Prince Mohammad University
Department of Electrical Engineering

Bioelectrical Impedance Analyzer (BIA)

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Project Advisor: Dr. Sadiq Alhuwaidi

April 16th, 2019

Outline

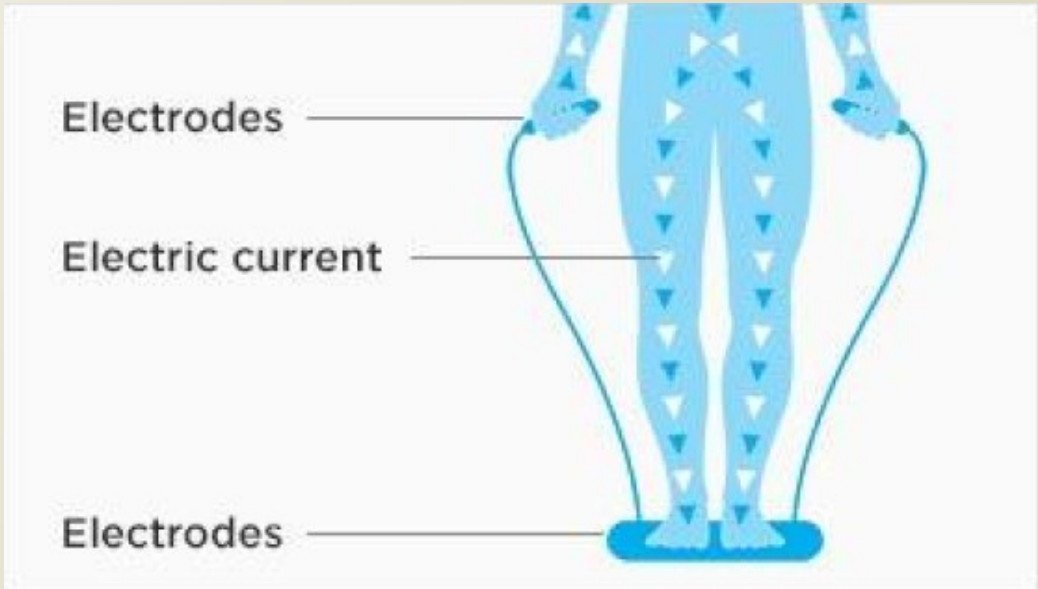
- Project Definition & Objectives
- Project Specifications
- Project Architecture
- Background & Previous Projects
- Design: Subsystems
- Design: Components Selection
- Project Management
- Estimation of Body composition
- Testing and Result
- Completed work
- References

Project Definition

To design a bioelectrical impedance analyzer that can measure human body impedance in order to estimate body fat percentage.

Project Objectives

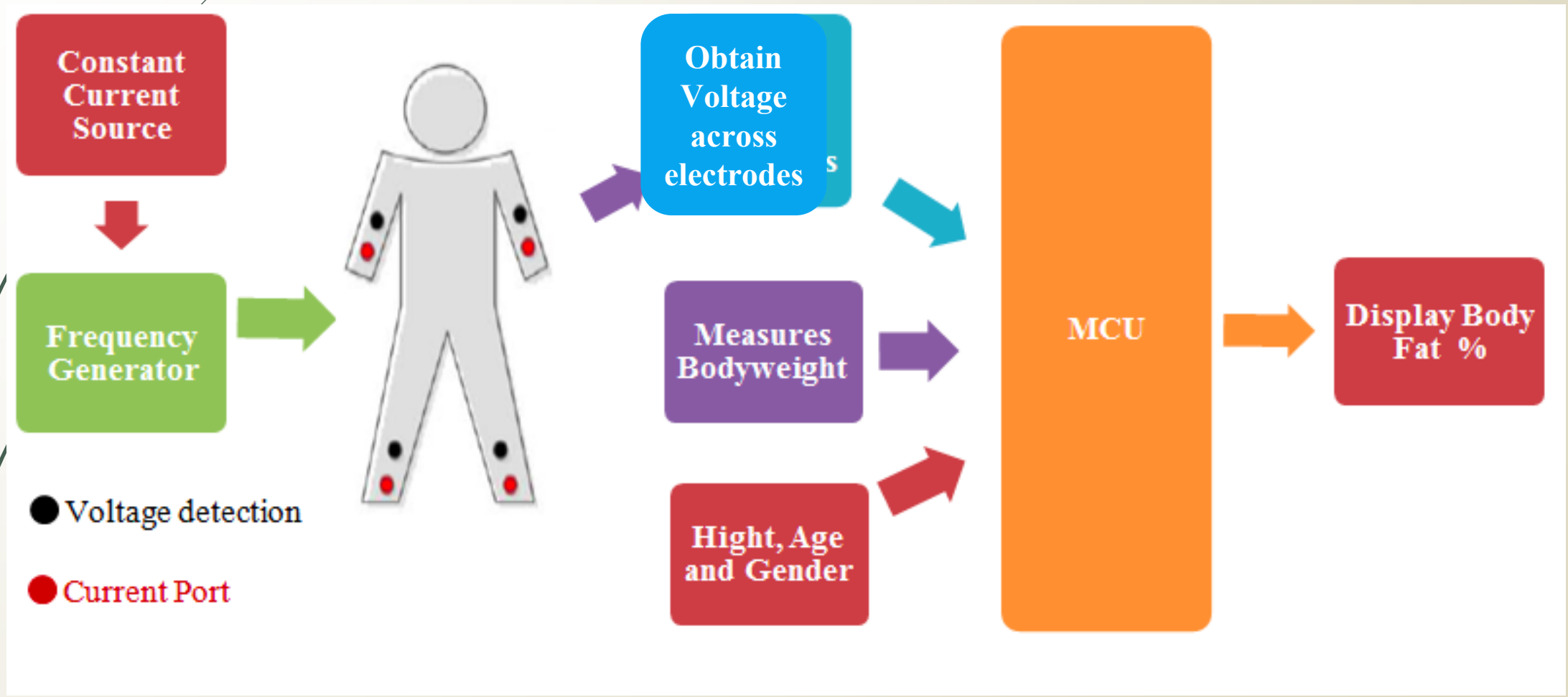
1. **Increase** public awareness about healthcare and obesity.
2. **Encourage** adoption of healthy lifestyle.
3. **Demonstrate** bioelectrical technique to estimate body fat percentage.



Project Specifications

1. Rechargeable Battery.
2. Operates for current range of 10µA up to 0.5mA.
3. Generates high frequency signal of 50 kHz / 100 kHz.
4. I/O Interface.
5. Measures human body impedance.
6. Displays data to end-user.

Project Architecture



Background: Problem

Obesity rate in Saudi Arabia

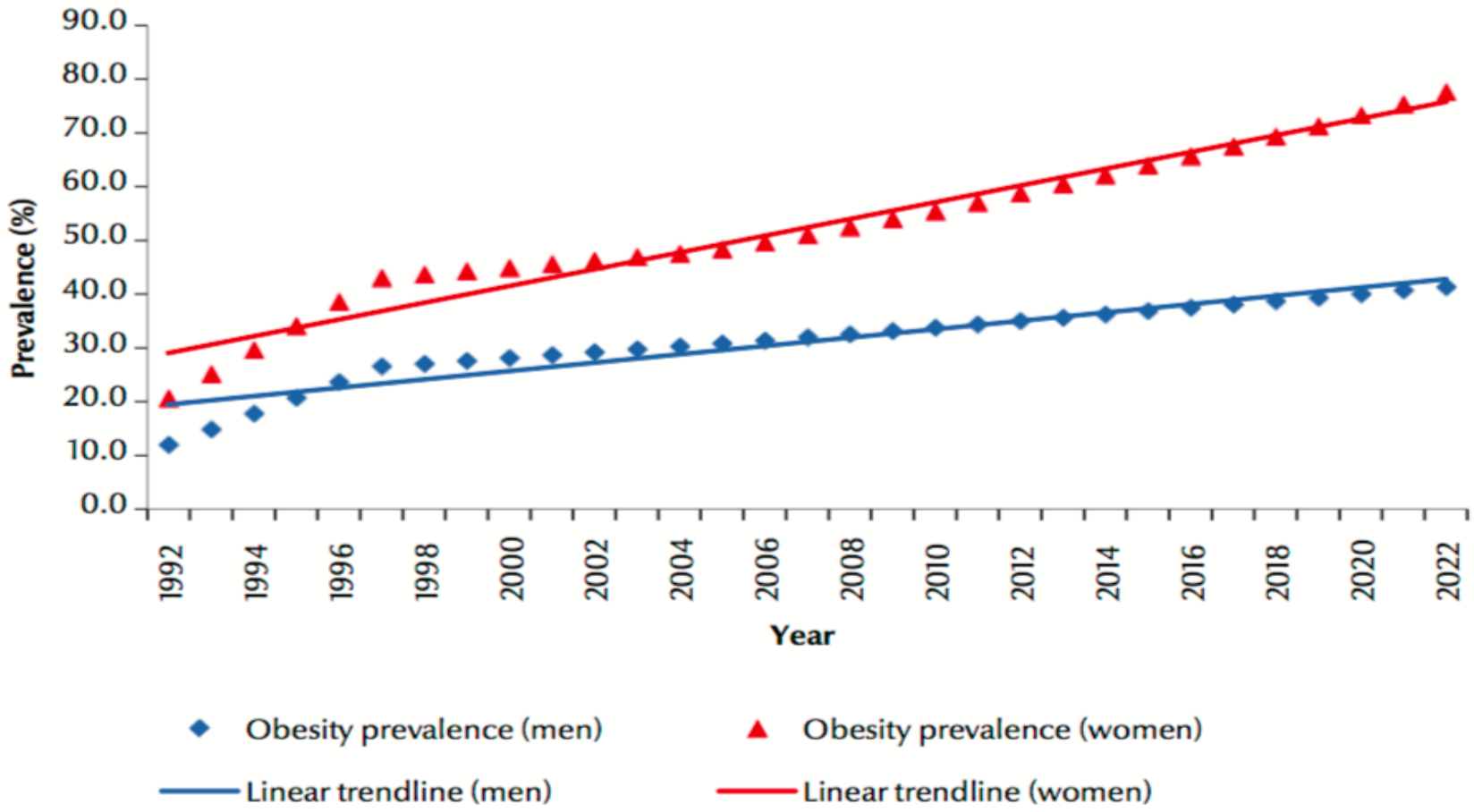
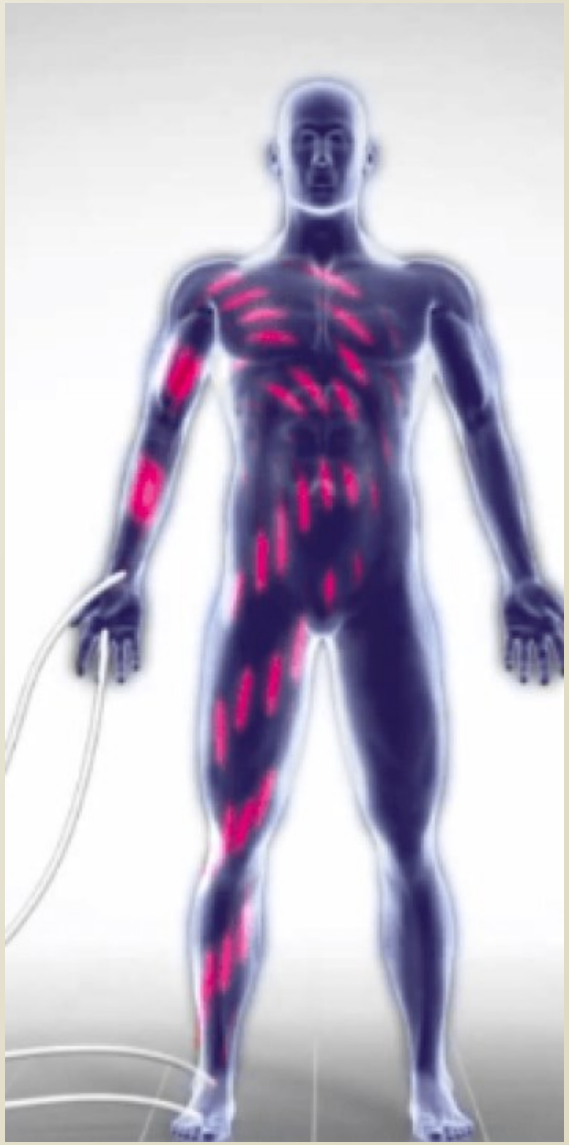


Figure 1 **Trends and future projections of the prevalence of obesity among adult men and women in Saudi Arabia, 1992–2022**

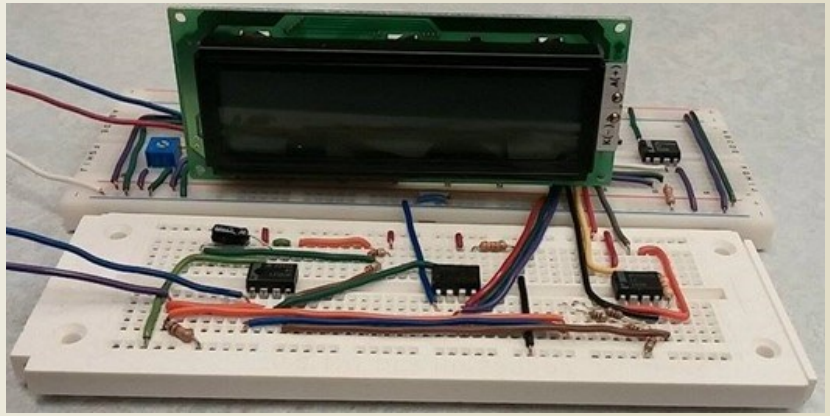
Background: BIA

- BIA determines the resistance to flow of the current as it passes through the body, it provides estimates of body water from which body fat is calculated.
- BIA is reliable, accurate and easy to use device.

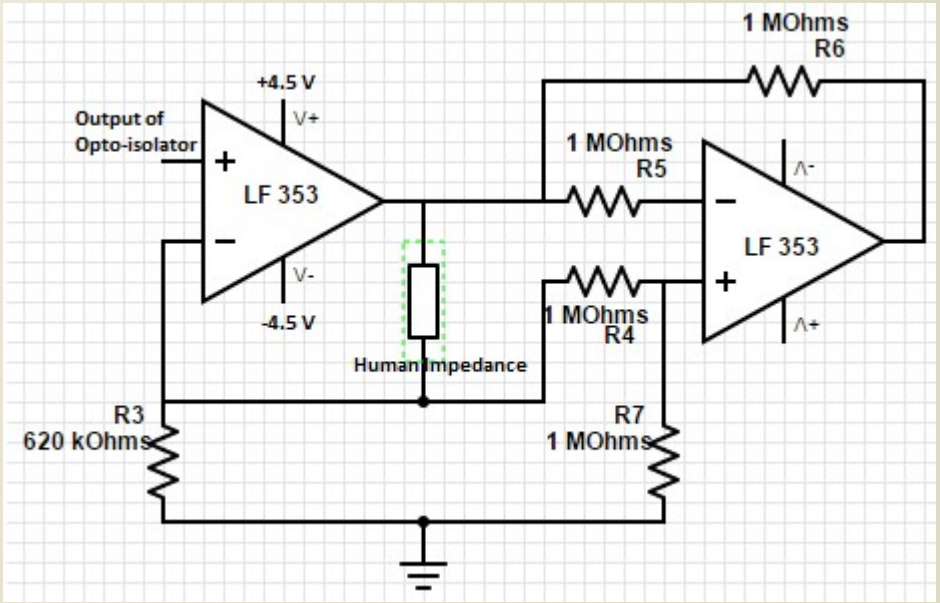


Previous Projects (1)

Bioelectrical Body Fat Analyzer, *Cornell University 2014*



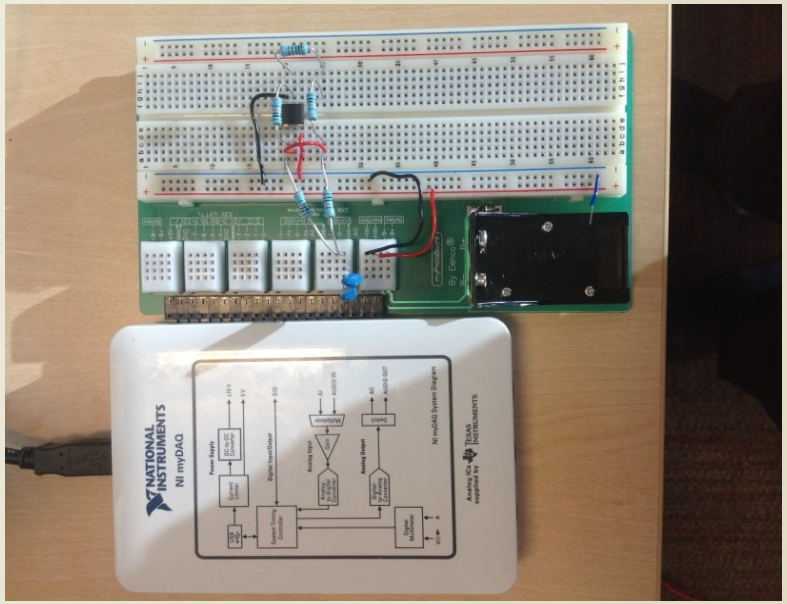
- Design and build a device which would measure body fat percentage of one's body.
- Estimate the water content of the human body.
- Design input signal isolation circuit.

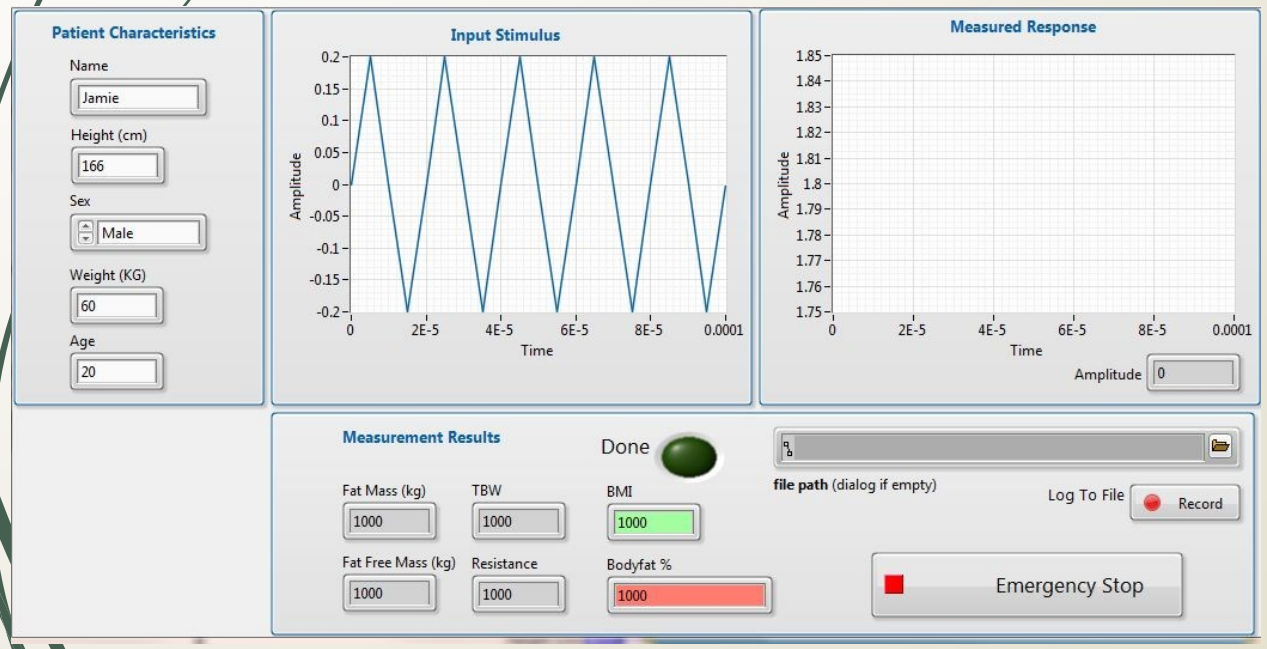


Previous Projects (2)

MyBIA - Bioelectrical Impedance Analysis for Bodyfat %, *National Instruments 2017*.

- Sending a very small current through two points on the body — approximately 800 mA at 50 kHz
- Wired connection to PC using Lab View application as interface for the project.

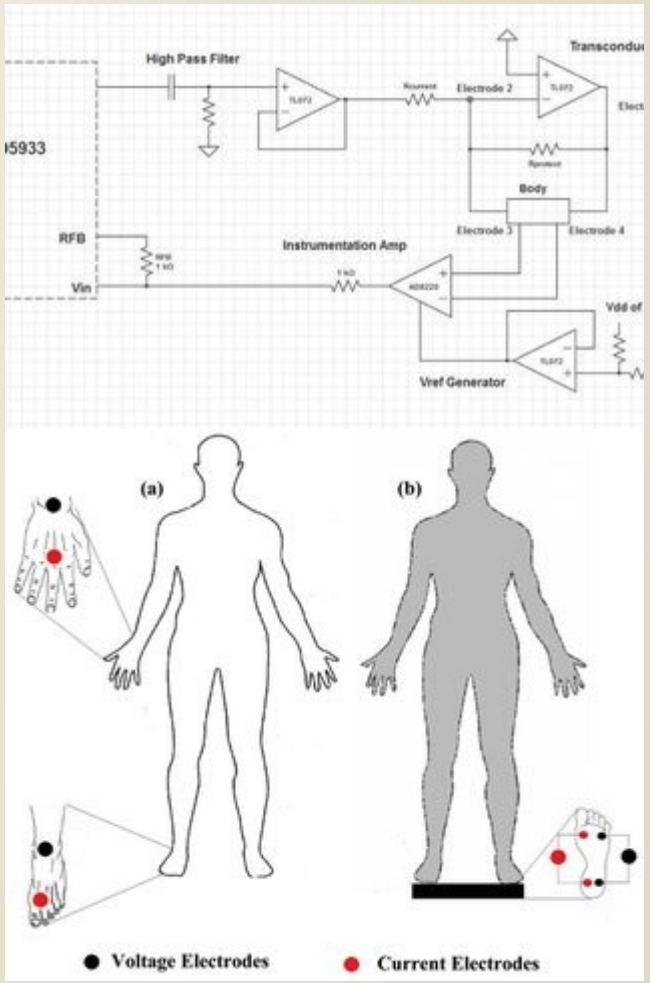




Previous Projects (3)

Body Composition Analyzer, Vanderbilt University, Ameen Farwana, Mikail Siddiki, 2015

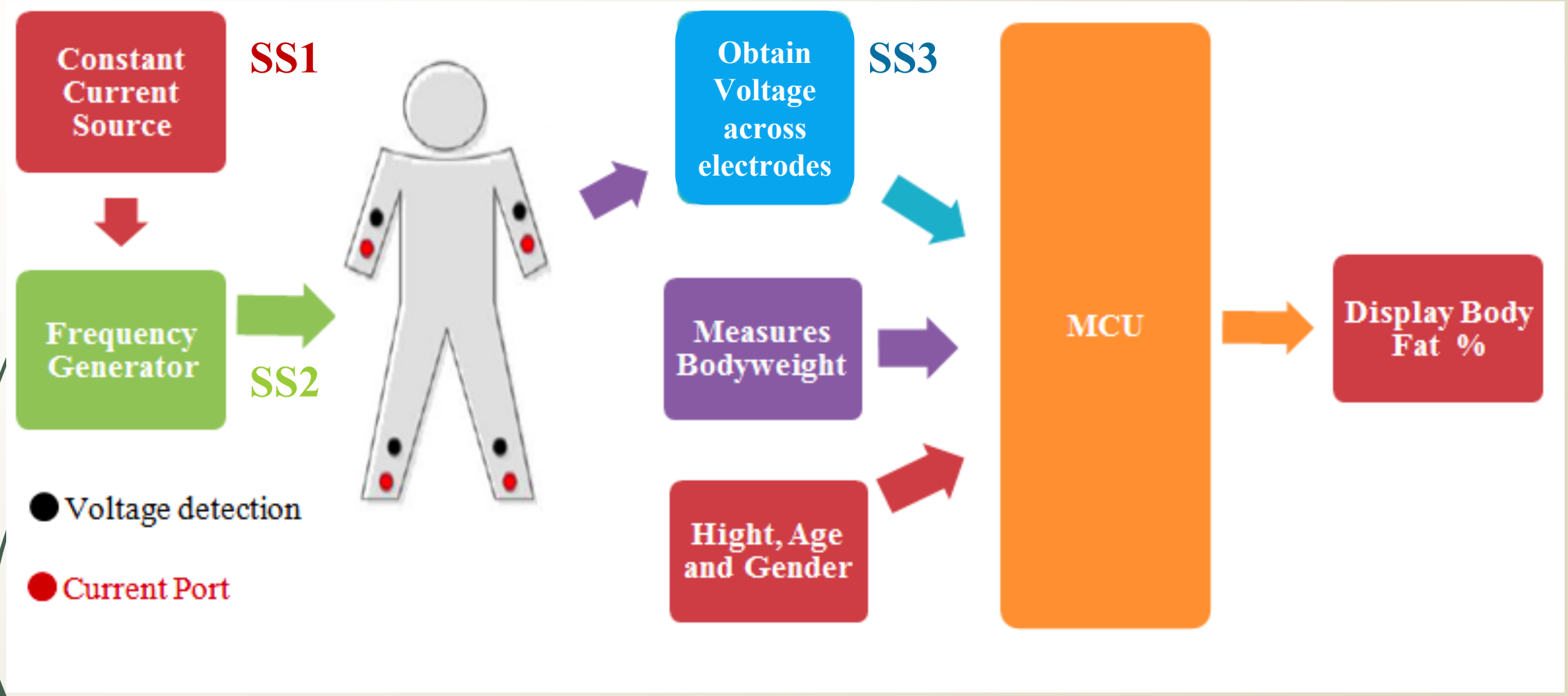
- Design a device which measure body fat.
- Design to Sent an electrical current to measure a difference in impedance between people with different fat compositions.



Previous Projects Summary

Projects	1	2	3	Our Project
Electrode systems	Two	Two	Two	Two
Frequency systems	Single	Single	Single	Dual
Frequency range	50 kHz	50 kHz	10 kHz	50/100 kHz
Current Range	10 µA	800 mA	10 µA	2µA
Rechargeable Battery				√
Display	√		√	√

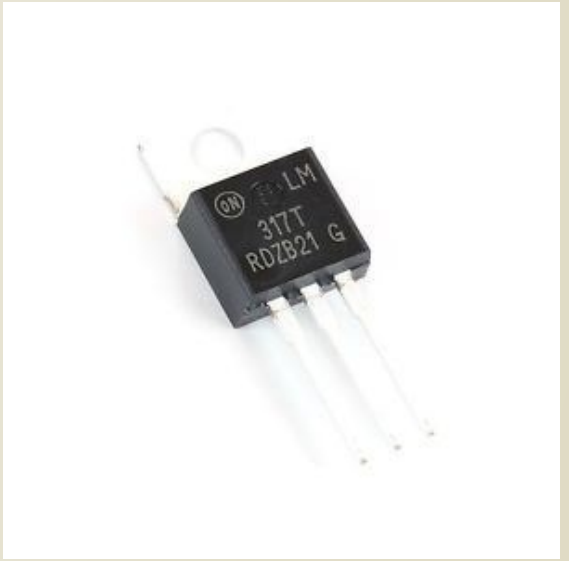
Design: Sub systems



Design subsystem 1 (Constant Current Source)

- After searching and discussing we prefer to use the constant current source inside the AD5933 IC. Because we need constant current source of 2uA and AD5933 can provide that.

Cont. Design subsystem 1

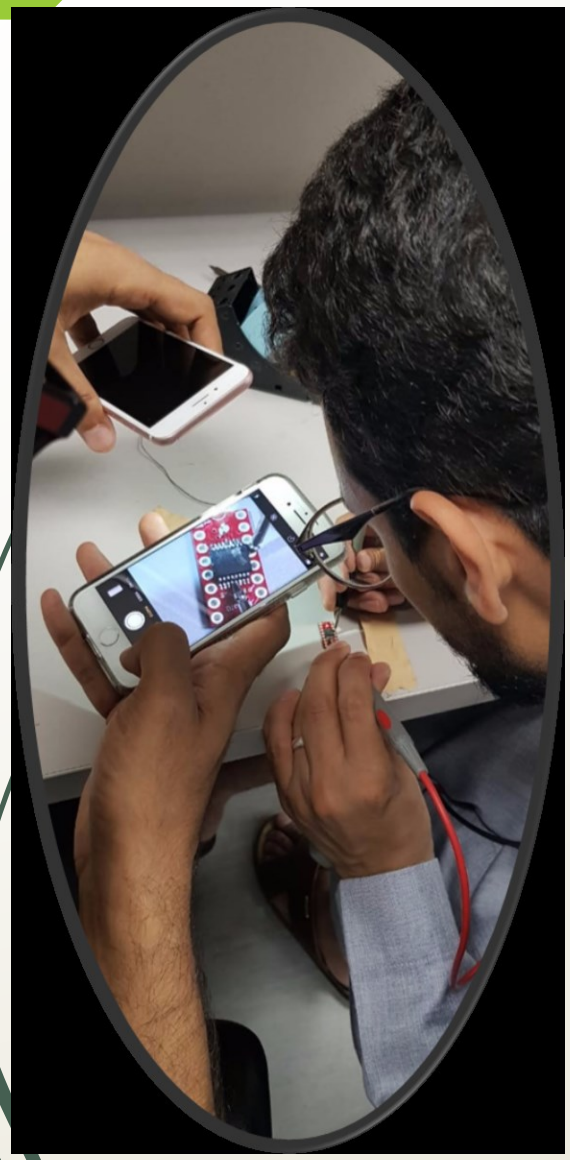


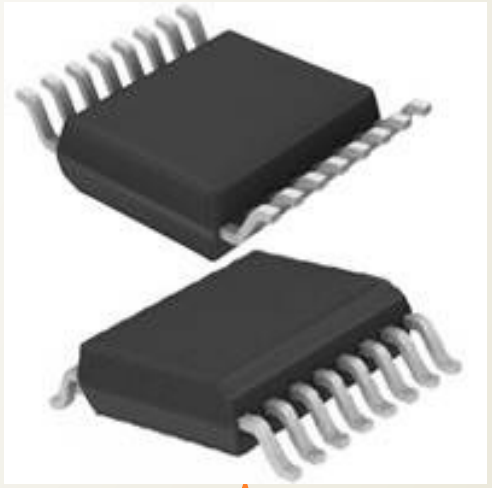
AD5933	**LM317T**
low power consumption	High drop out voltage
Rigid	Fragile
No need for heat sink	Need heat sink

Design subsystem 2 (Frequency Generator)

After searching and discussing we prefer to use frequency generator inside the AD5933 IC. Because we need the frequency to 50kHz or higher and AD5933 can provide that

Cont. Design subsystem 2



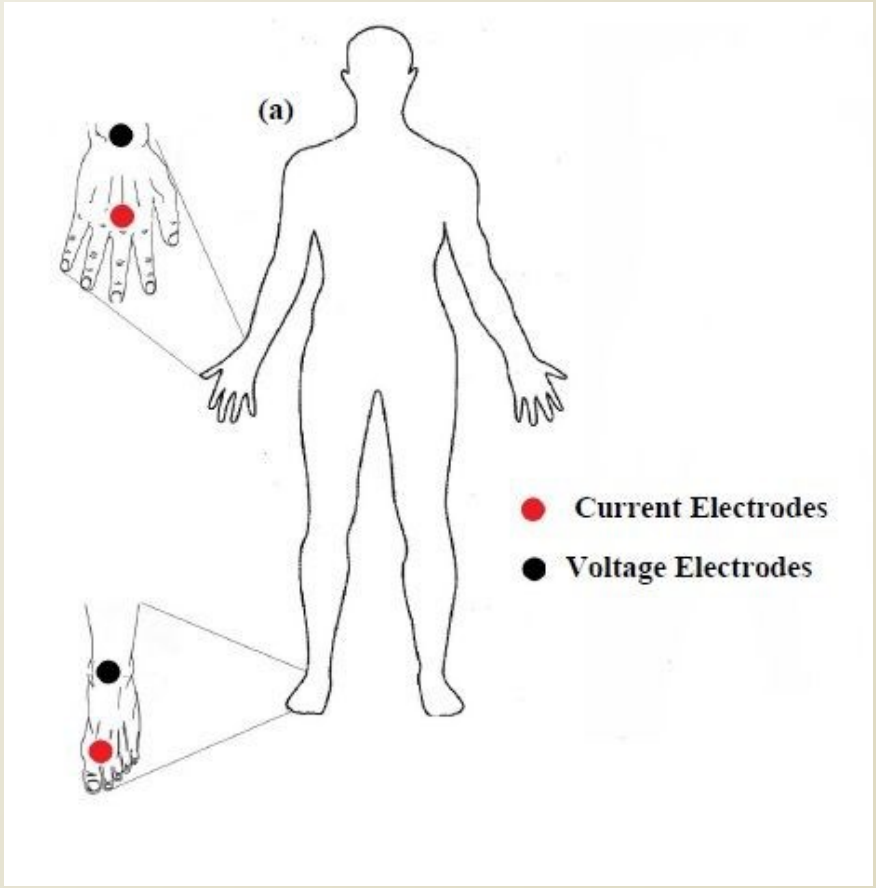


AD5933	NE555P timer
No need extra components	Need extra components
Software configuration	Manual adjustment/Calculation
Highly accurate output results	Accurate output results

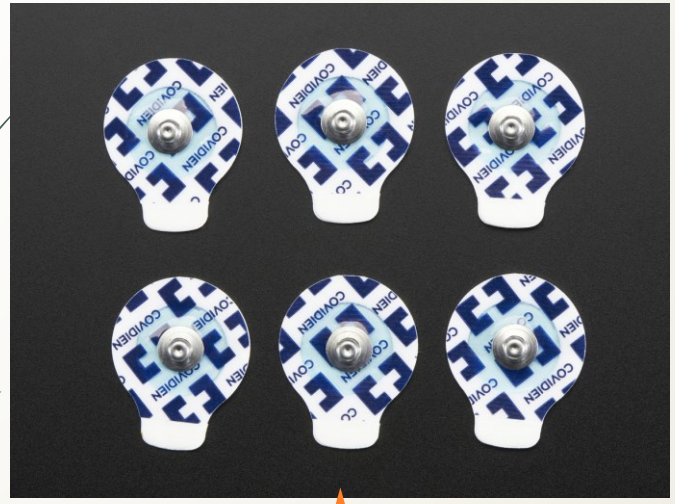
Design subsystem 3 (Electrodes)

- **Electrodes:**

We have chosen Covidien electrodes 530. Because it is appropriate for the most challenging of monitoring environments. The high quality foam substrate conforms easily to the skin to ensure electrical contact for consistent tracings



Cont. Design subsystem 3

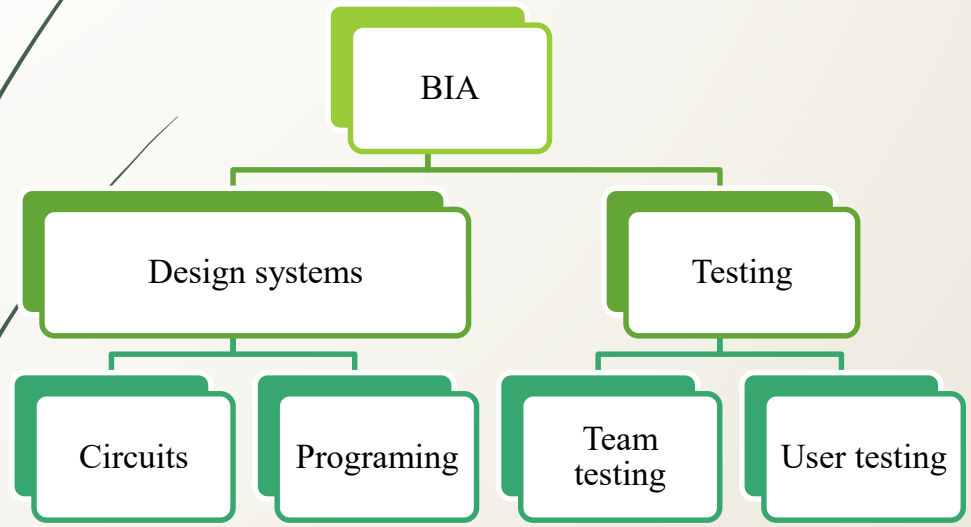


Covidien electrodes 530	BluFlex Electrodes
Used for body monitoring	Used for heart monitoring
Need Gel	Need Gel
Easy on skin	Strong on the skin

Project Management

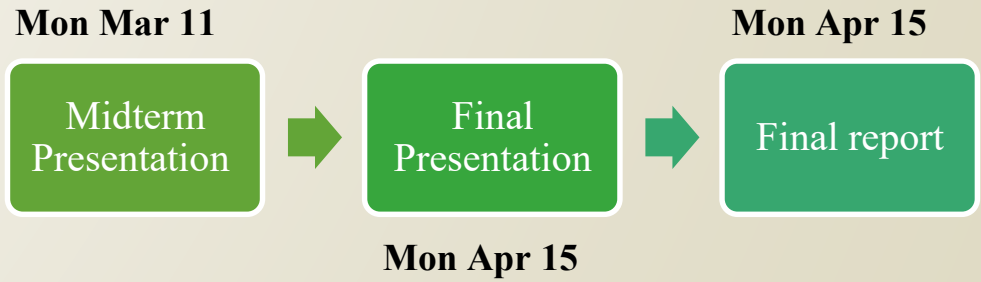
- **Planning**
- **Project Schedule Processes required to manage the time of the activities by identifying and documenting the specific actions to be done**

1. **Activity list 2. Milestone list**



Network diagram and work package

Milestone List



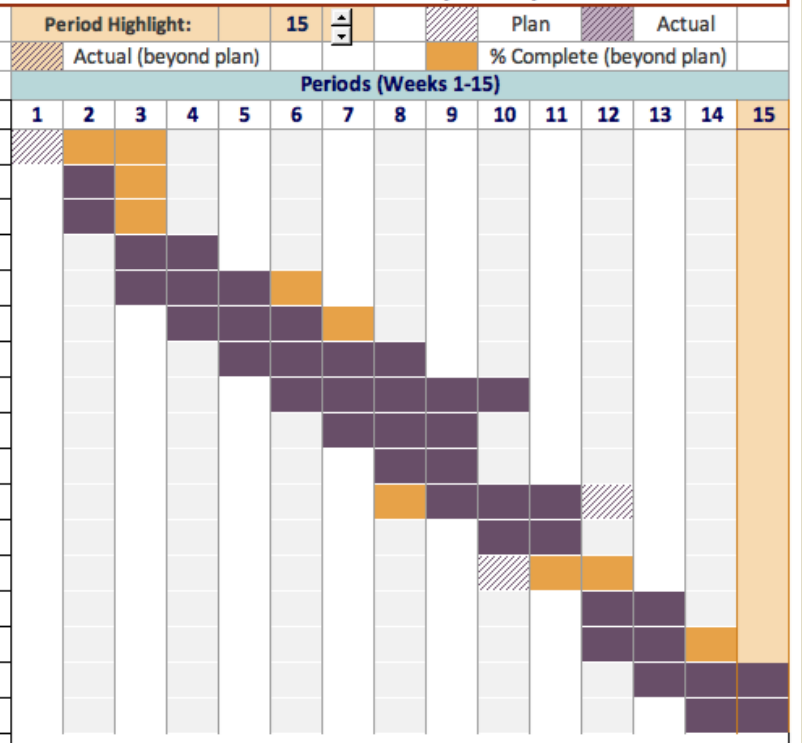
- **Estimate Activity Durations**
- Three estimates based on prior experience

Triangular distribution formula E=(O+M+P)/3	**O=Optimistic estimate**
	P=Pessimistic estimate

Project planning sheet

Title: Bioelectrical Impedance Analyzer	Advisor: Dr. Sadiq AlHuwaidi	Design II (ASSE 3)	Spring 2019
Abdulrahman Aloufi 201100677		Project PLAN & Progress	
Ahmed Alabdullatif 201302548		ProgRpt No. 15	
Ahmed Alqahtani 201400392		Plan updated (Date): Apr 16, 2019	
Ahmed Alzahrani 201303935		Instructor: Dr. Chedly B. Yahya	
Abdallah Alghamdi 201400016			

ACTIVITY	PLAN START	PLAN DURATION	Assigned To	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Write plan	1	1	ALL	2	2	100%
Design subsystem 1 (Determine body fat)	2	1	ALL	2	2	100%
Test subsystem 1	2	1	ALL	2	2	100%
Calibrate AD5933	3	2	AG, AA	3	2	100%
Measure voltage across resistor	3	3	AG, AA	3	4	100%
Measure voltage across body	4	3	AO, AQ	4	4	100%
Deterimine body fat content (Coding)	5	4	AO, AQ	5	4	100%
Implement user interface (keypad)	6	5	AQ	6	5	100%
Prepare midterm Presentation	7	3	AA	7	3	100%
Display data to end-user	8	2	AO	8	2	100%
Design subsystem 2 (Implement Industrail Desgin)	9	4	ALL	8	4	100%
Test subsystem 2	10	2	AZ, AA	10	2	100%
Implement industrail design	10	1	AQ, AG	11	2	100%
Prepapre final report	12	2	ALL	12	2	100%
Prepapre final presentation	12	2	AZ	12	3	100%
Prepare Project Demo	13	3	AQ, AG	13	3	100%
Submit Rpt/PPT/Brochure	14	2	AZ, AA	14	2	100%



Progress Details:	Issues (delay ...):
We have received a full-featured evaluation board for AD5933.	AD5933 needs to be programmed by assembly language,
We have managed to calibrate and measure unknown resistance across AD5933 using the evaluation board.	and we found few functions written in C++
We are planning to measure the voltage across human body.	thus, we have ordered a full-featured evaluation board for AD5933
	that provides graphic user interface software with frequency sweep
	capability for board control and data analysis.

Budget Estimate

Project Cost Process involved in estimating, budgeting managing and controlling costs

1. **Estimate Costs**

It is an approximation of costs of resources needed to complete project activities. (Quality, Risk)

2. **Determine Budget**

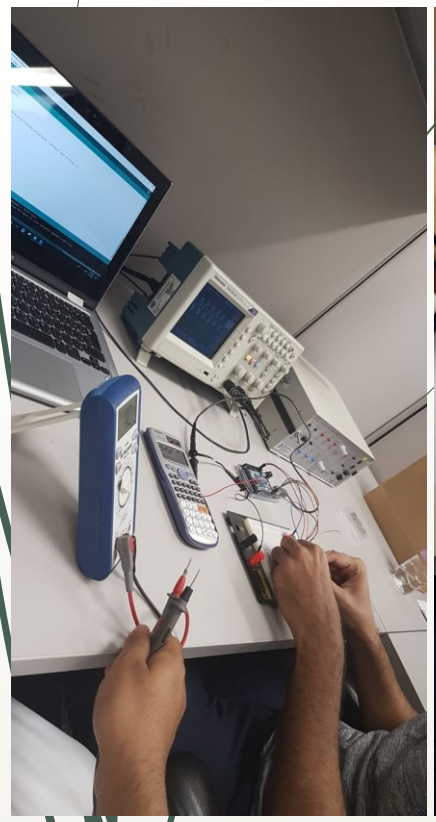
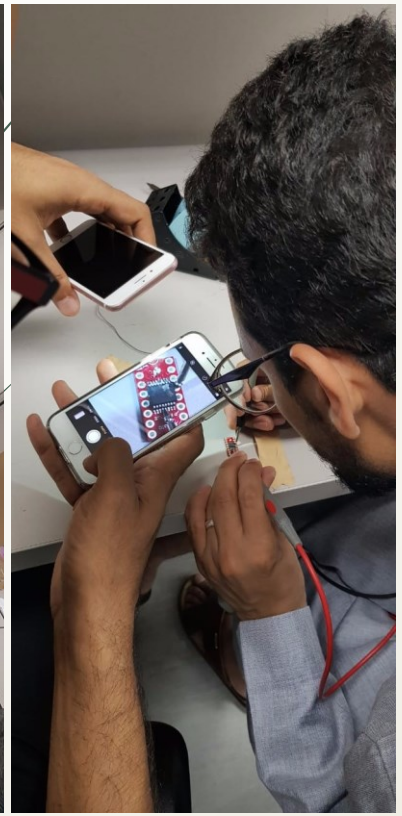
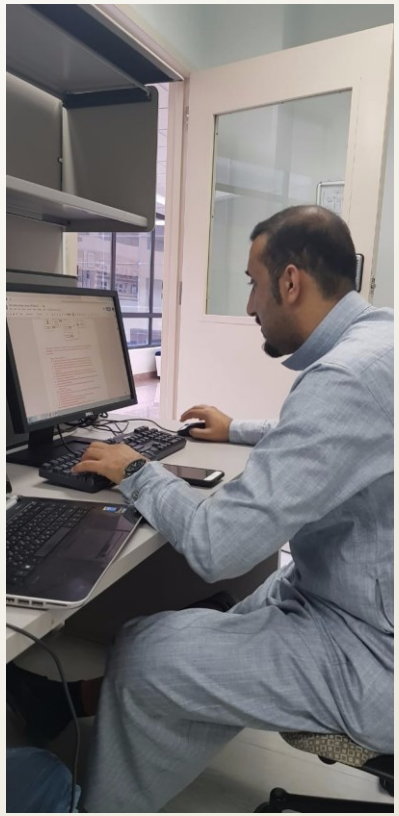
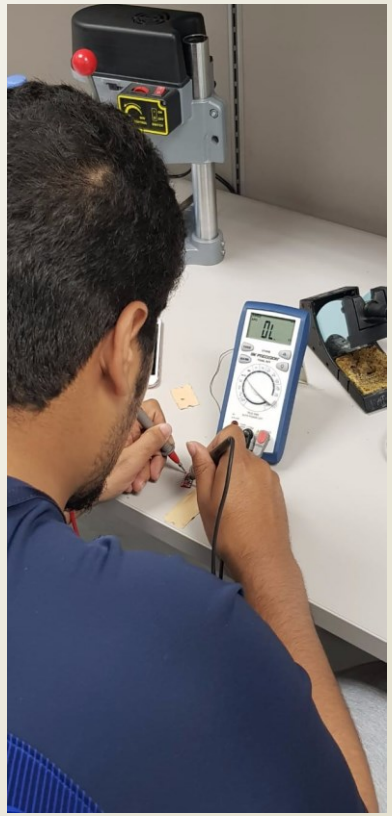
Determine cost baseline and estimated costs of individual activities.

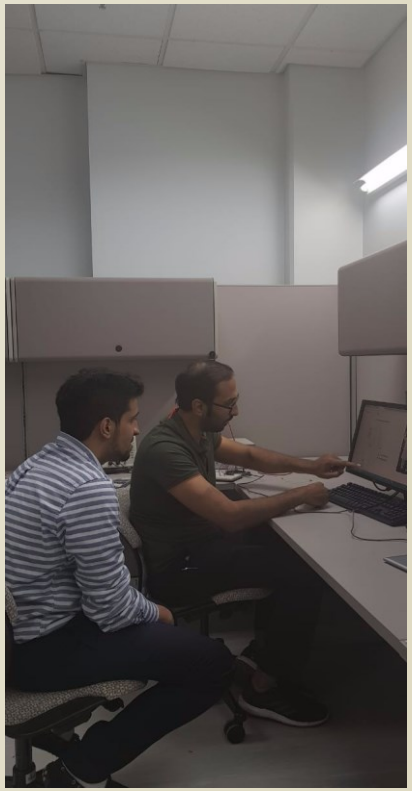
Item	Quantity	Unit Cost (SR)	Subtotal
Microcontroller	1	300	300
MCU Power Supply	1	20	20
Evaluation board	1	220	220
Display	1	20	20
Digital scale	1	200	200
Wires	2	12	24
Resistors &Capacitors	12	2	24
3D design	1	250	250
Single Use Electrode	4	50	200
Electrode Gel	1	50	50
Rechargeable Battery	1	100	100
I2C chip	1	20	20
Total			**1428**

Team task division

Tasks	AlQahtani	AlOufi	AlZahrani	Alabdullatif	AlGhamdi	Tasks Tatal
Search & Acquiring the components	30	10	20	15	25	100%
Design Subsystems	20	30	15	25	10	100%
Test Subsystem	10	20	25	20	25	100%
Writing reports & presentations	20	15	20	15	20	100%
Configuring the Software	20	25	15	25	15	100%

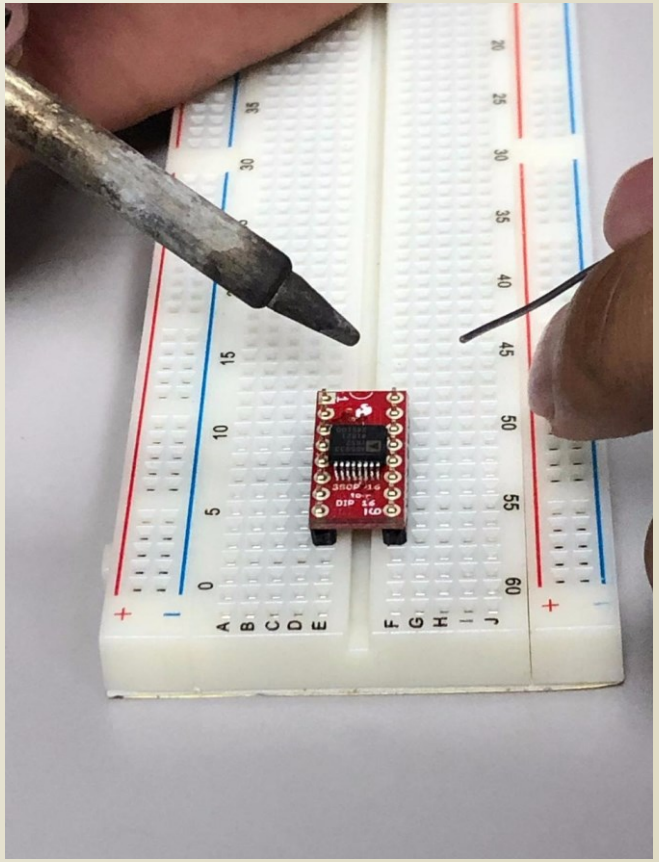
Design: Team Work



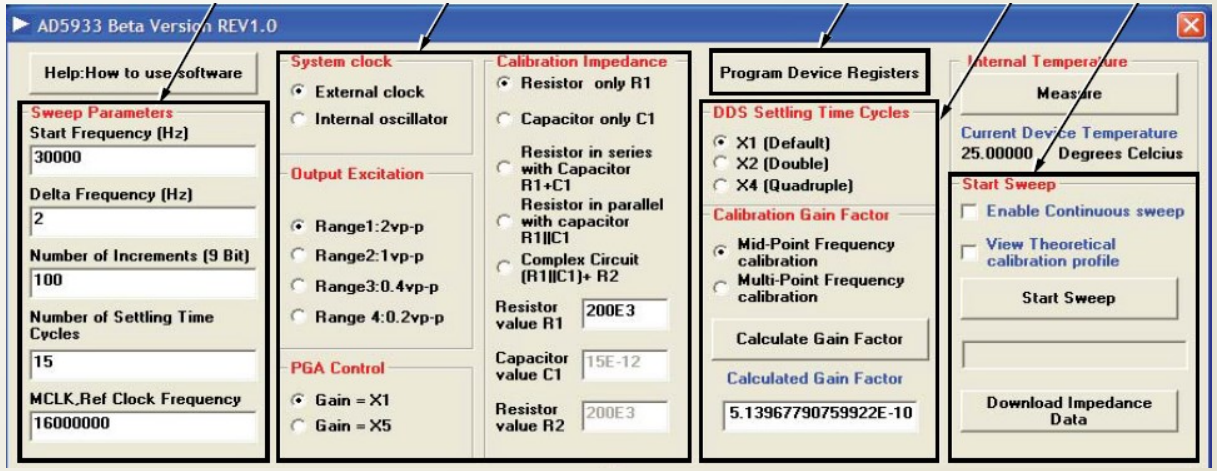
Project Management: Challenges

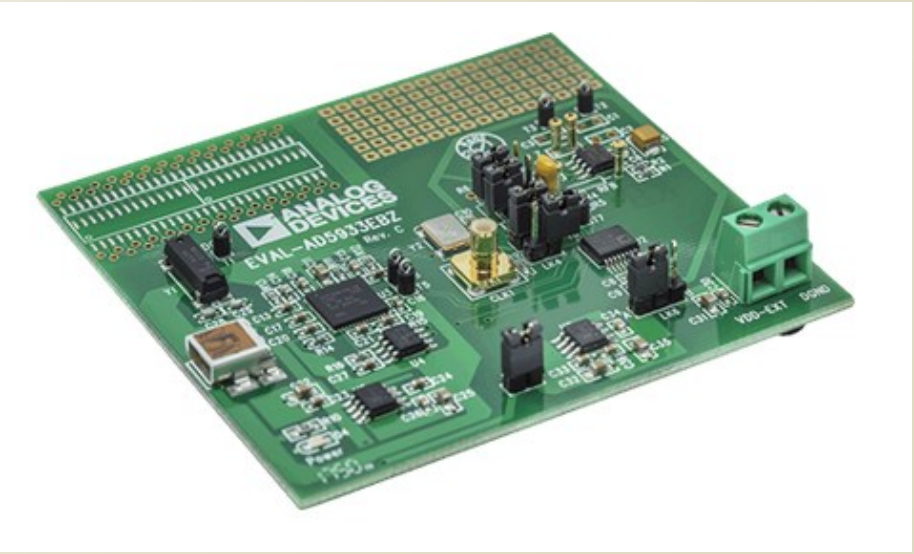
- We faced a hard time in soldering the AD5933 IC on the SSOP to DIP adapter. Because it is SMD IC (surface mounted device) and because its very small and sensitive.
- Some of the components were not available in our local stores. Therefore, we had to order them online and we had to wait for one month in order to get them.
- 3D printer take from us long time to get the right design for our demo



Project Management: Challenges

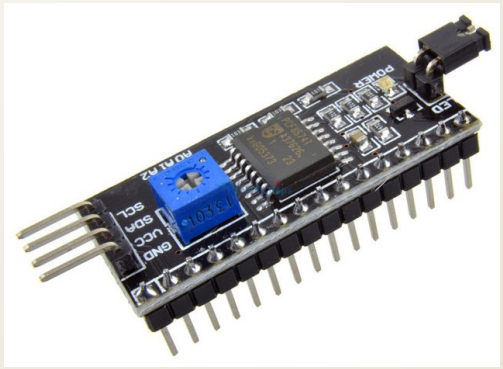
- The AD5933 needs to be programed by assembly language and we have found only few functions written in C++.
- Therefore, we have ordered a full-featured evaluation board for the AD5933 that provides graphic user interface software with frequency sweep capability for board control and data analysis.
- We are planning to work simultaneously on the IC and the board throughout the semester to save time.



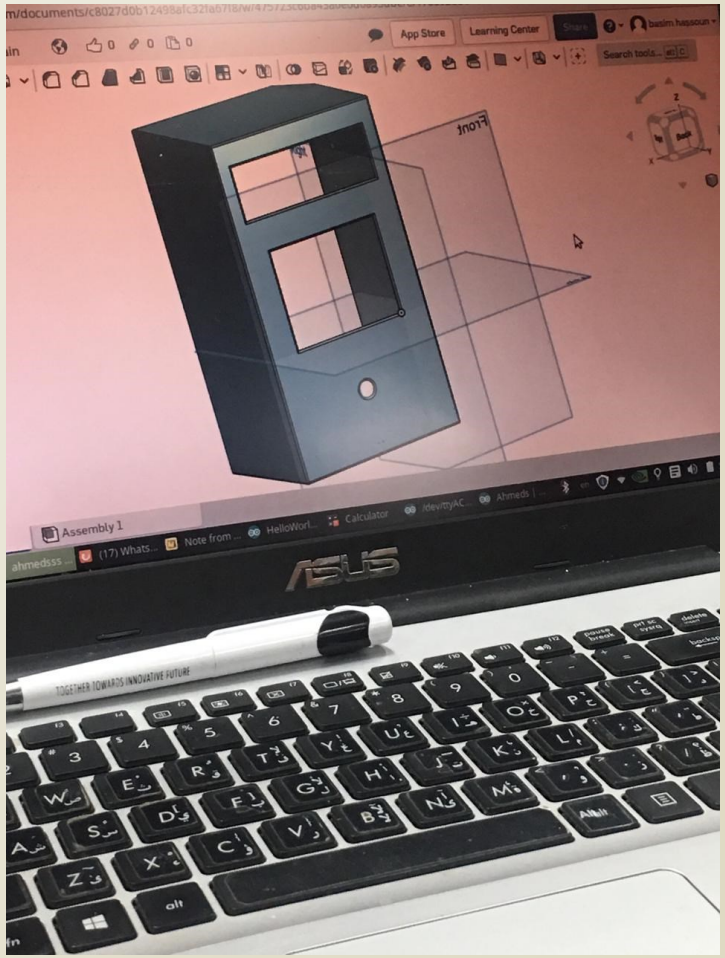


Project Management: Challenges

- **I2C Communication protocol**
- We faced a hard time to have communication between AD5933 board and Arduino through I2C serial communication protocol, so data is transferred between devices by two wires
- SDA (Serial Data) and SCL (Serial Clock).
- Research to find writing/reading Register Data to the AD5933



- **Self learning 3D design for our project**



Project Management: Safety

TABLES FROM I.E.C. 1000-05 AND ET 213:2007

Current (mA)	Effect	Time Duration
0.2 to 1.0	Threshold of perception	Not critical
10 to 16	Limit of 'let go', muscles contract	Minutes
30*	**Breathing difficult, 'safe' limit**	Seconds
50	Irregular heartbeat	1 heart beat or about 1 second
60	Respiratory problems, cannot breathe	
>60	Heart fibrillation, electric burns	

Magnitude of the Current	Physiological Effects
From 0 to 0.5mA	Perception possible (10 secs)
From 0.5 to 5mA	Perception and involuntary muscular contractions likely but usually no harmful electrical physiological effects (5 secs)
From 5 to 50mA	Strong involuntary muscular contractions. Difficulty in breathing. Reversible disturbances of heart function. Immobilization may occur. Effects increasing with current magnitude. Usually no organic damage to be expected. (2 secs).
From 50 to100mA	Patho-physiological effects may occur such as cardiac arrest, breathing arrest, and burns or other cellular damage. Probability of ventricular fibrillation increasing with current magnitude and time up to 1 sec. Above 2 secs probability of ventricular fibrillation is approaching 50%.

Estimation of Body composition

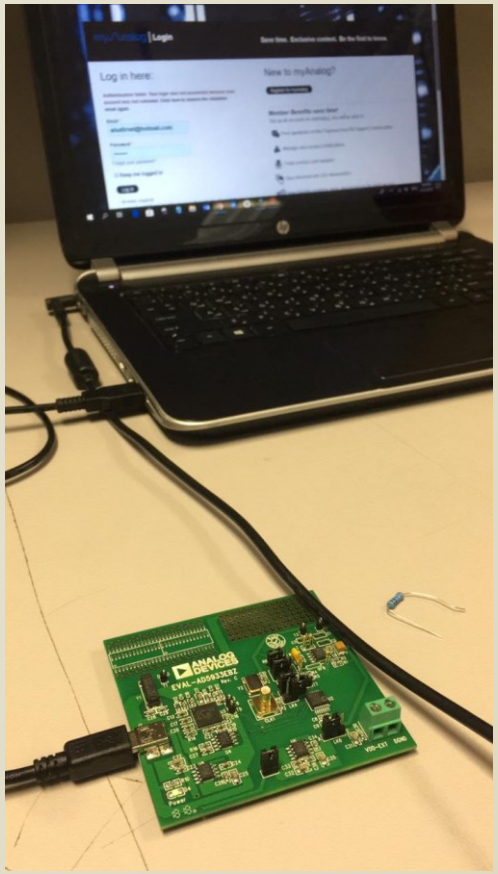
- In BIA method human body is assumed to be a uniform cylinder, so in equation (2.3) we can replace impedance of cylinder (Z) by Impedance of the body (Zbody); length of cylinder (L) by height of body (h) and volume of the cylinder (V) by volume of the conducting material in the body i.e. volume of the TBW. Thus by analogy, at high frequency (above 10 kHz) of alternating current, equation (2.3) becomes

$$VolumeOfTBW = \rho \frac{h^2}{Z_{body}} \qquad (2.5)$$

- The equations (2.5) to (2.7) give the body composition. When these equations are applied to the body, many assumptions are made including homogeneity, uniform current distribution and uniform cross sectional area.

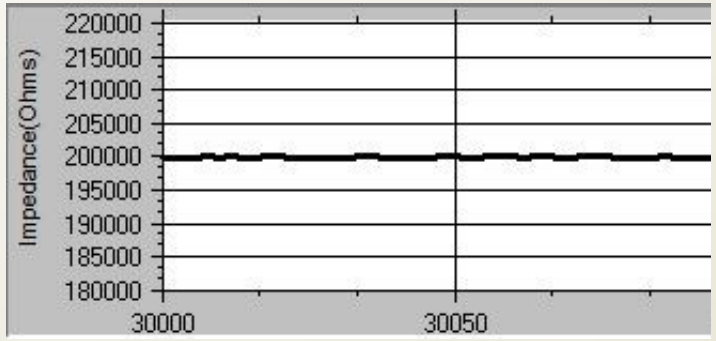
$$FatFreeMass(FFM) = \frac{TotalBodyWater(TBW)}{0.73} \qquad (2.6)$$

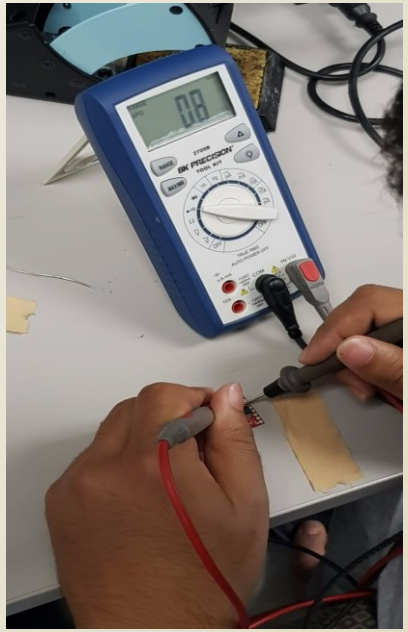
$$FatMass(FM) = Weight - FFM \qquad (2.7)$$

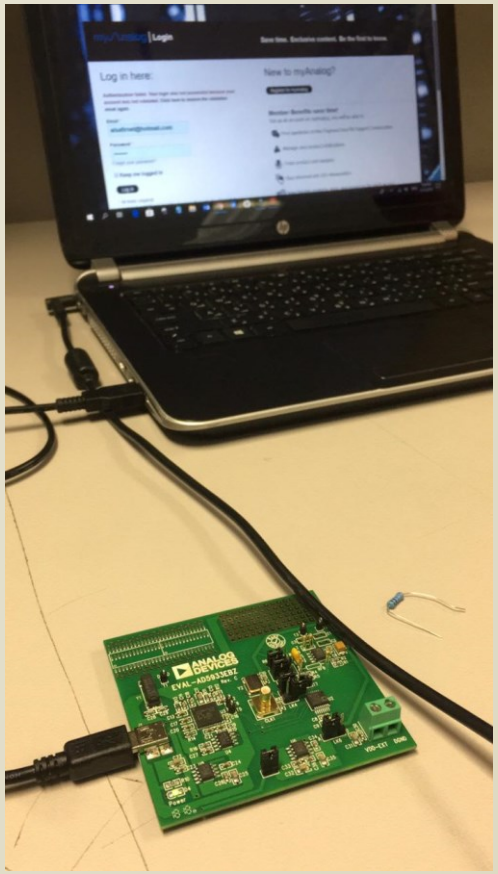


Testing and Result

- Measuring components length for 3D design
- Testing and check the continuity of the wires
- Soldering some of the components together
- Making sure that the AD5933 generate required hertz
- Calibrating and measuring unknown resistance across AD5933 by using the evaluation board.





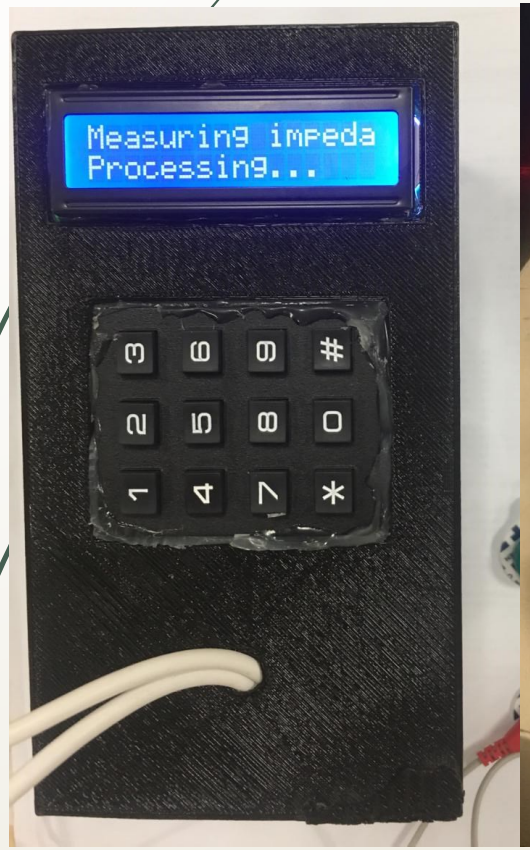


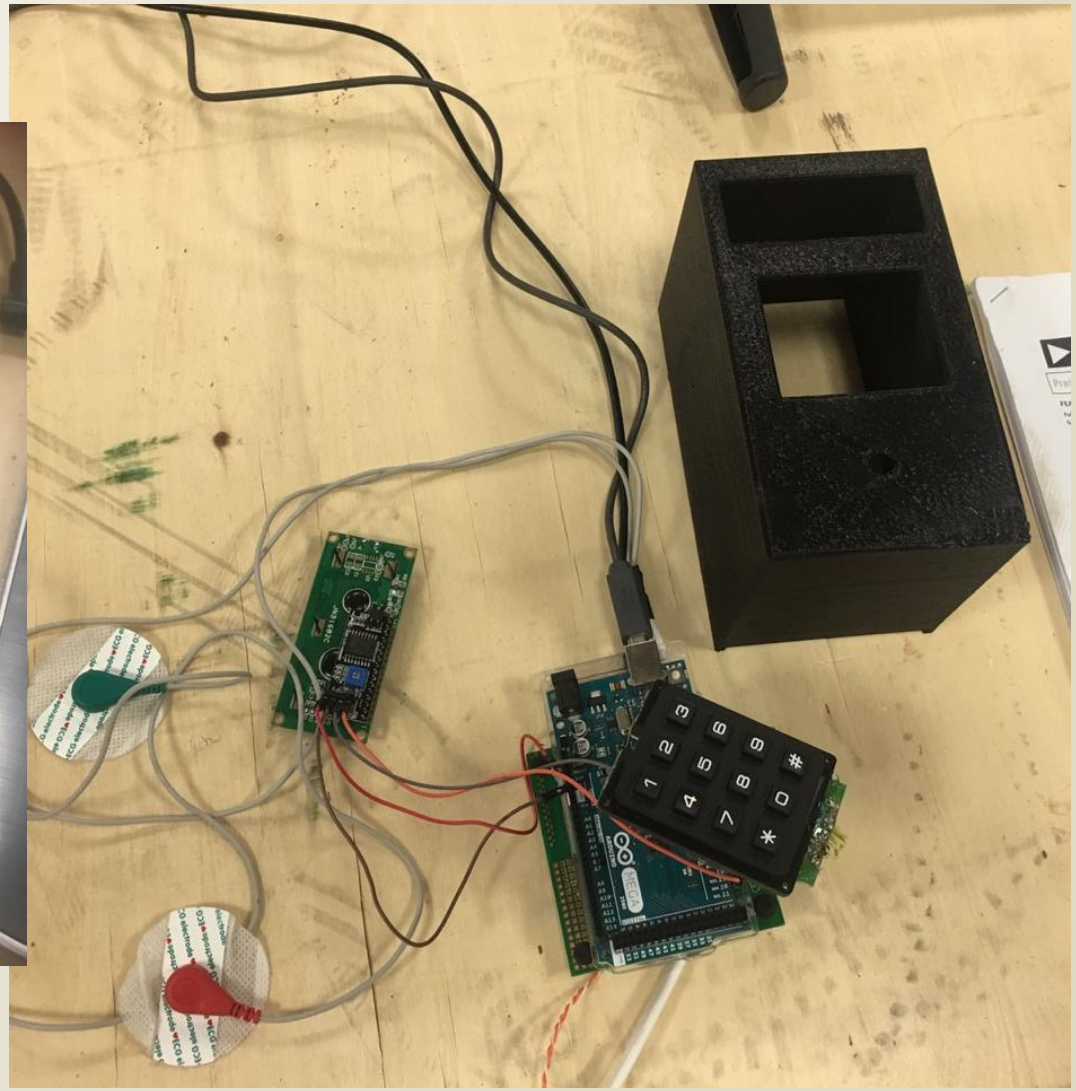
Testing and Result

- The designed bioimpedance analyzer was tested on ten subjects, with equal numbers between man and woman. The subjects were of broad age range between 20-64 years old with various heights and weights as well .

Subject No	h (cm)	w (kg)	g (M/F)	a (Yr)	Fat Mass %
1	157	56	F	23	31.07
2	149	58	F	49	38.18
3	145	40	F	20	20.16
4	147	66	F	64	49.43
5	162	74	F	51	44.52
6	175	556	M	22	14.35
7	165	54	M	23	15.75
8	161	62	M	24	21.27
9	168	80	M	42	37.24
10	158	64	M	31	28.08

Completed work (Pictures)





References

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- *Difference between BMI and BIA: http://www.differencebetween.info/difference-between-bmi-and-bia*

Thank you for listening!