voice within the patient's body cavity, it is usually done by using stethoscope.

Phua [1] classified 6 methods to measure heart rate. Those methods are electrical, optical, microwave, acoustic, mechanical, and magnetic. Up to now, electrical method using electrocardiograph (ECG) is well-recognized as the gold standard. But according to Coulson and Archer [2], using ECG as a measurement device is deemed impractical and Expensive.

Other than ECG, most popular methods that is currently developed among manufacturers is optical method. This method is not only developed by medical device manufacturers, but also manufacturers of smartphones. One of them is Samsung. In April 2014, Samsung Galaxy S5 was released with one of its features is heart rate measurement using optical acquisition method [3]. Smartphone applications software company on the Android OS or iOS also claims to be able to read the heart rate, for example: Heart Rate Monitor [4] on iOS and Instant Heart Rate [5] on Android. These applications can be classified as a heart rate measurement using optical methods for utilizing light and then recorded using smartphone's camera.

Biosignal is known to be susceptible to noise or artifact. Signal acquisition of data from a person's body is often mixed artifacts that can be caused by movement, ambient light, or the frequency of the mains voltage. The acquisition of the heart rate did also susceptible to artifacts. One method used to reduce or eliminate artifacts is to use the filter. Lee, in his paper [6], stated that in order to reduce artifacts that appear on the Pulse Oximeter using a digital filter method, filter bank and matched filter can provide 50% better performance than the method of moving averaging filter and adaptive filter.

Based on Lee, we want to show how to use a simple filter configuration as artifact removal of heart rate using optical method. The result of this experiment will be used as learning material for students in Department of Medical Instrumentation, Sanata Dharma Polytechnic of Mechatronics.

II. LITERATURE REVIEW

A. *Optical Sensor and Its Scanning Technique*

Using the approach of the optical sensor used in the Pulse Oximeter [7], the optical sensor that it possible to be used as acquisition device of the heart rate are as follows:

Sensor Photocell

The light intensity affects the resistance of the photocell sensor, photocell sensor therefore also referred to as a photoresistor sensors. Materials commonly used as a photocell sensor is cadmium sulfide (CdS) and cadmium selenide (CdSe). The relationship between the intensity of light as the resistance is as follows:

$$R = AE^{-a} \quad (1)$$

With R is the resistance of the device, A and a are constants that depend on the manufacturing process and the type of material [7]. Equation (1) indicates that the relationship between the light intensity and resistance is not linear.

Photodiode Sensor

Voltage or current produce by photodiode is proportional to the light intensity. Photodiode has two working conditions, mode of photovoltaic and photoconductive mode. Photovoltaic mode occurs when the photodiode in a zero-biased conditions, it is happened when there is no voltage difference at a p-n junction, so no current flows. The potential difference in the photovoltaic mode is commonly referred to as a built-in potential (V_{bi}). This photovoltaic effect is usually used in solar-cell.

Photoconductive mode occurred when photodiode is reverse-biased with cathode connected to the positive voltage and an anode connected to a negative voltage. In this mode, the light intensity is directly proportional to the output current generated by the photodiode.

Phototransistor Sensor

In general term, phototransistor sensor is similar to photodiode with a built-in current amplifier, 100-500 times greater sensitivity than the photodiode. When light hits the phototransistor sensor, base of the transistor generates a current which is then amplified by the transistor so that the flow coming out at the collector increases significantly.

B. Scanning Technique of Optical Sensor

Some terms often used in scanning with the light sensor are trough-beam, retro-reflective, and diffuse [8]. In through-beam scanning mode, sensor's transmitter and receiver are placed in a position facing each other. This scanning mode is more suitable to detect material that is opaque or reflective. This scanning mode is not suitable for transparent objects. Illustration of though-beam scanning mode is shown in Figure 1.

Reflective scanning mode and retro-reflective is the same scanning technique. The transmitter (emitter) and the receiver are located in one package. Illustration of the reflective scanning mode is shown in Figure 2.

Lights emitted by the transmitter will be reflected back to the receiver. When an object present, and block the lights emitted by the transmitter, the receiver will not receive any signal. Commonly, the detected distance of material is adjusted by the variation types of mirrors or reflectors. This scanning mode is not suitable for sparkling or shiny objects detection, because these objects can serve as a reflector so that the object becomes undetectable.

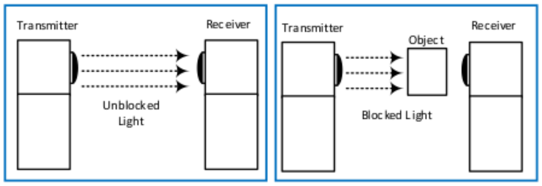

Figure 1 Trough-beam scanning mode; no material (left), and with material (right).

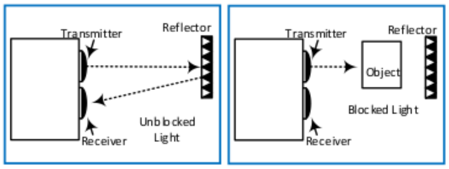

Figure 2. Reflective/retro-reflective no material (left), and blocked light (right)

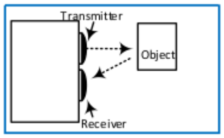

Figure 3. Diffuse scanning mode

The last mode is the diffuse scanning mode shown in Figure 3. This mode is similar to the reflective mode; only the object to be detected will serve as the mirror / reflector. When there is no object present, the beam from the transmitter will not be accepted by the receiver. When there is an object present, it will reflect light from the transmitter to the receiver.

C. Heart Beat Data Acquitision using Optical Method

Considering the availability of the components in local market and aligning with the goal of the research, this study was focused on the optical method. The acquisition of the heart rate with optical methods has been done by the electronic hobbyists. The results are displayed on their blog and already in the form of the product. Table 1 shows some heartbeat data acquisitions that can be found in the Internet.

First Order Passive RC-Analogue Filter

Filters can be categorized into analog filter and digital filter. Analog filters can be classified as a passive filter and active filter. Passive filter can be assembled using RLC components, while the active filter typically uses Operational Amplifier (OpAmp). According to the topology, the active filter that is popularly used is the Sallen-Key and Multiple Feedback (MFB). According to the method of its design and shape of the filter response, the filter can be designed by the method of Butterworth, Chebyshev, and Bessel. According to the response of the filter can be divided into low-pass filter, high-pass filter, band-pass filters, and band-stop filter.

In this paper, the type of filter that will be discussed is a passive RC filters. First order passive filter, both low-pass filter and high-pass cutoff frequency has a value of:

$$f_C = \frac{1}{2\cdot\pi\cdot R\cdot C} \quad (2)$$

The cutoff frequency lies in -3dB. Figure 4 and 5 shows the configuration of the components used in passive filter low-pass and high-pass.

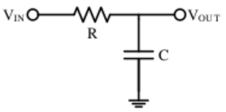

Figure 4. Low-Pass Passive RC Filter

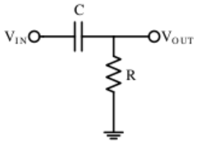

Figure 5. High-Pass Passive RC Filter

Table 1.Summary of heart beat data acquisition using optical method.

Author	Heart Beat Data Acquisition Specification
Joel Murphy, Yury Gitman [9]	Transmitter: LED Optical Sensor: APDS-9008 Scanning Method: *Diffuse* Amplifier: MCP-6001 Filter: Undescribed Data Acquisition Method: ADC Arduino Result: Product, *Open Hardware*, non-local components, BPM can be measured
Sean Michael Ragan [10]	Transmitter: *Infra-Red* LED (RadioShack #2760142) Optical Sensor: *Phototransistor* (RadioShack #2760142) Scanning Method: *Diffuse* Amplifier: LM324, Transistor 2N3904 Filter: Undescribed Data Acquisition Method: ADC Arduino Result: Tutorial, *Open Hardware*, BPM cannot be measured.
Raj Bhatt [11]	Transmitter and Optical Sensor: TCRT1000 Scanning Method: *Diffuse* Amplifier: MCP6004, Transistor 2N3904 Filter: » *High-Pass*: Passive RC, $f_c = 0{,}7$ Hz » *Low-Pass*: Active, $f_c = 2{,}34$ Hz Data Acquisition Method: Analog Discovery, ChipKIT Result: Tutorial, *Open Hardware*, non-local components, BPM cannot be measured.
Scott W. Harden [12]	Transmitter: Red LED Optical Sensor: *Phototransistor* Scanning Method: *Diffuse* Amplifier: MCP6004, Transistor 2N3904 Filter: Aktif, *Low-Pass*, f_c can be adjusted using potensio Data Acquisition Method: ADC Arduino Result: Tutorial, undescribed signal before and after filtering process, non-local components, non-local components, BPM cannot be measured
Jason Kim [13]	Transmitter: 940nm LED Optical Sensor: *Phototransistor* Scanning Method: *Through-Beam* Amplifier: MCP6002 Filter: » *High-Pass*: Pasif RC, $f_c \approx 5$ Hz » *Low-Pass*: Aktif, $f_c \approx 10$ Hz Data Acquisition Method: *Sound card* Result: Tutorial, filter described clearly, BPM cannot be measured, non-local components, BPM can be measured
National Instruments (White Paper) [14]	Transmitter: LED cahaya merah Optical Sensor: *Photoresistor* Scanning Method: *Through-Beam* Amplifier: *DAQ Assistant* (National Instruments) Filter: Digital, Band-Pass – 1 sampai 3 Hz Data Acquisition Method: *DAQ Assistant* Result: Tutorial, non-local components, BPM can be measured

III. DESIGN AND ANALYSIS OF HEART RATE DATA ACQUITISION USING OPTICAL METHOD

Because of this experiment will be used as teaching material for students in department of Medical Instrumentation, Sanata Dharma Polytechnic of Mechatronics. This section will describe and explain all the circuit and programming code that is used thoroughly.

A. *Preleminary Experiment*

Analog filter implementation can be performed using active filter and passive filter. In general use, the passive filter is more suitable for high-frequency (400 kHz). Theoretically, passive filter order 1 have slopes of 20 dB / decade or 20 dB / 10 Hz. Active filters suitable for use when needed amplification between input and output signals. If we designed high-pass active filter, then we will get attenuation at around 400 kHz or 1 MHz.

Figure 6 and 7 are the filter response from our experiments with 1st order of active filter and passive filter. The designed filter is high-pass filter with a cutoff frequency of 15.915 Hz (≈16 Hz). In the active filter using LM358 OpAmp with buffer configuration.

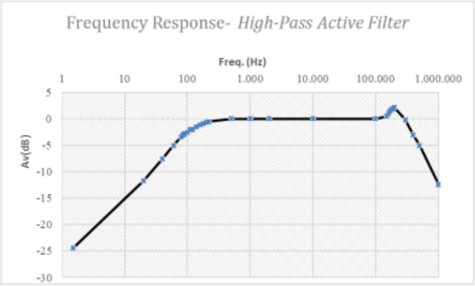

Figure 6. Preliminary experiment of filter response - high pass active filter with center frequency of 16 Hz (f_C≈16Hz).

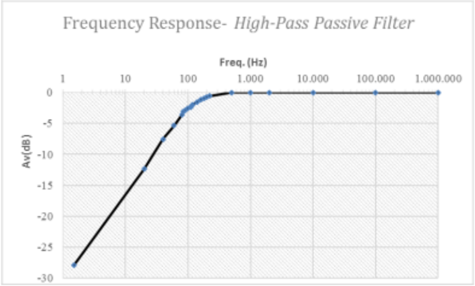

Figure 7. Preliminary experiment of filter response - high pass passive filter with center frequency of 16 Hz (f_C≈16Hz).

B. *Optical Method Heart Rate Data Acquitision*

Heart pumps blood passes through the arteries and veins. When blood passing through the arteries and veins, it builds a pulse that is similar to a triangle wave or sawtooth wave. In case of oxygen levels detection in the blood (oxygen saturation), usually used an optical sensor (photodiode and phototransistor). The optical transmitter usually infra-red with a specific wavelength (around 940nm). Therefore, by using such an approach, we designed an infrared as transmitter and phototransistor as its optical sensors as shown in figure 8. In this experiment, we used through-beam scanning method.

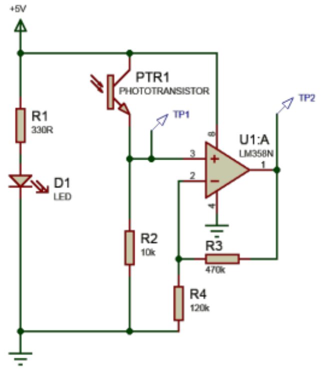

Figure 8. Optical sensor circuit using infrared and phototransistor; and Non-Inverting Amplifier OpAmp with gain of 5 (Av≈5).

As data acquisition device, we used Arduino Uno that connected to the computer. These are the Arduino code:

```
const int count = 250;
long time[count];
int values[count];
long between = 10000;
int counter = 1;
int start1;

void setup() {
 Serial.begin(9600);
 start1 = 0;
}

void loop() {
 if(start1 == 0) {
    time[0] = micros();
    values[0] = analogRead(3);
    start1 = 1;
   }

 if(micros()>=time[counter-
1]+between&&counter<count)
   {
    values[counter] = analogRead(3);
    time[counter] = micros();
    counter++;
   }

  else if(counter == count) {
    for(int i = 0; i < count; i++) {
      Serial.print(values[i]);
      Serial.print('\t');
      Serial.println((long)time[i]);
      counter++;
    }
  }
}
```

We employ ADC function from ATmega328 microcontroller which has a 10-bit degree resolution and ADC voltage reference is 5 V. When we connected test point (TP) 1 to pin A3 of the Arduino, the ADC reading is shown in figure 9. Because the voltage only shows in range of 330 mV up to 360 mV, we need to employ non inverting amplifier using LM358 with gain of 5. The result of amplification is shown in figure 10.

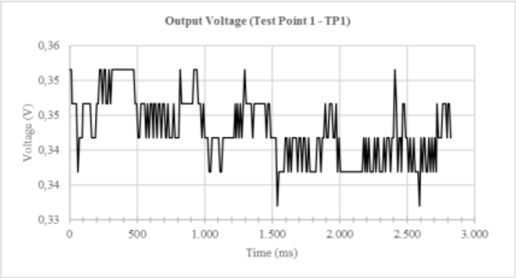

Figure 9. Output voltage of TP1

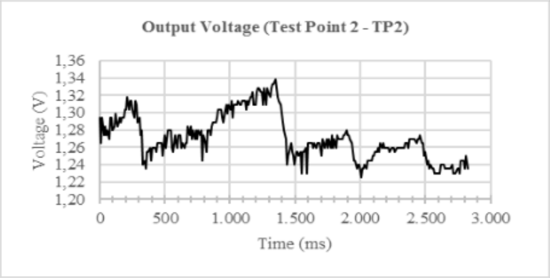

Figure 10. Output voltage of TP2

The second step is to design signal filtering. In this step and forward we only apply RC passive analog filter. The first filter is high-pass filter (HPF) with the center frequency of 16 Hz, this filter should remove DC component or DC offset of the signal. To design the HPF, first we were assuming the value of capacitor, because of the availability of resistance value is easier to find in our local market. We decided to use 470nF Capacitor. The center frequency of our HPF is 3.5 Hz. Then, we try to find the value of R by using in equation (3). The circuit implementation is shown in figure 11.

Before apply the filter to the circuit, we analyze the frequency response using NI ELVIS II+ and NI ELVISim. Figure 12 shows that the center frequency of HPF is approximately at 3.5 Hz (-3dB Gain).

$$R_5 = \frac{1}{2\pi f_C C_1}$$

$$R_5 = \frac{1}{2\pi (3{,}5Hz)\left(470 \cdot 10^{-9} F\right)} \quad (3)$$

$$R_5 = 96751\Omega \approx 100k\Omega$$

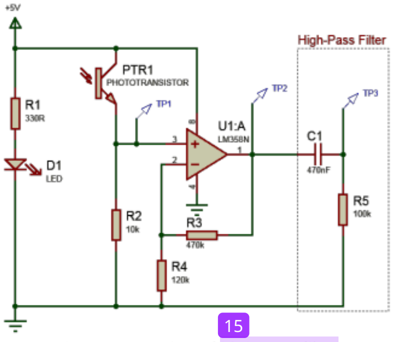

Figure 11. Design of high-pass filter

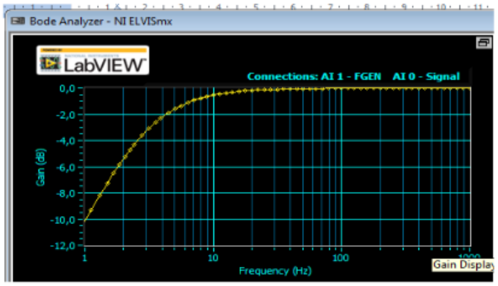

Figure 12. Frequency response of high-pass filter at 3.5 Hz center frequency

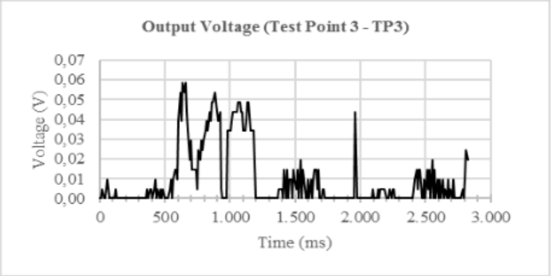

Figure 13.Output voltage of TP3

The output voltage of TP3 is shown in figure 13. The result did remove the DC component of the signal, but in the other hand the signals are attenuated drastically. The highest amplitude of measured signal is only around 6 mV. So, we need to employ amplifier circuit. The amplifier circuit is design to give 471 amplifications, because of LM358 datasheet specification (Output Voltage–High Limit) only gives typically 3.5 V with 5 V power source.

After the second stage amplification we also add low-pass filter (LPF) with the center frequency of 16 Hz. Similar to the HPF's design. at first we assume to use 100 nF capacitor. So, to find the value of the resistor, we use equation (4). The second stage amplification with gain of 471 and LPF circuit are shown in figure 14. The frequency response of the LPF is shown in figure 15.

$$R_8 = \frac{1}{2\pi f_C C_2}$$

$$R_8 = \frac{1}{2\pi (16Hz)\left(100 \cdot 10^{-9} F\right)} \quad (4)$$

$$R_8 = 99472\Omega \approx 100k\Omega$$

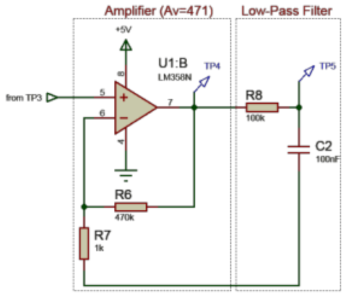

Figure 14.The second stage amplification with gain of 471 and LPF circuit

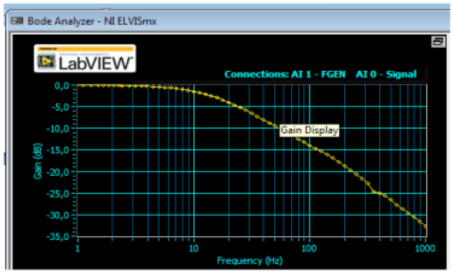

Figure 15. Frequency response of low-pass filter at 16 Hz center frequency

The measured signal in TP4 and TP5 are shown in figure 16 and 17, respectively.

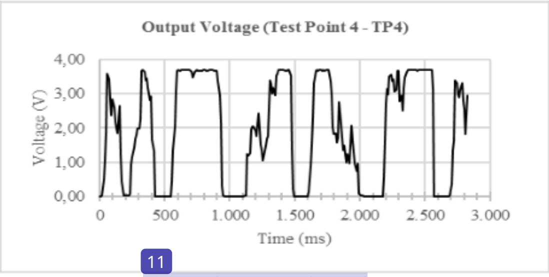

Figure 16. Output voltage of TP4

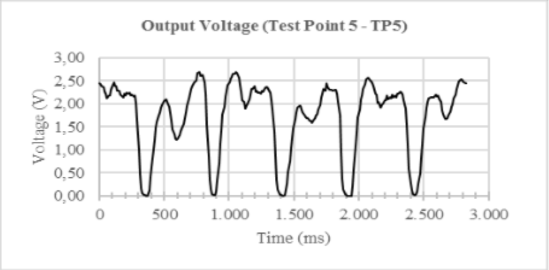

Figure 17. Output voltage of TP5

The output voltage of TP4 shows that there is a voltage clipping at 3.8 V due to OpAmp saturation voltage (Output Voltage–High Limit). But, when we employ the LPF circuit, the voltage clipping is removed. The output voltage of TP5 shows 5 heart beats from user's finger.

IV. CONCLUSION

The filter experiments for heart beat data acquisition has been conducted, the result showed that the output voltage of the filter with a cutoff frequency of 3.5 Hz and 16 Hz has been able to improve the results of the phototransistor sensor readings. Sensor signal conditioning of the phototransistor require a voltage amplifier circuit that can be read by the microcontroller with 10-bit ADC. The amplification process was done at 2 stage. The first amplification with a gain of 5, and a second amplification with a gain of 471.

ACKNOWLEDGMENT

This research was partially supported by Koordinasi Perguruan Tinggi Swasta – Wilayah V Yogyakarta – KOPERTIS V (English: Private High Education Coordinator – Region V)

REFERENCES

[1] C. T. Phua, G. Lissorgues, B. C. Gooi, & B. Mercier, “Statistical Validation of Heart Rate Measurement Using Modulated Magnetic Signature of Blood with Respect to Electrocardiogram,” International Journal of Bioscience, Biochemistry and Bioinformatics, vol. 2, Issue 2, pp. 110-116, March, 2012.

[2] M. Coulson, D. Archer, “Practical Fitness Testing: Analysis in Exercise and Sport,” London: A&C Black Publisher, 2009.

[3] Samsung Electronics America, April 2014, “Samsung Galaxy S5 User Guide,” Retrieved February 2016, from https://www.samsung.com

[4] Azumio Inc., April 2015, “Instant Heart Rate,” retrieved February 2016, from Google Play: https://play.google.com

[5] Plus Sport, September 2014, “Heart Rate Monitor: measure and track your pulse rate,” retrieved February 2016, from iTunes Store: https://itunes.apple.com

[6] J. Lee, W. Jung, I. Kang, Y. Kim, G. Lee, “Design of filter to reject motion artifact of pulse oximetry,” Computer Standards & Interfaces, vol.26, issue 3, pp. 241–249, May 2004.

[7] J. Schowalter, “Photodetectors and Amplifier,” in Design of Pulse Oximeters, J. G. Webster, London: IOP Publishing, 1997.

[8] SoftNoze, August 2001, “Photoelectric Sensors Theory of Operation,” retrieved February 2016, from SoftNoze: http://www.softnoze.com

[9] J. Murphy, Y. Gitman, September 2012, “Pulse Sensor Amped,” Retrieved from Pulse Sensor, http://pulsesensor.com

[10] S. M. Ragan, 2014, “Infrared Pulse Sensor. Retrieved from Make: We are all Make:” Retrieved February 2016, from http://makezine.com

[11] R. Bhatt, September 2012, “Introducing Easy Pulse: A DIY Photoplethysmographic Sensor for Measuring Heart Rate,” retrieved February 2016, from Embedded-Lab: http://embedded-lab.com

[12] S. W. Harden, April 2013, “Simple DIY ECG + Pulse Oximeter (version 2),” retrieved February 2016, from http:// www.swharden.com

[13] J. Kim, May 2014, “Pulse Detector: Concept. Retrieved from Dream it, Design it, Build it,” retrieved February 2016, from https://dreamitdesignitbuildit.wordpress.com

[14] National Instrument, August 2012, “Build Your Own Heart Rate Monitor,” retrieved February 2016, from National Instrument: http://www.ni.com

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