Project Report

Faculty of Engineering

Hochschule Wismar

July 9, 2020

Project with NXP FRDM-K66F Microcontroller and Development of an Analog Board of Pulse Oximeter

Submitted by:

Sachinkumar Pravinbhai Prajapati

Maharshi Patel

Indrajitsinh Solanki

Department of Electrical Engineering and Computer Science

Guided by Prof. Dr.-Ing. Jens Kraitl

Dr. Ulrich Timm

Abstract

- The pulse oximeter, a widely used noninvasive monitor of arterial oxygen saturation, has numerous applications in anesthesiology and critical care. Although pulse oximetry is considered sufficiently accurate for many clinical purposes, there are significant limitations on the accuracy and availability of pulse oximetry data.

- In this project, our aim is to design the Analog Sensor Board with H bridge in Eagle software and connect with the microcontroller. Also, we use the NXP K66F microcontroller to test various programs and learn its use and how it works.

• Introduction

- A pulse oximeter is a medical device that indirectly monitors the oxygen saturation of a patient's blood (as opposed to measuring oxygen saturation directly through a blood sample) and changes in blood volume in the skin, producing a photoplethysmogram that may be further processed into other measurements. The pulse oximeter may be incorporated into a multiparameter patient monitor. Most monitors also display the pulse rate. Portable, battery-operated pulse oximeters are also available for transport or home blood-oxygen monitoring.

- Pulse oximeters measure how much of the hemoglobin in blood is carrying oxygen (oxygen saturation). Pulse oximetry gives an idea about tissue perfusion by pulse waveform. Pulse oximeters sensor are designed for fit adult, pediatric, diabetic patients, infant patients. Pulse oximeters are used for quicker treatment for patients who are suffering from hypoxemia.

1) Function of Pulse Oximeter

- A blood-oxygen monitor displays the percentage of blood that is loaded with oxygen. More specifically, it measures what percentage of Hemoglobin, the protein in blood that carries oxygen, is loaded. Acceptable normal ranges for patients without pulmonary pathology are from 95 to 99 percentage. For a patient breathing room air at or near sea level, an estimate of arterial pO2 can be made from the blood-oxygen monitor "saturation of peripheral oxygen" (SpO2) reading. The purpose of pulse oximetry is to check how well your heart is pumping oxygen through your body.

- It may be used to monitor the health of individuals with any type of condition that can affect blood oxygen levels, especially while they're in the hospital. These conditions include:
  - Asthma
  - Pneumonia
  - lung cancer
  - heart attack or heart failure
  - congenital heart defects

- **HOW PULSE OXIMETER WORKS?**

This method is painless process and it will be able to tell us the oxygen saturation levels along with heart rate. This device place it on the fingertip and then a small beam of light pass through the blood which measures the amount of oxygen and transfers its reading to reading meter by wire or wirelessly. This device uses light – emitting diodes in conjunction with a light sensitive sensor to measure the absorption of red and infrared light. The difference between the oxygenated and deoxygenated hemoglobin makes the calculation possible.

The main advantages of this is it can rapidly detect the minute changes in how efficiently oxygen is being carried to the extremities from the heart, which include the legs and arms. The pulse oximeter is small device that attaches to the body part like toe or an earlobe but now it is commonly put on fingertip and often used in critical care rooms like hospitals.

2) Pulse Oximeter Sensors

- Pulse oximetry measures blood oxygen saturation (SpO2) non-invasively with an infrared sensor on the fingertip.
- The BluPRO technology in SpO2 sensors gives high accuracy even during movements.

Figure 1: SpO_2 sensor

- A pulse oximeter noninvasively measures the oxygen saturation of a patient's blood. This device consists of a red and an infrared light source, photo detectors, and a probe to transmit light through a translucent, pulsating arterial bed, typically a fingertip or earlobe.
- Oxygen saturation (SaO2) is a measurement of the percentage of how much hemoglobin is saturated with oxygen. Oxygen is transported in the blood in two ways: oxygen dissolved in blood plasma (pO2) and oxygen bound to hemoglobin (SaO2). About 97% of oxygen is bound to hemoglobin while 3% is dissolved in plasma. SaO2 and pO2 have direct relationships, if one is decreased so is the other. The relationship between oxygen saturation (SaO2) and partial pressure O2 (PaO2) is referred to as the oxyhemoglobin (HbO2) dissociation curve. SaO2 of about 90% is associated with PaO2 of about 60 mmHg.

3) NXP-FRDM K66 microcontroller

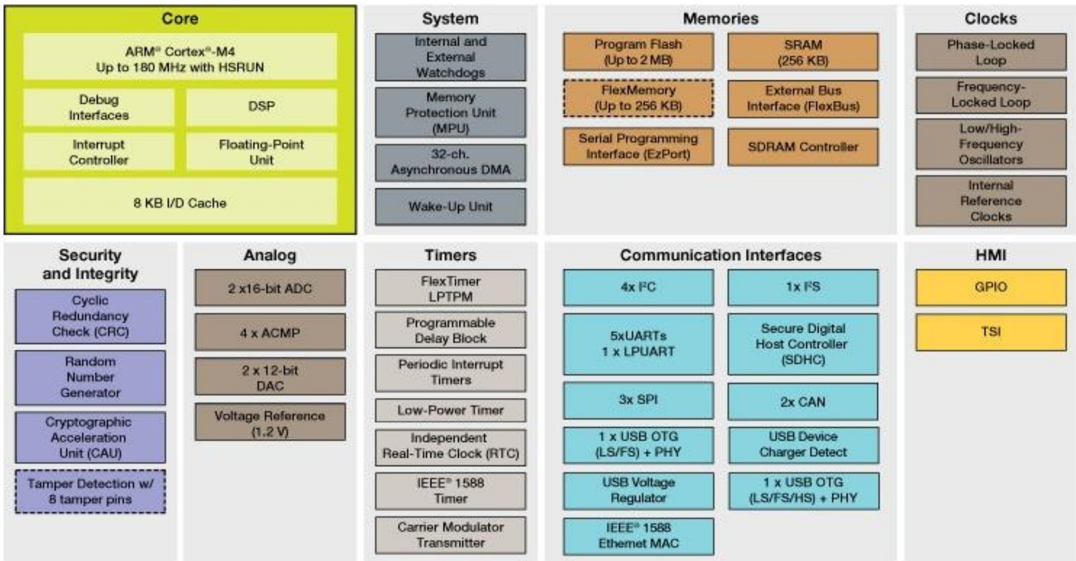

Figure 2: Block diagram

- **Components and Pin layout:**

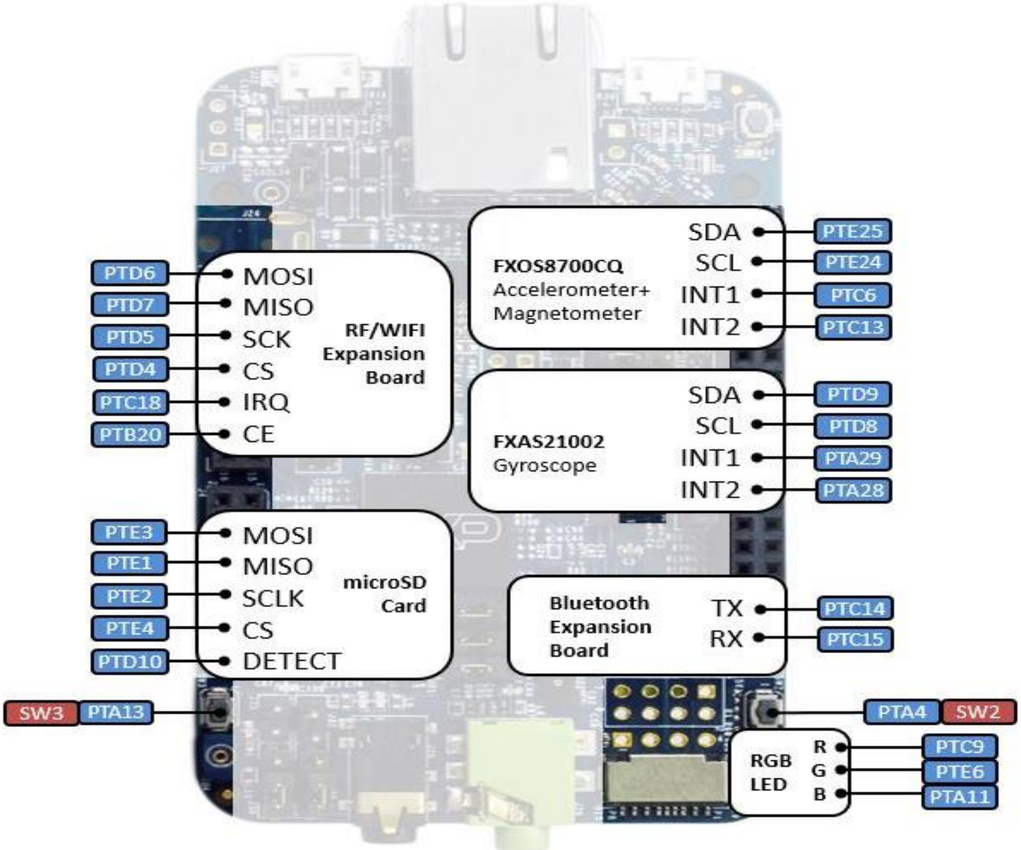

Figure 3: FRDM-K66F/K66

NXP-FRDM K66 Microcontroller:

- The NXP Freedom development platform is a set of software and hardware tools for evaluation and development. It is ideal for rapid prototyping of microcontroller-based applications. The NXP Freedom K66F hardware, FRDM-K66F, is a simple, yet sophisticated design featuring a Kinetics K series microcontroller, built on the ARM c Cortex R -M4 core.
- FRDM-K66F can be used to evaluate the K66 and K26 Kinetics K series devices. It features a maximum operation frequency of 180MHz, 2MB of flash, 256KB RAM, a high-speed USB controller, Ethernet controller, Secure Digital Host controller, and loads of analog and digital peripherals.

4) Programming Part (Mbed Software)

I. Basics in Embedded Programing µC with Mbed

- Sample Program 1: Dual input blinking LED

- Here, we included all the header files required for the Mbed platform and defined the dual input blinking LED. In this program we use bool button for Boolean value (0 and 1), when input is 0 and 1 then LED is OFF and ON respectively.

```cpp
#include "mbed.h"

DigitalOut myled(LED1);
DigitalIn input(p17);
// p17 is pin17 where the pulse generator is connected //

int states;
bool button;

    int main(){
        while (button ==1){

            switch(states){
                case 0:
                    input == 1;
                    myled = 1;
                    break;
                case 1:
                    input == 0;
                    myled = 0;
                    break;
                        }
                    }
                }
```

- **<u>Sample Program 2</u>: Create a system which count the number of times a digital switch is pressed or changed and lights an LED with 10 instances have been counted.**

```
Untitled11.txt x   .mbed x   main.cpp x

#include "mbed.h"
DigitalOut rled(p5);
DigitalOut gled(p6);
DigitalIn switch_input(p7);

int main () {

            int count = 0;
    rled = 0;
    gled = 0;

    while(count < 10) {
        if(switch_input == 1){
            int check_value = switch_input;

            while(check_value){
                if(check_value - switch_input == 1){
                count++;
                check_value = 0;
                }
            }
        }
    }

    rled = 1;
        gled = 1;

}

```

5) Schematic and PCB layout SpO2-front end

I. Schematic diagram of the analog front end:

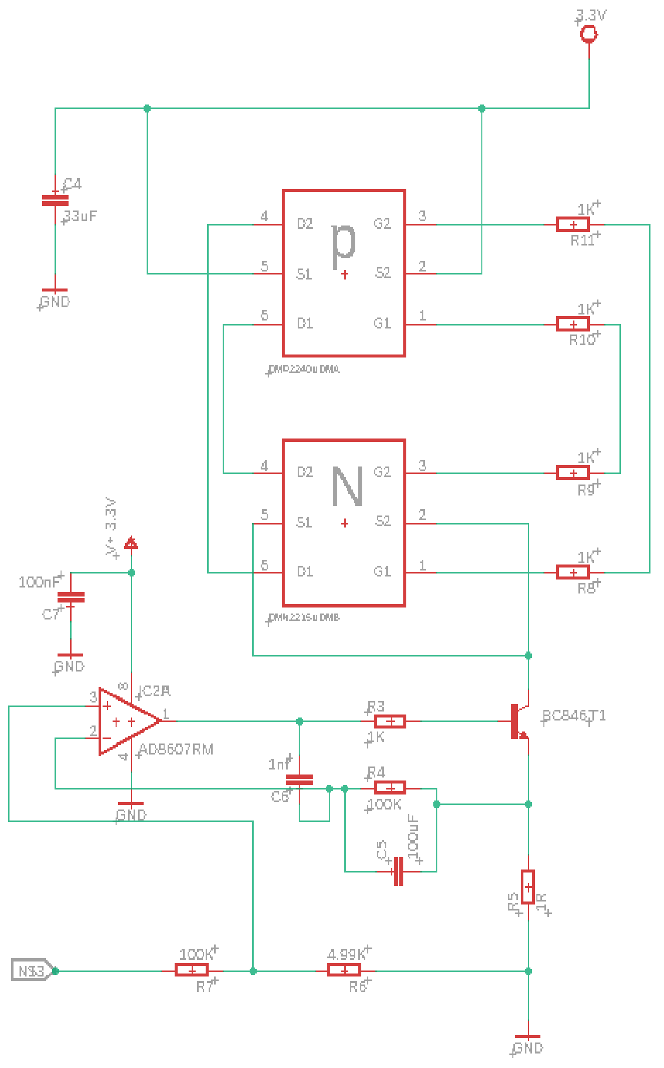

Figure 4: Schematic diagram of Analog Front End

- **Description of Schematic Diagram of Analog Front End:**

➢ The overall circuit diagram consists of two parts

(a) LED Driver
(b) Transimpedance Amplifier

(a) LED Driver Circuit

- The LED Driver Circuit consists of two parts:

(1) H-Bridge

(2) Current Source

(1) H-Bridge:

- It is a technique used to drive two LEDs using two wire power supply, that are antiparallel.

- The structure of H-Bridge consists of two P-MOSFETs and N-MOSFETs in which P-MOSFETs are in the upper part whereas N-MOSFETs are in lower parts. These two MOSFETs are driven by two pins, they are RED_D and IR_D. Each of these pins are connected to a pair of P and N-MOSFETs. Both pins are given power alternatively, that is RED_D is high then IR_D is low and vice versa.

- In the first case, when, pin RED_D is high it drives MOSFETs T4 and T3 which are the pairs of P and N-MOSFETs. This pair allows the current to flow through them and blocking MOSFETs T2 and T5 respectively and vice versa in 2nd case forming H-Bridge to flow the current that drives the LEDs using two wires.

(2) Current Source:

- The output of DAC (Digital to Analog Converter) of the microcontroller is given to the voltage divider circuit then the voltage divider output is feed to the Op-Amp to operate. There is a pair of resister and capacitor in the feedback to stabilize.

- The current source is a circuit of current sink. The output of the following is very high but the duration is very short so it does not damage the LED and we can say that just get an impulse.

(b) <u>Transimpedance Amplifier</u>

- Photon of light is incident in a photo diode, we get linear photo current. That is. Given in the reverse direction to the non-inverting input of the amplifier to stabilize the output. We use resister and capacitors pairs. The overall output of the amplifier is the product of the Current and Resistance. Overall, we can say that the transimpedance amplifier circuit as a current to voltage convertor in this case, as a small current is converted into voltage.

II. Board layout and Description:

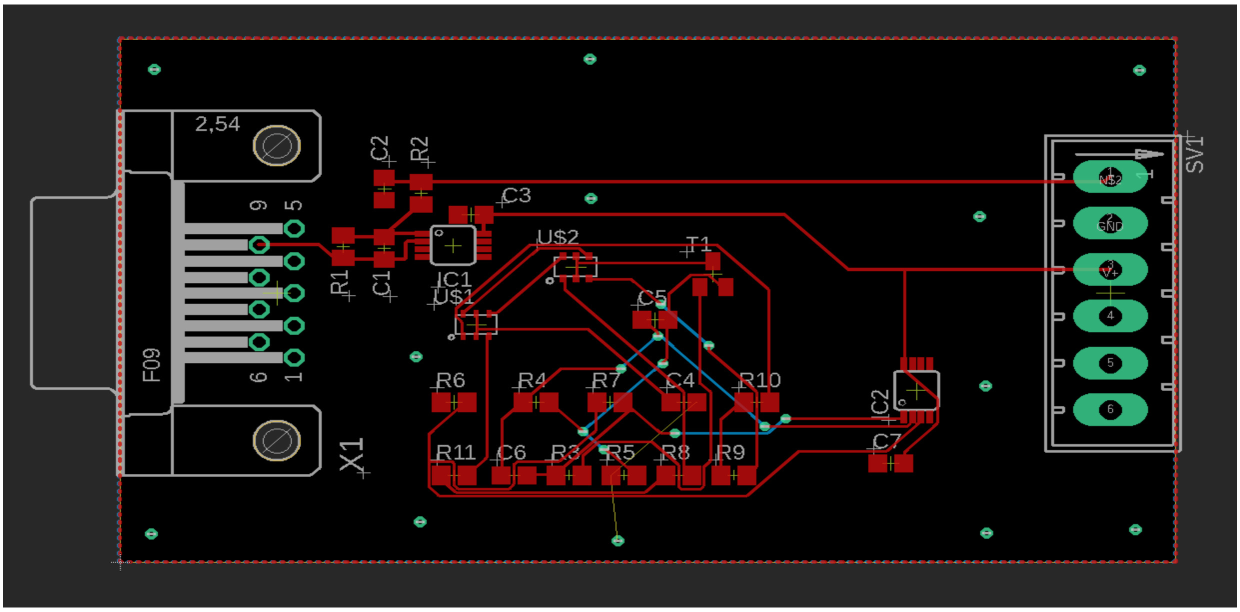

Figure 5: PCB board diagram

Description:

- After completion of schematic, we designed a board layout in which placed all the components of the schematic on the board layout and connected each of these components in the two layered connections that is layer 1 RED and layer 2 GREEN and also did the grounding for the board and then checked if there were any errors in the connections. Here, we work with precision and specific clearance in order to achieve the board layout.

6) Summary

- Overall, we have successfully designed the Analog sensor circuit of pulse oximeter and able to test some programs in the NXP K66 microcontroller.

7) Future Aspects

- Much work that focuses on obtaining accurate pulse-oximetry readings in low perfusion states and during movement is now in progress, as are efforts to miniaturize pulse oximeters and adapt them for wireless data transmission. To that end, one of the strongest and most innovative technologies supporting pulse-oximetry accuracy is signal extraction.

8) References

Website: https://en.wikipedia.org/wiki/Pulse_oximetry
Website: https://eu.nihonkohden.com/
Website: https://www.healthline.com/
Website: https://en.wikipedia.org/
Website: https://www.24x7mag.com/medical-equipment/
Website: https://os.mbed.com/