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Design of Electronic Data Acquisiton Unit for Laser Tomography System

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Abstract: In this work design of electronic data cquisition unit for Laser Tomography (LT) system has been presented. Electronic hardware, embedded software, PC interface program have been developed for this purpose. 850 nm 20 mW laser source has been used to test the device validity. General purpose photodiode collected back reflected diffuse optic laser light. Six different integration times have been used for data acquistion test. 10 microseconds to 300 microseconds integration times were specific test criteria. 10 microseconds integration time resolution has been achieved. Pic18f2550 microcontroller (Microchip, Boise, ID) has been used to control the device main board and for data transfer process. DDC112 is analog to digital converter (ADC) chip product of Burr-Brown™ and Texas Instruments™. DDC112 integrated circuit (IC) has analog current input and digital voltage output. It has embedded integrator used for data conversion for analog current to voltage. The device has been tested on left arm by laser source and general purpose pn photodiode. General purpose laser scanner device has been demounted. The photodiode which is inside the laser scanner has been wired to one of the two DDC112 IC input channels. 650 nm narrow band pass filter has been changed by 850 nm narrow band pass filter. 850 nm wavelength back reflected laser light has been collected over 850 nm band pass filter through forward biased optic photodiode.

Keywords: Laser tomography (LT), electronic hardware, embedded software, PC interface program.

Lazer Tomografi Sistemi için Elektronik Veri Toplama Ünitesi Tasarımı

Özet: Bu çalışmada Lazer Tomografi (LT) sistemi için elektronik veri toplama ünitesinin tasarımı sunulmuştur. Bu amaçla elektronik donanım, gömülü yazılımlar ve bilgisayar arayüzü programı geliştirildi. Cihazı test etmek için 850 nm 20 mW lazer kaynağı kullanılmıştır. Genel amaçlı fotodiyot geri yansıyan optik difüz lazer ışığını toplamaktadır. Veri toplama testi için 10 - 300 mikrosaniye arasında altı farklı spesifik entegrasyon süresi kullanılmıştır. Pic18f2550 mikro denetleyici (Microchip, Boise, ID) cihaz ana kartı kontrol etmek ve veri aktarım işlemi için kullanılmıştır. DDC112 entegre devre, analog akım girişi ve dijital gerilim çıkışı içerir. DDC112, Burr-BrownTM ve Texas InstrumentsTM firmalarının analogdan dijitale çevirici (ADC) çip ürünündür. Tasarlanan cihaz sol kol üzerinde lazer kaynağı ve genel amaçlı pn fotodiyot kullaınlarak test edilmiştir. Bu amaçla lazer tarayıcı içerisindeki değişiklikler yapıldı. İki DDC112 entegre tarayıcıdaki fotodiyota bağlandı ve ve 650 nm dar bant geçiren filtre 850 nm filtre ile değiştirildi. 850 nm dalga boyunda geri yansıyan lazer ışığı, bu filtre ve fotodiyot vasıtasıyla toplandı.

Anahtar kelimeler: Lazer tomografi (LT), elektronik donanım, gömülü yazılım, PC arayüzü programı.

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1. Introduction

Laser Tomography (LT) systems are emerging medical imaging technique. Laser is penetrating inside the heterogenuous tissue media. It scatters from cellular structures such as lipid membrane, nucleus and organelles. Blood dependent absorption spectrum is used for diffuse optical imaging (DOI) devices. Each chromophere has its own absorption spectrum wavelength band. Most absorbed laser wavelength scale by oxy-hemoglobin (HbO_2) and deoxy-hemoglobin (Hb) is the 800-850 nm. By using infrared blood dependent laser light source bloody voxels can be recovered by mathematical image reconstruction algorithms. Thus, the light intensity decreases on the back reflected collection surface. Back reflection, transmission through or mix of these geometries could be used while acquiring the mesaurement data. It is necessary to get into clinical cases for practical purposes. In this work portable, easy transport device gives beneficiary to the users. In this work portable device has been designed and implemented for general purpose use of biomedical DOI cases. Schematic and layout level of design has been accomplished. Electronic printed circuit board (PCB) has been fabricated, materials have been mounted on it. Embedded electronics software and PC interface programs have been written. Different integration times have been used for test purpose. Data have been acquired for six different integration times from 10 microseconds through 300 microseconds for specific experimental measurement. From source to detector distance has been selected 3 cm. For longer distances integration times could be bigger. Photodiode has been wired to input of DDC112 IC (Burr-Brown products of Texas Instruments, Texas, US) chip. Photodiode is generating analog current depend on the collected photon numbers. DDC112 is converting this analog current to analog voltage first. Then analog voltages are converted to digital voltages inside the chip by delta/sigma analog to digital converter (ADC). These are the steps of integration and conversion processes, respectively. Digital data have been transferred from DDC112 IC to pic18f2550 microcontroller (Microchip, Boise, US) via one wire by 20 bit resolution. Then digital data have been transferred through PC via USB serial communication wire. Photon accumulations are converted to electrical current by silicon (Si) pn junction photodiodes. Transferred photons build electrical current. To be able to evaluate this photocurrent, electrical current has to be converted to analog voltage. DDC112 is analog to digital converter (ADC) which has electrical current input and digital voltage output with integrator in it. With the more qualified and more input abilities DDC232 chip has been used in literature [1-7]. These works have shown that DDC integrator family can be used for biomedical optic imaging diffuse optic tomography (DOT) purposes.

2. Material and Method

2.1 Electronic PCB board of data acquisiton unit

Electronic design has been done base on the DDC112 analog current input digital voltage output analog to digital converter (ADC) chip [8]. Analog circuit requirement blocks have been implemented. In Fig 1 board level realization and box mounting can be seen. In Fig 2 and Fig 3 DDC112 IC, and Pic18f2550 microcontroller connection ports can be seen respectively. All the required connections have been done according to the data sheet manuals [8,9]. The DDC112 has two photodiode current inputs. Low light intensity current output pn Si junction devices, such as photodiodes could be forward or reverse bias connected to integrator’s inputs. Light is converted to electrical charges then charge is integrated to analog voltages by two integrators for each channel inputs. Thus, ADC and integration processes are done simultaneously. It has two inputs, the DDC112 does analog current-to-voltage integration, and ADC conversion. Integrator has 3 switched capacitors which has an opportunity to change integrator capacitance values by digitally controlled bits. These bits are Range0, Range1, and Range2 bits which is controlled by Pic18f2550 microcontroller. From 12.5 pF through 87.5 pF capacitance values can be changed according to light intensity. CONV signal is the integration time period duration. Integration times can be adjusted by CONV signal. DDC112 integrator has two running methods which are described in manual datasheet as continuous and non-continuous time periods. In this work non-continuous running method has been selected. Required timing chart has been given in Fig 9. When the data is ready DDC112 integrator is sending a data ready signal which is defined as Dvalid. Dvalid signal port can be seen in Fig 3. Dvalid signaling coming into Pic18f2550 microcontroller. When this signal pulls down from logic high to low level, microcontroller knows that integrator data are ready. This is good data ready communication between microcontroller and DDC112 integrator IC. According to Fig. 9. data acquisiton timing-chart, next step is DXMIT signaling which is coming from microcontroller to integrator. Once the DXMIT signal pulls down to logic low level by microcontroller Dvalid signal pushes up automatically inside the DDC112 integrator IC. Then 2x20 DCLK data clocks are driven to acquire the required two channel 2x20=40 bits digital data. Microcontroller gets the 40 bits digital voltage data. Data acquisiton is done. Example data acquisiton code has been presented. For system clock synchronisation, DCLK, Dxmit, and Conv signals have been synchronized by D-type Flip Flop as shown in Fig 4. The electrical system has two voltage sources one for analog voltage source 5vdc AVDD and the other one is digital voltage power source DVDD.

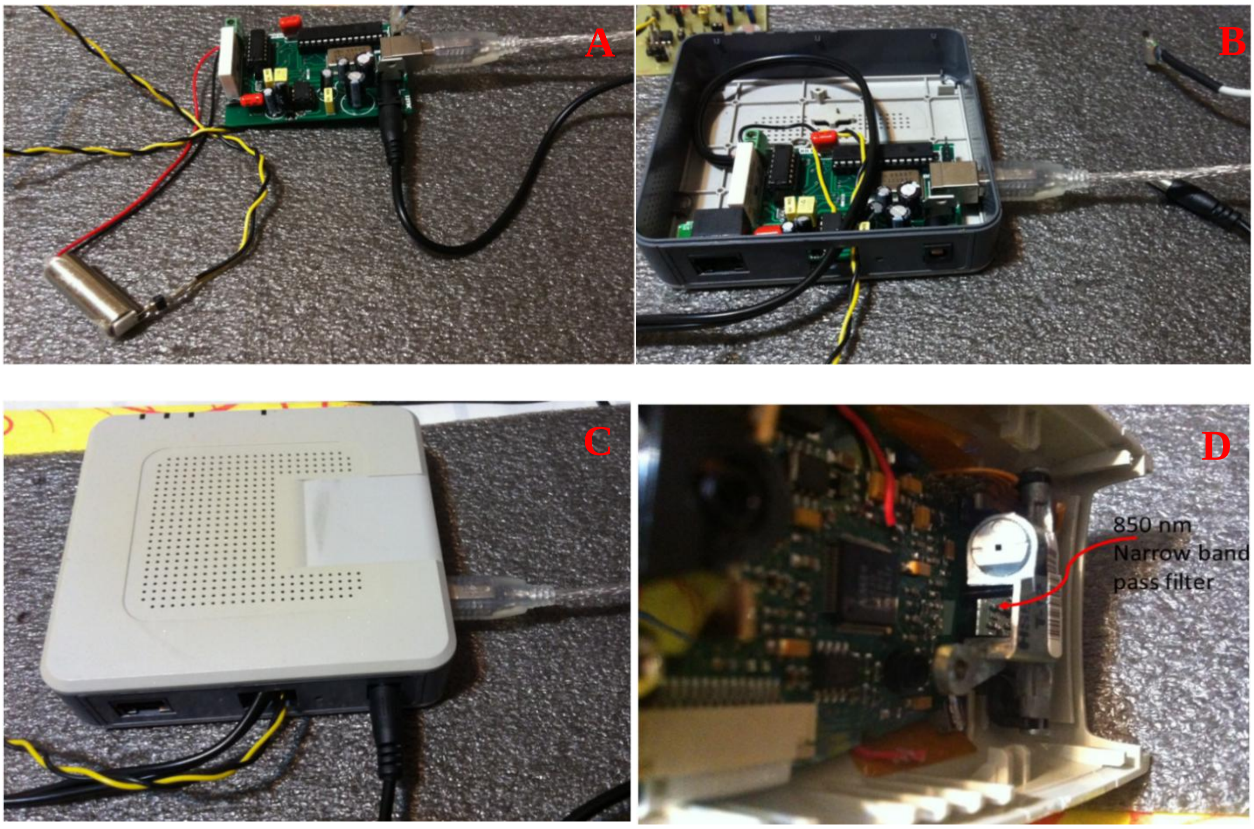

Figure 1. A. Electronic PCB board of data acquisiton unit with laser source and photodiode connected **B.**Electronic PCB board of data acquisiton unit inside the mechanical box **C.**Electronic PCB board of data acquisiton unit closed mechanical box **D.** Laser scanner with mounted 850 nm wavelength narrow band-pass filter

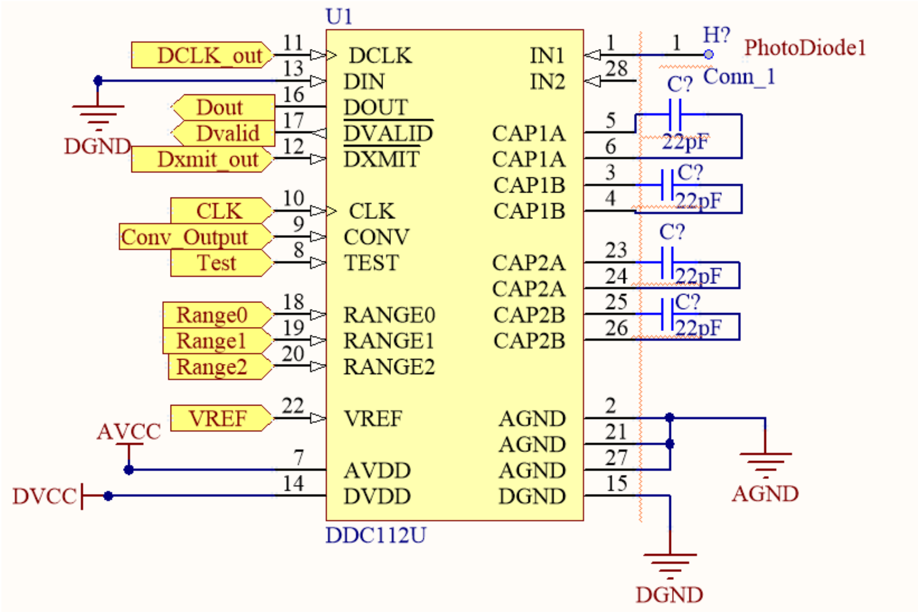

Figure 2. DDC112 IC chip ports.

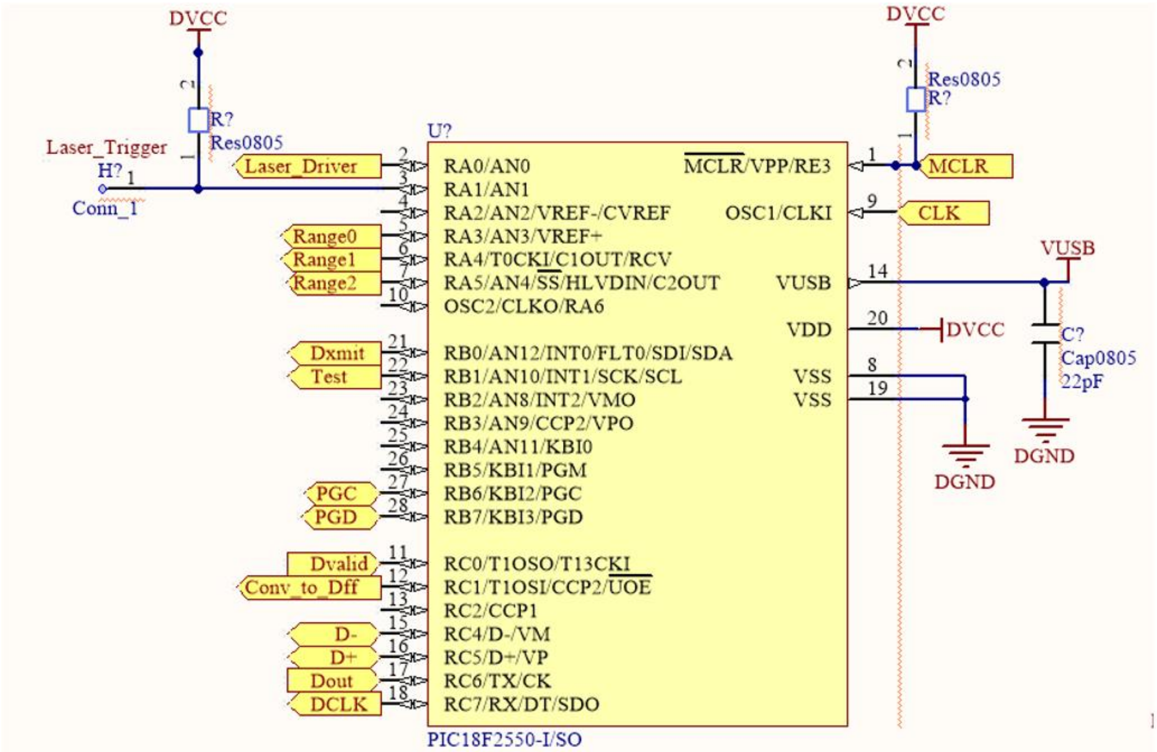

Figure 3. Pic18f2550 connection ports.

Dclk, Dxmit and Conv digital signals have been crossed over D-type flip flop to be able to synchronise all these three digital signals to system CLK signal. Conv signal is responsible for integration periods, Dclk and Dxmit signals are responsible for data transmission from ADC chip to microcontroller, respectively.

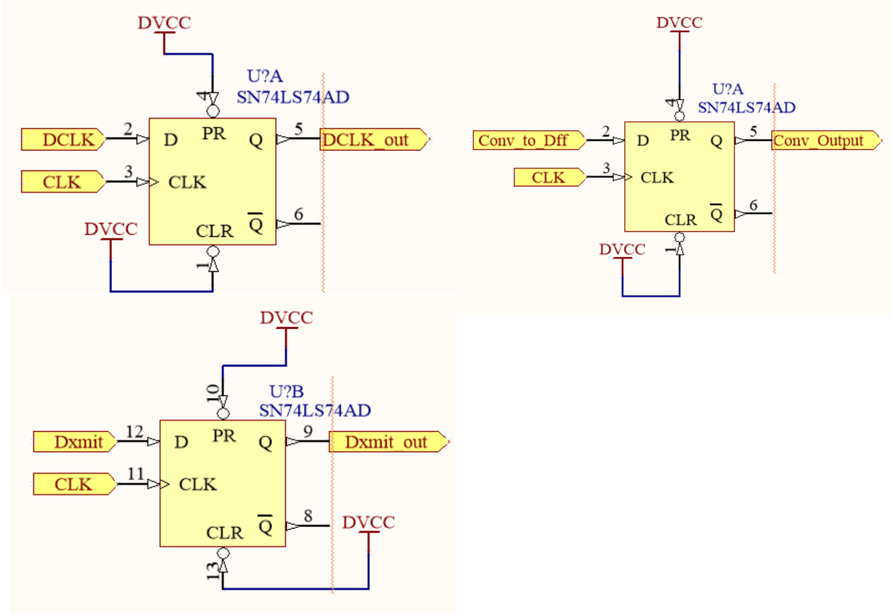

Figure 4. Dclk, Dxmit, and Conv signal resynchronizing.

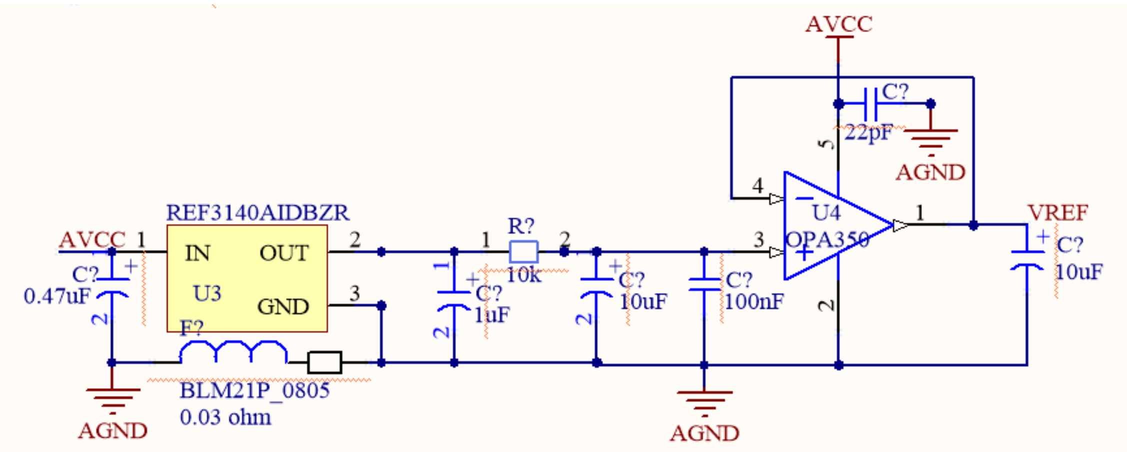

Figure 5. 4.096Vdc reference voltage generation circuit.

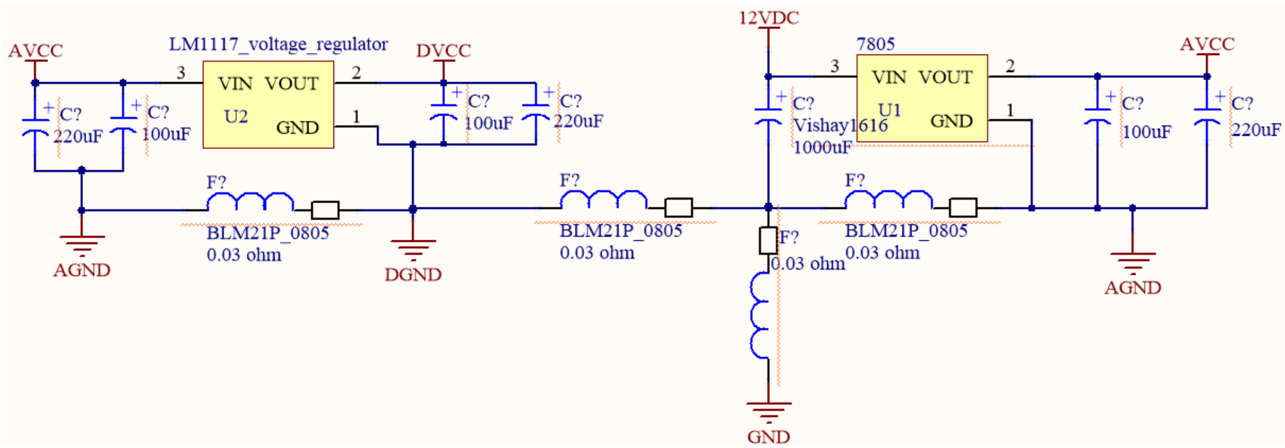

Figure 6. Analog and digital voltage source power line circuit.

In Fig 5 4.096 V DC voltage reference circuit can be seen. In this circuit datasheets have been used [8, 10, 11]. In Fig 6 how power requirements have been supplied could be seen. Between analog and digital voltage source grounds, ground to ground ferrit bead [12] can be seen.

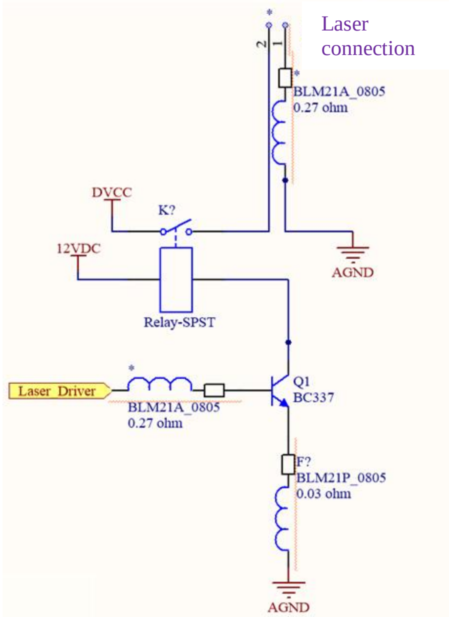

Figure 7. Laser source relay circuit.

In Fig 7 laser source drive relay circuit can be seen.

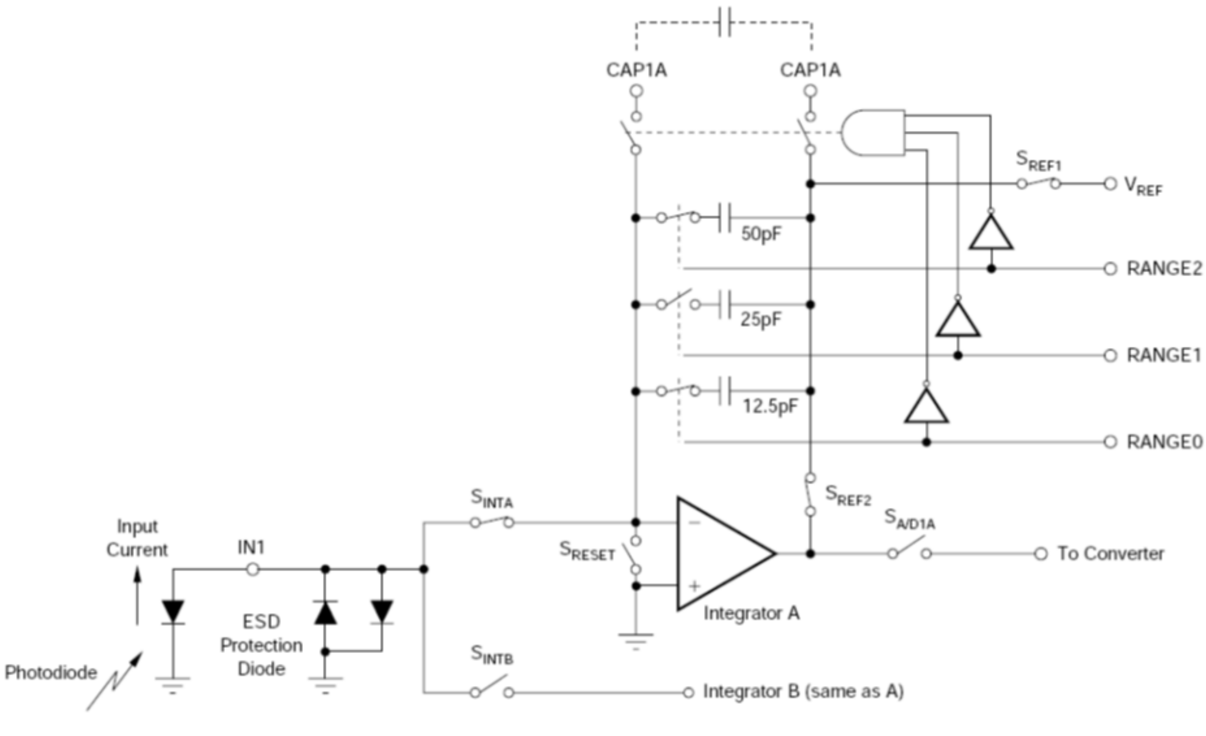

Figure 8. Integration process.

In DDC112 ADC chip, internally made 3 capacitors are resposible for integration processes. It has two integrator stages between externally connected photodiode and delta sigma ADC converter unit. There are integrator, reset, convert, hold switches connected to operational amplifiers. Internally made capacitors can be selected by digitally controlled range inputs which can be seen in Fig 8.

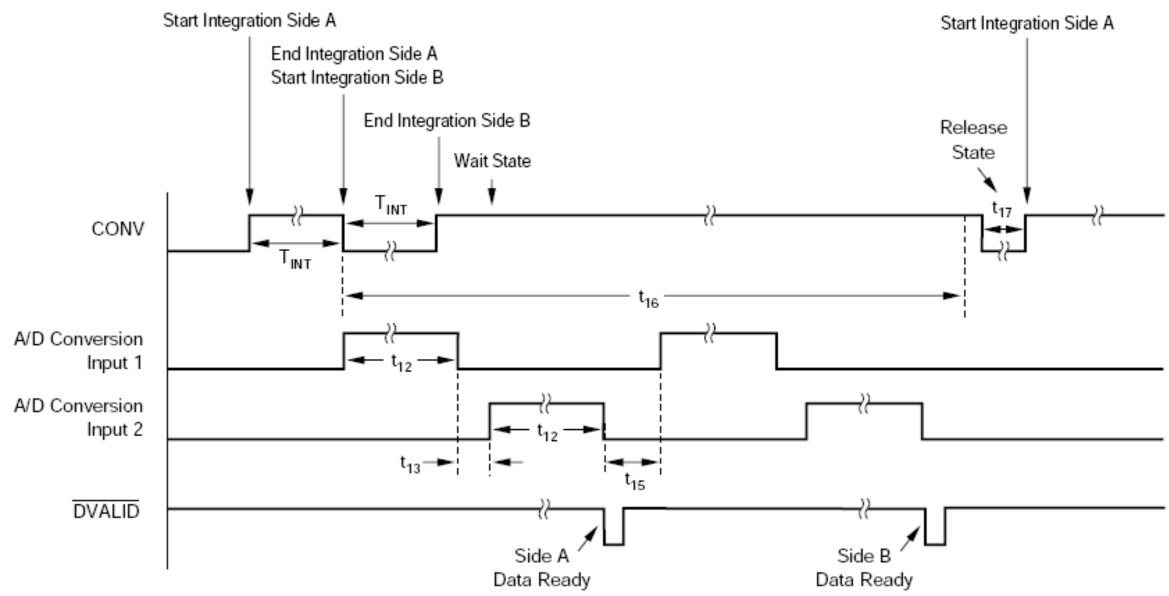

Figure 9. Analog to Digital Conversion timing chart.

Once the CONV signal has one exact logic 1 and logic 0 level, these two time intervals are two discrete integrator stage of integration pulses. In Fig 9 these two signals are seen. AD conversions are completed for both integrator stages, respectively. Once the two photodiode current inputs are converterted to digital data, DVALID signal is pulling down to logic low level and microcontroller is informed that 40 bit two channel data are ready.

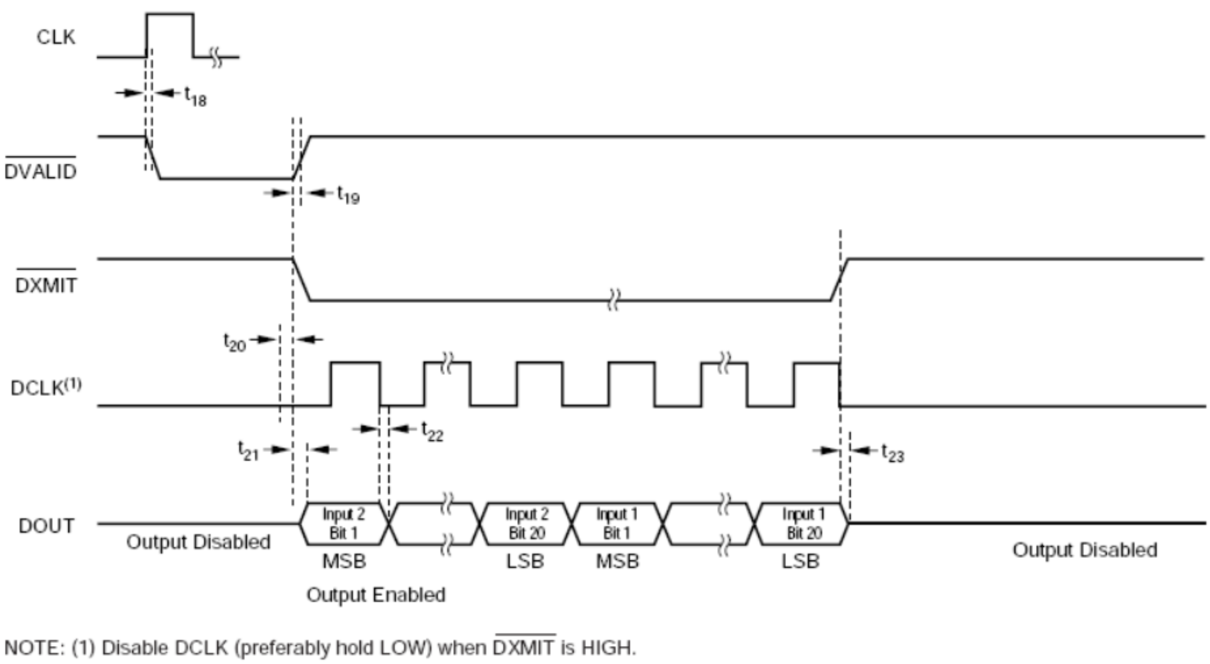

Figure 10. Data acquisition timing chart.

After DVALID data ready signal is acquired by microcontroller, microcontroller sends low level DXMIT logic 0 signal to DDC112 ADC chip. After sending DXMIT signal, 40 CLK signals (2 photodiode inputs, 20 bit for one input channel) are driven to be able to acquire the converted digital data from DDC112 as can be seen in Fig. 10.

```
        output_high(LASER_DRIVER);
        delay_ms(25);
          for(px=0;px<3;px++)
           {
              output_low(CONV);
              output_high(CONV);
              output_low(CONV);
                     delay_us(INT_TIME_final[px]);
                     output_toggle(CONV);
                     delay_us(INT_TIME_final[px]);
                     output_toggle(CONV);
                     delay_us(INT_TIME_final[px]);
                     output_toggle(CONV);
                     delay_us(INT_TIME_final[px]);
                     output_toggle(CONV);
                          while(input(DVALID));
                          while(!input(DVALID));
                             output_low(CONV);
                             output_high(CONV);
                             output_low(CONV);
                                   output_low(DXMIT);
                                   get_data();
                                   output_high(DXMIT);
                                         for(j=0;j<2;j++)
                                           {
                                              BUF_data_H[px][j] = BUF_X_H[j]; //MSB 16 bit
                                              BUF_data_L[px][j] = BUF_X_L[j]; //LSB  4 bit
                                            }
          }
       for(px=0;px<6;px++)
         {
               output_low(CONV);
               output_high(CONV);
               output_low(CONV);
                      delay_us(INT_TIME_final[px]);
                      output_toggle(CONV);
                      delay_us(INT_TIME_final[px]);
                      output_toggle(CONV);
                     delay_us(INT_TIME_final[px]);
                     output_toggle(CONV);
                     delay_us(INT_TIME_final[px]);
                     output_toggle(CONV);
                            while(input(DVALID));
                            while(!input(DVALID));
                                 output_low(CONV);
                                 output_high(CONV);
                                 output_low(CONV);
                                       output_low(DXMIT);
                                       get_data();
                                       output_high(DXMIT);
                                            for(j=0;j<2;j++)
                                            {
                                              BUF_data_H[px][j] = BUF_X_H[j]; //MSB 16 bit
                                              BUF_data_L[px][j] = BUF_X_L[j]; //LSB  4 bit
                                             }
           }
     output_low(LASER_DRIVER);
```

Example code is illustrated above to show how to acquire digital data. For six integration times six for loop cycles have been made. According to ADC timing chart, CONV signals have been applied for integration time realization. Then DVALID signal has been waited for data ready. Then DXMIT signal has been pulled down and by the get_data() function 40 digital bit data have been acquired. In this example, to acquire the clean raw data first 3 loop cycles have been thrown.

3. Results and Discussion

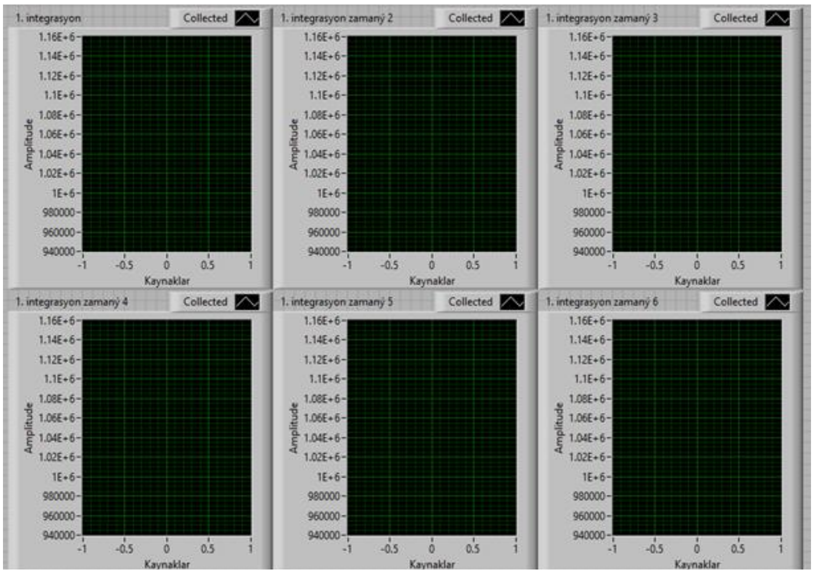

Figure 11. Data acquisition PC interface.

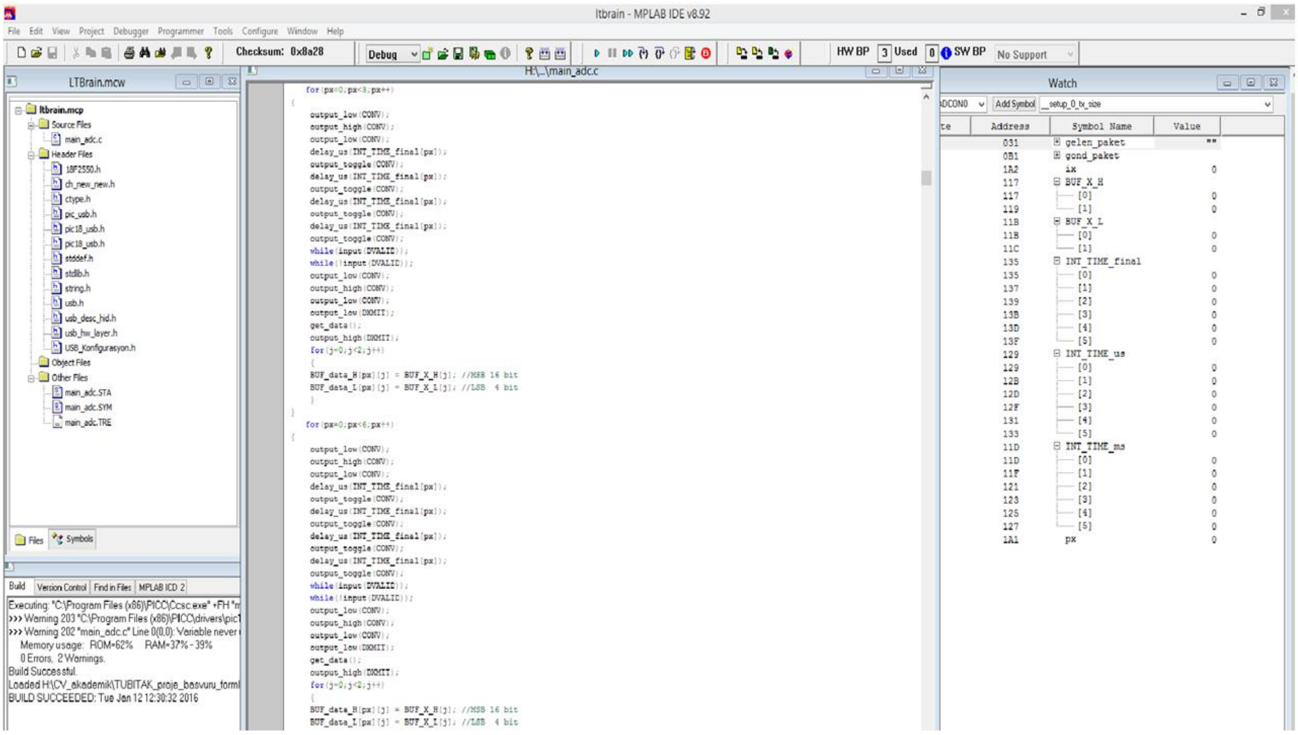

Figure 12. Embedded software debug mode.

In Fig 11 and Fig 12 data acquisition PC software and embedded software printed outputs can be seen. In debug mode, device has been run and data have been acquired.

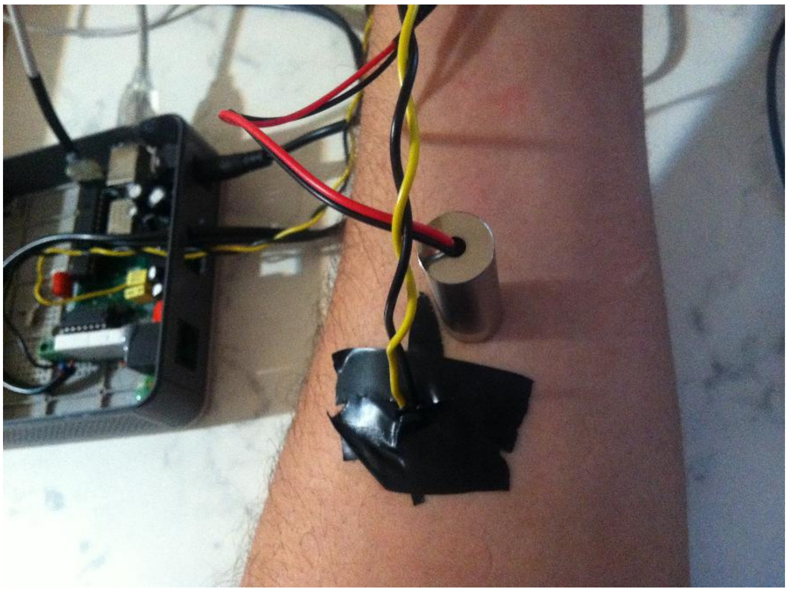

Figure 13. Experimental setup.

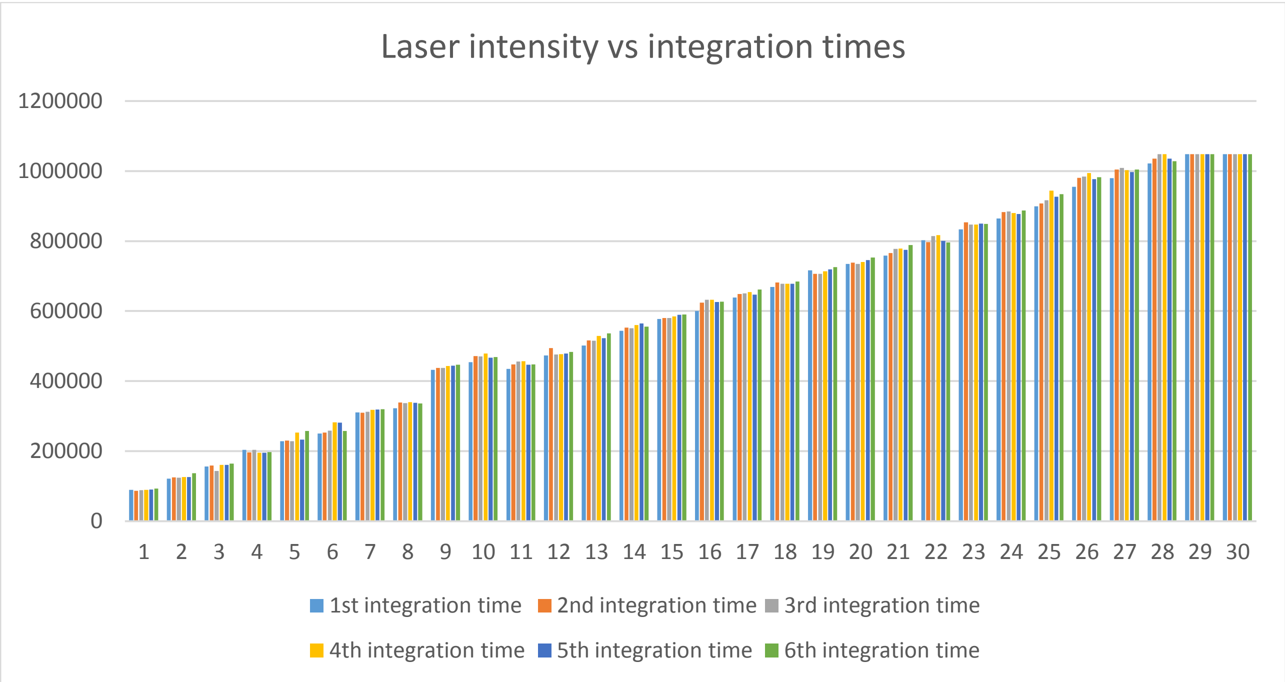

Figure 14. Experimental measurement data.

Experimental setup can be seen in Fig 13. 850 nm laser light has been sent into left arm tissue. Photodiode has acquired the back reflected diffuse light. Each 10 microseconds data have been collected. Data have been acquired six times in equal time period. Until 300 microseconds, data have been collected for total of 30 times and drawn as can be seen in Fig 13, respectively. From 90000 to maximum value of 1048575 data have been measured. First prototype of this device has been made and tested successively.

4. Conclusions

General purpose clinic electronic data acquisition unit for laser tomography system has been implemented and presented. The device data acquisition unit, integration and conversion processes have been done. Experimental data measurement have been realized. Digital data have been collected depend on the integration time periods, correctly. 10 microseconds resolution has been achieved. In the literature another DDC family DDC232 had been used for DOT breast imaging system [1-7]. One of the DDC IC family has been selected for integration and conversion processes again. In the breast imaging example, 49 channel inputs had been needed. One DDC232 IC has 32 photodiode channel inputs. Two of them had been used for 49 channel inputs. Data acquisition is the first step for diffuse optical imaging system design. For better reconstructed images, good acquired data are needed. Thus, one single chip has the effective abilities such as acquiring photon currents, integration and conversion, the single DDC112 IC chip has been used. Most of the traditional old works have more electronic PCB boards and big mechanic cases to accomplish this job. In this work only single chip has been used for digital data acquisition.

Acknowledgements

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