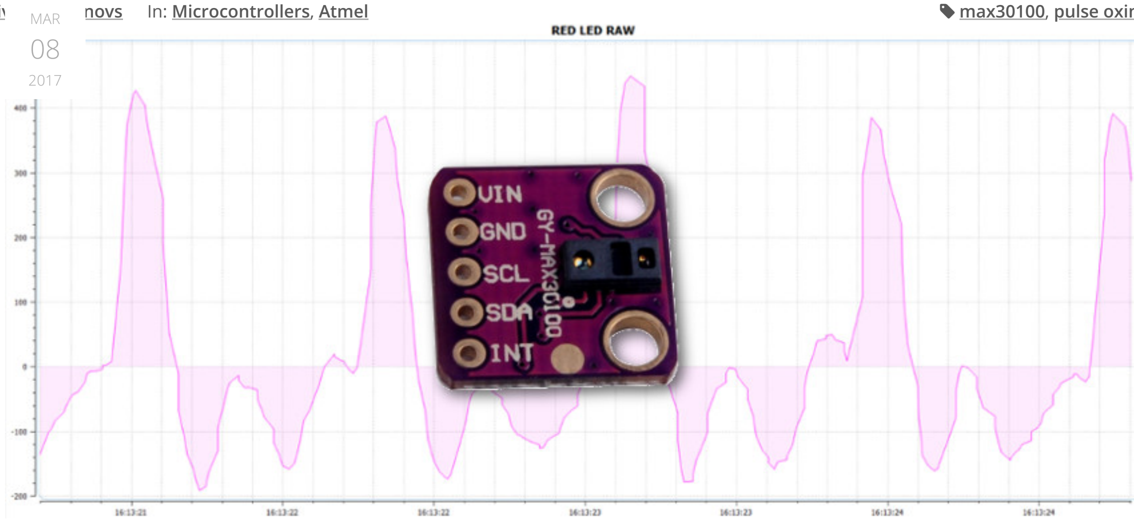
BLOG

Implementing pulse oximeter using MAX30100

by Rai novs MAR 08 2017 In: Microcontrollers, Atmel max30100, pulse oximeter, arduino 82 Comments



For my smart watch project I decided to experiment with sensors for reading pulse. Looking around I stumbled upon a sensor made by Maxim – MAX30100. For my surprise once I got my development board and delved into the sensor's datasheet I discovered it's not as simple as just wiring up the sensor to a microcontroller and reading the data. A lot of work you have to do yourself. In this tutorial, I'll try to explain what I've learned about pulse oximeter and how to make sense of their data.

Introduction

In this tutorial I'll briefly explain how a pulse oximeter works and how to make sense of the data coming from MAX30100. This article will be structured in a way where each consecutive step will be explained with why such filtering is applied and how it was calculated. Mainly the implementation consists of two parts: reading the pulse with IR LED only and calculating SaO_2 using both RED and IR LEDs.

By the end of the article you should be able to understand the various stages the signal goes through. These methods should be applicable to any sensor even the ones you make yourself or made by other manufacturers.

What is pulse oximeter?

A pulse oximeter is basically a device which can measure your pulse and oxygen saturation in your blood. Usually this sensor consists of two LEDs emitting light: one in Red spectrum (650nm) and the other one in Infrared (950nm). This sensor is placed on your finger or earlobe, essentially anywhere where the skin is not too thick so both light frequencies can easily penetrate the tissue. Once both of them are shined through your finger for example, the absorption is measure with a photodiode. And depending on the amount of oxygen you have in your blood the ratio between the absorbed red light and IR led will be different. From this ratio it is possible to "easily" calculate your oxygen level in your hemoglobin (see figure 1).

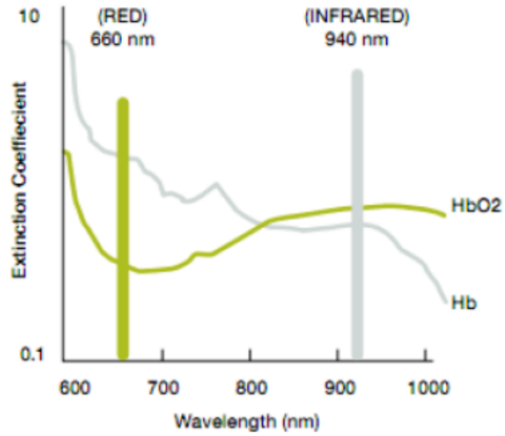


Figure 1 Hemogoblin light absorption graph

Really good explanation on the theory behind the pulse oximeter can be found here: https://www.howequipmentworks.com/pulse_oximeter/

It lacks details to implement the driver for MAX30100. But should give you a really good understanding about how in general these sensors operate.

What MAX30100 does and doesn't do?

Initially I thought that this sensor, MAX30100, will do everything for me. My **false assumptions** were that it will measure the pulse and the oxygen saturation levels automatically and put them in a register I can easily read through the I^2C, similar to BMP280. And that can't be further from truth, if you wanted.

Even though, MAX30100 doesn't do everything for you, it still does quite a bit to help with measuring the absorption between those two light frequencies. If you wanted to build your own sensor, it would definitely come out as a quite large circuit. Where you have to manually alternate between reading IR and RED led absorption, regulate the brightness manually of the LEDs with PWM, filter 50/60Hz noise out of the signals and more.

All of these things I mentioned in previous paragraph are done automatically by MAX30100. You just configure the sensor and then let it run, and it will store it's readings in a FIFO buffer. Only thing you have to do is then, go and read the FIFO data and make sense of it. Which, by the way, would be very similar if you created your own sensor. On that basis, this article should also help if you do use different sensor or make your own from scratch.

In short don't assume MAX30100 will do everything for you, a lot of deciphering will still be up to you.

Background information on MAX30100

First thing we have to do, is to connect the sensor to our microcontroller and read its data. I won't go in a lot of details; just some small notes and tips how it is done. Since I feel this is a rather simple process.

First some important background about MAX30100:

1. I^2C address of MAX30100: 0x57
2. Data is stored in a FIFO buffer. It can store up to 16 measurements, where each sample is size of 4 bytes. First two bytes are for IR measurement and last two bytes are for RED measurement.
3. FIFO buffer can't be read consequently with I^2C, since the FIFO points to the same address. You have to finish transaction for FIFO output address to contain the next values.
4. MAX30100 has built in 50/60Hz filter
5. If you want to just detect pulse, only IR is required
6. For oxygen saturation you'll need to enable both IR and RED LEDs
7. By changing sampling rate and pulse width of the LEDs you also change the ADC resolution. It is important to note that sample rate and pulse width are directly linked to each other. See datasheet page 19 table 8 and table 9 or see figure 2. Don't just configure them randomly.

Table 8. SpO_2 Mode (Allowed Settings)

SAMPLES (per second)	PULSE WIDTH (µs)			
	200	400	800	1600
50	O	O	O	O
100	O	O	O	O
167	O	O	O	
200	O	O	O	
400	O	O		
600	O			
800	O			
1000	O			
Resolution (bits)	13	14	15	16

Table 9. Heart-Rate Mode (Allowed Settings)

SAMPLES (per second)	PULSE WIDTH (µs)			
	200	400	800	1600
50	O	O	O	O
100	O	O	O	O
167	O	O	O	
200	O	O	O	
400	O	O		
600	O	O		
800	O	O		
1000	O	O		
Resolution (bits)	13	14	15	16

Figure 2 Sample Rate vs. Pulse width configuration table

To start reading the data from MAX30100 you only have to do two things:

1. Set the mode, I suggest in the beginning set it only to heart rate mode

2. Set the current for IR led

This will enable us to measure heart rate, once we are done with filtering. You can check how did I do it, by looking at three functions in my library: setMode(),setLEDCurrents() and readFIFO()

Reading IR data

Once you have managed to set up the MAX30100 for HR mode and read the raw IR data it should look something like in figure 3, once plotted:

Figure 3 RAW IR data, with visible oscillations

DC Removal

There are two things you should notice in the graph (figure 3):

1. The graph is oscillating slightly
2. It has a DC offset of 50 000 units

To properly be able to read the heart rate and SaO_2 we need to remove the DC signal and leave only the AC part.

It is actually very simple and can be done using these two equations:

$$w(t) = x(t) + \propto * w(t-1)$$

$$y(t) = w(t) - w(t-1)$$

y(t): is the output of the filter
x(t): current input/value
w(t): intermediate value, acts like the history of the DC value
α: is the response constant of the filter
If α = 1 then everything passes through
If α = 0 then nothing passes through
for DC removal you want the α as rather close to 1. I'll be using α = 0.95

If you want to read more about DC removal, here is a good tutorial and much more detailed description of how it functions: http://sam-koblenski.blogspot.co.uk/2015/11/everyday-dsp-for-programmers-dc-and.html

Here is the filter implemented in a code:

```
struct fifo_t {
  uint16_t rawIR;
  uint16_t rawRed;
};
dcFilter_t MAX30100::dcRemoval(float x, float prev_w, float alpha)
{
  dcFilter_t filtered;
  filtered.w = x + alpha * prev_w;
  filtered.result = filtered.w - prev_w;

  return filtered;
}
```

Once, we pass the signal through the DC removal filter, we should get a signal similar to the one in figure 4:

Figure 4 IR signal passed through DC Removal filter

As you can see in figure 4, we are now left with only the AC part of the signal, and it is oscillating around 0 DC value instead of 50 000.

Mean Median Filter

Now that we have DC filtered our signal, to further improve the ability to detect pulses we have to take the differential of the signal. Our pulse is where in the data we have suddenly the largest change in value.

However, I've decided to implement mean median filter instead of just taking the difference to further clean up the signal. This will give us the value change from the average, as the name implies. Here is my simple implementation of such filter:

```
struct meanDiffFilter_t
{
  float values[MEAN_FILTER_SIZE];
  byte index;
  float sum;
  byte count;
};

float MAX30100::meanDiff(float M, meanDiffFilter_t* filterValues)
{
  float avg = 0;

  filterValues->sum -= filterValues->values[filterValues->index];
  filterValues->values[filterValues->index] = M;
  filterValues->sum += filterValues->values[filterValues->index];

  filterValues->index++;
  filterValues->index = filterValues->index % MEAN_FILTER_SIZE;

  if(filterValues->count < MEAN_FILTER_SIZE)
    filterValues->count++;

  avg = filterValues->sum / filterValues->count;
  return avg - M;
}
```

After we pass the DC filtered signal through the mean difference filter we get a familiar signal which reassembles a cardiogram (see figure 5)

Figure 5 Mean Difference filtered IR signal

The really tall peaks are my heart beats. From this data it should already be quite easy to extrapolate my heartbeat, however if you look closely to the wave form, there are some higher level harmonies in the data. They are especially visible at the bottom part of the signal. We can filter them out easily if we pass the signal through a low pass filter or band pass filter.

Butterworth filter

To remove the higher level harmonies I shall be using Butterworth filter in low pass filter configuration. Technically it is a band pass filter. And also, any low pass filter would do just fine. It's just relatively easy to work with Butterworth. There is a good online tool for generating Butterworth filter constants for your desired frequencies: http://www.schwietering.com/jayduino/filtuino/

So to implement this filter we have to establish two variables: sampling rate (F_S) and cut-off frequency (F_C).

Technically the fastest sampling rate available for MAX30100 is 1kHz, nonetheless the configuration I've chosen is with long pulse width, which allows the sampling rate to be only 100Hz. So from this we can extrapolate that our sampling rate is 100Hz.

Next we need to choose the cut-off frequency. Since we are measuring heart rate, as far as I know, 220 BPM is dangerously high heart rate but still achievable in certain cases. So I've chosen that to be our maximum frequency we have to pass through.

Our fastest frequency we would require to let through, can be calculated like so:

$$f = \frac{220BPM}{60} = 3.66Hz$$

If we assume we want to measure as low as 50 BPM we can apply the same calculations:

$$f = \frac{50BPM}{60} = 0.83Hz$$

It is very important to remember that Butterworth filter work on a normalised frequency

$$R_n = \frac{F_C}{F_S}$$

So if your sampling rate is not spot-on 100Hz, Butterworth filter will start to cut-off different frequencies. In figure 6 you can see how quickly one loop finishes in my current implementation.

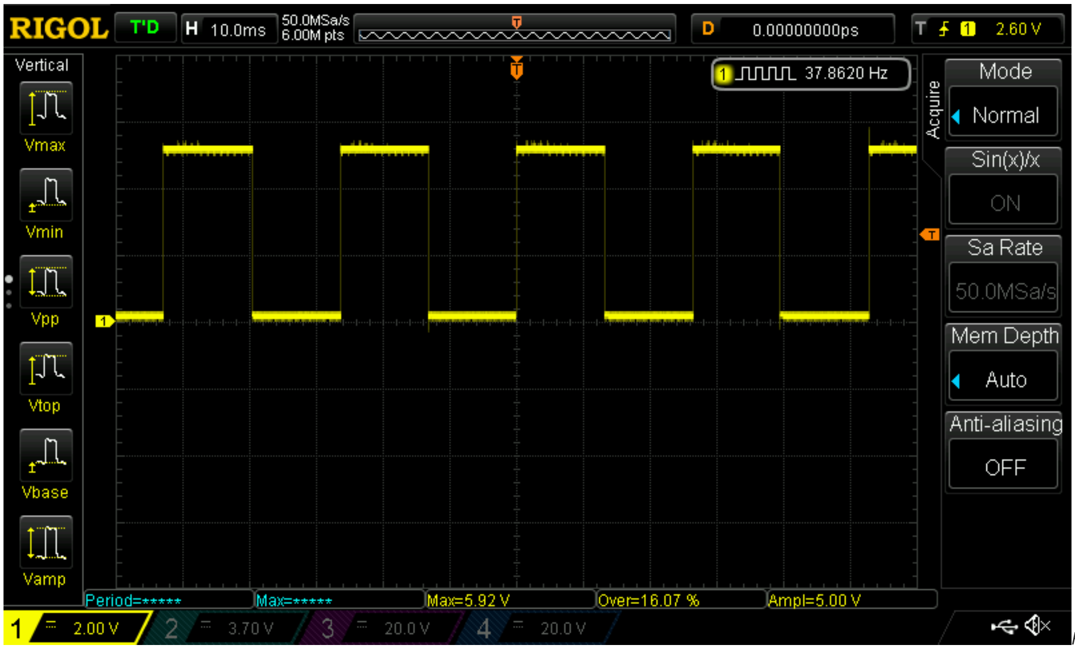


Figure 6 Diagram showing how quickly one loop finishes while reading and filtering MAX30100 data. Note that output pin is flipped every time a loop finishes. Actual execution speed is 75Hz

As you can see in the figure 6 our sampling rate is about 75Hz. Let's assume we actually implemented our Butterworth filter with F_S = 100Hz and F_C = 4Hz.

If we apply the normalisation, at our real F_S = 75Hz, our cut-off frequency would be F_C = 3Hz

And because of that we have a problem, our cut-off frequency is lower than our intended 3.66Hz. That means we could only measure up to 180BPM instead of our desired 220BPM. Nonetheless, if the update speed is even lower, we would cut-off even more frequencies we actually want to keep.

To fix this issue, we have two options available, either have a precise sampling rate or increase the cut-off frequency. Effectively increasing available sampling rate error margin and decreasing a bit the quality of the filtered signal.

I adopted the second option and chose a new F_C value.

$$F_S = 100Hz$$
$$F_C = 10Hz$$

That would give us ratio of:

$$R_n = \frac{100Hz}{10Hz} = 0.1$$

Assuming 220BPM or that is 3.66Hz is our target frequency. Butterworth filter would now still let through desired frequencies with as low as a sample rate of:

$$\frac{3.66Hz}{0.1} = 36.6Hz$$

In our real world example of F_S = 75Hz it would give us actual F_C = 7.5Hz.
I believe it is good enough for our filtering needs, because we don't need to be ultra-precise about filtering the signal; just enough to clear it up a bit and improve the signal for detecting peaks.

Taking into account our F_S = 100Hz and F_C = 10Hz, we get the following code for Butterworth filter:

```
struct butterworthFilter_t
{
  float v[2];
  float result;
};
void MAX30100::lowPassButterworthFilter( float x, butterworthFilter_t * filterResult )
{
  filterResult->v[0] = filterResult->v[1];

  //Fs = 100Hz and Fc = 10Hz
  filterResult->v[1] = (2.452372752527856026e-1 * x) + (0.50952544949442879485 * filterResult->v[0]);

  //Fs = 100Hz and Fc = 4Hz
  //filterResult->v[1] = (1.367287359973195227e-1 * x) + (0.72654252800536101020 * filterResult->v[0]); //Very precise butterworth filter

  filterResult->result = filterResult->v[0] + filterResult->v[1];
}
```

Once we pass the cardiogram looking signal, we get a much smoother signal out (see figure 7)

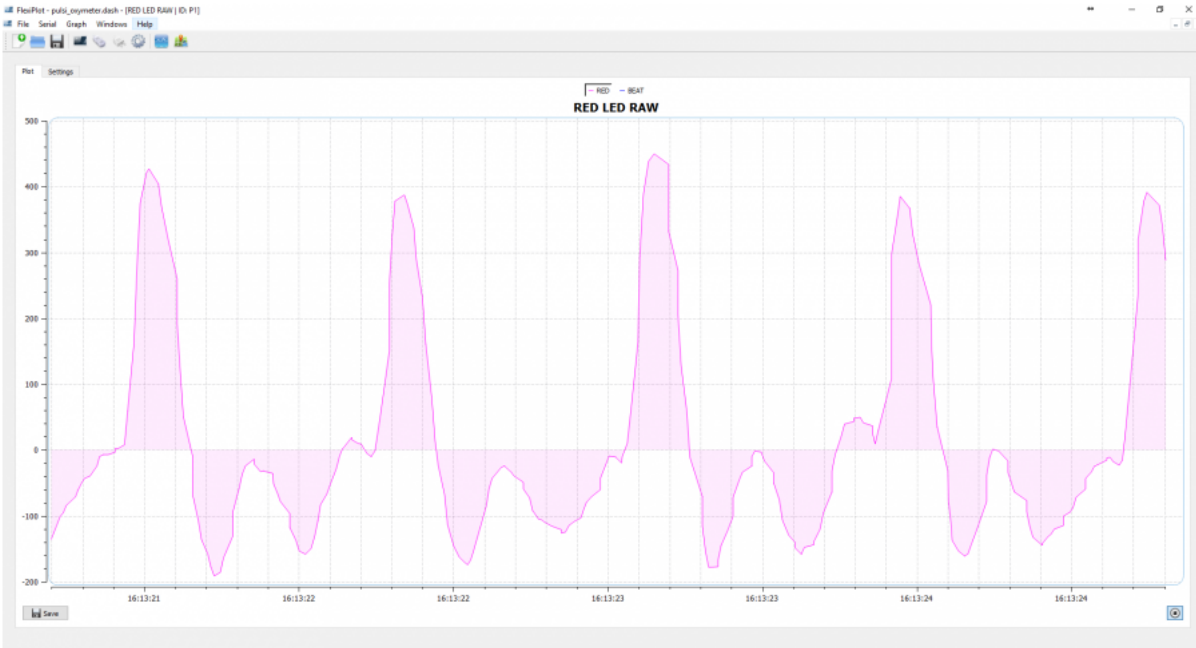


Figure 7 Butterworth filtered signal with Fs = 100Hz and Fc = 10Hz. Real sampling rate Fs = 75Hz, which gives Fc = 7.5Hz

And that is all we have to do for our IR output. At this stage it should be pretty clear where the pulses are, and as a matter of fact it generates a nice cardiogram.

Beat Detection

Now that we have a relatively clean signal from our MAX30100 we can start calculating the heart rate. I've decided to implement a very simple state machine. By no means is my design error free or industry ready. It isn't, and can easily miss-detect pulses or not detect them at all, but it is good as proof of concept.

Idea for the state machine is very simple. Once a threshold is reached, follow the curve. As soon as one or more times the signal starts to fall, save a timestamp. Once you have two timestamps, the difference between them is our measured delay between two beats. From this we can calculate the BPM.

Arduino has a nice function called millis(), which gives you a timestamp in milliseconds. If we get two timestamps we can calculate the heart rate using this equation:

$$BPM = \frac{60000}{\text{current beat timestamp} - \text{previous beat timestamp}}$$

On top of that because we are calculating in such a way BPM, I've decided to also implement a moving average filter on the BPM results. Just to give a more accurate measurement of the heart rate.

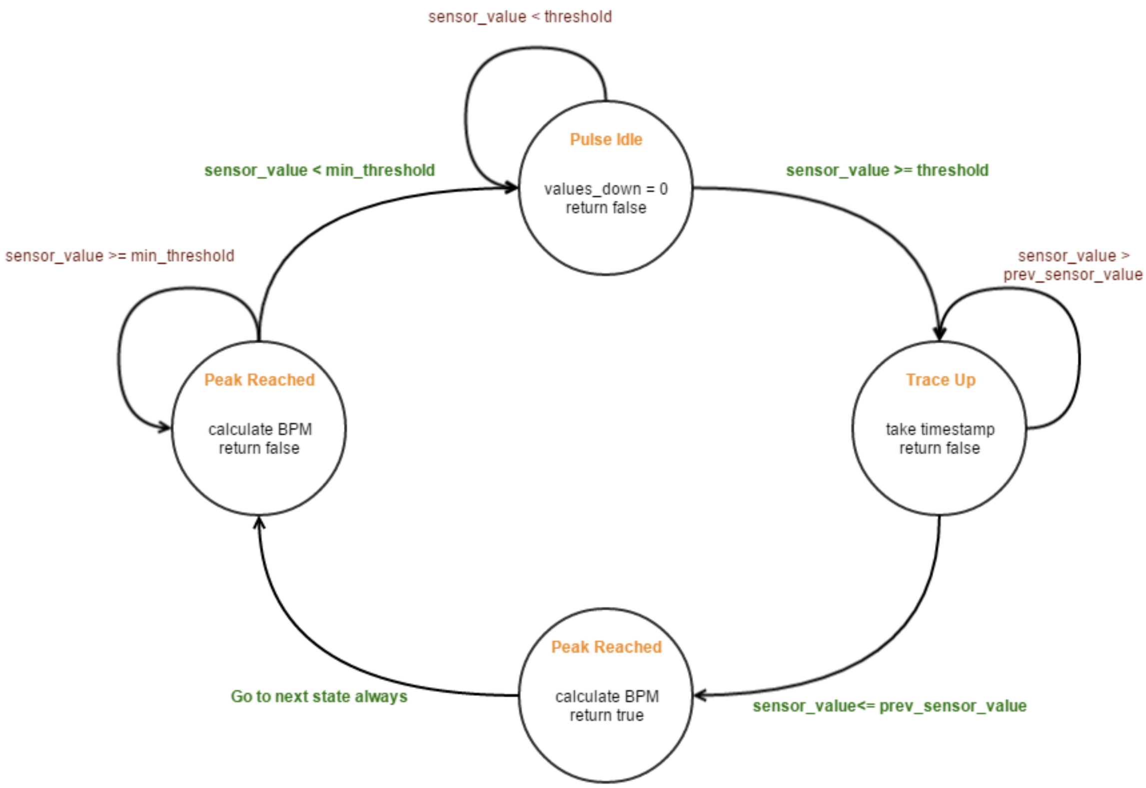


Figure 8 State machine diagram for detecting peaks

Finally here is the code which detects and measures pulse

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At this stage we have applied multiple filters to our signal. Moreover we also have detected the pulse and measured the heart rate. However, as previously mentioned, this state machine can still be greatly improved and should not be used in a real product.

Measuring SpO_2

As mentioned in the introduction, oxygen concentration can be measured by calculating the ratio between absorbed light from IR LED and Red LED. In this section I will explore how it is theoretically done, but due to some limitation the sensor won't be calibrated properly. Unfortunately for that you need proper empirical data to create a lookup table.

Balancing IR and Red Current

First of all, we have to switch the MAX30100 mode to SaO_2 + HR. That can be done by sending 0x03 to MODE config register. That will enable both LEDs and MAX30100 will start filling the FIFO buffer with readings from both light spectrums.

Also, RED readings should be passed through the same DC removal filter as IR readings. But it is not necessary to pass it through mean average filter and Butterworth filter, since we are not using RED light to detect pulses.

If you just enabled both LEDs with maximum output current of 50ma, you'll quickly realize that readings from Red LED will be extremely saturated. Also to be able to measure the ratios between our two readings, on base level their DC levels should be nearly identical (see figure 9 and figure 10).

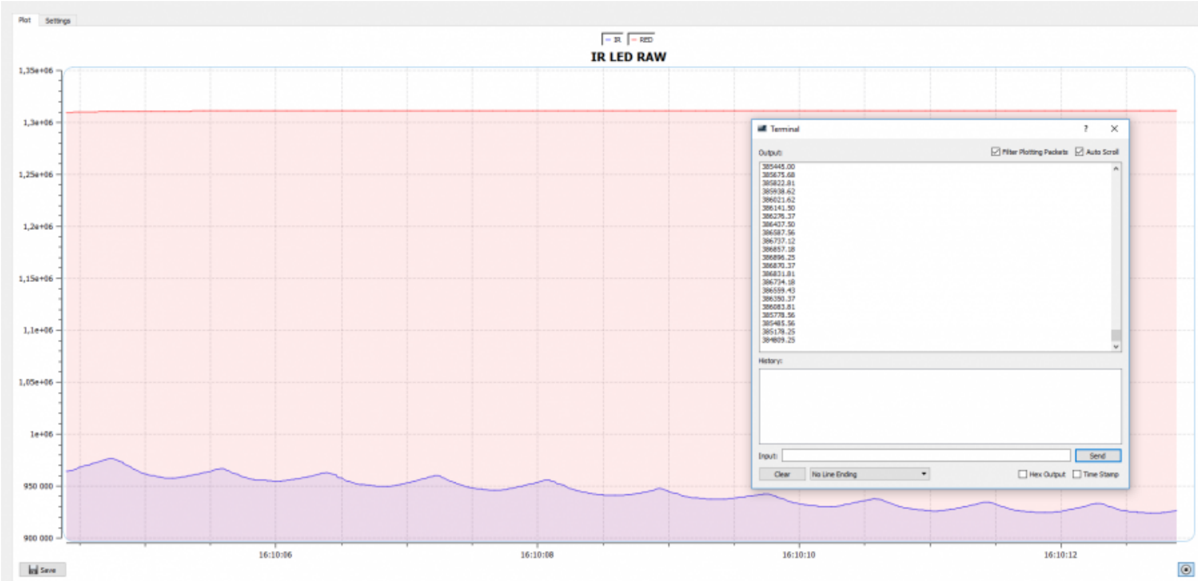

Figure 9 Mismatched DC levels. Difference is approximately about 380 000 (DC units). IR led has been set to 50ma and RED led to 50ma

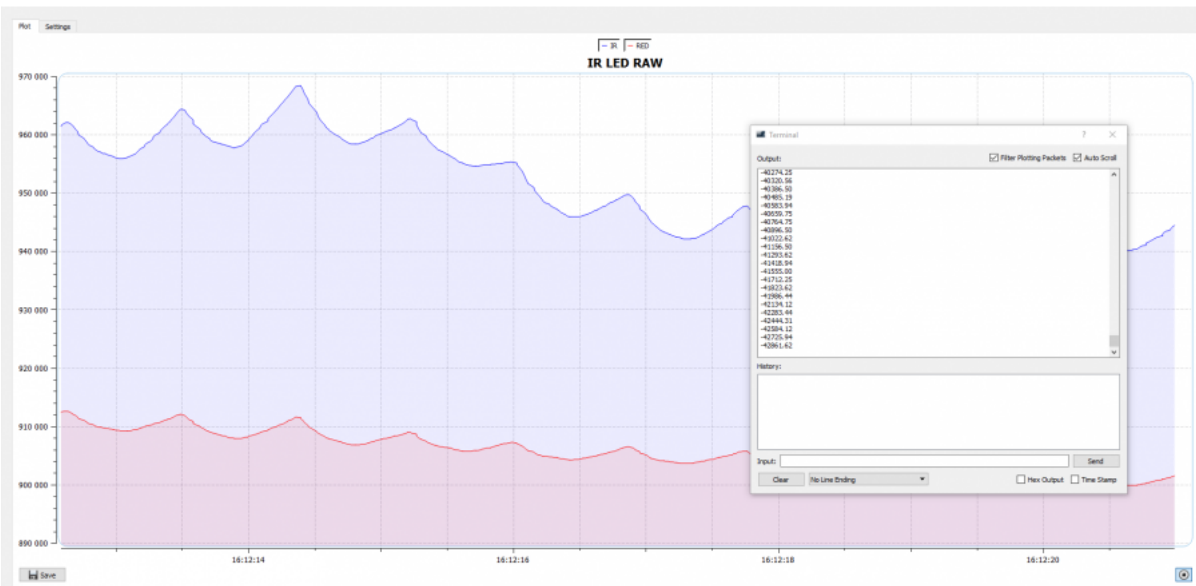

Figure 10 More closely matched DC levels. Difference now has been reduced to 42 000 (DC units). IR led has been set to 50ma and RED led to 27.1ma

Idea is very simple:

1. Check the difference between RED and IR DC readings
2. If $I_{RED} > I_{IR}$ then decrease I_{RED} current
   If $I_{RED} < I_{IR}$ then increase I_{RED} current

It is important to note, that I_{RED} shouldn't be changed instantly, but once in a while only if the difference is above certain threshold, which can only be determined by experimentation.

Here is the code I've implemented to balance I_{IR} and I_{RED}:

```
void MAX30100::balanceIntesities( float redLedDC, float IRLedDC )
{

  if( millis() - lastREDLedCurrentCheck >= RED_LED_CURRENT_ADJUSTMENT_MS)
  {
    //Serial.println( redLedDC - IRLedDC );
    if( IRLedDC - redLedDC > MAGIC_ACCEPTABLE_INTENSITY_DIFF && redLEDCurrent < MAX30100_LED_CURRENT_50MA)
    {
      redLEDCurrent++;
      setLEDCurrents( redLEDCurrent, IrLedCurrent );
      if(debug == true)
        Serial.println("RED LED Current +");
    }
    else if(redLedDC - IRLedDC > MAGIC_ACCEPTABLE_INTENSITY_DIFF && redLEDCurrent > 0)
    {
```

```
      redLEDCurrent--;
      setLEDCurrents( redLEDCurrent, IrLedCurrent );
      if(debug == true)
        Serial.println("RED LED Current -");
    }

    lastREDLedCurrentCheck = millis();
  }
}
```

As I said before, you have to choose a good magic value for acceptable difference between those two readings at base state. If you choose the magic value too little, it will result in a lot of oscillation (see figure 11)

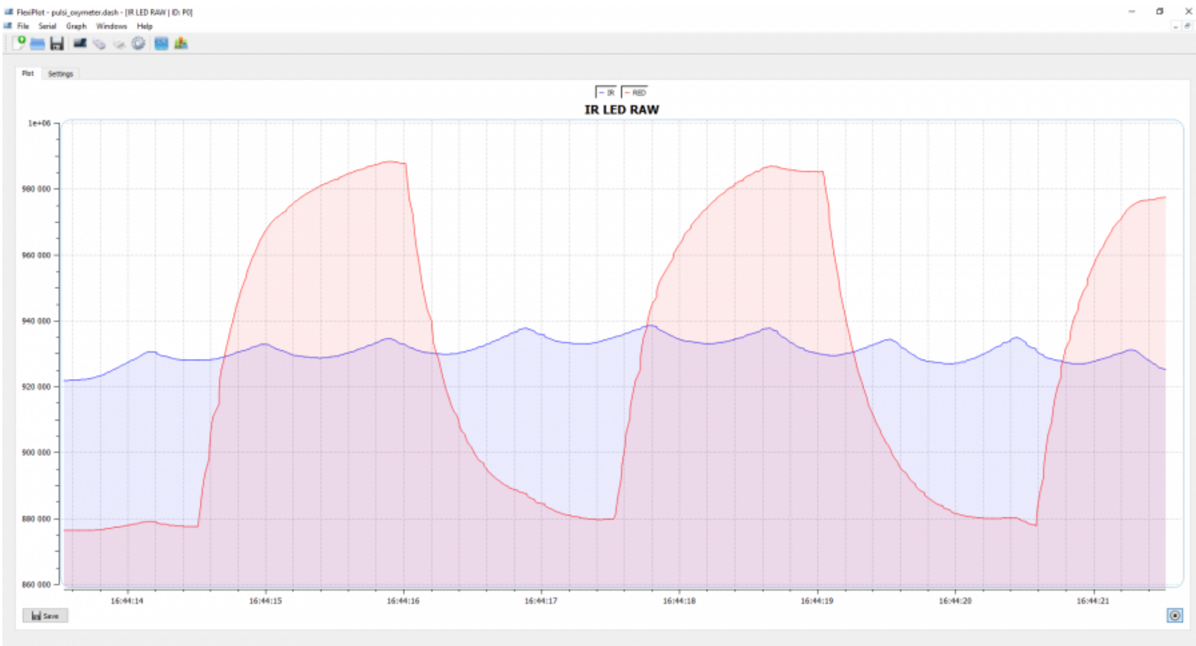

Figure 11 Oscillations invoked due to too little magic value. Magic difference in this example is set to 50 000

After some little experimentation I came to a good magic value of 65 000. This in my use case completely eliminated oscillations. And only in some rare cases the algorithm adjusted the current while being active for a while. Nonetheless, it adjusts wildly inaccurate intensity to match the I_{IR} immediately (see figure 12)

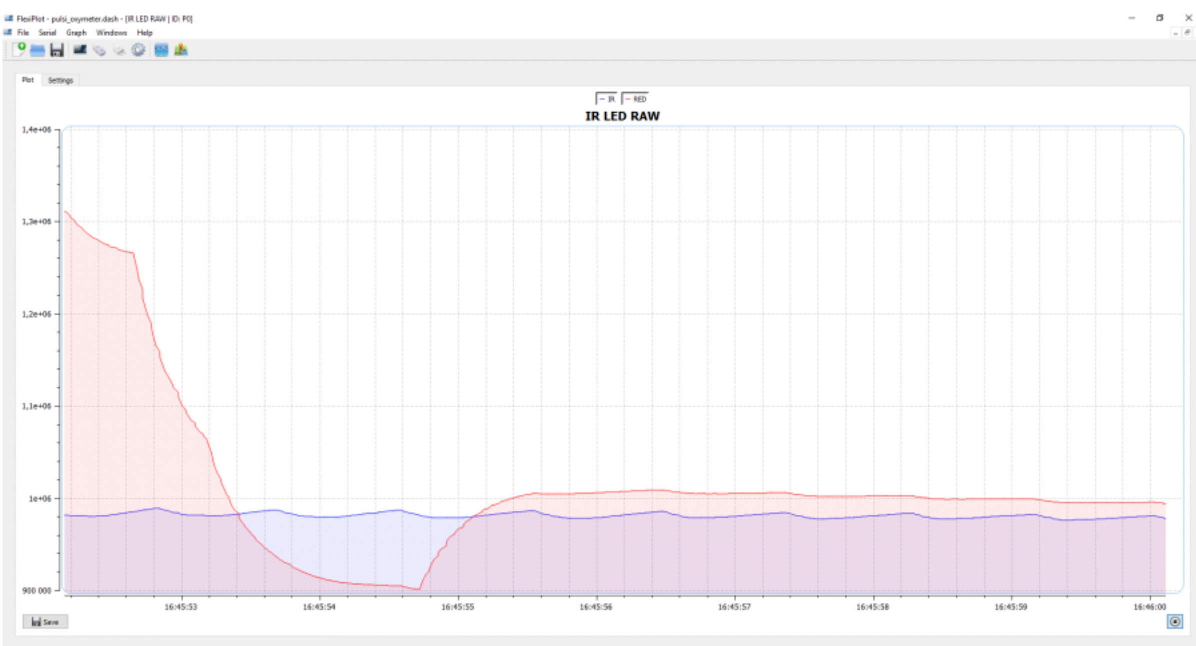

Figure 12 Good magic value of 65 000. Immediately balances out and stays stable

That is all we have to do before we can get into calculating the SpO_2 value.

A little bit of SpO_2 theory

In short SpO_2 is defined as the ratio of the oxygenated Hemoglobin level over the total Hemoglobin level.

$$SpO_2 = \frac{HbO_2}{\text{Total Hb}}$$

Our bodies' tissue absorbs different amounts of light depending on the blood oxygenation level. However it is important to note, that the characteristic is non-linear.

As mentioned before two different wavelengths are used IR (950nm) and RED (650nm). These two wavelengths are emitted towards your finger, earlobe etc. in alternating fashion. One is turned on, measurement is taken and then it is turned off. This repeats for the other spectrum. Basically, both of them are not measured simultaneously.

The ratio R between these two wavelengths is defined with the following equations:

$$R = \frac{AC_{\text{RMS RED}}/DC_{\text{RED}}}{AC_{\text{RMS IR}}/DC_{\text{IR}}}$$

Or it can also be expressed like this:

$$R = \frac{log(I_{AC})*\lambda_1}{log(I_{AC})*\lambda_2}$$

I_{AC} is the light intensity where only the AC is present. And λ_1 is for 650nm wavelength and λ_2 is for 950nm wavelength of light.

Quoting from TI article about pulse oximeter

> Once the DC levels match, then the SpO_2 is calculated by dividing the logs of the RMS values

As you know, we have already balanced our DC levels, and only thing left to do is to calculate RMS for both I_{IR} and I_{RED}

If you don't know, calculating basic RMS value is extremely simple; you just have to take the sum of squares of your signal, average them and then take square root of the average. It won't be true RMS, but more than enough for our application.

See this article for basic explanation: http://practicalphysics.org/explaining-rms-voltage-and-current.html

I also want to stress out, that RMS values how to be calculated for the whole signal, not only when there is a pulse. And it is advised to reset it once in a while; otherwise it will hold whole historical garbage data. In my final implementation I reset RMS every 4 heart beats.

Now that we have calculated the RMS values for both of our wavelengths, and also calculated ratio R value, only thing left to do is to calculate the actual SpO_2 value.

This is where it gets very interesting. To be able to have precise measurements of the oxygen saturation, you'll need to calibrate the sensor. There is no formula which fits them all.

Nonetheless a standard model of computing SpO_2, which is referenced basically in all text books, is as follows:

$$SpO_2 = 110 - 25 * R$$

As I said before, the relationship is non-linear. But standard model is clearly suggesting a linear relationship which is not true. See figure 13 for an excellent comparison between empirical and theoretical R to SpO_2

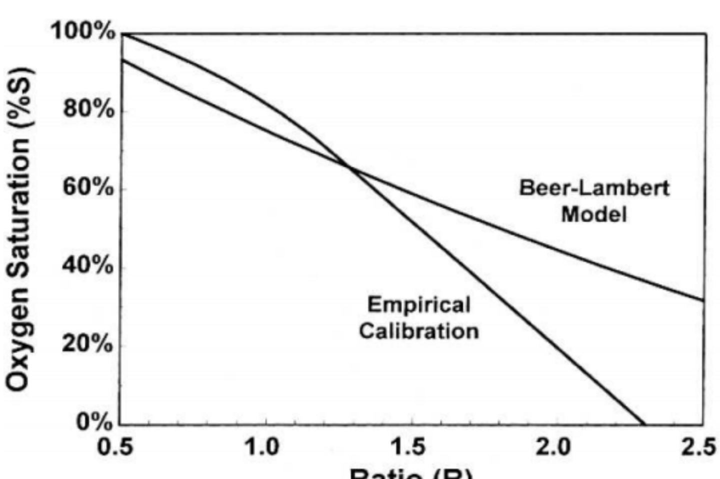

Figure 13 Empirical and Theoretical R to SaO_2. Source: http://www.ti.com/lit/an/slaa274b/slaa274b.pdf

Also you should notice that even with empirical calibration, once the oxygen saturation drops below 80% you can safely assume a linear relationship.

Here is where I had a problem. I don't really have a way of calibrating MAX30100 sensor. Neither have I a calibrated pulse oximeter for reference or other means of determining my real SpO_2

Once I implemented all these calculations in practice, I got my RMS ratios between:

0.84 – 0.86

According to standard model it would yield SpO_2 between 88.5% and 89%. Or according to the TI empirical curve: ~90%.

It still feels rather low, since I'm expecting at least 94% for a healthy human being. Unless I'm being very unhealthy at the time of measuring my oxygen saturation. Also, I live next to the sea, maybe about 3m above sea level. So my altitude shouldn't be a factor for low oxygen levels.

My decision, not being the most scientific, was to just assume I have oxygen levels of 94% and I adjusted the standard model accordingly.

$$SpO_2 = 110 - 180 * R$$

I really have to stress out! This is not a scientific or proper way of determining SpO_2. You must have a proper calibration in place; this is merely an estimate (and extremely poor at that)!

Nonetheless, here are the final results after implementing everything I have described in this article (see figure 14).

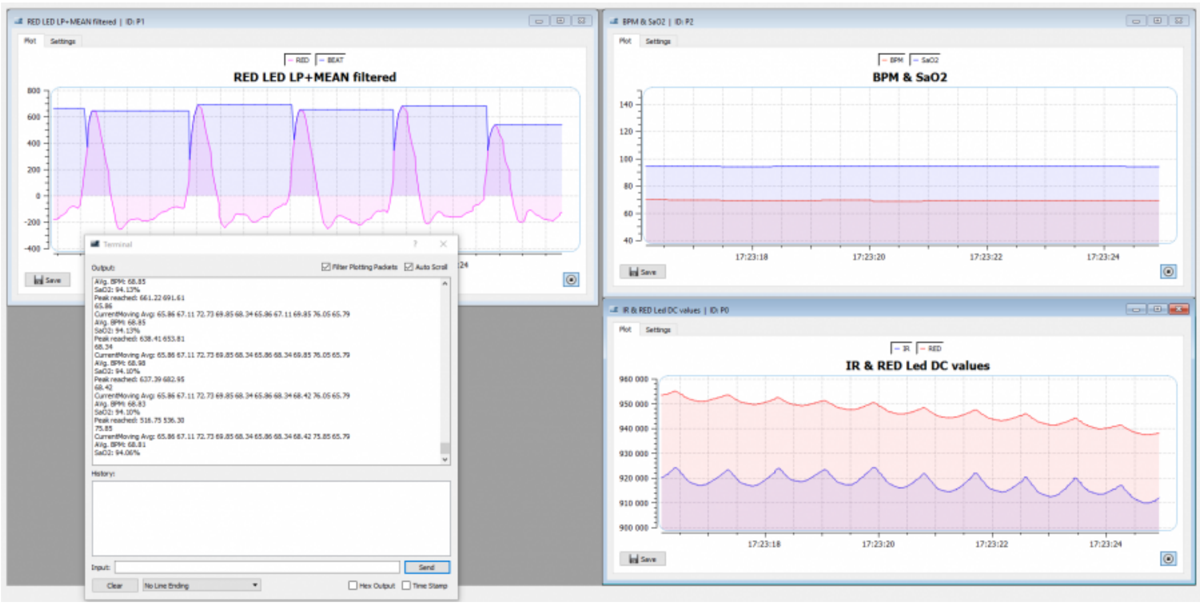

Figure 14 Reading from final implementation of the MAX30100 driver

In figure 14, you can see that my pulse rate is about 68.81 BPM and O_2 concentration around 94.06%. I'm absolutely certain about the accuracy of heart rate measurements, since I was able to cross-check it multiple times with Omron blood pressure measuring device, which also measures BPM. At this particular instance, Omron measured my BPM to be 68.

Conclusion

It was not as simple as I first anticipated to measure heart rate and oxygen saturation in your blood. But with persistence I was able to achieve good enough understanding on the DSP involved and the theory behind measuring SpO_2 to implement it from scratch. Not only all of this is applicable to MAX30100 exclusively, but similar techniques and calculations should be done on either your own self-made sensor or a sensor manufactured by a different company than Maxim. MAX30100 gives just the convenience of integrating a rather complicated analog circuit in extremely small package. However, from quick tests, I must say that measuring heart rate from wrist is extremely difficult with this sensor. Essentially it is impossible with the current algorithm for detecting peaks. Also it is important to remember that in the article when measuring oxygen saturation I have not properly calibrated the sensor, merely adjusted standard model to fit what I felt is right. It is highly advisable that if you do use this sensor for measuring SpO_2, you must calibrate it properly.

Code

You can either download the library from github here: https://github.com/xcoder123/MAX30100

Or from my server directly:
[Download: max30100.zip (7.48K)]

Sample Usage

```
#include <Arduino.h>
#include <math.h>
#include <Wire.h>

#include "MAX30100.h"

MAX30100* pulseOxymeter;

void setup() {
  Wire.begin();
  Serial.begin(115200);
  Serial.println("Pulse oxymeter test!");

  //pulseOxymeter = new MAX30100( DEFAULT_OPERATING_MODE, DEFAULT_SAMPLING_RATE, DEFAULT_LED_PULSE_WIDTH, DEFAULT_IR_LED_CURRENT, true, true
  pulseOxymeter = new MAX30100();
  pinMode(2, OUTPUT);

  //pulseOxymeter->printRegisters();
```

```
}

void loop() {
  //return;
  //You have to call update with frequency at least 37Hz. But the closer you call it to 100Hz the better, the filter will work.
  pulseoxymeter_t result = pulseOxymeter->update();


  if( result.pulseDetected == true )
  {
    Serial.println("BEAT");

    Serial.print( "BPM: " );
    Serial.print( result.heartBPM );
    Serial.print( " | " );

    Serial.print( "SaO2: " );
    Serial.print( result.SaO2 );
    Serial.println( "%" );

    Serial.print("{P2|BPM|255,40,0|");
    Serial.print(result.heartBPM);
    Serial.print("|SaO2|0,0,255|");
    Serial.print(result.SaO2);
    Serial.println("}");
  }



  //These are special packets for FlexiPlot plotting tool
  Serial.print("{P0|IR|0,0,255|");
  Serial.print(result.dcFilteredIR);
  Serial.print("|RED|255,0,0|");
  Serial.print(result.dcFilteredRed);
  Serial.println("}");

  Serial.print("{P1|RED|255,0,255|");
  Serial.print(result.irCardiogram);
  Serial.print("|BEAT|0,0,255|");
  Serial.print(result.lastBeatThreshold);
  Serial.println("}");



  delay(10);

  //Basic way of determening execution of the loop via oscoliscope
  digitalWrite( 2, !digitalRead(2) );
}
```

MAX30100.h

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MAX30100.cpp

</> Expand Source

This article is also available in PDF format:

Download: max30100.pdf (1.87M)

Thanks Hackaday for publishing my article: http://hackaday.com/2017/03/11/pulse-oximeter-is-a-lot-of-work/

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Comments (82)

- **Moe DABE** 3 months ago

  Hey bro, this is an amazing tutorial! i am trying to do something similar myself and i got stuck at heartrate calculation, the formulas you got in the tutorial are not showing can you tell me the formula you used to calculate the heartrate please, thanks in advance.

  Reply

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Reply

Pranav Batra 8 months ago

I am new here I want to know where to add these files in the arduino folder.

Reply

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Reply

Kim 8 months ago

can i ask sth. I am very new about the electronic. what is the unit of Y axis in every graph?

Reply

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Reply

Kim 8 months ago

can i ask sth. I am very new about the electronic. what is the unit of Y axis in every graph?

Reply

Tatiana 9 months ago

Hello

I'm using the ESP32 target and the DC filter is not working... it is on 0 value, do you know how can I fix that?... the IR and RED value of data are working well, but in the DC filter it is going to 0.

Thanks

Reply

Ricky 9 months ago

I tried to port to STM32 Hal, but can not count on heart beat,

I have filtered and got a value from IR

Do you have the code in C ?

Thanks

Reply

Rick 9 months ago

I tried to port to STM32 Hal, but can not count on heart beat,

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Rick 9 months ago

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Thanks

Reply

Jessica Roggers 1 year ago

Enter for Free to Win a $100 Amazon Gift Card! and Santamedical Pulse Oximeter

https://gleam.io/sVfla/enter-for-free-to-win-a-100-amazon-gift-card-and-sm1100-silver-pulse-oximeter

Reply

Jessica Roggers 1 year ago

Small portable size makes it easy to handle and carry. Helpful for athletes and pilots to obtain quick and precise oxygen saturation readings.

https://www.amazon.com/Santamedical-Generation-Fingertip-Saturation-batteries/dp/B000ORVXPA

Reply

Alpinist 1 year ago

Hi,

Thank you for this nice article. I have a question. Can you explain the Mean Median Filter please? What is M? What should be MEAN_FILTER_SIZE?

Regards

Reply

---

obiwan 1 year ago

Great work! I'm using this as a basis for a lab and it's working great. One note: I think you're SpO2 calculation is missing the wavelength parameters? Correct me if I'm wrong.

Reply

---

obiwan 1 year ago

Also, I think constantly balancing the LED intensities is problematic, because the absorbances of hemoglobin at different wavelengths should be different. I think balancing should happen once against a neutral background.

Reply

Harish 1 year ago

The easiest way to monitor your heart beat & oxygen saturation & temperature with Pulse Oximeter

Reply

Felipe Moura 1 year ago

Raivis Strogonovs,

Congratulations for your very nice work and explanation!

How many time do you put in this project ?

Reply

Alex 2 years ago

Do you have the schematic of connection to arduino?

Reply

Saif 2 years ago

Can anyone tell me which sensor is best for animal heart rate detection?

Reply

David 2 years ago

Brilliant, thanks!

Reply

---

jessica roggers 2 years ago

Fingertip #pulse #oximeter color OLED SM-1100S Integrated with SpO2 probe and processing display module Small in volume、light in weight and convenient in carrying Operation of the product is simple ,low power consumption!!! buy now at www.amazon.com https://www.amazon.com/Santamedical-Generation-Fingertip-Saturation-batteries/dp/B018HC7FJ6

Reply

Gurin Products 2 years ago

I am pleased with its performance and how user-friendly it is. The display is brightly lit and very readable. I can check my oxygen saturation and heart rate instantly. The resolution is excellent and I can see on a graph the strength of my pulse graphically.amazon.com

Reply

Nazmi Febrian 2 years ago

Hi,

Your code is very useful for beginner to start programming MAX30100. Every step is very clear. Thank you very much.

Regards,

Nazmi

Reply

---

jessica roggers 2 years ago

The newly upgraded SantaMedical Generation 2 Finger Pulse Oximeter is an accurate way to check pulse rates and blood oxygen saturation levels. Buy Now at santamedical.com

Reply

---

jessica roggers 2 years ago

This SM-165 finger pulse oximeter device is one of the best and the latest inventions from SantaMedical. The product perfectly displays the readings of saturation levels of blood oxygen and the pulse rates. Buy Now at www.santamedical.com
 SantaMedical Pulse Oximeter

Reply

Harish 2 years ago

The newly upgraded SantaMedical SM-165

```
<a href="https://www.walmart.com/ip/Santamedical-Generation-2-SM-165-oxi-Fingertip-Pulse-Oximeter/320834284" > Santamedical SM-165 Finger
```

is an affordable and accurate way to check pulse rates and blood oxygen saturation levels. Buy Now at Walmart.com

Reply

Harish 2 years ago

The newly upgraded SantaMedical Generation 2 Finger Pulse Oximeter is an affordable and accurate way to check pulse rates and blood oxygen saturation levels. Buy Now at Walmart.com

Reply

Harish 2 years ago

Self-adjusting finger clamp plus simple one-button design allows for easy operation. Small portable size makes it easy to handle and carry. Buy Now at Amazon.com

Reply

Harish 2 years ago

Quickly measure your oxygen saturation (SpO2) and pulse rate with Santamedical SM-165 Pulse Oximeter that delivers matchless accuracy & easy to operate. Buy Now at Santamedical.com

Reply

Julie 2 years ago

Hello,

I am working with the MAX 30105 to sense heartbeat. I have just set it up by specifying the led currents, sample average, led mode, sample rate, pulse width and adc range.

Then I clear fifo and then try to read its first value. However, reading the values of the FIFO and of the read and write pointers always gives me 0.

Is there something I am missing in order to get it to take samples?

Thank you

Reply

---

ahMAX30100 2 years ago

Hi,I studied thoroughly your article and got too much confusion clear.but the problem is my RED led does not light up.

Thats why I am not able to calculate the HB and Spo2.What shuld I do for.

Reply

---

krish 2 years ago

We are giving away a $100 Amazon gift card to one lucky winner on November 30th, 2017. We hope the winner will use it to buy their

favorite Santamedical Pulse Oximeter on Amazon but they can use it however they like :)
There are 7 ways to enter (all free) so you can have up to 12 entries for even more chances to win!
Enter below by clicking on each of the buttons and enter up to 12 times for free! (no purchase necessary)
Pulse Oximeter Giveaway

Reply

Gaurav Kumar 2 years ago

OFFER : Buy SM-1100S #PulseOximeter at 25% discount on Amazon
#Thanksgiving #Christmas #Newyear #Blackfriday
Save 25% each on Qualifying items offered by Oximeter Superstore when you purchase 1 or more.
Discount is 25%
OFFER Price - 14.21
This is the link of the product, code is MOTFUVMO

https://goo.gl/CH7dxk

Reply

Gurin Products 2 years ago

A Pulse Oximeter is a healthcare device that is used to measure pulse rate and blood fresh air vividness of an individual. Blood fresh air vividness is also denoted as Spo2 by doctors and is very important in the medical care field. Many individuals have their issues or issue that requires the statistic of their Spo2 stages. These wellness issues differ significantly but the common denominator is that they need to continuously monitor the blood fresh air vividness stages to ensure that they are at their normal healthy stages.

Reply

KORI 2 years ago

Hello,

This code is working perfectly for me, but i cannot find where i can increase the current of the LED, becuase, i have nice reading on the finger, but as many other user it will be more pracitlce to use this measurments on the wrist, did you try to measure the beats on the wirst is that even possible ? Because i thought that if you can increase the current it would be possible to achieve readings where the skin is thicker, what do you think ?

Thank you again for the reply

Reply

---

sai pavan 2 years ago

Arduino: 1.8.4 (Windows 8.1), Board: "Arduino/Genuino Uno"

Build options changed, rebuilding all
C:\Users\acer\Documents\Arduino\sketch_oct07a\sketch_oct07a.ino: In function 'void loop()':

sketch_oct07a:24: error: 'pulseoxymeter_t' was not declared in this scope

pulseoxymeter_t result = pulseOxymeter->update();

^

sketch_oct07a:27: error: 'result' was not declared in this scope

if(result.pulseDetected == true)

^

sketch_oct07a:50: error: 'result' was not declared in this scope

Serial.print(result.dcFilteredIR);

^

Multiple libraries were found for "MAX30100.h"
Used: C:\Users\acer\Documents\Arduino\libraries\MAX30100
Not used: C:\Users\acer\Documents\Arduino\libraries\MAX30100lib
exit status 1
'pulseoxymeter_t' was not declared in this scope

This report would have more information with
"Show verbose output during compilation"
option enabled in File -> Preferences.

hey! any one can please help me regarding this error the program shows while executing in arduino IDE software

Reply

---

abdirahman hadi 2 years ago

pls may I know the circuit diagram for this project and the details component of it
how i can build the power supply

Reply

Gurin 2 years ago

Here's a Quick Way to monitor Oxygen level without help of Doctor
https://goo.gl/R2X3hq

Reply

---

ali reza Khakshoor 2 years ago

Help me !!!

Reply

Mouse 2 years ago

Hi !

First, thank you very much for all these details !

I would like to know more about the sampling rate. I need to get a sampling rate of at least 500hz, but 1khz would be perfect.

Thank you !

Best regards

Reply

KORI 2 years ago

Hello,

Great explanation and work on the heart beat monitor sensor,

But i would like to ask you one question, i m having trouble to read proper data, when i put the finger on the sensor you can see that the graph is not showing the correct results,

Maybe is there interference from the wires that connect Arduino and the MAX30100 sensor, did you had any issue like this in your experience ?

Ah yes and another think the sensor is quiet hot when i put the finger on it, should i limit the current? I use your code from above.

Thank you

http://imgur.com/a/VBnvk

Reply

Raivis Strogonovs 2 years ago

I'm not sure if I updated the code in the article. But there was one glitch regarding pulse width and LED current. And the waveform more or less looked like the one you have screenshotted.

It has been fixed on the github: https://github.com/xcoder123/MAX30100

Try it, and let's if that fixes it

Reply

KORI 2 years ago

Hello,

Thank you for the fast feedback i uplouded the code, but i have some problems

So in the link bellow i have two pictures, the upper is when i have my finger on it and the second is when the sensor dont have anythink on it.

http://imgur.com/a/a4Yud

So i can see that the RED LED is making the measurment and showing a small beat (but is not clear), but the IR LED is not measuring anythink.

So when there is nothing on the sensor there are some wierd measurment of the scale so (its not 0 like should be).

So i think that the problem is in the sensor board that is maybe damaged or because of the wire is making this strange signal, what do you thik ?

The board that i use is

https://www.aliexpress.com/item/Heart-Rate-Click-MAX30100-modules-Sensor-for-Arduino/32709038996.html?spm=a2g0s.9042311.0.0.ZdF708

Thank you again for your support

Reply

---

nathalia 9 months ago

Hello

I have the same problem as you. My IR signal is not working , it is saturated. I'm using the same board (green) and I don't know how to fix that, please help me :). How do you fix that?

Thank you.

Reply

---

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Thank you.

Reply

Chou Koksal 2 years ago

Hi, You work is kind of great for new learner. In my project I am thinking of using device to measure heart rate of mouse animal which is around 1000bpm (5 times higher than human). I want to know whether this device can measure that extream bpm. For SP02 maybe I won't use it. You can reply by my email choukoksol@gmail.com. Thank you in advance :-)

Reply

Orlando Hoilett 2 years ago

Hi there,

I too have found that the MAX3010x chips have taken a bit of work to use correclty. I haven't been able to consistently obtain pulse on my wrist. I was wondering if you ended up using it for your smartwatch project?

Thanks for the tutorial.

Reply

Raivis Strogonovs 2 years ago

Hola,

Unfortunately, I don't think you can have accurate measurements on your wrist. I was thinking about it other day, maybe with much better peak detection, or even FFT it might be possible to **estimate BPM.** Problem is, that the skin around wrist is just too thick.

I believe even commercial sport watches suffer from the same problem, I tested on Garmin, it had an error of up to 10% on a wrist, and basically no error when measuring with finger.

Reply

Orlando Hoilett 2 years ago

Hi,

Thanks for the reply. It looks like we had similar issues with this device. I honeslty couldn't even discern peaks in the raw signal 99% of the time. I tried the MAX30101, which has a green light, because Maxim said green light should be better for thick tissue. To no avail, unfortunately. Just wondering if you had a different experience and could point me in the right direction, but it looks like we're at the same spot.

Again, thanks for the tutorial.

Reply

---

spairo 2 years ago

add flexiPlot to max32105, library from Spark Fun Electronics.

Reply

ThePuiu 2 years ago

Hi,

Can a pulse monitoring bracelet be made with this sensor? You can only use your fingers?

Reply

Jeff 2 years ago

HI :) thanks for your code.

But I had a some problem that uploaded on Arduino uno.

how can I fixed this problem?

===

max30100:25: error: 'pulseoxymeter_t' was not declared in this scope

pulseoxymeter_t result = pulseOxymeter->update();

Reply

Sameer Desai 3 years ago

Please help me out. I am getting the following readings. All BPM and Sa02 are zero readigs.. I am interfacing the MAX30100 using my Arduino Yun. Thanks in advance.

BEAT
BPM: 0.00 | SaO2: 0.00%
{P2|BPM|255,40,0|0.00|SaO2|0,0,255|0.00}
{P0|IR|0,0,255|4230.00|RED|255,0,0|266.00}
{P1|RED|255,0,255|-3083.09|BEAT|0,0,255|0}

Reply

Raivis Strogonovs 3 years ago

Hola,

It would be helpful to visualize the data you are receiving from to MAX30100.

If you can install FlexiPlot: https://github.com/xcoder123/FlexiPlot/releases

And add 3 line charts to the dashboard and connect it to your microcontroller, it should start plotting the data

Reply

Sameer Desai 3 years ago

I know this must be a silly query . I am using my Arduino Yun and I did plot 3 line graphs like you said but I don't know how to go about further. Besides a while ago I g
91.03% reading on Sa02 while for BPM it was ovf. After that 1 occurrence it is back to all zeroes.

Reply

Inn 3 years ago

Hey again Raivis, do you know how I can append a sound, when the heart beat come?

Reply

Inn 3 years ago

Hey again Raivis, do you know how I can append a sound, when the heart beat come?

Reply

Inn 3 years ago

It's perfect now, thank you Raivis! I was wondering about a sound signalization on the BEATS, is there any easy way to make it happen? Regards!

Reply

Raivis Strogonovs 3 years ago

In a normal micro-controller environment, I'd probably throw an interrupt.

But in arduino, I'd go for simple timestamp method:
The library already does everything for you regarding pulse detecion

Just add a beeper to one of your pins, or LED. Then in the if statement regarding "beat detected", save a timestamp and enable the beeper, then add another if statement before to check if enough time has passed between the detection and when beeper was enabled.

Let's say on every beat we want 20ms pulse, the loop would look something similar to this:

```
if( millis() >= beatDetectedTimeStamp + 20 )
{
    digitalWrite(YOUR_BEEPER_PIN, LOW);
}

if( result.pulseDetected == true )
{
    beatDetectedTimeStamp = millis();
    digitalWrite(YOUR_BEEPER_PIN, HIGH);
...
...
```

Reply

---

inn 3 years ago

Hello, could you explain how you vizualizate the data? How we can use that "FlexiPlot"?

Reply

[Raivis Strogonovs](#) 3 years ago

Hola Inn,

Here is an actual packet you have to send through serial: "{P0|Roll|255,0,0|25|Pitch|0,255,0|56}"

This packet will send two data points to a ploter window with ID "P0".
One data point will be labeled "Roll" with color "255,0,0" which is Red and the value 25.
The other data point will be labeled "Pitch" with color "0,255,0" which will be green and value 56

Note: packet must be finisdhed with new line. In arduino print the final "}" with Serial.println("}"); or if you are using pure C, must be done similar to this "printf("}\n");"

Here is an example function for arduino, which will generate the correct packet:

```
void printForFlexiPlot( const char* plotID, const char* curveName, const char* color, double value )
{
  Serial.print("{");
  Serial.print(plotID);
  Serial.print("|");
  Serial.print(curveName);
  Serial.print("|");
  Serial.print(color);
  Serial.print("|");
  Serial.print(value);
  Serial.println("}");
}
```

You can send a single data point like this:

```
printForFlexiPlot("P0", "MQ2 Sensors", "255,0,0", (double) 45);
```

Also I've published some small instruction on github:

Sample data sent from uC to FlexiPlot
Basically, it will send a real time update of two separate data points to flexi for plotting on the same plane with ID "P0"

{P0|Roll|255,0,0|25|Pitch|0,255,0|56}

Note a packet consists of
-ID of plot
-Name of real time value (Roll)
-Color in RGB format (Red)
-Value (25)

-Name of real time value
-Color in RGB format
-Value

And you can repeat this pattern as much as you like.

It also supports XY plane plotting. For more details in settings tab hover over properties and you will see examples of packets.

[Reply](#)

[Inn](#) 3 years ago

Thank you for the fast replay, Raivis! But i still don't get the concpet of the real time data vsualization that you used in your case."FlexiPlot" is something like processing sketch or...? Is it downloadable? I was also wondering why when I place my finger on the sensor the intesity of the light doesn't change regarding to BalnceIntensity function?

[Reply](#)

Raivis Strogonovs 3 years ago

It is not a sketch, it is a standalone application built with Qt and qwt
You can download it here
https://github.com/xcoder123/FlexiPlot/releases

Real time plotting is done automatically by flexiplot. You setup a plotting widget with real time line chart (default), once it recevies a data point from arduino, it will automatically assign time stamp to it, and append it to the end of line chart. In widget settings you can setup how many data point you want to save (default is 500), and when it reaches the maximum amount of data points it will just start "rotating" the real time graph to the left.

Also RED and IR balancing is done on default settings about every 500ms, when you call the update method to the object.
If it would require to change the balance when you place the finger it would, but what I've noticed when working on the sensor, that the balance it reaches without any finger placed is already good. In some rare cases I can see adjustments done by the algorithm

Reply

Inn 3 years ago

Thank you Raivis! I have just one more question... How can I get the RED LED LP+MEAN filtered as yours? Maybe missing something in the source code... my signal is reversed. It would be nice if you give me an example. Regards!

Reply

Inn 3 years ago

http://imgur.com/ATJEhem here's my result

Raivis Strogonovs 3 years ago

Hola,

Great that you got the FlexiPlot up and running. From the terminal it looks like you are using my code.

In that case add two more line widgets to the dashboard. You are at the moment only visualizing the currents between IR and RED. I think mean filtered (which will also reverse the graph) is sent to line graph with id "P1"

Anyway Just make sure you have graphs with ids "P0", "P1" and "P2"

Inn 3 years ago

http://imgur.com/kCA46oX Finally I get it! But isn't there too much noise? How you think, your signal was much cleaner

---

Inn 3 years ago

http://imgur.com/kCA46oX

Raivis Strogonovs 3 years ago

Hola,

Interesting indeed. I uploaded the code to my board as well, and got exactly your noisy results. Lucky for me I had my old test code, which I used to generate the images you see in the article.

I compared the registers and the code, and when I converted spaghetti code into a class, I made a typo. I forgot to add these two lines in the class constructor:

```
setSamplingRate( samplingRate );
setLEDPulseWidth( pulseWidth );
```

In anyway, I updated the code, added some more error checking and fixed the typo. You can either download the code here from my website, github or copy it fro m the article

Hopefully it should work now for you as well.

Inn 3 years ago

It's perfect now, but do you know how I can append a sound, when the heart beat come?

Inn 3 years ago

It's perfect now, but do you know how I can append a sound, when the heart beat come?

Reply

---

najwa 3 years ago

can you help me in this code ?

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Required fields are marked *.
Your email will not be published or shared anywhere. It is **only** used to notify of any replies

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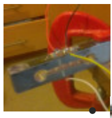
Email Email
Website
Website
Comments

Submit Comment

MOST POPULAR

-  **Strain Gauge based weight sensor (load cell)**
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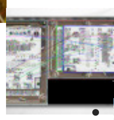
-  **Complete guide using SURF feature detector**
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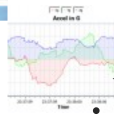
-  **MEMS (Part 1) - Guide to using accelerometer ADXL345**
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  Your style is so interesting contrasted with different people I've perused stuff from. Much obliged to you for posting when you have the chance, Guess I will just bookmark this page.

TAGS

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