Feb 2022- Jan 2023

Day Book

MEng project- Biosensor System Design for COPD patients

Peggy Pei
S2134810

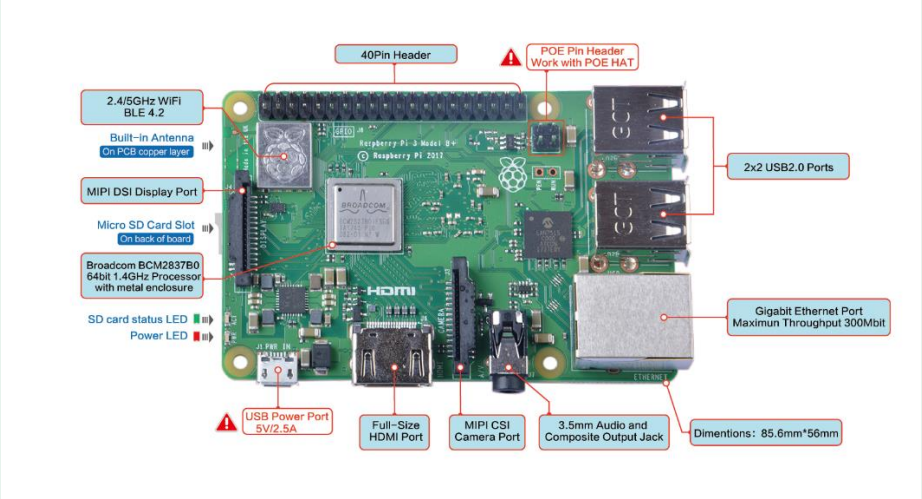
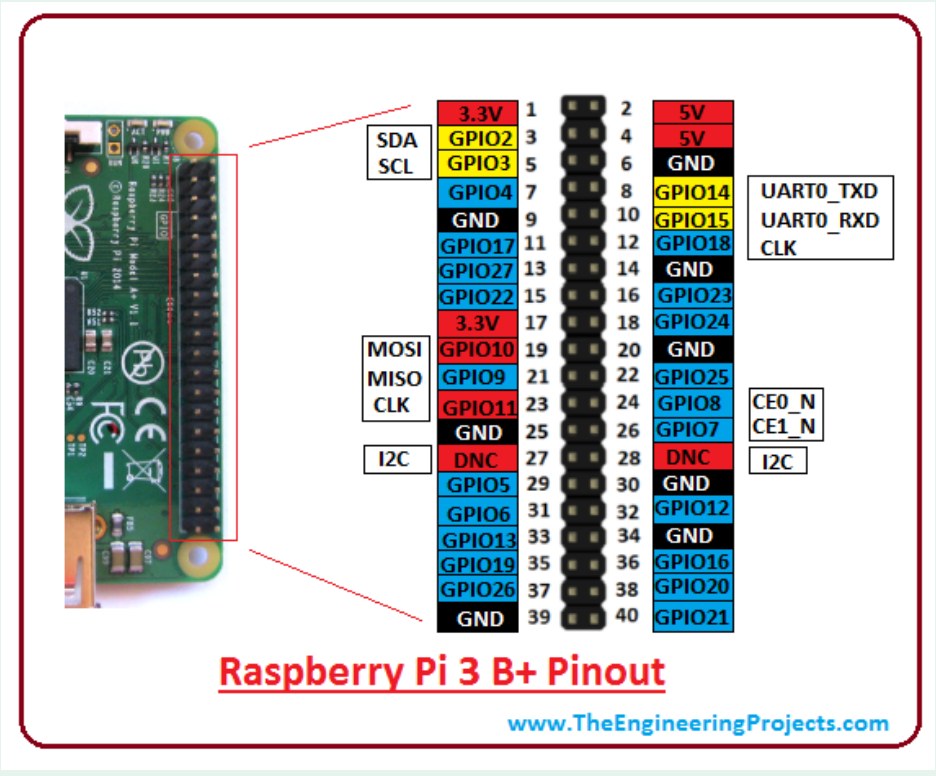
Outline

<Phase One>

<Phase Two>

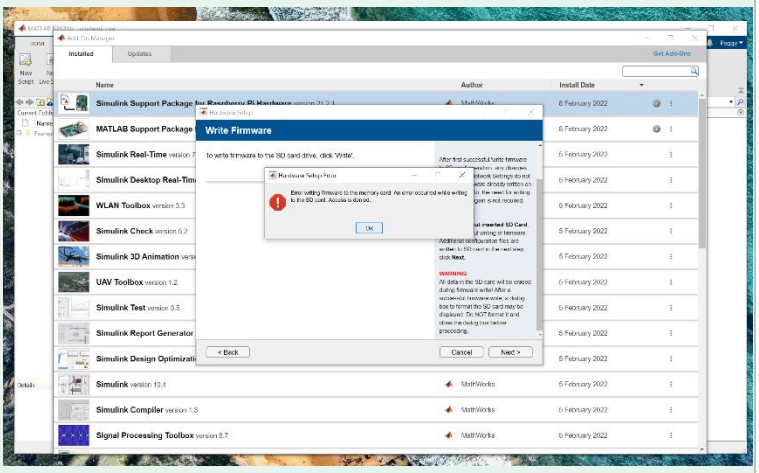
Day book - MEng project

NAME	DATE
Peggy Pei	7/2/2022

EQUIPMENT	Simulink Website: Getting Started with Simulink Support Package for Raspberry Pi - YouTube Raspberry Pi 3 Model B+ - Seeed Studio
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	*Raspberry pi 3B+* Diagram for functional blocks of Raspberry Pi 3B+:  Pinout for Raspberry Pi: 

Problem:

Simulink cannot be applied to Pi.



Expected reason:

The size of SD card is required to be at least 8GB, but the initial SD card got from the kit is somehow only 3.99GB, which may be caused by some manufacture problems.

Solutions:

1) Get a new SD card with 16GB above.(delivered date: 9th Feb)
2) Using ethernet cable to directly connect pi to the host computer.(If solution 1 would not work)
3) Email Mathwork.(If solution 2 would not work)

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NAME	DATE
Peggy Pei	8/2/2022

EQUIPMENT	Website: [Temperature Sensor Comparison | Variohm] **NTC:** [Thermistors and NTC Thermistors (electronics-tutorials.ws)]
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	*Sensor choice* **Potentiometric sensor evaluation** Double sides to measure(Both inhalation and exhalation) can be either positive and negative. ***Temperature sensor evaluation*** Temperature Sensor Comparison The below table shows a temperature sensor comparison

Temperature Sensor Type	Advantages	Applications	Temperature Range
Temperature Probe	• Customisation options • Wide temperature ranges • Highly accurate • Cost effective • Stock models available	• Industrial monitoring • Patient monitoring • Transit • Computers • Home appliances • HVAC • Laboratory • Motorsport • Food and beverage	• Range will depend on sensing element
NTC Thermistors	• Highly sensitive • Perfect for small temperature ranges • Easy to use • Fast response • Standard two wire connection	• Environmental monitoring • Aerospace applications • Medical devices • Communications and computing equipment • White goods	• Usually, -40°C to 125°C but can go to 325°C
RTD Sensors	• Highly accurate • Good stability • Good linearity • Consistent • High temperature ranges	• Automotive applications • Engineer temperature • Power electronics • Computers • Consumer electronics • Aerospace applications	• -196°C +850°C
Thermocouples	• Wide temperature range • Highly rugged • Best for high temperatures	• Industrial Applications • Science • OEM applications • Biotech	• 95°C – 1260°C

Cost comparison:

RTD sensor	3.12£
NTC Thermistors	0.52-1.44£

NTC thermistor may firstly be considered here.

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NAME	DATE
Peggy Pei	10/2/2022

EQUIPMENT	**Q3:** [Publish Data from Raspberry Pi Sense HAT to WebSocket Server - MATLAB & Simulink Example - MathWorks United Kingdom]

EVENT

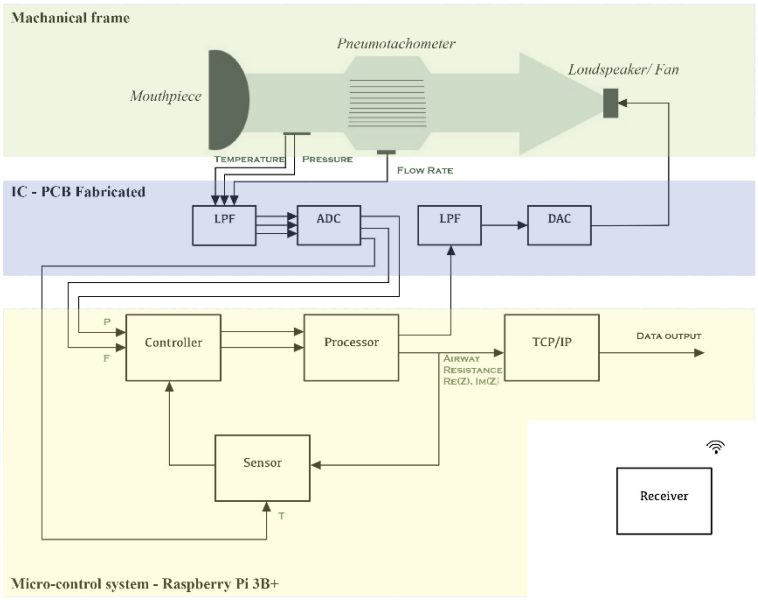
- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

Question:

1. How to use temperature controller improve accuracy of pneumotachometer?
   Searching a cooling method for temperature control (Directly cool down temp or compensate temperature effect-relationship between temperature and airway resistance?)
2. How to use fan or loudspeaker generate signal required?
   Figuring out Fan law.
   Making a comparison for fan and loudspeaker when low frequency(5-30Hz) is required.
3. How to send data?
   Figuring out the Bluetooth protocol of Raspberry pi
4. How to calculate airway resistance?
   Read more materials.

Initial block diagram of system:

<Block Diagram of Biosensor System>



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NAME	DATE
Peggy Pei	11/2/2022

EQUIPMENT	Website: ADC0808 Pinout, How to Use & Datasheet (components101.com) MIKROE-55 Mikroelektronika, LCD Module, 2 x 16 Character with Blue Backlight | Farnell HW-060B 1602 LCD 5V Yellow-green Screen IIC I2C Interface Module 1602 LCD Display Adapter Board Sale - Banggood UK home automation - How can one control AC power (220V) with a Raspberry Pi? - Raspberry Pi Stack Exchange Control Raspberry Pi Wireless Sockets (433MHz) - Tutorial (tutorials-raspberrypi.com)
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	*PT meeting* 1. Consider other advanced signal generator(Electromagnetic field +membrane) that can take place Fan and loudspeaker. (Continue later) 2. Temperature impact on Pneumotachometer does not have the linear relationship with flow rate, consider add a heater to provide the constant temperature in control system, which may also need to consider high voltage risk(220v above) Heating cable(2-3m) wrap around device, switch could be controlled by micro-controller. How to use Pi to generate 220v? Mechanical Relay: Single Channel Relay for Raspberry Pi Pico– The Pi Hut Solid State Relay – SSR can be used as power supply switch which is safer and easier to operate compared to mechanical relay. **Wireless switch controlled by raspberry pi, need a** Programmable smart socket ie: ikea.com/gb/en/p/tradfri-wireless-control-outlet-00364477 Further to read: Rasp Pi as a Remote Control Device » Raspberry Pi Geek (raspberry-pi-geek.com) 3. Voltage amplifier is needed if choose to drive fan or loudspeaker. (With Q1, continue later) Extend: 4. Display embedded in raspberry pi LCD display on chips: **MIKROE-55** **LCD1602+ I2C interface (chosen)** ADC 0808: 8 bit, 8 channel analogue signal supported

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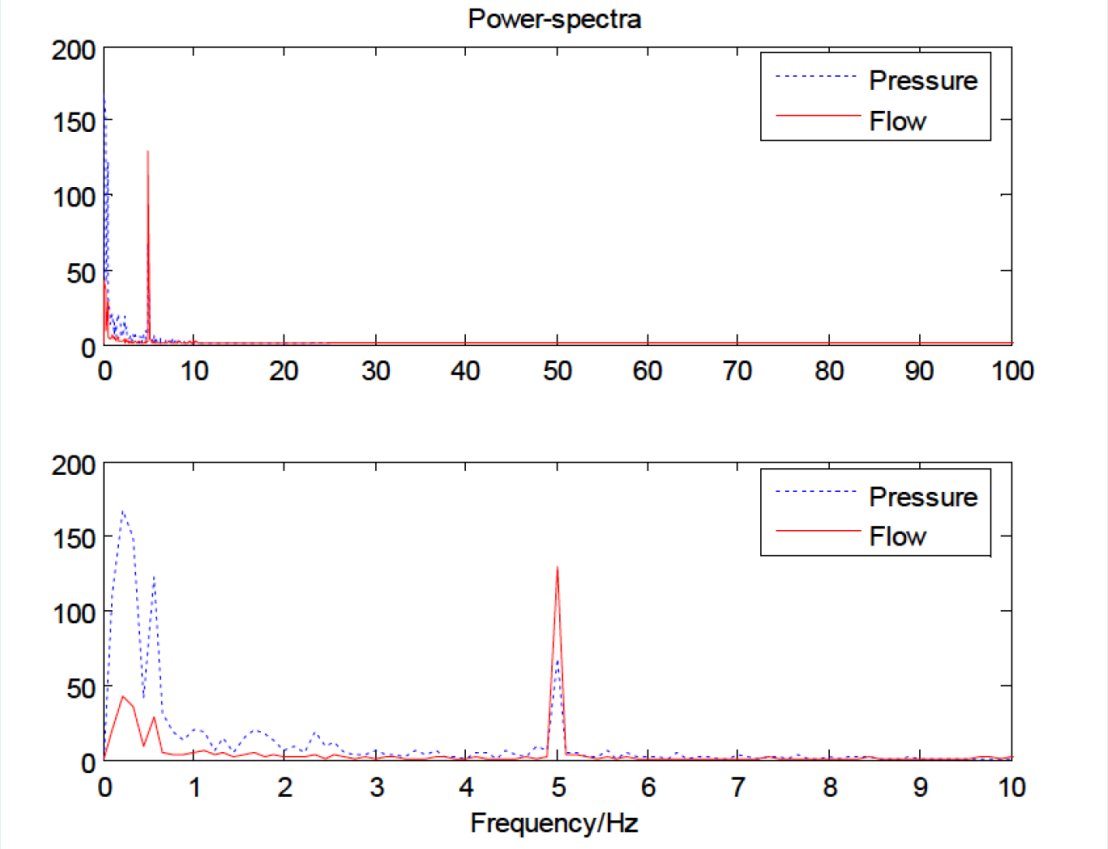
NAME	DATE
Peggy Pei	15/2/2022

EQUIPMENT	**Paper:** *Journal of Advances in Biomedical Engineering and Technology*, 2016, *3*, 14-20 **Website:** 3D Printed Linear Voice Coil Actuator (Open Source) - Bing video
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Paper: To overcome this problem, Dubois and his colleagues in 1956 first introduced the forced oscillation technique (FOT) as an alternative method for measuring respiratory resistance, which does not require active cooperation of the test subject (Check this paper later: Scott B, Jonathan P, Burton L, *et al*. Impulse oscillometry: interpretation and practical applications. J Chest 2014;146(3): 841-847.) VCA(Voice coil actuator)- expensive but accurate compared to solenoid. DSP- Simulink supported with DSP system toolbox(Check tutorial on: Get Started with Audio Signal Processing Using Raspberry Pi - MATLAB & Simulink Example - MathWorks United Kingdom) The spectrum waveform of flow and pressure signals before digital filtering:  All the effective components relevant to respiratory system impedance estimation are below 20Hz, LPF needs to filter out high-frequency and power-line noise interference. Airway resistance calculation:

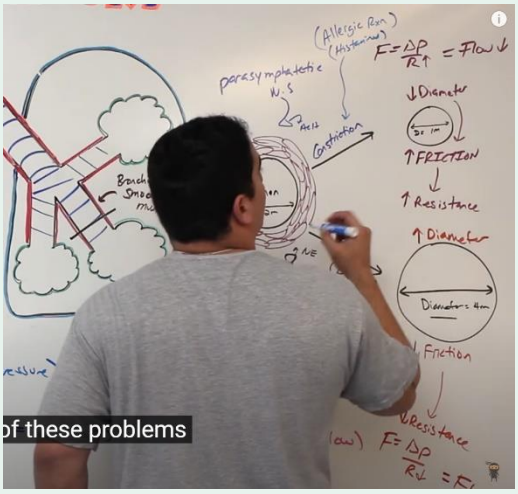
The respiratory system impedance is then expressed in the form of respiratory system resistance (Rrs) and reactance (Xrs) as :

$$|Z_{rs}| = \sqrt{R_{rs}^{\ 2} + X_{rs}^{\ 2}} \quad (10)$$

$$\varphi_{rs} = \tan^{-1} \frac{X_{rs}}{R_{rs}} \quad (11)$$

Therefore,

$$Rrs = Z\cos\varphi$$
$$Xrs = Z\sin\varphi \quad (12)$$



Rrs- viscous resistance of the airways and the lung tissues

Xrs-the elastic and inertial resistance of the airways and the lung tissues.

(Check some medical materials and figure out how doctor diagnose with airway resistance)

A video link attached: Respiratory | Airway Resistance - YouTube

A blog contains normal value to compare:

Oscillometry – The future of estimating pulmonary functions - Karnataka Paediatric Journal (iap-kpj.org)

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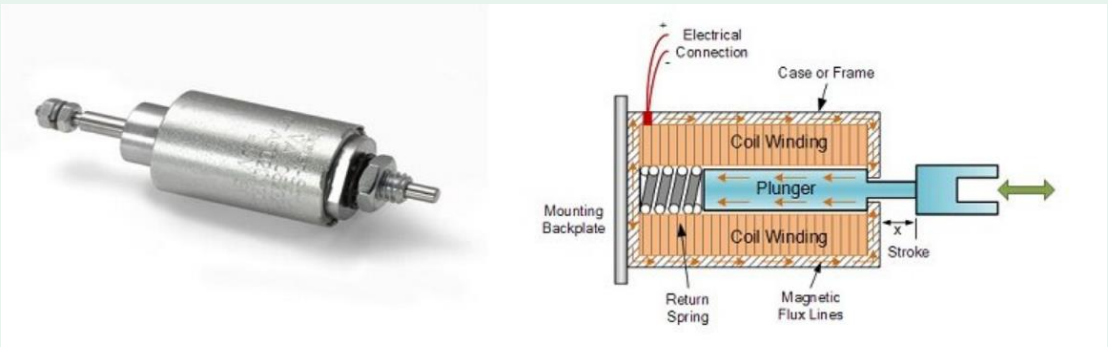
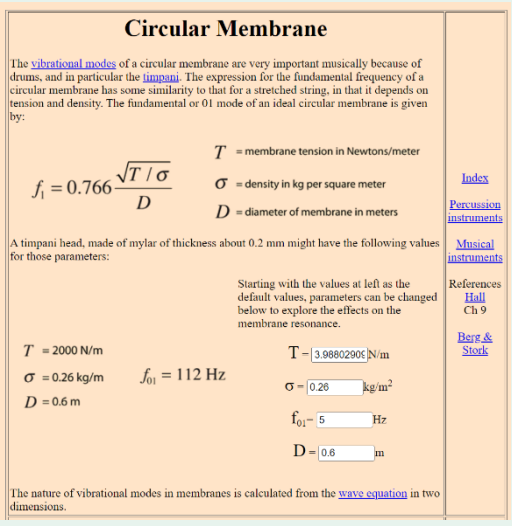
NAME	DATE
Peggy Pei	16/2/2022

EQUIPMENT	Website: Linear Solenoid Actuator (emworks.com) The Circular Membrane Problem (trinity.edu) Circular Membrane Modes (gsu.edu) Circular Membrane (drum head) Vibration - Bing video
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	*Linear solenoid actuator:* An electromagnetic device that converts electrical energy into a mechanical pushing or pulling force or motion.  ***Figure 1** - Electromechanical Solenoid* Cost: 5~10£/each , DC drive, ideal to be 6v 350mA. *Vibrations of a circular membrane*  **Circular Membrane** The vibrational modes of a circular membrane are very important musically because of drums, and in particular the timpani. The expression for the fundamental frequency of a circular membrane has some similarity to that for a stretched string, in that it depends on tension and density. The fundamental or 01 mode of an ideal circular membrane is given by: $f_1 = 0.766\frac{\sqrt{T/\sigma}}{D}$ T = membrane tension in Newtons/meter σ = density in kg per square meter D = diameter of membrane in meters A timpani head, made of mylar of thickness about 0.2 mm might have the following values for those parameters: T = 2000 N/m σ = 0.26 kg/m D = 0.6 m f_{01} = 112 Hz Starting with the values at left as the default values, parameters can be changed below to explore the effects on the membrane resonance. T = 3.98802906 N/m σ = 0.26 kg/m² f01 = 5 Hz D = 0.6 m The nature of vibrational modes in membranes is calculated from the wave equation in two dimensions. Index Percussion instruments Musical instruments References Hall Ch 9 Berg & Stork *The membrane tension(In this case, provided by solenoid actuator)*, defined as the force per unit length acting on a **cross-section** of membrane

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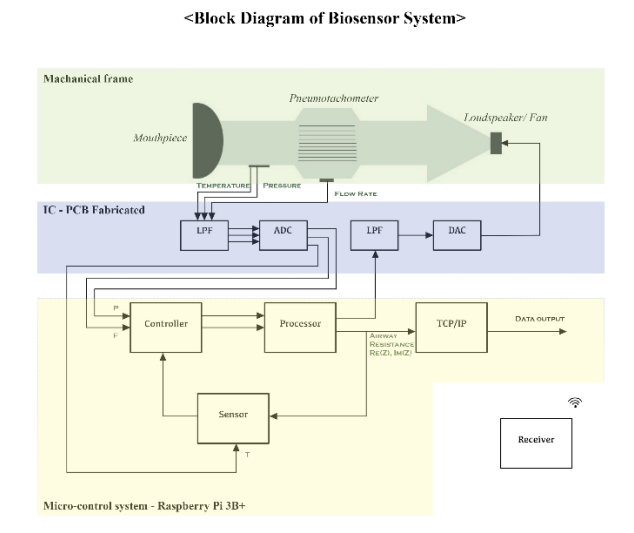
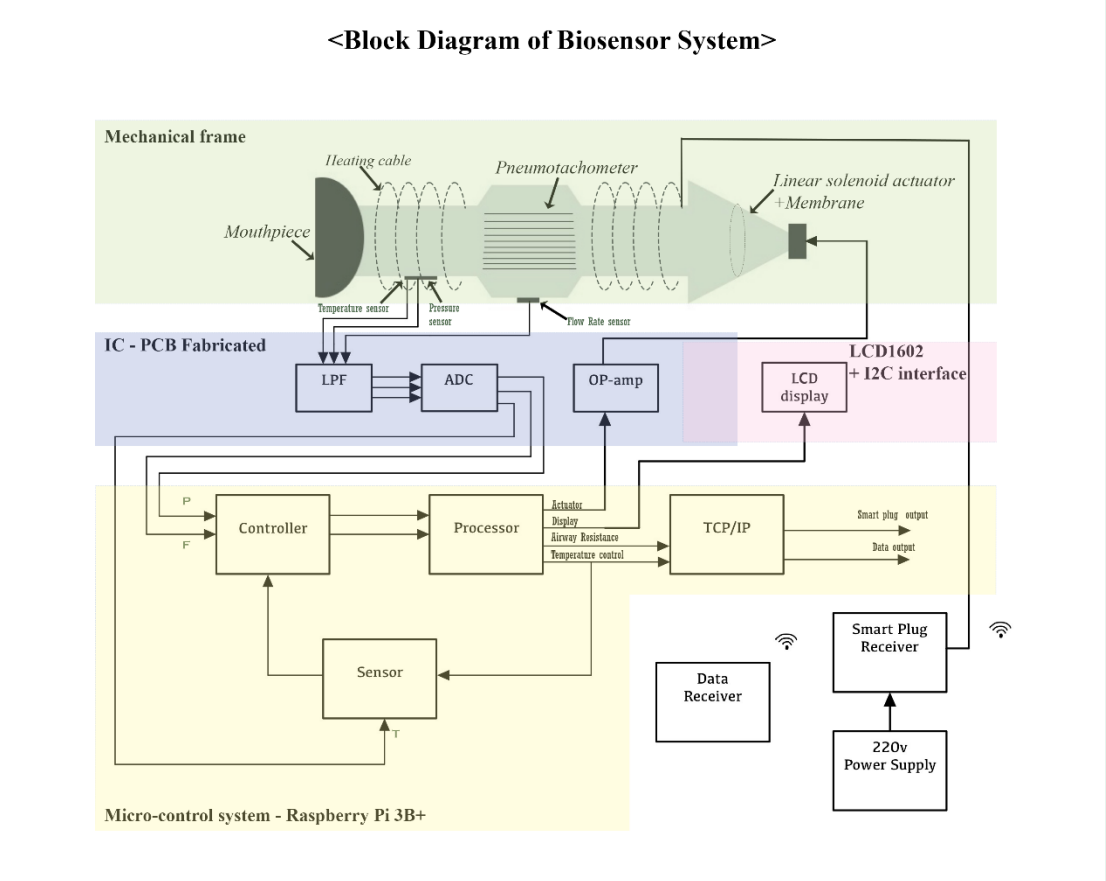
NAME	DATE
Peggy Pei	17/2/2022

EQUIPMENT	Notability, photoshop
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Initial block diagram:  2nd Block Diagram: 

	Modification: 1. Use linear solenoid actuator and a circular membrane to generate AC. 2. Shape of signal generator is changed. 3. DAC and LPF then are cancelled out as solenoid needs DC 6-12v(prefer 6v). 4. Add heating cables incorporated with the temperature sensor. Temperature difference could be diminished between inside and outside of the tube to prevent vapour condensing on sensors that results in inaccuracy of pneumotachometer. 5. Add multiple TCP/IP. As the operation voltage of heating cables is 220v(high voltage), which may cause critical risks if heating cables are directly connected with IC and microprocessor. Therefore, remote control is attempted. IP address of a Smart plug connected by WIFI can be obtained so that TCP/IP protocol of raspberry pi is executed for remoting control of this high voltage. 6. Add LCD display, LCD1602+ I2C interface is chosen. Question: 1. How to use LSA and membrane to generate a sinusoidal AC? 2. Can microprocessor provide power supply for signal generator?(with op-amp) 3. How to integrate power supply for whole system? Cost updated: (To be continued)

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NAME	DATE
Peggy Pei	18/2/2022

EQUIPMENT

Website:

Cables

Time 3094Y White 4-Core 0.75mm² Heat Resistant Cable 10m Coil | Cable | Screwfix.com

White 0.75mm 5 Core 3095Y (H05V2V2-F) Round Heat Resistant Flexible Cable flex | eBay

Smart plug:

TRÅDFRI, Wireless control outlet - IKEA

LCD1602+ I2C interface

HW-060B 1602 LCD 5V Yellow-green Screen IIC I2C Interface Module 1602 LCD Display Adapter Board Sale - Banggood UK

LSA

DC DC 4.5V, 40 g/2 mm Solenoid Electromagnet, Saim Open Frame Actuator Linear Mini Push Pull Solenoid Electromagnet 2PCS : Amazon.co.uk: Business, Industry & Science

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Resource list)*

Cost of new resources

Equipment	Cost
Heating cables	4 cores: £6.22/10m 5cores: £14.44/10m
Smart plug	£12/each
LCD1602+ I2C interface	£3.3/each
Linear solenoid actuator	4.5v £6.4/two
Membrane	*

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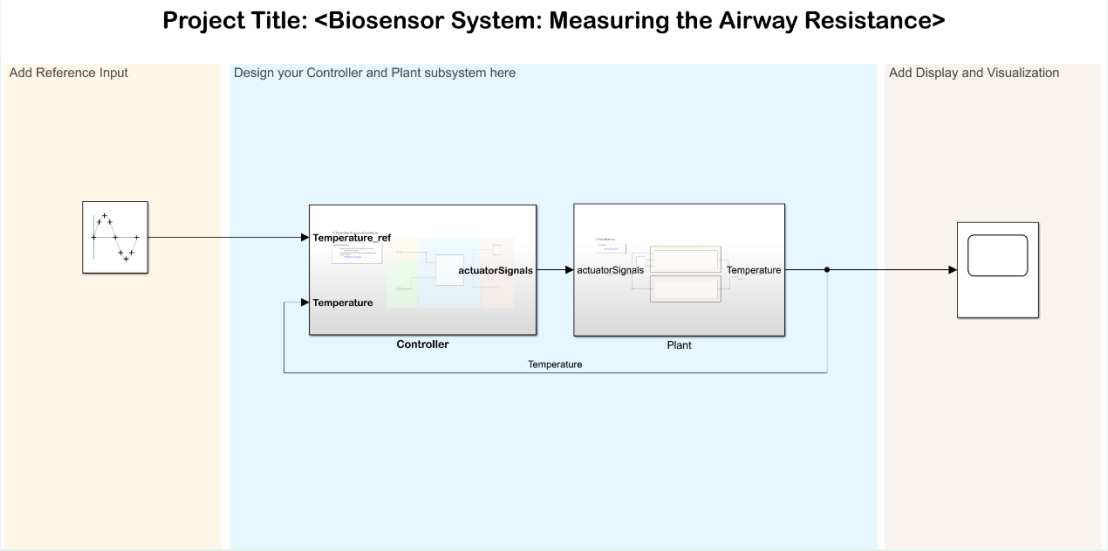
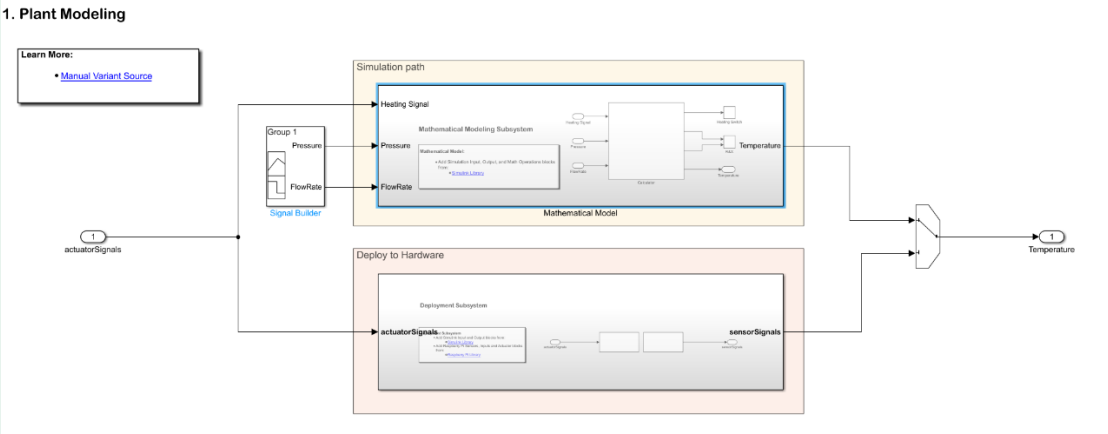
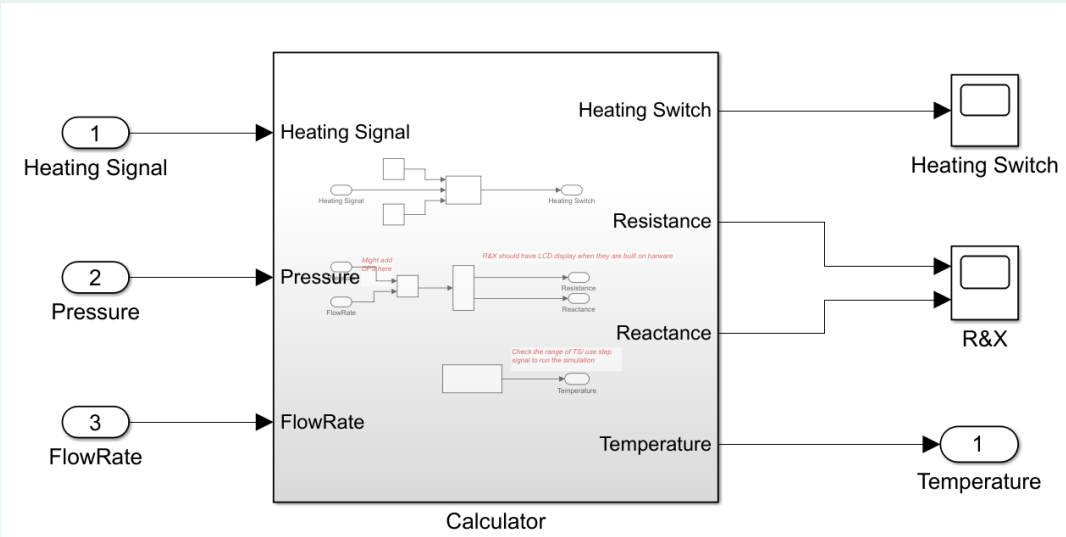
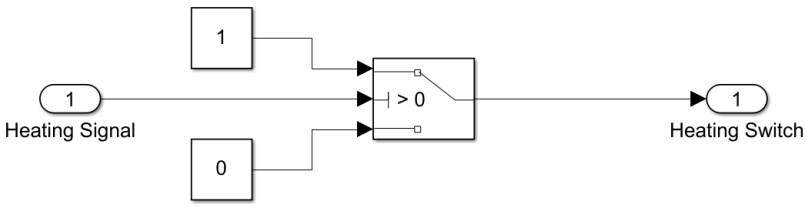
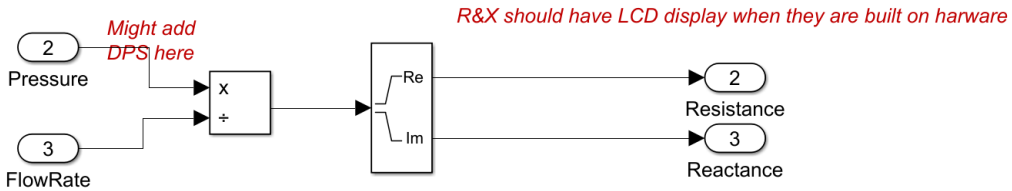
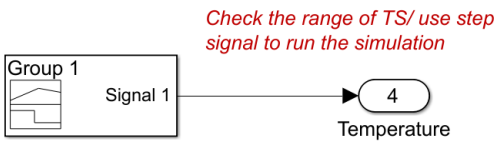
NAME	DATE
Peggy Pei	23/2/2022

EQUIPMENT	MATLAB
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	**Question:** **1. Revise the reference for real data of FOT device** Temperature sensor: Pressure: Flow rate: **2. Revise the structure of control systems in previous project(Mini drone)** PID components Controller- Temperature control system Plant- Calculate the resistance and reactance+ display Initial design (For simulation):  


1
Heating Signal
Heating Signal
2
Pressure
Pressure
3
FlowRate
FlowRate
Heating Switch
Resistance
Reactance
Temperature
Heating Switch
R&X
1
Temperature
Calculator


1
1
Heating Signal
| > 0
0
1
Heating Switch


Might add
DPS here
R&X should have LCD display when they are built on harware
2
Pressure
3
FlowRate
x
÷
Re
Im
2
Resistance
3
Reactance


Check the range of TS/ use step
signal to run the simulation
Group 1
Signal 1
4
Temperature

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NAME	DATE
Peggy Pei	24/2/2022

EQUIPMENT	MATLAB PAPER: **Portable Forced Oscillation Device for Point-of-care Pulmonary Function Testing*** Jian Cao, Ashutosh Sabharwal, Fellow, IEEE
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	*Reference data* **Temperature:** pneumotaches are more or less at room temperature this means that the water vapor in exhaled air can condense on the resistance element (screen or tubes). Condensation acts to increase the resistance through the pneumotach and at least one study showed that after a series of exhalations expiratory volume can be overestimated up to 7% because of condensation. Solution: Heating cables heat the tube before ex/inhalation Lung temperature: 37C Room temperature 20C Thermistor Equation $B_{(T1/T2)} = \frac{T_2 \times T_1}{T_2 - T_1} \times \ln\left(\frac{R_1}{R_2}\right)$ Where: T_1 is the first temperature point in Kelvin T_2 is the second temperature point in Kelvin R_1 is the thermistors resistance at temperature T1 in Ohms R_2 is the thermistors resistance at temperature T2 in Ohms NTC temperature sensor may need an amplifier as current is always below uA. **Pressure& Flow Rate:** Low frequency 5HZ Why: By converting the entire signal into the frequency domain, we observe that breathing noise and its higher harmonics are mainly below 2 Hz, whereas the excitation signals are greater than or equal to 5 Hz. Thus, we use a 3rd order Butterworth filter to separate the excitation signal from the breathing noise ultrasonic flow sensor against a series of standard sine waves generated by the PWG device, with a frequency between 0:25 Hz and 0:5 Hz and an amplitude from 0.5L/s to 2.0L/s to approximate real tidal breathing frequency and amplitude.

$$Z_{rs}(f)=\frac{P_{rs}(f)}{V_{rs}(f)}=R_{rs}(f)+iX_{rs}(f), f\in[f_{min}, f_{max}], \quad (1)$$

where R_{rs} corresponds to the frictional force exerted on airflow by the airway, and X_{rs} represents the elastic and the inertial components of respiratory system [5]. Fig. 1

Oscillatory pressure waves = AC (Loudspeaker/ fan/ solenoid actuator)-

Data from past FOT paper/test(Expect to get)

of Rrs and Xrs appeared to be reasonably consistent with the physiological values as predicted. Through the calculated, the average of the Rrs is 4.61±1.33 $cmH_2O{\cdot}s{\cdot}L^{-1}$, Xrs is -4.12±1.79 $cmH_2O{\cdot}s{\cdot}L^{-1}$, similar to the published artical results of Rrs is 4.55±0.97 $cmH_2O{\cdot}s{\cdot}L^{-1}$and Xrs is -3.16±1.36 $cmH_2O{\cdot}s{\cdot}L^{-1}$ [11].

1 kPa = 101.97442889221 mmH2o. 0.1KPa~=1cmH2O

We tested the accuracy of the device by measuring two mesh screen type mechanical models with calibrated resistive load of *2.5cmH2O/L/s, 10.0cmH2O/L/s* (Hans Rudolph Inc), that approximated the

Variable	Reference	Simulation Setting
Temperature	Pneumotach accuracy | PFTBlog (pftforum.com)	Constant (Tref= 37C), Measuring the current
Pressure	Portable Forced Oscillation Device for Point-of-care Pulmonary Function Testing* Jian Cao, Ashutosh Sabharwal, Fellow, IEEE	Sinewave, Amplitude:+- 0.2Kpa, 0.5HZ
Flow rate		Sinewave, Amplitude: +- 0.5L/s, 0.5HZ

resistance value of healthy adults and COPD patients.

ADC MCP3008

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NAME	DATE
Peggy Pei	25/2/2022

EQUIPMENT	Website: Analog Input Using SPI - MATLAB & Simulink Example - MathWorks United Kingdom
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	*Data transfer interface of Raspberry pi* Raspberry pi has ***Serial, SPI and I2C*** interfaces for data transfer. **Serial :** The Serial interface on Raspberry Pi has receive (Rx) and transmit (Tx) pins for communication with serial peripherals. **SPI :** Serial Peripheral Interface (SPI) is a synchronous serial data protocol used for communicating with one or more peripheral devices. in an SPI connection, there are five pins on Raspberry Pi for SPI interface : ▪ **MISO (Master in slave out)** – Master line for sending data to the peripherals. ▪ **MOSI (Master out slave in)** – Slave line for sending data to the master. ▪ **SCK (Serial Clock)** – Clock generated by master to synchronize data transmission ▪ **CE0 (Chip Enable 0)** – To enable or disable devices ▪ **CE0 (Chip Enable 1)** – To enable or disable devices **I2C :** The I2C interface pins on Raspberry Pi allow you to connect hardware modules. I2C interface allows synchronous data transfer with just two pins – **SDA (data line)** an **SCL (Clock Line)**. SPI: SPI is a synchronous, full duplex master-slave-based interface. The data from the master or the slave is synchronized on the rising or falling clock edge. Both master and slave can transmit data at the same time. *MCP3008 is a 10-bit, 8-channel analog to digital converter (ADC) with an SPI interface.* I2C: Inter-Integrated Circuit (I2C) is a protocol for communicating with low-speed peripherals. Depending on the model and revision of your board, Raspberry Pi™ hardware has one or two I2C buses. Each bus has an I2C Central connected to two bidirectional lines, serial data line (SDA), and serial clock (SCL). These two lines are connected to a pair of pins, such as I2C1_SDA (GPIO2) and I2C1_SCL (GPIO3), on the GPIO header *Related to hardware design*

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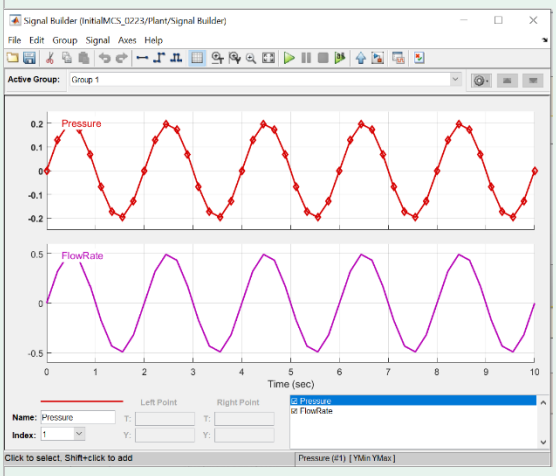
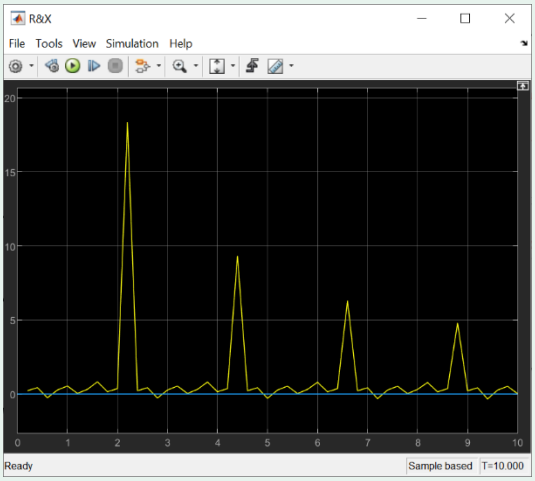
NAME	DATE
Peggy Pei	1/3/2022

EQUIPMENT	Website:
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	**Signal generate in Simulink:** Normal sine wave function can only generate real signal.   Use NCO function: Generate real or complex sinusoidal signals - Simulink - MathWorks United Kingdom s **DSP in Simulink:** **How to connect LCD display in Simulink on raspberry pi?** I2C interface Digital temperature sensor TMP102(Read Temperature from TMP102 sensor - MATLAB & Simulink Example - MathWorks United Kingdom) also needs I2C interface. (TMP102 datasheet: TMP102 Low-Power Digital Temperature Sensor With SMBus and Two-Wire Serial Interface in SOT563 datasheet (Rev. H) (ti.com)) Solution: Use LCD1602 only, which needs extra coding for initializing LCD display.

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NAME	DATE
Peggy Pei	2/3/2022

EQUIPMENT

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

Impedance estimation algorithm

Since the portable device has relatively lower SNR compared to large commercial devices, we estimate the respiratory impedance using cross- and auto-spectrum rather than directly compute the ratio of FFT to improve the estimator's performance against noise [14].

$$\hat{Z}(f) = \frac{P(f) \cdot V^*(f)}{V(f) \cdot V^*(f)} = \frac{G_{PV}(f)}{G_{VV}(f)}, \qquad (2)$$

where G_{PV} is the cross-power spectrum between oscillatory pressure and flow, and G_{VV} is the auto-power spectrum of flow. G_{PV}, G_{VV} are computed using Welch's averaged periodogram method [16]. The window length and window

Compare 2 approaches:

1. Directly calculate FFT to compute the impedance.
2. Use coherence formula to compute the impedance. (FOT-EMBC: low SNR)

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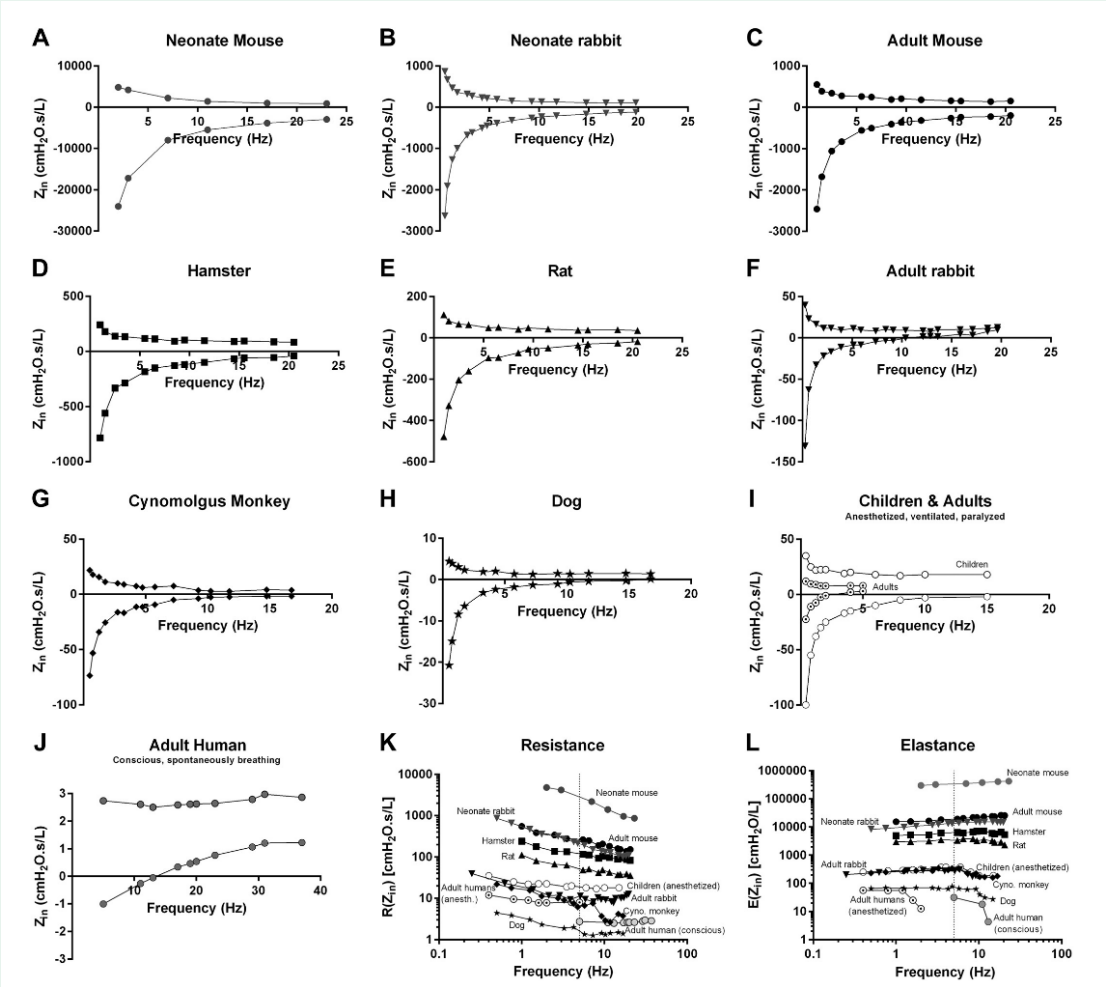
NAME	DATE
Peggy Pei	3/3/2022

EQUIPMENT

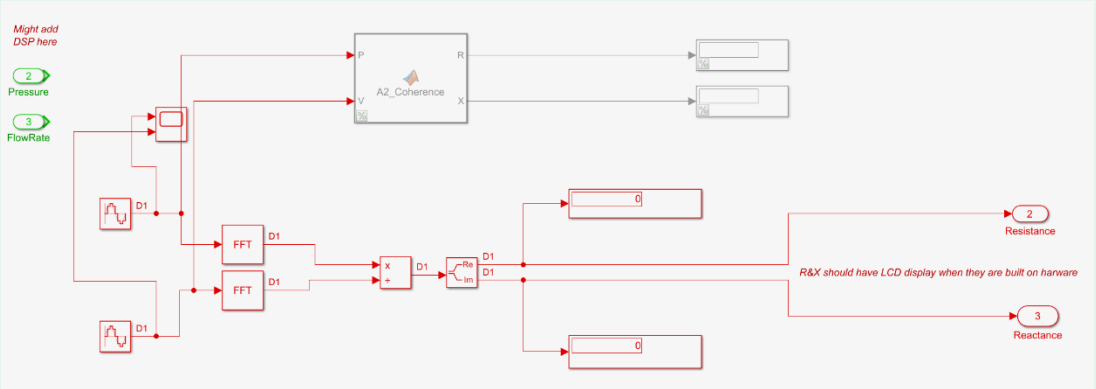
EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

Reference of airway impedance in different species:



Set 2 approaches to compute resistance and reactance, but cannot get proper result:



```
function [R,X] = A2_Coherence(P,V)
        %L= length(P);

        Cpv=cpsd(P,V,hamming(100),80,100);
        Pvv = pwelch(V,hamming(100),80,100);
        Z=Cpv/Pvv;
        R=real(Z);
        X=imag(Z);
```

Problems:

1. Length of input signal is always 1.(Should set discrete sinewave signal here? What is the sample per frame?)
2. Reactance is always 0 (almost)

Would try:

Update settings of input signals.

1. Read windows/ periodograms.
2. Read principle of Airway resistance again.
3. Use Matlab coding to verify whether whole logic is correct instead of Simulink.

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	4/3/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Auto power spectrum & Cross power spectrum The Autopower Function… Demystified! (siemens.com) (watch later) PT meeting 1. Figure out signal model for lung function 2. Build up an electrical model for impedance measurement.(Simulink have electrical components, may be check help for it firstly before using LT SPICE) 3. Read more oscillometry.

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	8/3/2022

EQUIPMENT

Paper:

Rajagiri A, Diong B:Evaluation of Augmented RIC Model of Child Respiratory Impedance Based on Impulse Oscillometry Data Proceedings of the IEEE Region 5 Technical Conference, San Antonio, Texas2006, 291-295

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others*

1. Respiratory system:

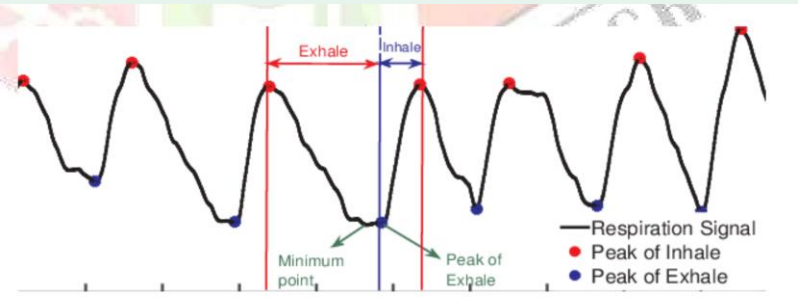


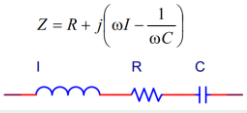
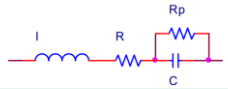
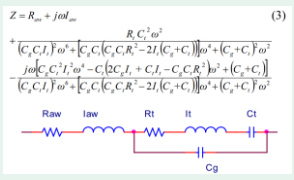
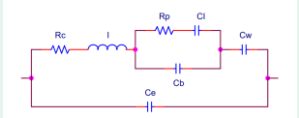
Fig.1. Normal respiration signal [1]

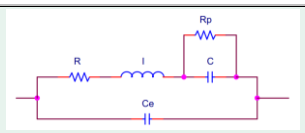
(Respiratory Signal Processing and Monito.pdf)

It is reasonable to use sinewave to represent respiratory signals when running the simulation.

Reactance happens because of phase difference between pressure(P) and flow rate(V).

2. Electrical mode of respiratory system

Comparison for different RIC models		
Model	Diagram	Notes
Basic model	$Z = R + j\left(\omega I - \frac{1}{\omega C}\right)$ 	For the RIC model, estimation of R was a one dimensional linear LS(least squares) optimization problem while two dimensional linear LS optimization was used to determine the I and C values
Extend model	$Z = R + \frac{R_p}{1+(\omega R_p C)^2} + j\left(\omega I - \frac{\omega R_p^2 C}{1+(\omega R_p C)^2}\right)$ 	Rp: the additional peripheral resistance associated with the compliance allows for the frequency dependence observed of typical real impedance data, nonlinear LS algorithm
DuBois model	$Z = R_{aw} + j\omega I_{aw}$ (3) 	Airway and tissue resistance (Raw, Rt) Airway and tissue inertance (Iaw, It) Tissue and alveolar compliance (Ct, Cg) nonlinear LS algorithm
Mead model		nonlinear LS algorithm

Augmented RIC model		nonlinear LS algorithm Ce (see Fig. 5) is intended to model extra thoracic compliance, which is thought to increase the real part of the respiratory system's impedance at the higher frequencies due to upper airways shunt effects, as observed in a significant proportion of the IOS data under analysis

Estimation errors:

it is seen that the augmented RIC model provides the best fit, followed closely by Mead's model, while the RIC model provides the worst fit

Conclusion:

the DuBois model yielded the least estimation errors for the given data sets of normal children and children with asthma. But they are also unrealistic compared to the augmented RIC models.

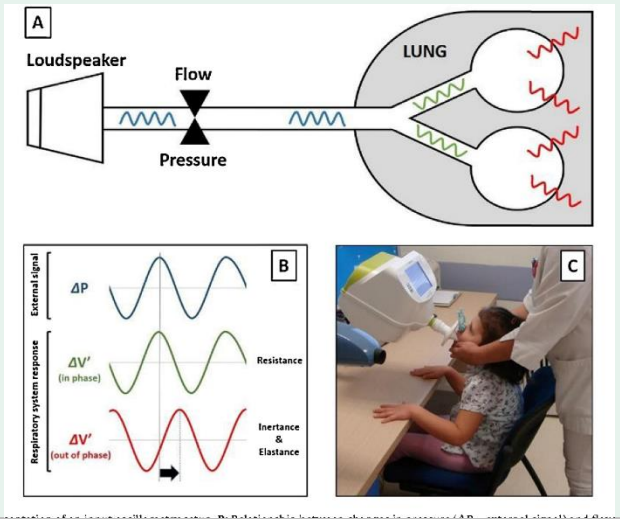
the augmented RIC model's parameter estimates were more in line with what's expected in these patients and normal subjects.

Augmented RIC model is chosen for computing algorithms.

3. Calculate the impedance of a circuit (Fourier transform)
   FFT…(Check syntax)
   Fourier transform at specific frequency (5-30Hz)

   Why there would be a difference between different RIC models?

Specific frequency?



The Forced Oscillation Technique in Paediatric Respiratory Practice. | Semantic Scholar

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	10/3/2022

EQUIPMENT

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

Algorithm for computing respiratory impedance

Function:

1. FFT two input signals(Time domain).
2. Get Z(W) according to :$Z(\omega) = \frac{P(\omega)}{V(\omega)}$.
3. Find the value of peak frequency.
4. Extra real part and imag part of the complex value under peak frequency.

Algorithm:

1. How to do the complex division(MATLAB support) ?

   MATLAB doesn't support complex division, write an extra function.

```
function y=CPXdiv(u1,u2)

a=real(u1);
b=imag(u1);
c=real(u2);
d=imag(u2);

y=CPXdiv((a*c+b*d)/(c^2+d^2)+(b*c-a*d)/(c^2+d^2)*1i);
end
```

   (Not enough input arguments.)

2. How to find peak value?

   'Findpeaks' doesn't work, change the function with 'max'

   Basic logic to find frequency at maximum amplitude for a Fourier series:

```
Fs= 1000;
t = 0:1/Fs:1-1/Fs;

x_t = cos(2*pi*10*t) + 0.5*randn(size(t));
[F1,X_F]= fourier(t,x_t,'sinus');
%ABS=abs(X_F);
[PKS,LOCS]=max(X_F);
disp(PKS)
disp(LOCS)
disp(F1(LOCS))
```

SIGNATURE

Day book - MEng project

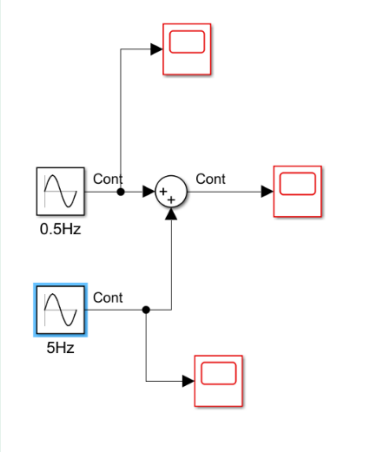
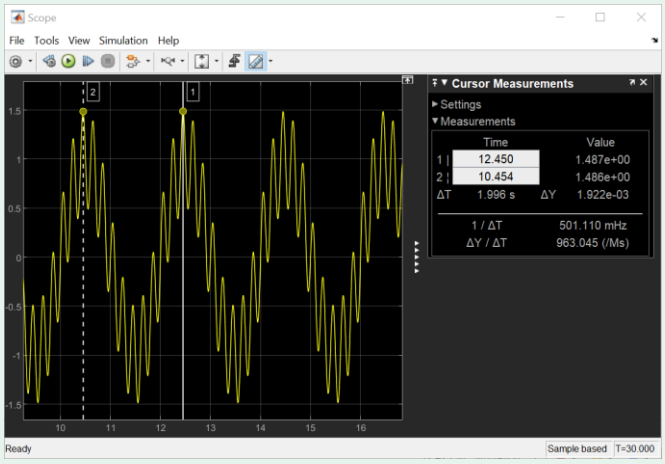
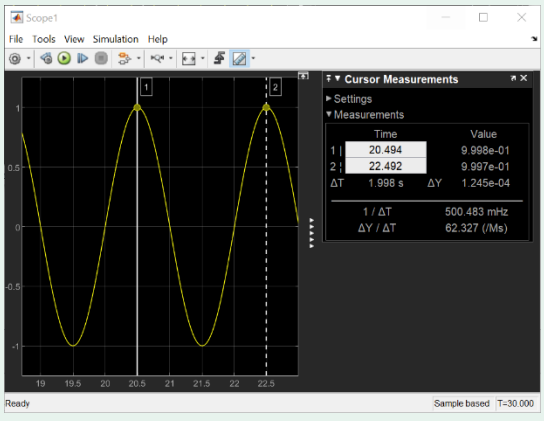
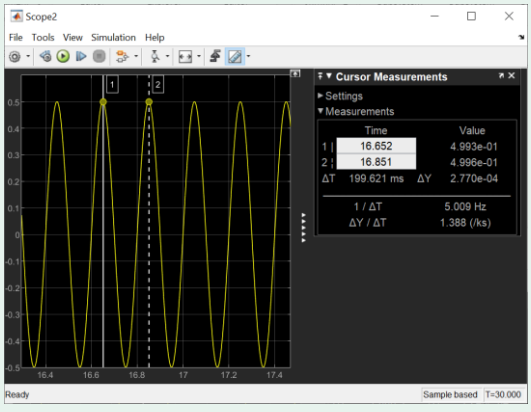
NAME	DATE
Peggy Pei	11/3/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Spontaneous breathing: breathing frequencies, which typically range from 0.1 to **0.3 Hz** with harmonics that could reach **3–10 Hz.** Limitation: Depends much more on different group of people. Ie: height/lung volume. Hardly can be predicted. PT Meeting 1. Pressure contains tidal breath and activating signal .(0.5Hz +5Hz) 2. Flow rate is under desired frequency which is driven by AC generator.(5Hz). 3. Impedance is computed at specific frequencies. (Z(f), f: 5Hz-30Hz) 4. Basic RIC model is used at the very beginning, then different model could be compared at phase 2 stage when have collected enough data. Circuit model is often used for prediction. 5. Fabricated device can be used , extra 3D print need to be considered to integrate every part(heating circuit). 6. Linear solenoid actuator is chosen as the first stage for AC generator. However, principles and airflow dynamics(Bring other impedance for whole system) still are needed to figure out before the end of the 1st phase. 7. Unknown impedances inside of the device have to be considered and declared.

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	15/3/2022

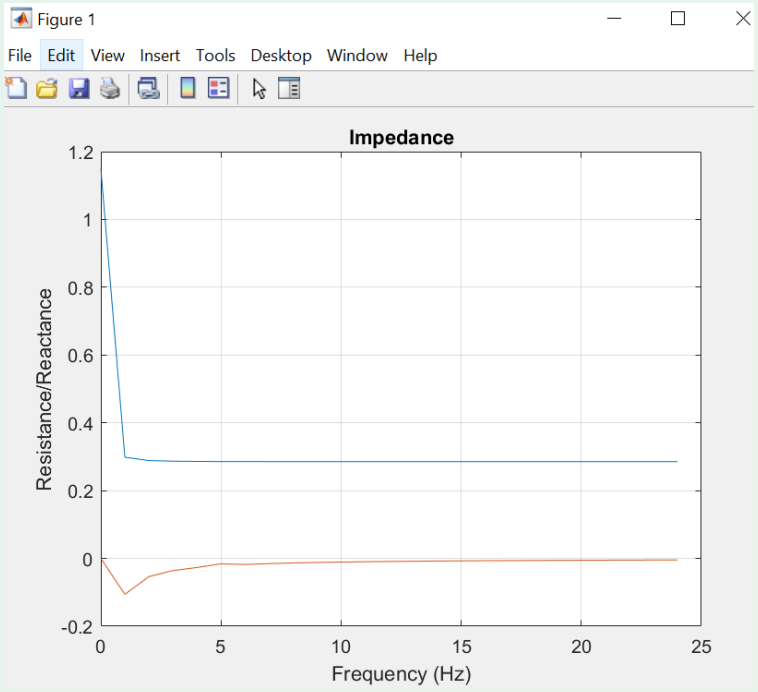
EQUIPMENT	MATLAB
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Simulation Can run on the script but not on the Simulink. Debugging struggle, find help on coding :XX **Are ADC/DAC needed?** Yes, The Raspberry Pi has no analogue GPIO. **Oscillometric generator:** Pressure wave:   Result:   Frequency should be at 0.5Hz(as same as tidal breath)

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	16/3/2022

EQUIPMENT	

EVENT
 	
☐ *Reading materials*
☐ *Laboratory*
☐ *Design*
☐ *Others (Device test)*
	Result on script
	
	Initial test:
	Input
	`p_t = 0.2*cos(2*pi*0.5*t) +0.0005*cos(2*pi*5*t)+0.2*cos(2*pi*0.5*t+1.5*pi);`
	`v_t = 0.6*cos(2*pi*0.5*t)+0.2*cos(2*pi*0.5*t-pi/3);`
	
	Result:
	 
	
	Problem:
	1. Doesn't have 'AX'.
	2. Resistance may get wrong tendency.(Solved- phase shift should be at 2*pi*(180~270)
	
	'The impulses generated by the loudspeaker travel superimposed on normal tidal breathing through the large and small airways, with higher frequencies reflecting back from the large airways to the mouth and lower frequencies traveling deeper into the lung before returning.'
	States that reduce the elasticity of the lung, such as fibrosis and hyperinflation, make capacitance increasingly negative.
	The area of reactance (AX) is another common parameter used in interpreting IOS. AX represents the total reactance (area under the curve) at all frequencies between 5 Hz and Fres. Th is single value, therefore, comprises all the frequencies measured by IOS where the elastic properties of the lung (again, represented by capacitance) dominates over inertance.

	Forced oscillation: MIT 8.03SC Fall 2016 Textbook Chapter 2: Forced Oscillation and Resonance Read tomorrow:(!) OSCILLATION MECHANICS OF THE RESPIRATORY SYSTEM: APPLICATIONS TO LUNG DISEASE (nih.gov)

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	17/3/2022

EQUIPMENT	Paper: Oscillation mechanics of the respiratory system: Applications to lung disease. Kaczka, David W. Dellacá, Raffaele L.
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	FOT advantages: 1. Impedance data, especially when interpreted with models unique to specific physiologic mechanisms and/or pathologic alterations, do provide very unique insight into structure-function relationships; 2. FOT approaches require minimal subject cooperation, a considerable advantage when dealing with pediatric or critically-ill patients. Z is expressed with a magnitude, to account for relative differences in the amplitudes between the sinusoidal pressures and flows, as well as a phase angle, to account for time shifts (i.e., leads or lags) between them. where j is the unit imaginary number, defined as $\sqrt{-1}$. For the respiratory system, resistance arises from the viscous flow of gas through the airways [35], as well as energy losses associated with the deformation of the parenchyma [36] and chest wall [37]. For frequencies below 10 Hz, reactance is comprised of an inertial component (I) due to acceleration of gas in the central airways, as well as an elastic component (E) due to the recoil of the parenchyma and chest wall: $$X(\omega) = \omega I - \frac{E}{\omega} \quad (3)$$ Resonance frequency: impedance would be due solely for resistive losses. For low frequency: At ω_o, the magnitude of impedance will be at a minimum. Over low frequencies (i.e., $\omega << \omega_o$), inertia will have a negligible contribution to impedance, and the reactance will be determined largely by the recoil of the parenchymal or respiratory tissues. In this situation, it is common practice to express reactance as elastance as a function of frequency [38-40]: $$E(\omega) = -\omega X(\omega) \quad (5)$$ If Pao is measured relative to the pressure at the pleural surface (Ppl, often approximated using an esophageal balloon in the living subject)(Use of esophageal balloon pressure-volume curve analysis to determine esophageal wall elastance and calibrate raw esophageal pressure: a bench experiment and clinical study (nih.gov)) $(P_{ao}' - P_{pl})/\dot{V}$ is the input impedance of the lungs alone (Z_L). For frequencies within the commonly used 4-32 Hz band width, this can usually be accomplished with a loudspeaker system with appropriate dynamic response3449, which may be placed in parallel with a mechanical ventilator or other respiratory assist devices50-53.

More recently, low frequency pressure waveform shave been generated with considerable fidelity using a proportional solenoid valve incorporated into a closed-loop system, as this allows for fine control of both mean and oscillatory components of airway pressure.12/40/56

However in awake subjects, such low frequency measurements require considerable training and cooperation to allow complete relaxation of the diaphragm and chest wall muscles383957.

Pressure Measurement:

which may be obtained at the airway opening38, around the body surface31, within the esophagus62, or even within the airways or alveoli63-65.

Be transduced relative to atmosphere by differential sensors.

reluctance transducers/ piezoresistive transducers

Flow measurement:

Pneumotachographs;

of the mesh screen or capillary tube type (Fleisch) variety68.

All pneumotachographs have unique dynamic responses that will systematically distort the measured magnitude and phase of any oscillatory flow, depending on frequency 72.

pneumotachographs may require correction for transducer asymmetry and finite common-mode rejection ratio76.

Signal processing:

1. Directly FFT computing

   Obviously this method becomes quite time consuming, depending on the desired frequency resolution and range, and is impractical for serial impedance measurements to assess the temporal dynamics of a pharmacologic agonist84.

2. Auto/Cross-power spectrum

$$Z(\omega) = \frac{G_{P\dot{V}}(\omega)}{G_{\dot{V}\dot{V}}(\omega)} \qquad \gamma^2(\omega) = \frac{|G^2_{P\dot{V}}(\omega)|}{G_{\dot{V}\dot{V}}(\omega)\, G_{PP}(\omega)}$$

   The advantage of this periodogram approach is that it readily yields the so-called coherence function (γ 2) between flow and pressure at each frequency.

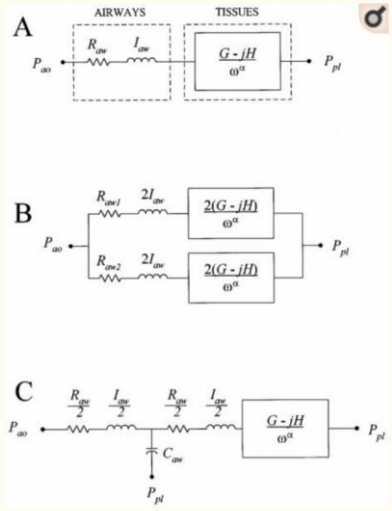
   For the purposes of assessing the quality of impedance data, coherence values less than 0.95 are usually discarded3839.Nonlinearities in the respiratory system may result in a distorted estimate of Z or γ 28889.

3. Optimal Ventilator Waveform (OVW)

   More practical and efficient method for measuring low frequency input impedance in humans.

   In this case the impedance can be obtained from algorithms based on cross-correlation9697, Fast Fourier Transforms5398, or various recursive and non-recursive least square techniques478799-102

Inverse modelling of impedance



Open in a separate window

Figure 5

Various models used to describe oscillatory mechanics of the lungs. (A) Model consisting of homogeneous airways with resistive (R_{aw}) and inertial (I_{aw}) components in series, with 'constant-phase' viscoelastic tissues containing parameters for tissue damping (G) and tissue elastance (H). (B) Inhomogeneous airways model with two separate parallel pathways, each containing distinct airway resistive parameters (R_{aw1} and R_{aw2}) but identical I_{aw} parameters and identical tissue compartments (C) Model containing an airway compliance parameter (C_{aw}) to account for the shunting of oscillatory flow into

Model	Diagram	Notes
Basic model		For the RIC model, estimation of R was a one dimensional linear LS(least squares) optimization problem while two dimensional linear LS optimization was used to determine the I and C values
Extend model		Rp: the additional peripheral resistance associated with the compliance allows for the frequency dependence observed of typical real impedance data, nonlinear LS algorithm
DuBois model		Airway and tissue resistance (Raw, Rt) Airway and tissue inertance (law, It) Tissue and alveolar compliance (Ct, Cg) nonlinear LS algorithm
Mead model		nonlinear LS algorithm
Augmented RIC model		nonlinear LS algorithm Ce (see Fig. 5) is intended to model extra thoracic compliance, which is thought to increase the real part of the respiratory system's impedance at the higher frequencies due to upper airways shunt effects, as observed in a significant proportion of the IOS data under analysis

Otherwise, 5 models collected before would be analysed.

COPD:

Chronic obstructive pulmonary disease (COPD) refers to either **chronic bronchitis, emphysema,** or a combination of the two.

Chronic bronchitis: Chronic productive cough without a discernible cause for more than half the time over a period of two years.

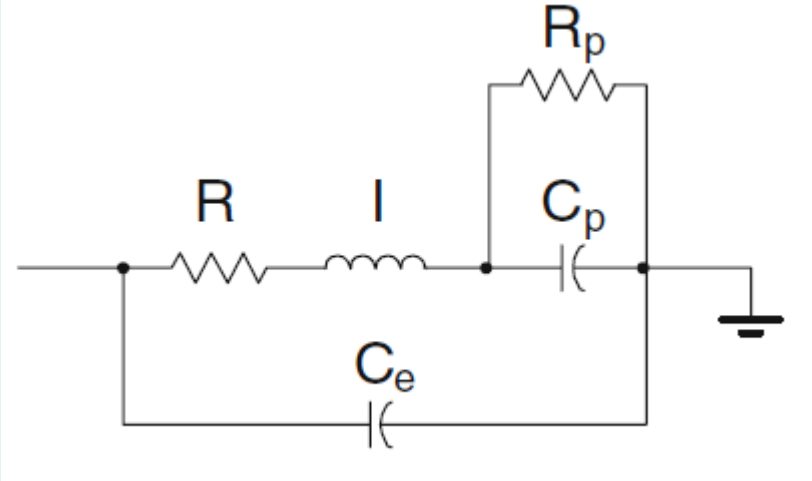
Emphysema is an anatomic diagnosis, characterized by a pathological enlargement of air spaces distal to terminal bronchioles and progressive destruction of the alveolar walls. The reduction in activity of elastase inhibitors, resulting in destruction and disorganization of elastin fibers in the lung.

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	28/3/2022

EQUIPMENT	LT Spice
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Simulate RIC model by LT Spice The aRIC (augmented RIC circuit) model for respiratory system is used to mimic lung function

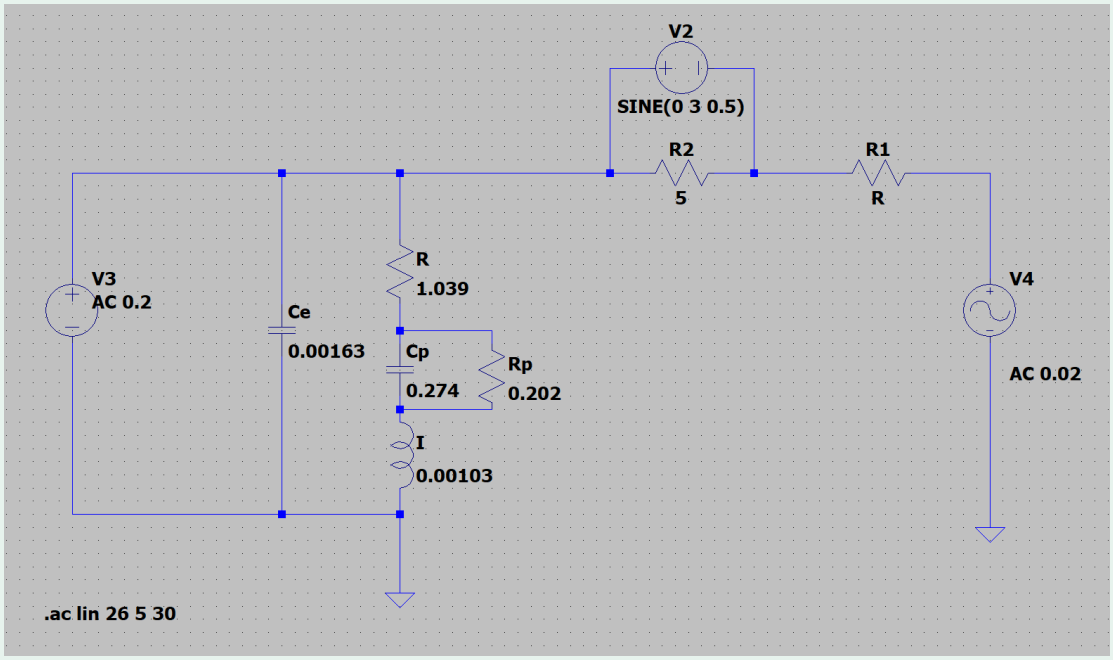


Set initial parameters from previous study:[The_augmented_RIC_model_of_the_human_res]

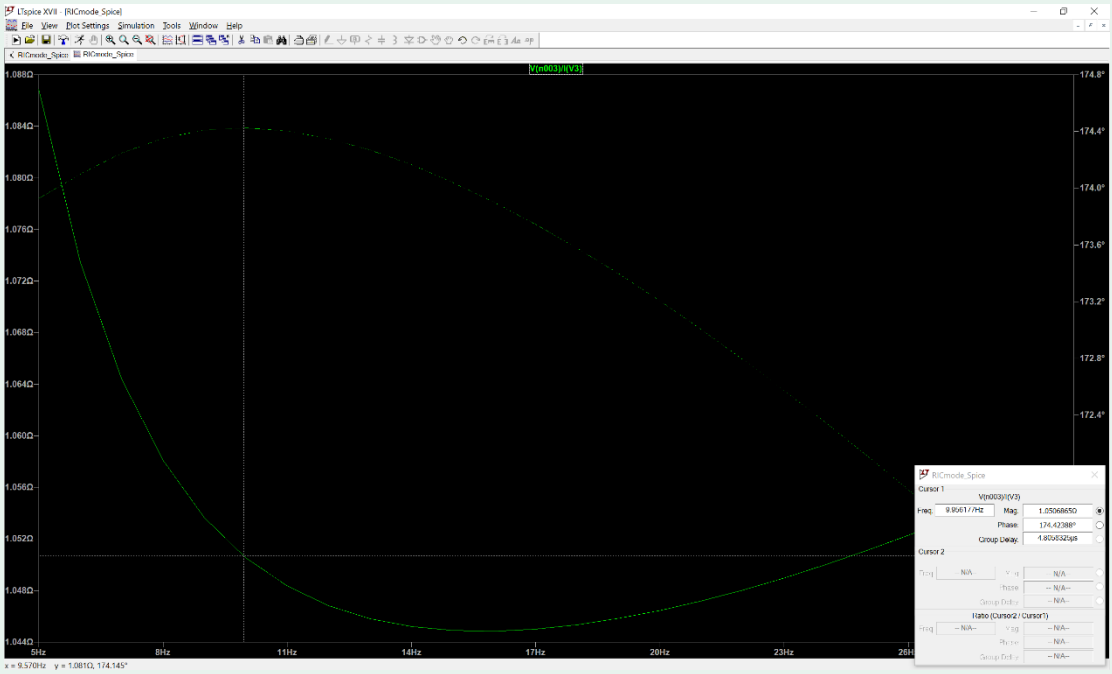
Assume: female, 173cm height

Parameter	Value
V1 (Pressure)	Amp: 0.2kp,f=0.5
R	0.2051
Rp	0.202
I	0.00103
Cp	0.274
Ce	0.00163
V2(Flow)	Amp:3, f=0.5
R2(Resistance of flow)	5
V3(Actuator)	Amp: 0.02,AC F:5~25
R3(Resistance in tube)-not sure	0.004

Final RIC circuit built in LTSpice:



Impedance Measurement:



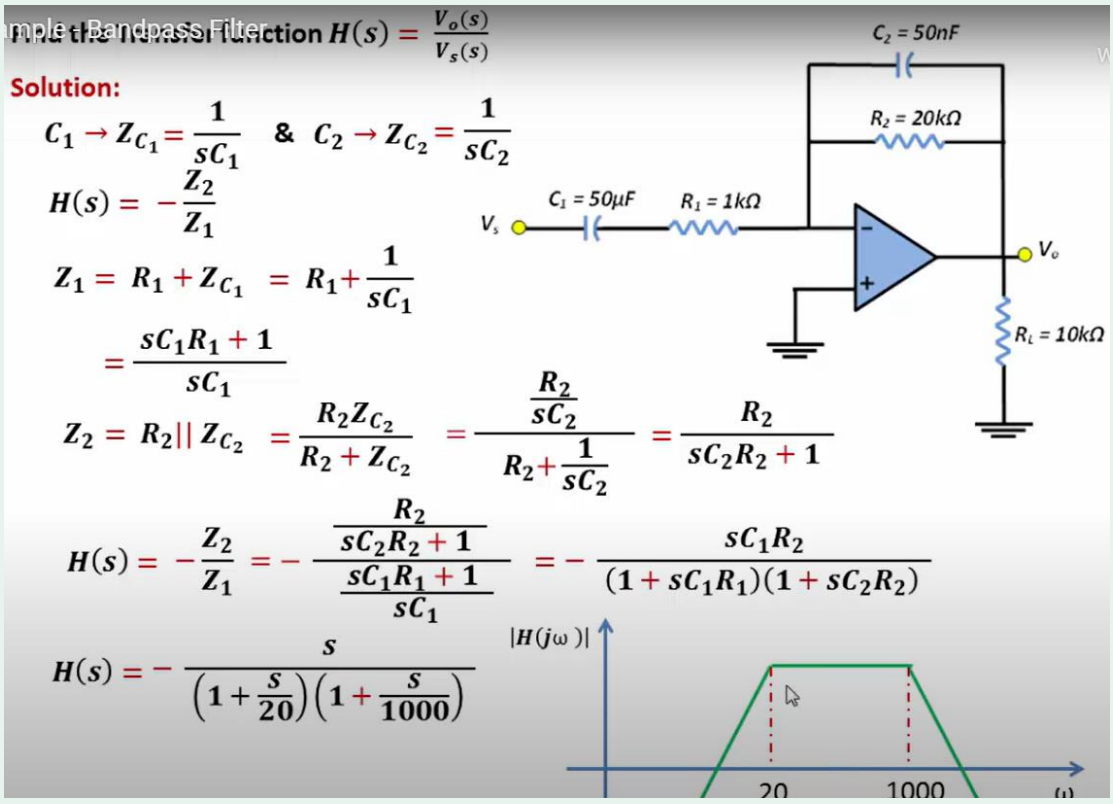
According to trace of phase change, compliance dominants at frequency from 5Hz to 9.96Hz, whereas inertance dominants at frequency from 9.96Hz to 30Hz. Resonant frequency is 9.96Hz in this case.

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	29/3/2022

EQUIPMENT	LTSPICE
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Bandpass +ADC circuit design Requirement: 1. Bandpass filter; 2. Take-up voltage for ADC is 3.3v, considering a proper gain 3. Band: 2-35Hz; 4. 4 orders using Sallen-key Topology , -20dB/dec. Simpler bandpass circuit shown below



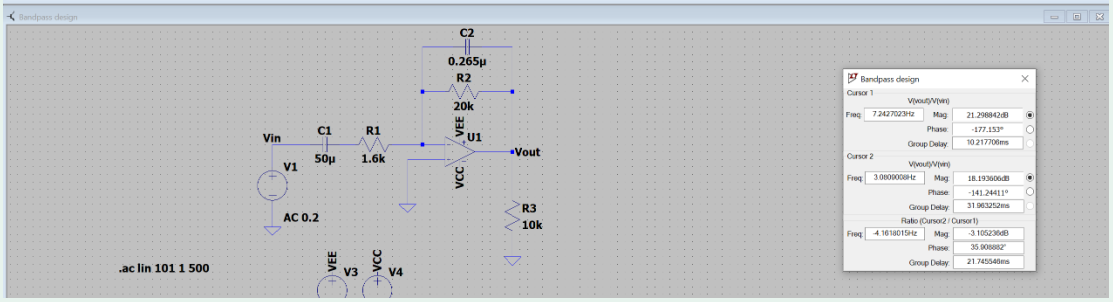
SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	30/3/2022

EQUIPMENT	LTSPICE
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	*Bandpass filter design* Result: (table, images, and text below)

Parameter	Design Value	Simulation Value
F1	2Hz	3.08Hz
F2	30Hz	34.50Hz



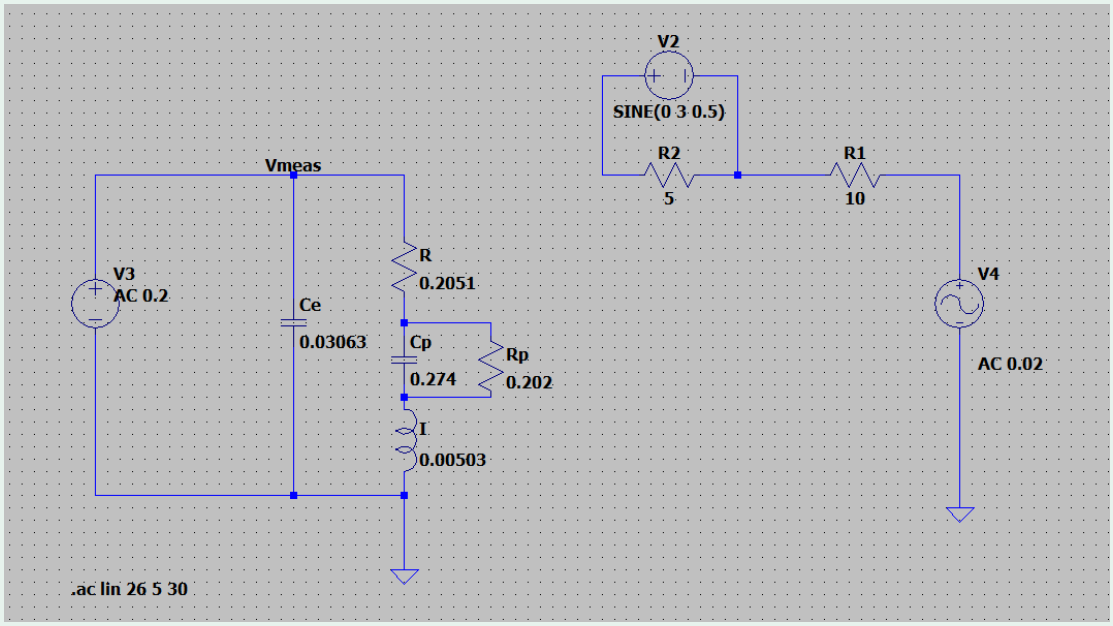
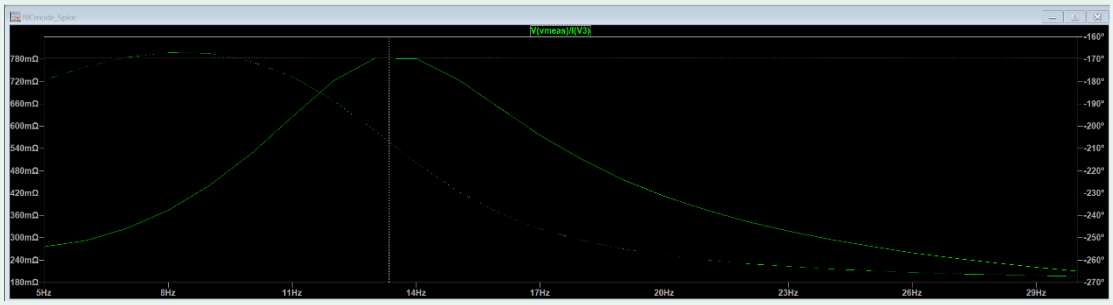
ADC model in Spice

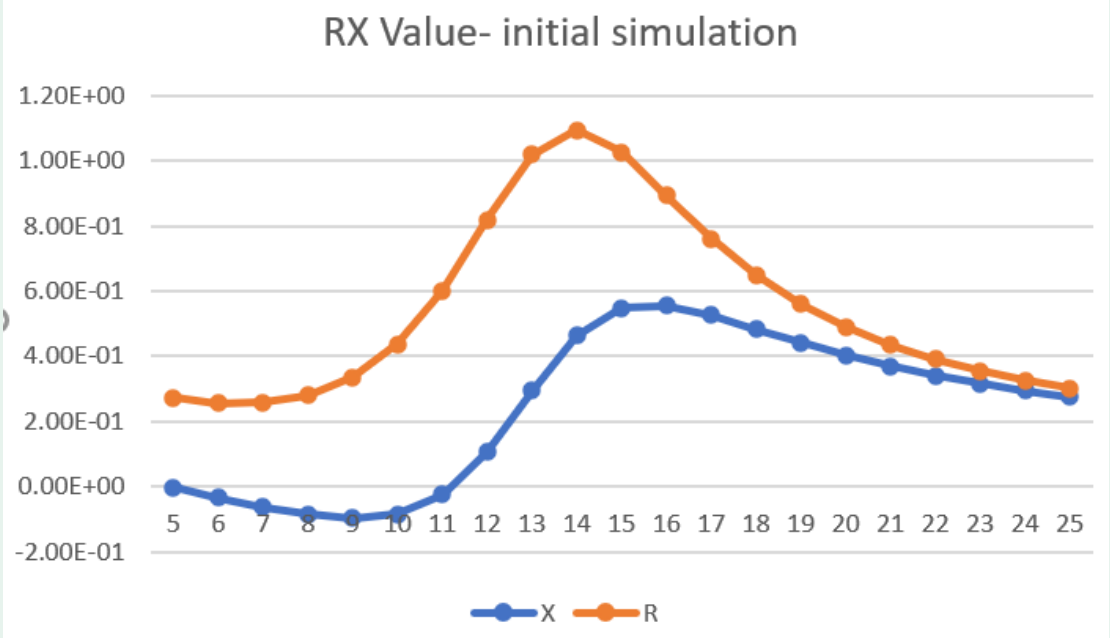
Use specific chip(decided before). Is there any need to simulate in LTSPICE?

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	31/3/2022

EQUIPMENT	LTSPICE
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Simulation for RIC model of measuring respiratory impedance ***Parameter adjustment***   Initial simulation result- Parameters still needs to be change, but trend can be fitted. Resonant frequency is 13Hz, AX area occurs.

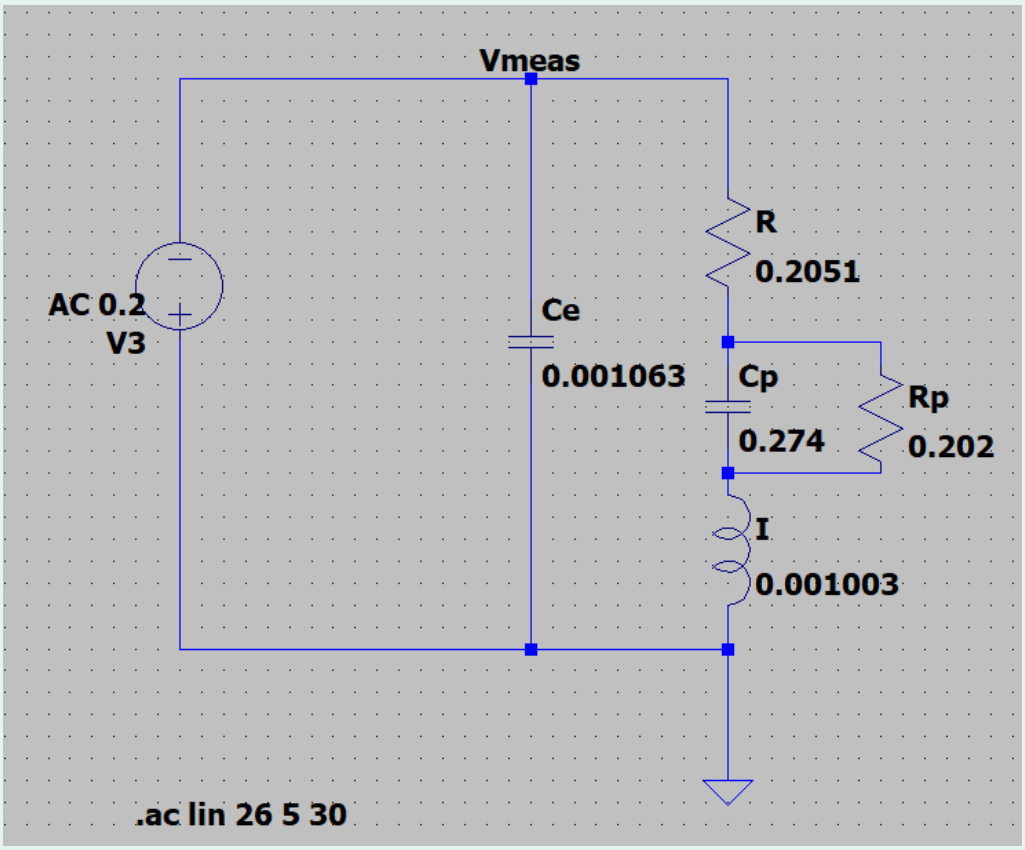

RX Value- initial simulation
1.20E+00
1.00E+00
8.00E-01
6.00E-01
4.00E-01
2.00E-01
0.00E+00
-2.00E-01
5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
X
R

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	9/4/2022

EQUIPMENT	LTSpice
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others*	*Amended Simulation* Problem: Wrong direction for driving voltage in previous simulation. This causes wrong phase computed for impedance.



This simulation has proved that the augmented RIC model (aRIC) could be perfectly fit in theory. Therefore, we will use aRIC model to compute the respiratory impedance in practical.

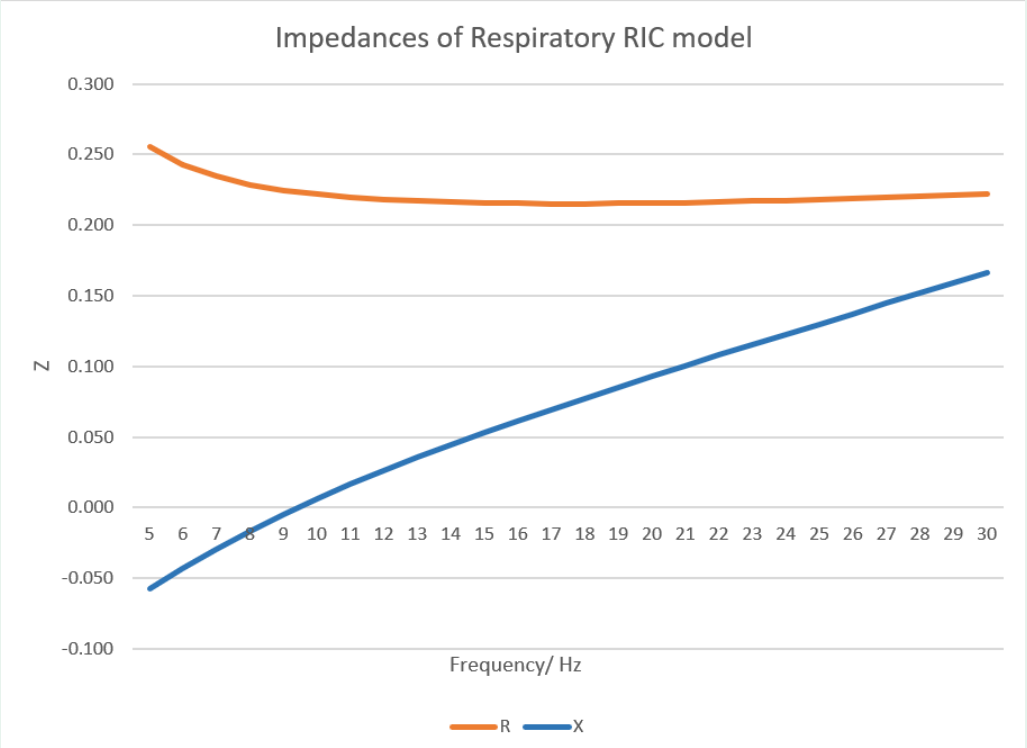
More Simulations could be run to verify effect of each component.

Electrical component	Physiological meaning
R /Ω	Large airway resistance (R in units of cmH2O/l/s or kPa/l/s)
Cp / F	Peripheral airway compliance (C—units of l/cmH₂O or l/kPa)
Rp /Ω	Peripheral airway resistance
Ce / F	Extra thoracic compliance due mainly to upper airways shunt effects
I /H	large airway inertance (I—units of cmH2O/l/s2 or kPa/l/s2)

Unit conversion will be explicitly explained in phase 1 report.

Amended results:

Frequency/Hz	R	X
5	0.255	-0.058
6	0.243	-0.043
7	0.235	-0.029
8	0.229	-0.017
9	0.225	-0.005
10	0.222	0.006
11	0.220	0.016
12	0.218	0.026
13	0.217	0.035
14	0.216	0.044
15	0.216	0.053
16	0.215	0.061
17	0.215	0.069
18	0.215	0.077
19	0.215	0.085
20	0.216	0.093
21	0.216	0.100
22	0.216	0.108
23	0.217	0.115
24	0.218	0.123
25	0.218	0.130
26	0.219	0.137
27	0.220	0.145
28	0.221	0.152
29	0.221	0.159
30	0.222	0.166



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Day book - MEng project

NAME	DATE
Peggy Pei	16/4/2022

EQUIPMENT

LTSpice Excel

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

2nd control experiment:

Compliance effect

What're effects from Cp and Ce?

0.5Ce	AX towards left, min reactance decrease
0.5Cp	AX towards right, min reactance increase
5Ce	AX towards right, min reactance increase
5Cp	AX towards left, min reactance decrease

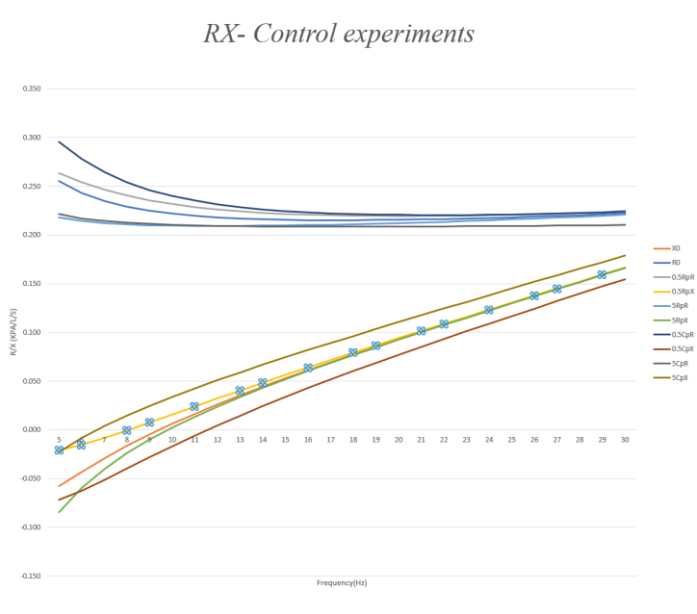
Use excel drawing;(in single graph)

Correction:

Instead of using Ce, we should focus on effects brought by peripheral impedance, Therefore, change variable from Ce Cp to Rp Cp.

0.5Rp	AX towards left, min reactance decrease
0.5Cp	AX towards left, min reactance decrease
5Rp	AX towards right, min reactance increase
5Cp	AX towards right, min reactance increase

According to results given by 2009 study, COPD patients has far more big Cp compared to health person. This result also fits physiological principle that COPD patients do have bigger small airway impedance which is caused by the obstruction of their airways.



Day book - MEng project

NAME	DATE
Peggy Pei	23/9/2022

EQUIPMENT

Website:

[MOOC - FreeRTOS on STM32 - YouTube]

[Getting Started With STM32 and Nucleo Part 3: FreeRTOS - How To Run Multiple Threads w/ CMSIS-RTOS - YouTube]

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

MCU CHOICE

NUCELO-L433RC-P

A single microcontroller cannot be multi-tasking, which means FreeRTOS is needed for the concurrent tasks.

In this project, MCU is designed to handle multitasks as:

-Temperature control

-Sensor data analysis

-Power LS actuator

-USB PD (In the future)

One core, one execution in time.

NUCLEO-L433RC-P **MULTITASK IN TIME**

- The **scheduler** is an algorithm determining which task to execute.
  - Is select one of the task being ready to be executed (in READY state)
  - There are few mechanisms controlling access to CPU for tasks (timeslice, preemption, idle)
- In FreeRTOS **round-robin** scheduling algorithm is implemented
- Round-robin can be used with either **preemptive** or **cooperative** multitasking

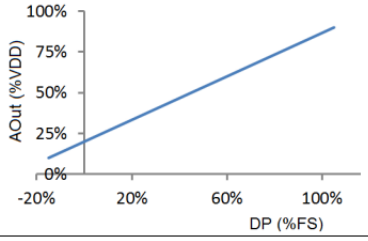
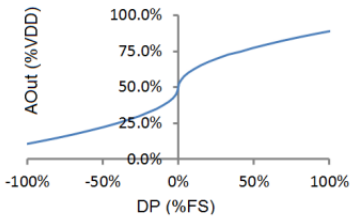
Pressure sensor choice

2608377.pdf (farnell.com)

Bidirectional measurement;

Configuration	SDP806/SDP816-500Pa	SDP806/SDP816-125Pa
Linear	– 50 to 500 Pa (-0.2 to 2 inH$_2$O)	- 12.5 to 125 Pa (-0.05 to 0.5 inH$_2$O)
Square Root	– 500 to 500 Pa (-2 to 2 inH$_2$O)	- 125 to 125 Pa (-0.5 to 0.5 inH$_2$O)

3.1 OCS: Output Curve Selection Input

Config.	Polarity	Description	Conversion to physical values AOut[V], VDD[V], Differential Pressure (DP) [Pa]	
Linear	Low (GND)	Analog output is configured as a linear output. The sensor is not fully bi-directional in this configuration: -10% full-scale to 100% full scale. 	500Pa	$DP = \frac{750 \cdot AOut}{VDD} - 150$
			125Pa	$DP = \frac{190 \cdot AOut}{VDD} - 38$
Square Root	High (VDD)	Analog output is a fully bi-directional output with square root conversion. The benefits are that the bidirectional output has a more stable zero point and higher sensitivity at lower pressures 	500Pa	$DP = sign\left(\frac{AOut}{VDD} - 0.5\right) \cdot \left(\frac{AOut}{VDD \cdot 0.4} - 1.25\right)^2 \cdot 525$
			125Pa	$DP = sign\left(\frac{AOut}{VDD} - 0.5\right) \cdot \left(\frac{AOut}{VDD \cdot 0.4} - 1.25\right)^2 \cdot 133$

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Day book - MEng project

NAME	DATE
Peggy Pei	30/9/2022

EQUIPMENT	STM32-NUCLEO-L433RC-P
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	1. RTOS LED example test Getting Started With STM32 and Nucleo Part 3: FreeRTOS - How To Run Multiple Threads w/ CMSIS-RTOS - YouTube 2. ADC on STM32: Getting Started With STM32 & Nucleo Part 4: Working with ADC and DMA - Maker.io - YouTube Read Sensor value: For both differential pressure sensor & Temperature sensor Use a serial monitor(Give back value) 3. DMA(Direct memory access) Circle store(Make sure data will be stored again when buffer is full.) 4. Fourier transform with HAL on STM32. Only available to F4/F7 series…(Might need to change MCU) MCU requirement lists: 1. OS: RTOS (Multi-task controlling) 2. ADC>=3; 3. DMA>=2; Consider STM32F429I-DISC1 STM32F4 Discovery Board ADC Tutorial with HAL ADC Driver (microcontrollerslab.com) HAL Library 14- Fast Fourier Transform for STM32Fxxx - STM32F4 Discovery (stm32f4-discovery.net) Preliminary design: -Using **touch screen- TOUCHGFX** instead of *pushbutton* as UI (to power subsystems and deliver result) (How to customise touch screen on STM32F429I: First TouchGFX 4.18 Project and using it in STM32CubeIDE - Change Screen with virtual button - YouTube)

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Day book - MEng project

NAME	DATE
Peggy Pei	1/10/2022

EQUIPMENT	Web/ touchGFX/ STM32CUBEIDE
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Preliminary design for using TOUCHGFX as user interface Function: Start button/ Progress bar/ ADC display

Function	Specification	Interface
Start Screen: **Start button** **Text explanation**	-Start measurement (Start activating the actuator after hitting this button) -Store the data in RAW	TouchGFX to: Actuating/Sensor/Heating
Ongoing Screen: **Progress bar** **Home button**	-show the time progress(30 secs) -return back to start page	TouchGFX to: Clock
Result Screen: **Data display** **Plot display** **Data store button**	Displace respiratory impedances at key frequencies (R_5/X_5/R_20/x_20) Display impedance vs frequency(label AX)	TouchGFX to: MCU Raw

Use MVP(model view presenter) to present result from the code
Wildcard range (ASCII)
0x20-0x7f
Plot display: Dynamic Graph Widget - TouchGFX - YouTube

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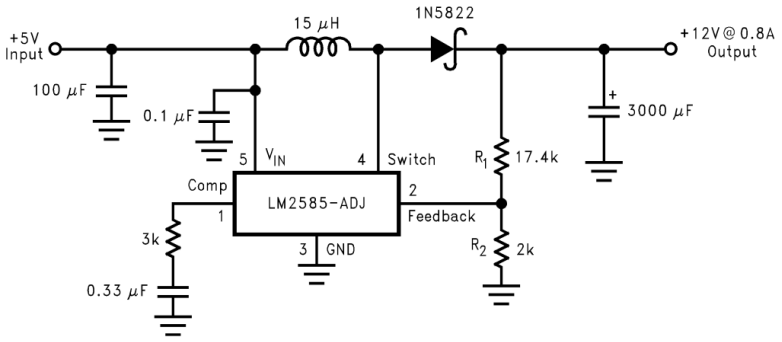
Day book - MEng project

NAME	DATE
Peggy Pei	3/10/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Week 2 summary 1. Power system: ~~-Change PD protocol from a nominal 9V charger (existing).~~ ~~-Add boost converter circuit(9V-12V)~~  **Figure 50. Boost Regulator** LM2585S-12/NOPB Found an existing 12V switching adaptor! No booster needed! 2. Changed MCU {why: 1. FFT of HAL-Library for STM32 only available at F4,F7 series. 2. Add UI, take place of pushbutton, easy to manipulate and display data(BLE module may become peripheral). } - Multi-tasking control needs RTOS (Luckily, STM32 can do) - Touch screen as user interface controls start, display numerical results and plots(desired). More programming is required. STM32F429I-DISC1  Software: STM32CUBIDE+TouchGFX

Week3 Plan:

1. Programming:

   -Return value on serial monitor

   -ADC modules of STM32F4

   -Sensor data capture (Differential sensors & STM32-L433RC-P)

   -Data storage(RAW? DMA?)

   -Respiratory impedance computation (MATLAB .c file from last semester)

   -FFT in HAL.lib of F4 series: Tutorial 1 Tutorial 2 GITHUB code

   -Get familiar with TouchGFX UI design

2. Electronics schematics + simulation

   {

   ~~ADP7142(3.3v regulator) (finished both)~~

   ~~New boost converter (Finished schematics)~~ 12v charger available, no booster needed.

   ~~Load switch circuit (Finished none)~~

   }

3. Hardware test (linear solenoid actuator)

   Get on WED, test natural frequency

TODO Today:

- ~~Load switch circuit (schematics, check SPICE model)~~

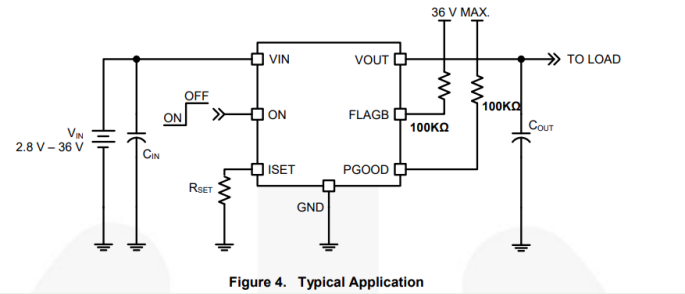


Figure 4. Typical Application

Vin=12V

ON: MCU, active low

V_{IH}	ON Input Logic HIGH Voltage	V_{IN}=2.8 to 36 V	2.0			V
V_{IL}	ON Input Logic LOW Voltage	V_{IN}=2.8 to 36 V			0.8	V

I_limt, R_set

Table 1. R_{SET} Selection Guide

R_{SET} (kΩ)	Current Limit [A]			Tol. (%)
	Min.	Typ.	Max.	
111	2.00	2.50	3.00	20
124	1.79	2.24	2.69	20
147	1.51	1.89	2.27	20
182	1.22	1.52	1.83	20
220	1.01	1.26	1.51	20
274	0.81	1.01	1.22	20
374	0.59	0.74	0.89	20
549	0.40	0.51	0.61	20

C_in=10uF, C_out=0.1uF

Spice model isn't available, wire on breadboard.

- Programming; serial monitor/ impedance calculation
- ~~Tidy up all parts on bench~~

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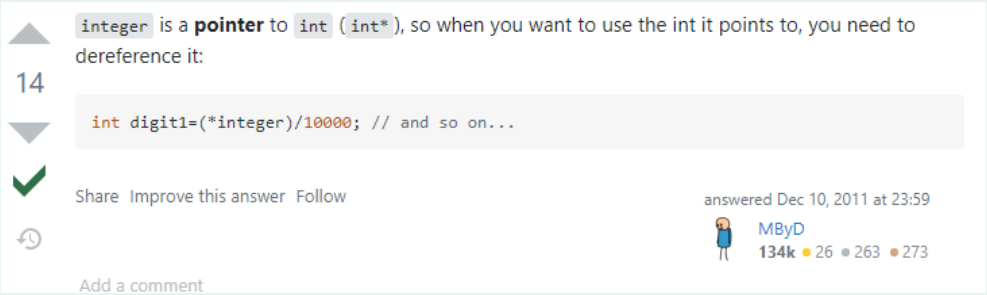
Day book - MEng project

NAME	DATE
Peggy Pei	4/10/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	TODO today: 1. Programming: ~~-serial monitor on STM32CUBEIDE~~ ~~-ADC (Read analogue input)~~ ~~-Data storage~~ (DMA directly saved in RAW) -Computation: 1. Convert digital reading to analogue voltage value. 2.FFT 3.Impedance calculation 2. Paper work ~~-Update block diagram(Add UI)~~ -**ADC on STM32F4** Requirement: 12 bit, 3.3V operating voltage(Check the voltage output range for sensors) ***Differential pressure sensor*** -Analogue output, Vout=10%-90% Vdd, Vdd=3.3v -Estimated value: -100~250Kpa, 50%*3.3V ***Temperature sensor*** 700~900mV Resolution: Resolution = 3.3V/2^12 = 3.3/4095 = 0.8mV Therefore, for every 0.8mV on ADC input, the digital value will increment and if we apply 3.3V to the input pin of ADC, the digital output value of ADC will be 4095. Similarly, if we measured a digital value of ADC with an STM32F4 microcontroller, we can convert it back into a voltage by multiplying it with the resolution value. For example, the measured digital output value is 3500, we can convert it into a voltage by multiplying it by 0.8mV. Input Voltage = 3500 x 0.8mV = 2800mV or 2.8V Convert back to **analogue value** to do more computation. CUBEIDE ADC&DMA Digital reading from ADC will be stored in RAW, shown in **live expression pale**, according to DMA method.

Analogue value convetered:

1. invalid operands to binary / (have 'uint16_t *' {aka 'short unsigned int *'} and 'int'



`integer` is a **pointer** to `int` (`int*`), so when you want to use the int it points to, you need to dereference it:

```
int digit1=(*integer)/10000; // and so on...
```

14

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answered Dec 10, 2011 at 23:59

MByD

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2. How to read data from memory??

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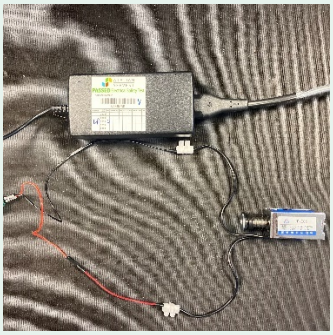
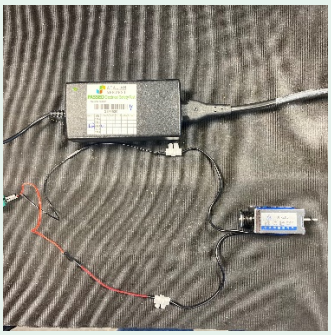
Day book - MEng project

NAME	DATE
Peggy Pei	5/10/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	TODO today: ~~1. Linear solenoid actuator: Frequency test~~ 2. Programming: **- Memory:** ~~1. Difference between RAW and flash memory?~~ 2. Array computation? 3. How to access data after DMA? 4. Estimate how much memory will be used during 30 sec /time **-Computation:** 1. Convert digital reading to analogue voltage value. 2.FFT 3.Impedance calculation Done: 1. Solenoid   -Test procedure: Used power switch(12v) directly power it. -Result: works fine, V_in=12v, I_out= 1.4A, Load switch R_set=~182k ohm -Note: serious time delay, input>>output, consider spring effect. -**Further plan:** Design a switch circuit when receive load switch component; Send out PWM signal mimic different frequencies, test how to arrange time delay; ~~Order rubber.~~ (24th OCT) 2. Programming: -Flash memory VS RAM Flash memory is non-volatile and can hold data even without power, unlike RAM. Compared to either type of RAM, flash memory speed is significantly slower(CPU needed). Because of its reduced power consumption, persistent nature and lower cost, flash is used

for storage memory, in devices such as SD cards, USB drives and SSDs, RAM is used often for calculation.

STM32F429zi ***VS*** STM32L433rc:

- Memories
  - Up to 2 MB of Flash memory organized into two banks allowing read-while-write
  - Up to 256+4 KB of SRAM including 64-KB of CCM (core coupled memory) data RAM
  - Flexible external memory controller with up to 32-bit data bus: SRAM, PSRAM, SDRAM/LPSDR SDRAM, Compact Flash/NOR/NAND memories

Memories
- Up to 256 KB single bank Flash, proprietary code readout protection
- 64 KB of SRAM including 16 KB with hardware parity check
- Quad SPI memory interface

DMA: access to ram, not flash. Flash write causes CPU.

-programming

How to access ping-pong DMA raw

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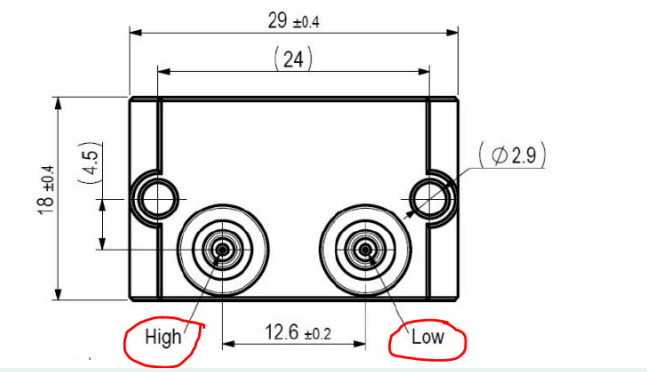
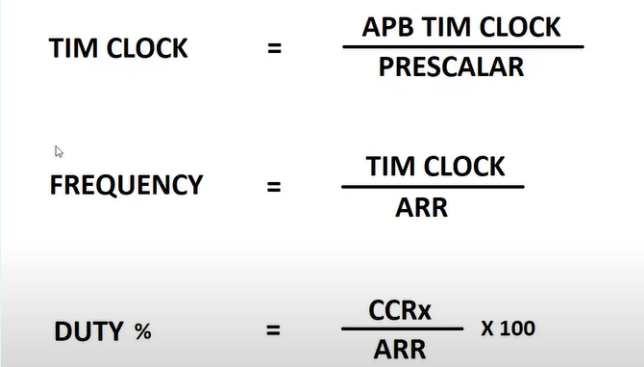
Day book - MEng project

NAME	DATE
Peggy Pei	6/10/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	TODO today: ~~1. Pressure sensor Test(Analogue input)~~ 2. Programming: -FFT -Impedance calculation Done: Pressure sensor - Works fine - Result range: Pressure sensor(V_P0=1.7v) Pneumotachometer(V_P0=1.7v) -Note: Bi-direction  Pressure sensor: High P0(open-air), low P_tube. FFT - CMSIS DSP software lib on STM32F4 #include arm_math.h - Reference project: Audio DSP on STM32 Issues now: 1. Analogue reading is not correct. 2. Impedance computation: How to send out PWM signal and customise voltage? How to control temperature through analogue temp reading? How data storage in RAM? How to process amount of data (40secs)? How to use timer in STM32? How to compute according to timer? How to set up RTOS? How to customise TOUCHGFX? How to use Target PCB fabricated? Does filter needs to be designed? (Yes maybe bandpass 2HZ-50HZ)

Day book - MEng project

NAME	DATE
Peggy Pei	7/10/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	TODO today: 1. Programming: -Send out PWM signal in sequence (5Hz to 30Hz, 2secs/each) -Check out ADC output -Timer on STM32 STM32 PWM Controller Tech  APB TIM CLOCK: 80MHz ARR- Auto reload value : 100 Duty=90% CCRx=90; Duty 50% CCRx=50; Send out pwm signal has to choose DMA(Memory to Peripheral) HAL_TIM_PWM_Start(); Manually start PWM CCR/ARR register Change duty cycle: pulse, CCR 1122 update: Pulse doesn't make difference. Change frequency: ARR

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Day book - MEng project

NAME	DATE
Peggy Pei	8/10/2022

EQUIPMENT

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

Send out frequency sweeping (5Hz to 30Hz)

The PWM period ($1/F_{PWM}$) is defined by the following parameters: ARR value, the Prescaler value, and the internal clock itself which drives the timer module F_{CLK}. The formula down below is to be used for calculating the FPWM for the output. You can set the clock you're using, the Prescaler, and solve for the ARR value in order to control the FPWM and get what you want.

$$F_{PWM} = \frac{F_{CLK}}{(ARR + 1) \times (PSC + 1)}$$

Ref above

In other situations, you'll need to adjust the ARR value. Therefore, you'll need to know the relationship between it and the PWM resolution. This is not a new formula, it's derived from the first one and the F_{PWM} equation that you've seen earlier in this tutorial. We'll need it in later tutorials for designing our Motor driver library and some other applications.

$$Resolution_{PWM}[Bits] = \frac{log(ARR + 1))}{log(2)}$$

ARR affects the resolution of pwm signal, maybe PSC should be the factor altered to do the frequency sweeping.

TODO:

Test PA0, frequency shall be altered.

Useful links:

Dynamically change PWM frequency with interrupt with STM32 - Electrical Engineering Stack Exchange

STM32 PWM Example - Timer PWM Mode Tutorial – DeepBlue (deepbluembedded.com)

HAL #8: HowTo - Timer PWM - YouTube

PWM Configuration in STM32F103 to Control DC Motor | Embedded Programmer - YouTube

Hands-On with STM32 Timers: Custom Signal Generation using PWM and DMA , Part 1 of 2 - YouTube

21/10/22 update:

PCLK=72MHz in STM32F429

```
49
50  //----------Frequency Sweeping function---------------//
51  HAL_TIM_PWM_Start( &htim4, TIM_CHANNEL_1 );
52  HAL_TIM_OC_Start(&htim4, TIM_CHANNEL_1);
53  htim4.Instance->ARR=720000;
54  htim4.Instance->CCR1=htim4.Instance->ARR * 0.50;
55
56  for(FreqSweep=5; FreqSweep<=30;FreqSweep++){
57        FreqSweepConverter=1000/FreqSweep +1;
58        htim4.Instance->PSC=FreqSweepConverter;
59        pres=htim4.Instance->PSC;
60        HAL_Delay(2000);
61  }
62
```

Day book - MEng project

NAME	DATE
Peggy Pei	10/10/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Week3 summary: -Electronics : 1. Finished all interface circuit.(Load switch & LDO) 2. Tested Pressure sensor (works fine) 3. Tested LSA(works fine, serious time delay, need switch circuit to test frequency sweeping function) -Software: 1. ADC 2. ~~DMA~~(RAM & Flash memory) ~~3. Send out actuating signal(Frequency sweeping)~~ TODO: - Test all electronics parts on bench. - Design PCB. - Get correct pressure sensor input. - FFT& impedance calculation. - Data storage. - Temperature control logic (after get all parts) ADC new module: L433RC-P: 0~4096, Vmax=3.6V(instead of 3.3V) ADC verified, works fine Next: -find way to use ADC interrupt and read data from memory for computation. -Put LSA in series(big resistors) to check whether time delay will be diminished.

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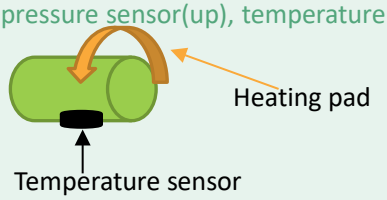
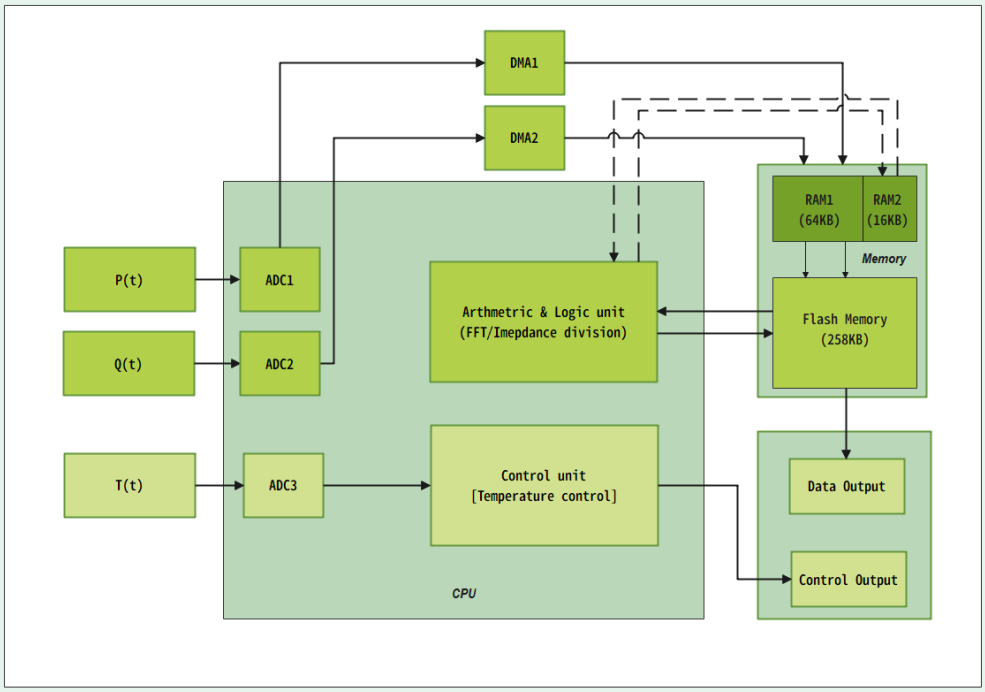
Day book - MEng project

NAME	DATE
Peggy Pei	12/10/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	***TODO:*** 1. Electronics: ~~-LDO on bread board.~~ Fabricate a PCB board instead. ~~-LSA in series with a large resistor to see whether time delay will be affected.~~ Even more serious, do consider the maximum current resistor can afford…(do not need) ~~-Test heating pads.~~ Works fine. Attach just between two pressure sensor(up), temperature sensor could be attached down side.  2. Programming: - Integrate coding logic - Tutorial: how to access flash and RAM --- Coding Logic: 

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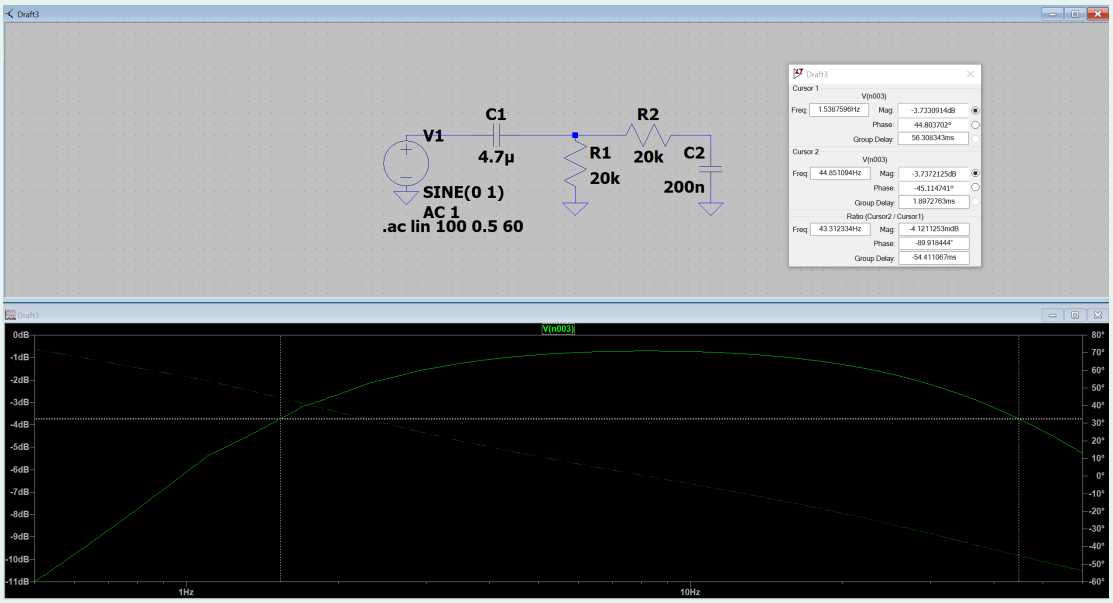
Day book - MEng project

NAME	DATE
Peggy Pei	14/10/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	TODO: 1. F4 discovery board: -TouchGFX design -Apply all module(ADC, Frequency Sweeping) -FFT 2. ~~Analogue band pass filter(2Hz-50Hz) design/simulation/PCB~~ Band pass filter design: Passive RC filter WHY: 1. No need to amplify signal. 2. No Op-amp available 3. PCB integration is ideal The first half of the circuit diagram is a passive RC high pass filter. This filter will allow the signals which have frequencies higher than the lower cutoff frequency (fc-low). And attenuate the signals which have frequencies lower than (fc-low). $F_{clow} = \frac{1}{2\pi R_1 C_1}$ The second half of the circuit diagram is a passive RC low pass filter. This filter will allow the signals which have frequencies lower than the higher cutoff frequency (fc-high). And it will attenuate the signals which have frequencies higher than (fc-high). $F_{chigh} = \frac{1}{2\pi R_2 C_2}$ The band or region of frequency in which the band pass filter allows the signal to pass that is known as Bandwidth. The bandwidth is a difference between the higher and lower value of cutoff frequency. $Bandwidth = F_{chigh} - F_{clow}$ F_L=1Hz, F_H=40Hz Design &Simulation result


Draft3
C1
4.7µ
R2
20k
C2
200n
V1
SINE(0 1)
AC 1
.ac lin 100 0.5 60
R1
20k
Cursor 1
V(n003)
Freq: 1.5387599Hz
Mag: -3.7330914dB
Phase: 44.803702°
Group Delay: 56.308343ms
Cursor 2
V(n003)
Freq: 44.851094Hz
Mag: -3.7372125dB
Phase: -45.114741°
Group Delay: 1.8972763ms
Ratio (Cursor2 / Cursor1)
Freq: 43.312334Hz
Mag: -4.1211253mdB
Phase: -89.918444°
Group Delay: -54.411067ms

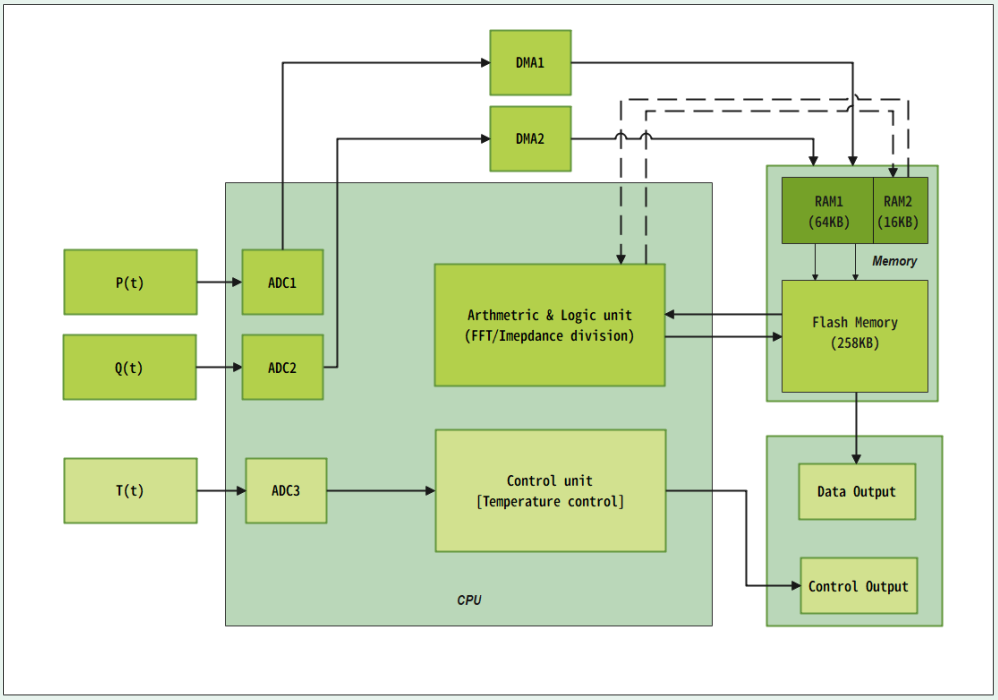
V(n003)
0dB
-1dB
-2dB
-3dB
-4dB
-5dB
-6dB
-7dB
-8dB
-9dB
-10dB
-11dB
80°
70°
60°
50°
40°
30°
20°
10°
0°
-10°
-20°
-30°
-40°
-50°
-60°
1Hz
10Hz

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	17/10/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Week 4 summary: 1. Programming part: -Verified ADC function of L433 -Structured programming logic



-Structured UI

-Did some research on memory management. (Calculation needs to be done today)

ADC sample rate/ single measure time/ RAM size and Flash memory size.

2. Electronics part

-Designed a passive bandpass filter (1.5Hz to 40 Hz)

	F_high/Hz	F_low/Hz
Design	1.7	40
Simulation	1.54	44.59

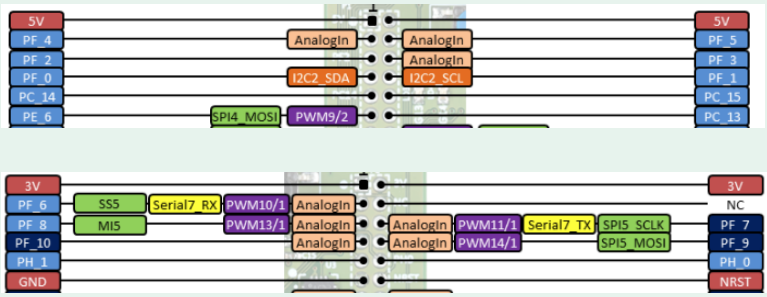
-PCB design

Parts small, didn't test on breadboard.

-Connector design

Subsystem	Input	Output
Sensor system	VDD_PS OCS_PS V_P0 GND	3V3 3V3 V_P0 GND

	VDD_FS OCS_FS V_F0 GND VIN_t VOUT_t GND	3V3 3V3 V_P0 GND 3V3 ANAIn GND
Power system	12V GND	3V3 GND
Heating system	EN_HP GND	V_HP GND
Actuating system	EN_LSA GND	V_LSA GND
MCU	3V3 V_P V_F GND	EN_HP EN_LSA



-How to place temperature sensor?

---

1. Pcb SIZE

   High: >PINSIZE:>15.24mm

   Pin gap: 50.8mm

   Width: 66mm

   Pin set edge: 6.33mm

   How to set your pcb board size perfectly

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	18/10/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	TODO: ~~1. PCB~~ ~~Add a temperature sensor pins(3 connectors)~~ ADC SAMPLE RATE ~~Copper Pours and Gerber Files~~ 2. UI Design for STM32F4 3. ADC/Frequency Sweeping test on STM32F4 Export related files of PCB design for populating.

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Day book - MEng project

NAME	DATE
Peggy Pei	19/10/2022

EQUIPMENT	Website Youtube
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	TODO: ~~1. Calculate ADC sample rate& RAM needed.~~ ~~2. Test Frequency sweeping function on STM32F429~~ To synchronize A/D conversion and timers, the ADCs could be triggered by any of TIM1, TIM2, TIM3, TIM4, TIM5, or TIM8 timer. ADC Setting: 1. Sample rate: According to the Nyquist Theorem, the sampling rate/frequency needs to be at least twice as much as the highest frequency in the signal to recreate the original analogue signal. The following equation is used to find the Nyquist frequency: fNyquist = 2fMax Where, fNyquist = Nyquist frequency, fMax = The max frequency that appears in the signal **Alternatively, choose 100 Hz as the sample rate of frequency.** 2. Resolution The resolution depends on both the bit length and the reference voltage. These equations help you figure out the total resolution of the signal that you are trying to input in voltage terms: Sample ADC Resolution Formula: Step Size = VRef/N Where, Step Size = The resolution of each level in terms of voltage VRef = The voltage reference (range of voltages) N = Total level size of ADC To find N size, use this equation: N = 2n Where, n = Bit Size 12-bit ADC is used 1 bit represent 2 states, 12 bit gives 2^12=4096 states Memory size in STM32F429ZI

```
/* Memories definition */
MEMORY
{
  CCMRAM    (xrw)    : ORIGIN = 0x10000000,   LENGTH = 64K
  RAM    (xrw)    : ORIGIN = 0x20000000,   LENGTH = 192K
  FLASH    (rx)    : ORIGIN = 0x8000000,   LENGTH = 2048K
}
```

Sampling time formula in STM32F429(Reference manual rm0090)

13.5 Channel-wise programmable sampling time

The ADC samples the input voltage for a number of ADCCLK cycles that can be modified using the SMP[2:0] bits in the ADC_SMPR1 and ADC_SMPR2 registers. Each channel can be sampled with a different sampling time.

The total conversion time is calculated as follows:

T_{conv} = Sampling time + 12 cycles

Example:

With ADCCLK = 30 MHz and sampling time = 3 cycles:

T_{conv} = 3 + 12 = 15 cycles = 0.5 µs with APB2 at 60 MHz

Result:

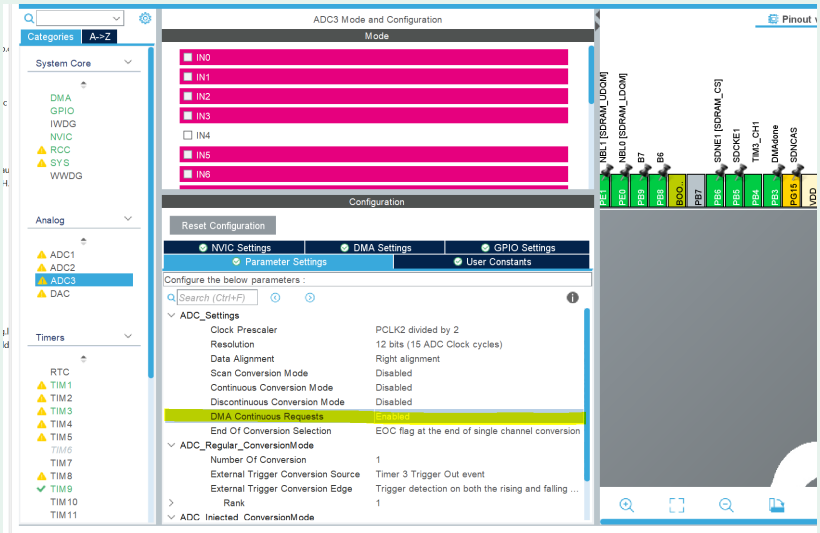
Configuration: F_s=4kHz, DMA bufferlength =8000;

Use external clock to define specific ADC sample rate.

[TIM3, PB4]

Use external GPIO_OUT to check the buffer state(interrupt of ADC callback).

Carefully follow this **tutorial setting**, note one error in this video is that **DMA continuous requests** has to be enabled.



Finally, DMA buffer(8000) is filled within 2 secs as what I want.

TMR:

1. Verify the value for frequency sweeping.
2. How to operate RTOS task
3. FFT in F4

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Day book - MEng project

NAME	DATE
Peggy Pei	21/10/2022

EQUIPMENT

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

TODO:

1. ~~Verify frequency sweeping function~~
2. ~~RTOS operation rules~~
3. FFT
4. UI design

DONE:

1. Modified frequency sweeping function as

```
49
50  //----------Frequency Sweeping function---------------//
51  HAL_TIM_PWM_Start( &htim4, TIM_CHANNEL_1 );
52  HAL_TIM_OC_Start(&htim4, TIM_CHANNEL_1);
53  htim4.Instance->ARR=720000;
54  htim4.Instance->CCR1=htim4.Instance->ARR * 0.50;
55
56  for(FreqSweep=5; FreqSweep<=30;FreqSweep++){
57         FreqSweepConverter=1000/FreqSweep +1;
58         htim4.Instance->PSC=FreqSweepConverter;
59         pres=htim4.Instance->PSC;
60         HAL_Delay(2000);
61  }
62
```

2. FreeRTOS

   Oskernelstart(); means OS start, will **never reach to the infinite while loop**.

   Define multiple task, use **function void();**

   Define **different priorities** if functions require the same operational time;

   Change HAL_Delay to **OS_Delay.**

   ControTech Tutorial

   vTaskDelayUntil

   Enable

   Other functions

   osThreadSuspend

   osThreadResume

   osThreadTerminate(Cannot be resumed again)

   osDelayUnitil Block the task for sometime and automatically resume again.

   ControTech Tutorial2

   Semaphore: make sure task wouldn't be executed even it has higher priority.

   How to store sensor data using FreeRTOS

3. USE USB Host on STM32F429i to store the data from the disk.

4. FFT

File> F429_Initialization gives configuration and compiling of ADC function/ frequency sweeping function/ FreeRTOS.

Set a new project F429_FFT.

Arm_math.h error

(FIXED: include dsp library folder, check tutorial here)

FFT WORKS

FFT computation flowchart

P(t) analogue to P(t) digital

P(t) digital back to analogue pressure(check the pressure sensor datasheet)

P(t)-FFT-P(F)

Choose N according to sample rate of fft: link1 / link2

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Day book - MEng project

NAME	DATE
Peggy Pei	24/10/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	WEEK5 SUMMARY - Programming: 1. Verified and tested all functions on STM32F4 board, using RTOS. 2. Developed FFT algorithm, using ARM_MATH.h CMSIS library. TODO of WEEK6: - Programming 1. UI Design 2. Tested FFT function - Electronics 1. Populated my board 2. Tested all functional subsystems Ideally, all programming and electronics part will be finished within following 2 weeks.

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	25&26/10/2022

EQUIPMENT

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

UI BUG

1. Files missed after opening codes generated by touchgfx on STM32CUBEIDE
   Solution: Update new ide version, now Touchgfx 4.20 matches with STM32CUBEIDE 1.10.1.
2. Touchscreen presses not detected on versions D/E of STM32F429-Discovery board
   After installing demo firmware, touchscreen can be detected, however, it failed again when deploy custom project again.
   Suspect touchscreen initialisation needs to be done. More research tomorrow.

HAL Library 23- TOUCH for STM32Fxxx - STM32F4 Discovery (stm32f4-discovery.net)
Touchgfx Touch Panel Routine (st.com)
STM32 Setting Up Touchgfx Embedded class #2 - YouTube

Possible issue	Solution	Result
Driver not installed	Add new files to driver path follow a tutorial.	Not working
Firmware version	-Install demo firmware through TRUESTUDIO, touchscreen works perfectly; -Install demo firmware through STM32CUBEIDE 1.10.1 , touchscreen cannot work functionally.	Suspect there's a mismatch between software version.
Software version	-Use STM32cubeide 1.9.0 run the demo file. Touchscreen works functionally.	Touchgfx version isn't match with CUBEIDE.
	-Use Stm32cubeide 1.9.0 run touchgfx 4.19.1, touchscreen cannot work functionally.	Software match, suspect code function enable issue.

Touchscreen can function but presses on button cannot be precisely detected…

Detect region error, All buttons have to be set in middle. Flip the display from vertical to horizontal, touchscreen works perfectly!

Problem solved

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Day book - MEng project

NAME	DATE
Peggy Pei	27/10/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	*UI Design by TouchGFX* Background color: #C4FAFF #3D3D3D Personal inform: -Name -Age -Date Scroll List Widget -Save data -Check resistance graph -Check reactance graph How to use dynamic graphs to display ADC data [7:45] --- FreeRTOS along TouchGFX *Heap size is crutial --- ADC & FFT Arm_math.h TIPs: Add .h Add include path to GCC compile/ arm_math.h file path at workspace. Add library Property setting can refer to **F429_RTOS_fft**.

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Day book - MEng project

NAME	DATE
Peggy Pei	28/10/2022

EQUIPMENT

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

Programming:

- HardFault_handler

  Very useful Q&A.

  Solution:

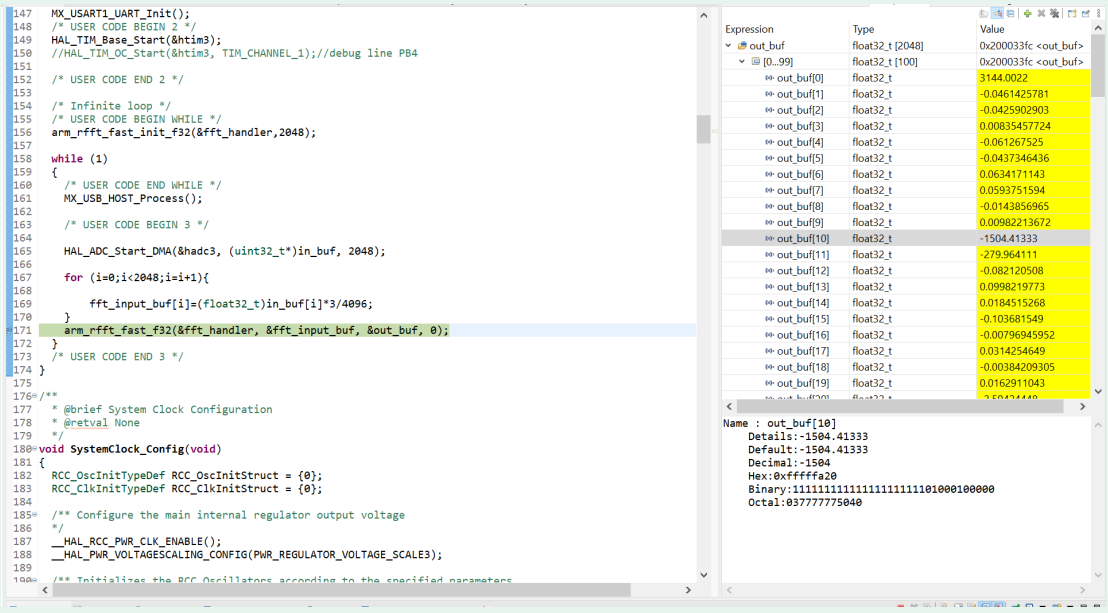
  1. Increase Stack size
  2. Increase output buffer size of FFT(2048), cannot just use the number of value needed (100).

ADC on STM32F429 Full voltage range: 0~3V

Project F429_FFT verified arm_math.h FFT function.

Process:

- Use ADC(Sampling frequency set to 2.048Khz) input a sinewave with frequency 5Hz
- Convert ADC output(Digital value) to Anlogue value.
- Use arm_rfft_fast_f32 function(FFT length=2048),get peak exactly at fft output buffer [10,11], representing 5Hz.



```
MX_USART1_UART_Init();
/* USER CODE BEGIN 2 */
HAL_TIM_Base_Start(&htim3);
//HAL_TIM_OC_Start(&htim3, TIM_CHANNEL_1);//debug line PB4

/* USER CODE END 2 */

/* Infinite loop */
/* USER CODE BEGIN WHILE */
arm_rfft_fast_init_f32(&fft_handler,2048);

while (1)
{
  /* USER CODE END WHILE */
  MX_USB_HOST_Process();

  /* USER CODE BEGIN 3 */

  HAL_ADC_Start_DMA(&hadc3, (uint32_t*)in_buf, 2048);

  for (i=0;i<2048;i=i+1){

      fft_input_buf[i]=(float32_t)in_buf[i]*3/4096;
  }
  arm_rfft_fast_f32(&fft_handler, &fft_input_buf, &out_buf, 0);
}
/* USER CODE END 3 */
}

/**
  * @brief System Clock Configuration
  * @retval None
  */
void SystemClock_Config(void)
{
  RCC_OscInitTypeDef RCC_OscInitStruct = {0};
  RCC_ClkInitTypeDef RCC_ClkInitStruct = {0};

  /** Configure the main internal regulator output voltage
  */
  __HAL_RCC_PWR_CLK_ENABLE();
  __HAL_PWR_VOLTAGESCALING_CONFIG(PWR_REGULATOR_VOLTAGE_SCALE3);

  /** Initializes the RCC Oscillators according to the specified parameters
```

Expression	Type	Value
out_buf	float32_t [2048]	0x200033fc <out_buf>
[0...99]	float32_t [100]	0x200033fc <out_buf>
out_buf[0]	float32_t	3144.0022
out_buf[1]	float32_t	-0.0461425781
out_buf[2]	float32_t	-0.0425902903
out_buf[3]	float32_t	0.00835457724
out_buf[4]	float32_t	-0.061267525
out_buf[5]	float32_t	-0.0437346436
out_buf[6]	float32_t	0.0634171143
out_buf[7]	float32_t	0.0593751594
out_buf[8]	float32_t	-0.0143856965
out_buf[9]	float32_t	0.00982213672
out_buf[10]	float32_t	-1504.41333
out_buf[11]	float32_t	-279.964111
out_buf[12]	float32_t	-0.082120508
out_buf[13]	float32_t	0.0998219773
out_buf[14]	float32_t	0.0184515268
out_buf[15]	float32_t	-0.103681549
out_buf[16]	float32_t	-0.00796945952
out_buf[17]	float32_t	0.0314254649
out_buf[18]	float32_t	-0.00384209305
out_buf[19]	float32_t	0.0162911043

```
Name : out_buf[10]
    Details:-1504.41333
    Default:-1504.41333
    Decimal:-1504
    Hex:0xfffffa20
    Binary:11111111111111111111101000100000
    Octal:037777775040
```

Note that:

1. Output data from ADC have to be converted back to analogue value, amplitude of fft input matters.
2. Resolution of FFT depends on sampling frequency and FFT length. In this case, 2.048KHz/2048=1Hz. Output correspond to coefficient of arm_rfft_fast_f32 can be check in doc: Real FFT Functions (keil.com).
3. Other Programming note: integer division returns an integer. By casting one of the

	operands to double or explicitly declaring a literal double you can force the division expression to return a double and not truncate after the decimal place `fft_input_buf[i]=(float32_t)in_buf[i]*3/4096;`

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Day book - MEng project

NAME	DATE
Peggy Pei	30/10/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	TouchGFX UI design Tutorial: 1. How to use progress bar 2. How to display static graph(Result) 3. How to input text string Wildcard- How to Update the TouchGFX GUI from other tasks 4. How to do transition Solution: button transition 5. Integrate different tasks along with RTOS

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Day book - MEng project

NAME	DATE
Peggy Pei	31/10/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Week6 summary: 1. Programming: - FFT done. - FreeRTOS done. - TouchGFX &STM32CUBEIDE conversion done. - UI design and test half done. TODO at week 7: 1. Integrate UI and previous code together. 2. Populate PCB board and Test it. 3. Test actuating system with PCB board. 4. Consider loudspeaker as plan B. --- FFT function match with ADC converter/ Actuating signal doesn't match with ADC converter.

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Day book - MEng project

NAME	DATE
Peggy Pei	1/11/2022

EQUIPMENT

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

TODO:

1. FreeRTOS synchronisation issue.
2. Integrated FreeRTOS with TouchGFX.

- FreeRTOS synchronisation:

  Why:

  osDelay() brings asynchronization between different tasks. In this case, I am aiming to read NewBuffState(meaning that adc buffer[4096] has been filled) as a statement to control whether frequency sweeping should be called.

  However, sharing a global variable will mess up between different tasks. Changing the priority of tasks doesn't update this same variable at the same time. After research, Queues (xQueueCreate, xQueueReceive, xQueueSend) can be the most efficient way to update/ send/ receive data between different tasks under FREERTOS.

  Useful links:

  Q&A: c - freeRTOS: How to pass data between tasks? - Stack Overflow

  Tutorial: FreeRTOS on STM32 v2 - 13h Passing items over queue - LIVE lab - Bing video

  Problem solved!

New Code:

```
void StartAccuating(void const * argument)
{
  /* USER CODE BEGIN StartAccuating */

  //----------Frequency Sweeping function----------------//

      HAL_TIM_PWM_Start( &htim4, TIM_CHANNEL_1 );
      HAL_TIM_OC_Start(&htim4, TIM_CHANNEL_1);
      htim4.Instance->ARR=720000;
      htim4.Instance->CCR1=htim4.Instance->ARR * 0.50;

      //Get ADC state from task1.
      osEvent retvalue;

  /* Infinite loop */


  while(1){

      if(FreqSweep<=30){

          retvalue=osMessageGet(ADCstateHandle, osWaitForever);
          if(retvalue.value.v==1){
                      FreqSweepConverter=1000/FreqSweep+1;
                      htim4.Instance->PSC=FreqSweepConverter;
                      FreqSweep++;
          }
       }

      if(FreqSweep==31){
          osThreadTerminate(AccuatorHandle);
      }
  }
  /* USER CODE END StartAccuating */
}
```

Old Code:

```
void StartAccuating(void const * argument)
{
  /* USER CODE BEGIN StartAccuating */

  //----------Frequency Sweeping function----------------//

      HAL_TIM_PWM_Start( &htim4, TIM_CHANNEL_1 );
      HAL_TIM_OC_Start(&htim4, TIM_CHANNEL_1);
      htim4.Instance->ARR=720000;
      htim4.Instance->CCR1=htim4.Instance->ARR * 0.50;

  /* Infinite loop */
  for(FreqSweep=5; FreqSweep<=30;FreqSweep++)
  {
              FreqSweepConverter=1000/FreqSweep +1;
              htim4.Instance->PSC=FreqSweepConverter;
              pres=htim4.Instance->PSC;
              osDelay(2000);
  }
  if(FreqSweep==31){
      osThreadTerminate(AccuatorHandle);
  }
  /* USER CODE END StartAccuating */
}
```

Temperature control logic:

PF0(EN_HP) gpio_out

PC3(adc value of temp sensor in reality) jumper from PF6(in design) to PC3.

Temperature control function:

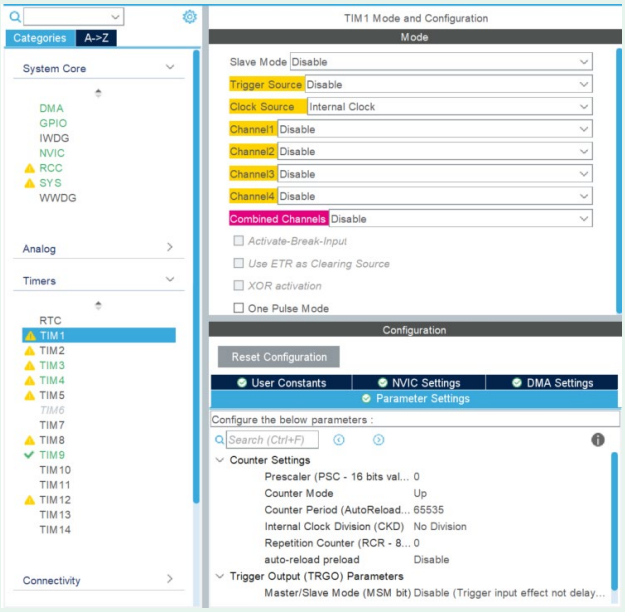
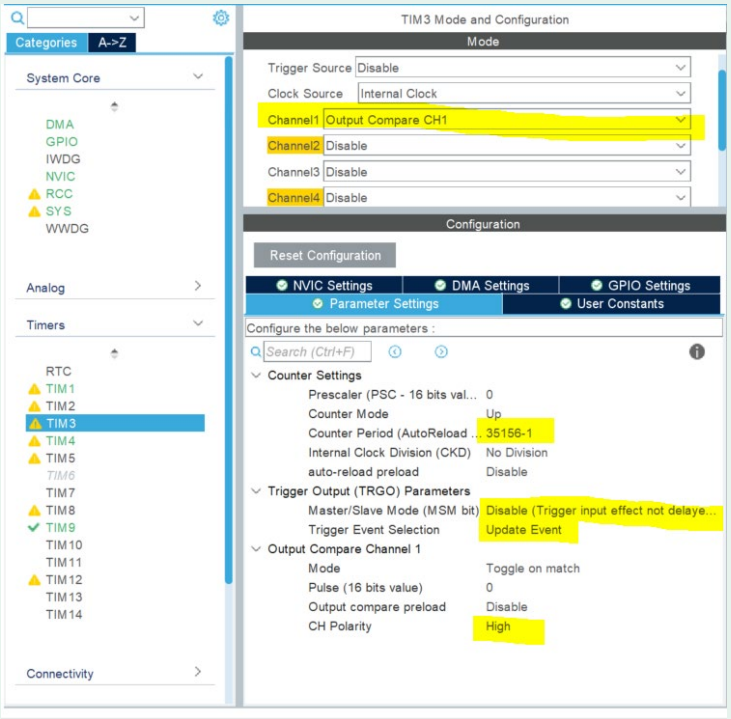
```
void TemperatureControl(void const * argument)
{
  /* USER CODE BEGIN TemperatureControl */

  /* Infinite loop */
  for(;;)
  {
    HAL_ADC_Start(&hadc1);
    // Poll ADC1 Perihperal & TimeOut = 1mSec
     HAL_ADC_PollForConversion(&hadc1, 1);
     Temp_Vdigital=HAL_ADC_GetValue(&hadc1);

    Temp_Vanalogue=(float)Temp_Vdigital*3/4096;
    Temp=(Temp_Vanalogue-0.5)/0.01;

    if(Temp<=35){
        HAL_GPIO_WritePin(GPIOF, GPIO_PIN_0, GPIO_PIN_SET);
    }
    else
        HAL_GPIO_WritePin(GPIOF, GPIO_PIN_0, GPIO_PIN_RESET);
    osDelay(500);
  }
  /* USER CODE END TemperatureControl */
}
```

Use ADC polling method, read single value per 500ms (save memory& remember to enable ADC continuous conversion model) to enable heating mat on and off.

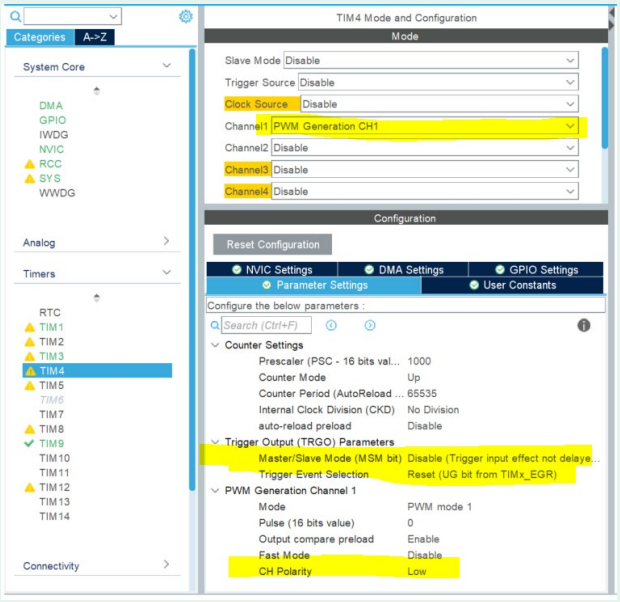
SIGNATURE

Day book - MEng project

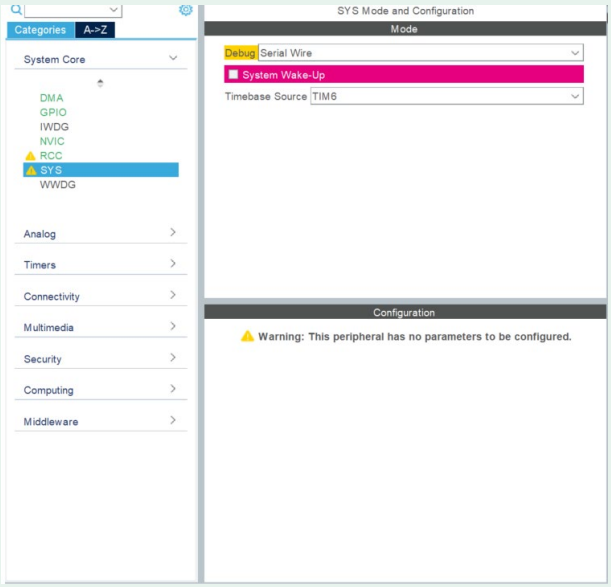
NAME	DATE
Peggy Pei	2/11/2022

EQUIPMENT	STM32CUBEIDE TOUCHGFX
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	*Integration* ~~1. Timer:~~ - Timer 1: Internal Clock  - Timer 3: ADC sampling frequency 

- Timer 4: Frequency sweeping function



-Timer 6: System clock



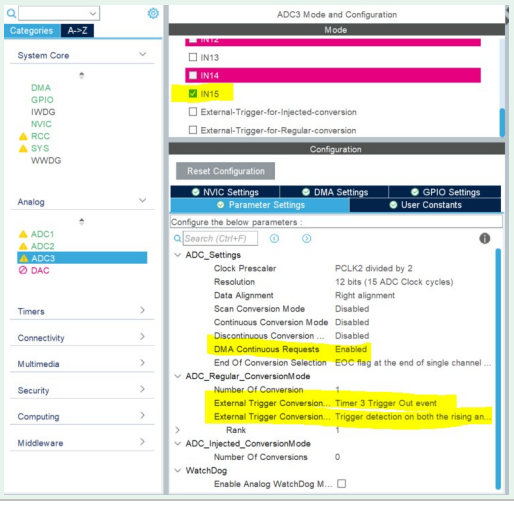
~~2. ADC:~~

-ADC3_IN4: Temperature Sensor

-ADC2_IN13: Flowrate sensor

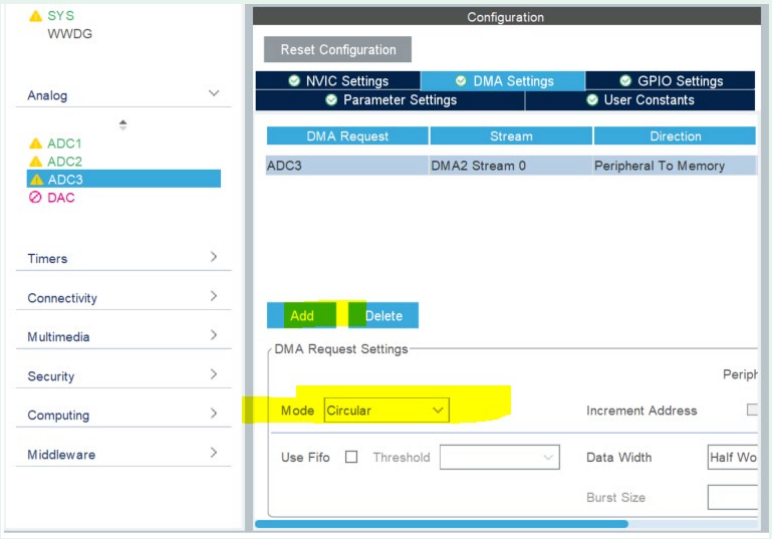
-ADC1_IN11: Pressure sensor PC1

Sampling frequency: 2.048KHz Triggered by timer 3

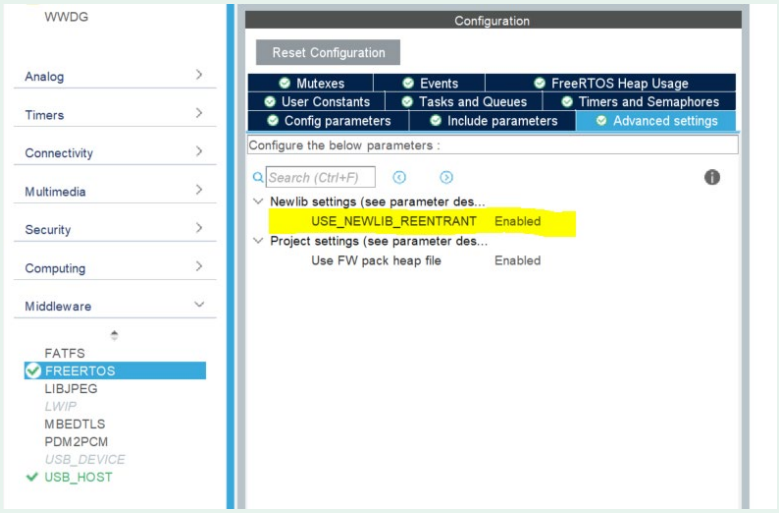


~~3. DMA setting:~~

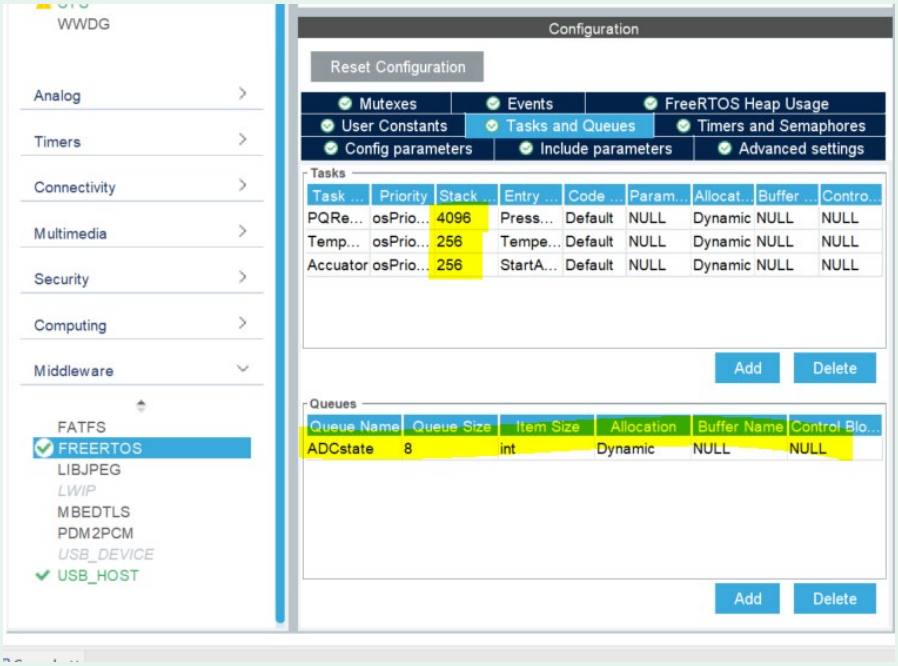
Circular(inside of ADC [2&3] setting)



~~4. FreeRTOS Setting:~~



Task and queue:

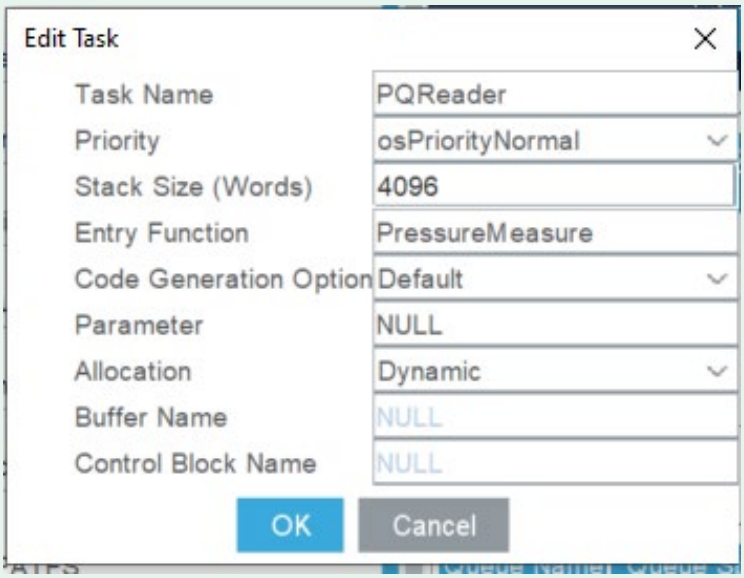


Be careful of stack size & priority(ALL same)

ERROR: ***Undefined reference to osMessageGet/Put from cmsis_os.h***

Opposite from answer but after change to OsMessageQueueGet, works functionally.
OsMessageGet/Put for CIMSIS.V2
OsMessageQueueGet/Put for CIMSIS.V1.

Task configuration example:



FreeRTOS Interface: CMSIS_V1

~~5. FFT computation function~~

-include arm_math.h related files and path.
-Include DSP library.

~~6. Temperature control function~~

Problem:
It is shamethat PIN out of PCB cannot be directly fed into MCU board after using TouchGFX to map out its memory(ie: Use LTDC FMC – SDRAM external memory method and pinout cannot be customised)

As pins are limited after using 20+ pins under this method, I couldn't find extra pin to match PCB layout. External jumper and modification on connectors may be required. (Or fabricate another board…)
Lets do the PCB test first.

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Day book - MEng project

NAME	DATE
Peggy Pei	3/11/2022

EQUIPMENT

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

TODO:

- User USB to output data
- Transfer data from different tasks.
- Populate my pcb board

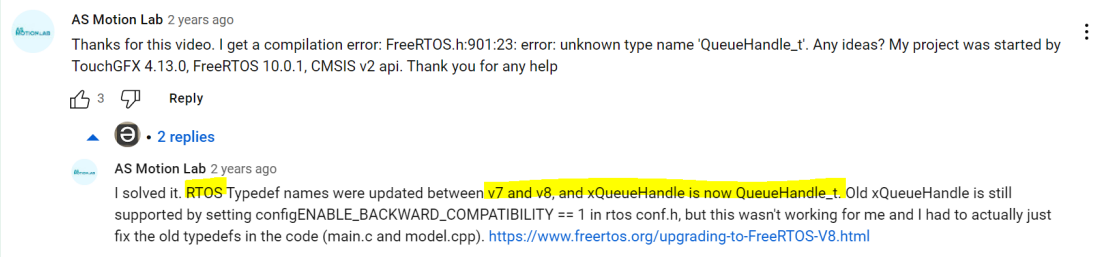
Tips:

Wildcard wide range: 0x20-0x7f (Control Tech).

xQueue series

- is included in “FreeRTOSConfig.h” instead of “FreeRTOS.h”
- must include “queue.h” as well.

1. xQueue shouldn’t be used, otherwise it needs FreeRTOSConfig.h to correct.



2. **xQueue function** cannot be used here!! It is the simple queue founction without using CIMSIS_V. However, our project is based on CIMSIS_V2, therefore, use **osMessageQueue function instead**. (Very important)

Queue is the best tool pass data from different tasks in FREERTOS.

Use Queue to deliver function data.

Model View Presenter(MVP):

1. Write a new task
2. Go to Model.cpp, define external variable: ie: extern int x; Go to ModelListener.hpp, define the virtual void function of presenter.
3. Go to presenter.cpp >presenter.h, add virtual void function of view that will be called. Write this function back to presenter.cpp file
4. Go to view.cpp, write the real execute code in virtual function of updateview; Go to View.hpp, define virtual void function of updateview.

Function name in view should be **exactly same** as the function name defined in TouchGFX.

Tutorial:

Touch GFX #5. Display UART data on the Screen using MVP (Model View Presenter) - YouTube

How to update other tasks from the TouchGFX GUI - YouTube

	Todo: - Display data on Graph. - Progress Bar - USB storage

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Day book - MEng project

NAME	DATE
Peggy Pei	6/11/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	*USB-OTG(on the go) store data* Tutorial: [STM32] STM32F4 USB HOST + Pendrive: Writing to text file - YouTube Even's weblog: USB storage with STM32F4-Discovery and CubeMX (evenlund.blogspot.com) Configuration: 1. USB-OTG-HS(half speed) OTG-FS cannot be used under freeRTOS and SDRAM model. 2. Host only- activate VBUS- mass storage model- USB clock 48MHz. Warning: Warning in sd_diskio.c - osMessageQueuePut integer from pointer without a cast #145 Instead of using NULL use the appropriate priority (osPriorityNone, defined in cmsis_os2.h, as suggested in this post) *Progress bar embedded* *Tutorial ref:* TOUCH GFX #3. Progress BARS || Display ADC Value - YouTube - Still use MPV(model- presenter- view) protocol, add handleTickEvent function to check screen update depending on its resolution. - Use Queue to transfer& update data instead of using external variables. (More reliable and less asynchronization issue.)

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	7/11/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Output data: Static graph Memorymanage_Handler error: Stack size of queue has to be big enough.(25 float data needs at least 128 bytes) Use FreeRTOS ***queue*** to synchronise different tasks. Directly use ***External variables*** to output array to graph and USB. Data scale needs to adjust.(y-axis: -3 to 3 now) Output data: USB port

```
/* Create and Open a new text file object with write access */
if(f_open(&MyFile, "Measurement Data.TXT", FA_CREATE_ALWAYS | FA_WRITE) != FR_OK)
{
  /* 'STM32.TXT' file Open for write Error */
  USB_Error_Handler();
}
else
{
  /* Write data to the text file */

  f_printf(&MyFile,"Measurement data for COPD patient: [Name], [Gender],[Age].\n");
  f_printf(&MyFile,"Respiratory resistance:\n");
  for(i=5;i<31;i++){
      f_printf(&MyFile,"%.4f\n",Resistance[i]);
  }
  f_printf(&MyFile,"Respiratory reactance:\n");
  for(m=5;m<31;m++){
      f_printf(&MyFile,"%.4f\n",Reactance[m]);
  }
  res=f_printf(&MyFile,"Date:\n");
 // res = f_write(&MyFile, wtext, sizeof(wtext), (void *)&byteswritten);
  if(res!= FR_OK)
 // if((byteswritten == 0) || (res != FR_OK))
  {
    /* 'STM32.TXT' file Write or EOF Error */
    USB_Error_Handler();
  }
  else
  {
    /* Close the open text file */
    f_close(&MyFile);
    HAL_GPIO_WritePin(GPIOG,GPIO_PIN_14,GPIO_PIN_SET);
```

f_printf: output strings/ f_write: output binary.

Useful tutorial about how to use fatfs to write a TXT file.

Test tmr.

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Day book - MEng project

NAME	DATE
Peggy Pei	8/11/2022

EQUIPMENT

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

WEEK 7 summary:

1. Finished integration of TouchGFX and STM32.
   Control system(Programming part):

   Progress: Design -> Test -> Verify -> Done.

Subsystem	Function	Progress
Sensor	Read pressure sensors- ADC conversion	Done
	Impedance calculation- FFT	Done
Actuator	Frequency sweeping – PWM Generation	Done
Heating	Read Temperature sensor – ADC conversion	Done
	Temperature control logic	Done
UI	Touchscreen manipulation	Done
	Display graph on touch screen	Done
	Save data through USB	Testing

2. Got PCB board last Thursday, found errors on last Friday, Redesigned a new board on last Friday, will get new board this Tuesday.
   Errors:
   - Wrong IC was chosen. FPF2701MX instead of v
   - Touch screen uses FMC(Flexible memory controller) to approach SDRAM, 20 pins are used including the original one I chose as the input of pressure sensor.

TODO this week:

1. Programming
   ~~-Check correlation of data from pressure/ flowrate sensor.~~
   -Finish USB storage test.
   (Monday)

2. Electronics:
   -Populate my PCB
   -Test it and integrate it on the main board.
   (Tuesday& Wednesday)

3. Mechanical
   - Get familiar with SolidWork.

- Print Electronics case.
- Print pneumotachometer connector.

(Any spare time, before Friday)

Done:

1. Sensor conversion

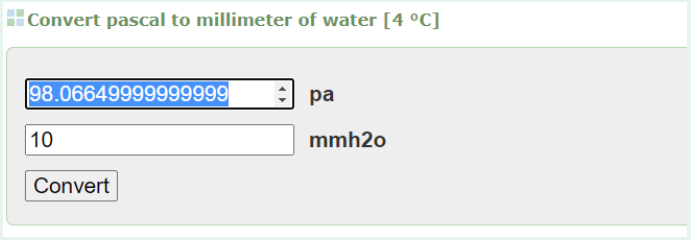
Pressure sensor: PA

500Pa	$DP = sign\left(\frac{AOut}{VDD} - 0.5\right) \cdot \left(\frac{AOut}{VDD \cdot 0.4} - 1.25\right)^2 \cdot 525$

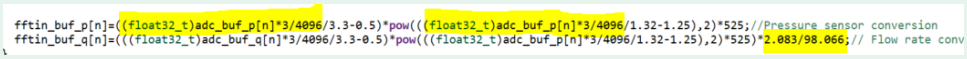
Flow rate:

MLT300L, assume it is linear between +-300L/min, Calibrated point is (10mmH20-> 125L/min)

According to:



Get final conversion calculated by equations:



Unit:

P: Pa (Kpa expression is limited due to the resolution of TouchGFX)

Q: L/s

2. USB-OTG-FS needs extra PHY(ic), use USB to transfer data isn't reliable, searching for more approaches (ie: TTL-USB converter?)

   Use BLE module still (HC-05[UR communication]+ STM32)

HC05 BLUETOOTH MODULE WITH STM32 - YouTube

Sprint: convert float to srtring then send out by UART(only read ASCII, otherwise data will be binary).

- Add float flag on Stm32 printf float variable - Stack Overflow
- How to use UART to Transmit Data in STM32 || Poll || Inetrrupt || DMA (controllerstech.com)
- c - Send Data With Usart STM32 - Electrical Engineering Stack Exchange

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Day book - MEng project

NAME	DATE
Peggy Pei	9/11/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Change data transfer protocol from USB to BLE UART functions correctly, however, HardFault_handler was reached every time call sprintf() function. None business with over stack flow. Doubt that Sprintf cannot be used when touchGFX embedded in FREERTOS!!! Write own print function to print float to string, here're some useful links: c - Convert float to string without sprintf() - Stack Overflow Convert a floating point number to string in C - Tutorialspoint.dev

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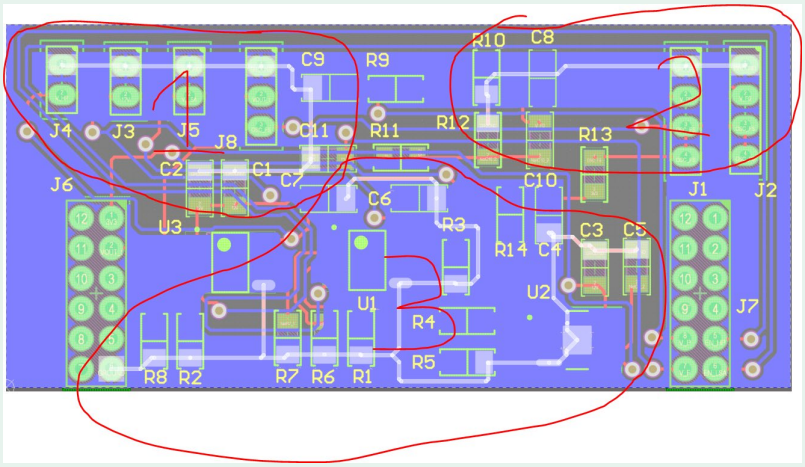
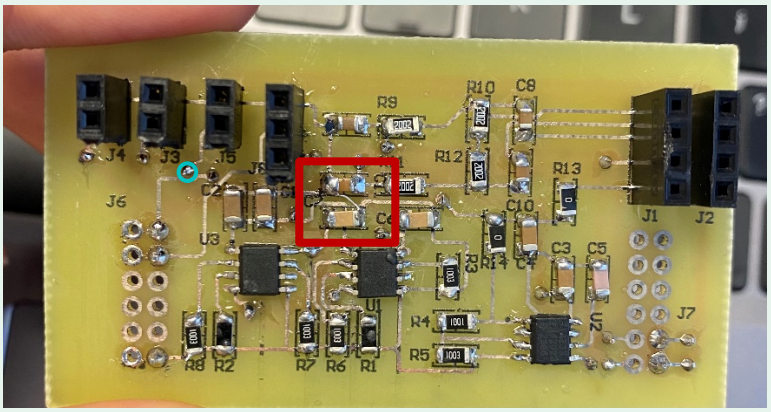
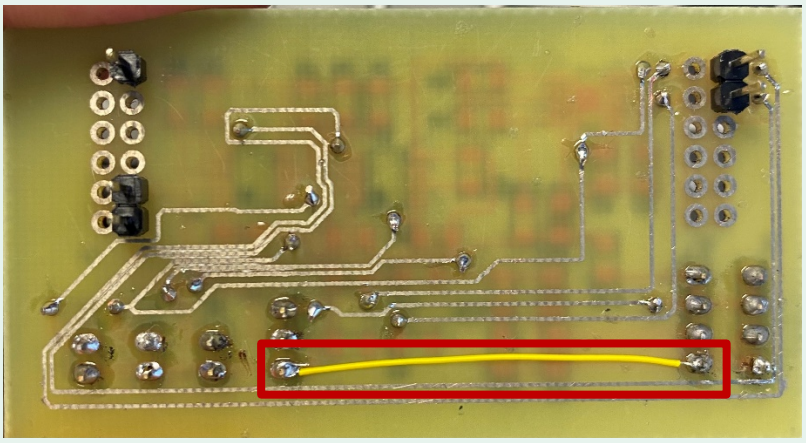
Day book - MEng project

NAME	DATE
Peggy Pei	10/11/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Test PCB Summary: As lab in the Uni can only manufacture prototype board, which brings many issues. Problems I came across with include: - Ground pour was deleted(Manufacture issue). - Via needs extra soldering ions(Manufacture limits). - Through hole pins have to be soldered on both side to reach tracks on different layers. Before the function test on board, few modifications have been done:  After modification: 



- Add jumper to connect three ground track(Red blocks)
- Fill all vias (blue circle)
- Solder both side of through hole header.

Function Test:

Function block	Progress
Power	Done
3V3 Regulator	Done
U1- Load switch for HP	Done
U3- Load switch for LSA	Output always 12V, ISET=0.99v Turns out there's one pin of IC that was badly soldered. Everything works fine after optimisation. Done

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Day book - MEng project

NAME	DATE
Peggy Pei	11/11/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	TODO: - Programming: ~~1. Sprint function replace.~~ 2. BLE UART connection(?) UART on STM32 works fine, but mobile cannot receive data… - Electronics: 1. ~~Test LSA/~~ ~~power system~~ LSA works perfectly!!!!! ~~2. Connect BLE module.~~ --- Current limit issue on ADP7142ARDZ-3.3-R7 Operating current of STM32F429I-DISC1 board: ~200mA under 3.3V Maximum load regulation current is 200mA LOAD REGULATION[1] $\Delta V_{OUT}/\Delta I_{OUT}$ I_{OUT} = 100 µA to 200 mA 0.002 0.004 %/mA Solution: Use 3v3 on current board to power sensors. Make another board to power MCU. Connect temperature sensor, BLE modul.(ADP7104ARDZ-3.0-R7).

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Day book - MEng project

NAME	DATE
Peggy Pei	14/11/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Week8 summary: 1. Electronics: -Populated and tested my board, functionalities have been verified. However, ***Load current limit***(200mA for ADP7142ARDZ)of current 3v3 regulator doesn't match with our requirement(250mA operating current from STM32F429I-DISC1). Solution: Cannot simply take place it with another IC, as original circuit design has to be changed. Design and manufacture ***another board***, with functionalities of 3V3 power MCU/ BLE module/ Temperature sensor+ LPF. 2. Programming: -***USB otg cannot be used*** as a peripheral on board. Use BLE module to transfer data UART on code works fine, connection between mobile- BLE- STM32 needs to be further clarified. 3. Mechanism: -LSA can work even send signal up to 30Hz. Design a reliable& stable mechanism for it is essential. Work hard on SolidWork this week. SolidWork may be only available on remote, check: Remote software | The University of Edinburgh

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Day book - MEng project

NAME	DATE
Peggy Pei	15 &16 /11/2022

EQUIPMENT

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

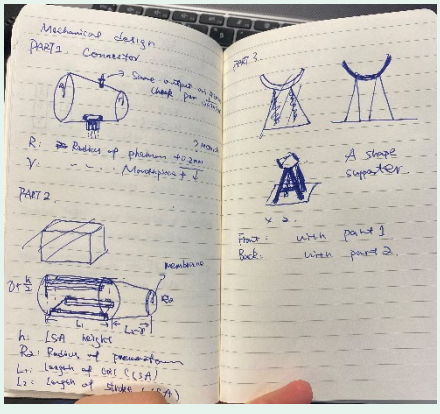
Mechanical design

Data collection:

Three parts:

1. Connector between Mouthpiece and pneumotachometer, with pressure sensor on.
   -includes temperature sensor room.
2. Actuator room, cubic, with back supporter.
3. Front supporter.
4. (Alternatively) PCB studio.

	Data of CAD design		
Part	Parameter	Spec	Value/ mm
1	R1	>Radius of Pneumotachometer	29.4/2(26.1+3+0.3)
	r1	<Radius of mouthpiece	33.4/2(31+2+0.4)
	r_s*2=d_s	=diamater of pressure sensor tube	3.4-4.8-6.1
	L_t	=Length of temperature pcb connector	10.4
	W_t	=Width of temperature pcb connector	2.1
2	R2	>Radius of Pneumotachometer	12.95
	R3	>half height of LSA	24.4-28.4
	L1	Length of coil + tail of LSA	81.5
	L2	Length of half stroke of LSA	10.6
3	N/A	N/A	N/A



General width=1.5mm

Sensor tube width=0.5mm

Connection of different parts: <13.4mm

LSA turnal width = 1.5mm

Turnal gap width=30.5mm

Turnal length =40.7mm

Measured by a digital caliper

LSA SPEC:

https://www.aliexpress.com/item/32812673024.html

Most data need to be measured by ruler myself later

Watch tutorial of Onshape

	PART1 ***Junction length: 8mm*2*** ***Sensing length:20mm*** ***PART2*** ***Breathing air outlet shall be added.*** ***LSA STUDIO*** ***High: 28.6mm*** ***Full compressed:*** ***Body length =70mm, stroke length =12.5mm*** ***Natural state(no compression):*** ***Stroke length=24.5mm***

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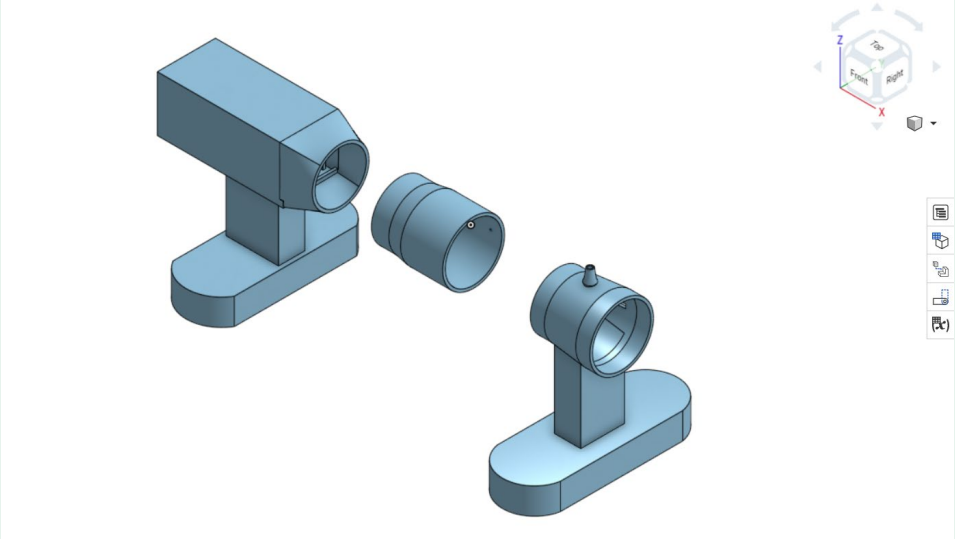
Day book - MEng project

NAME	DATE
Peggy Pei	17/11/2022

EQUIPMENT	Onshape(website)
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	*Summary of preliminary mechanical design*



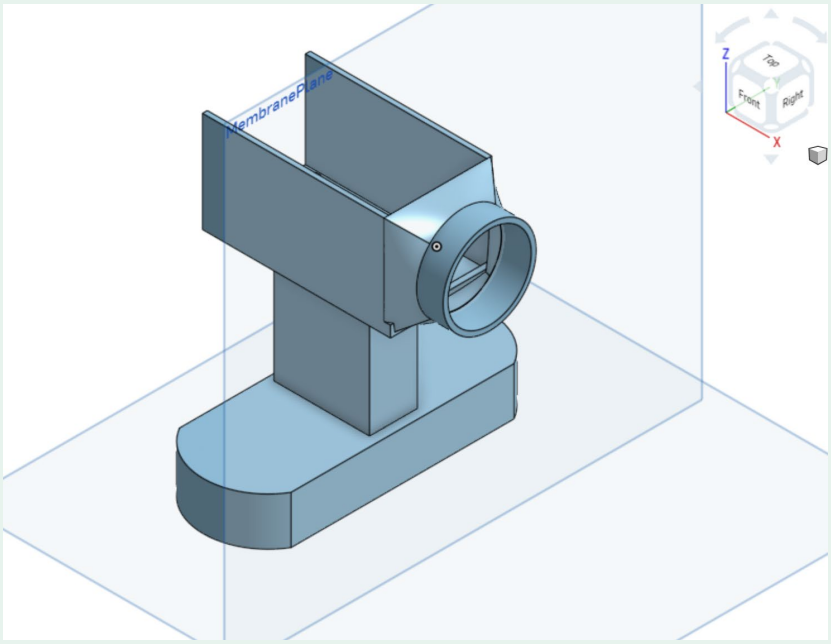
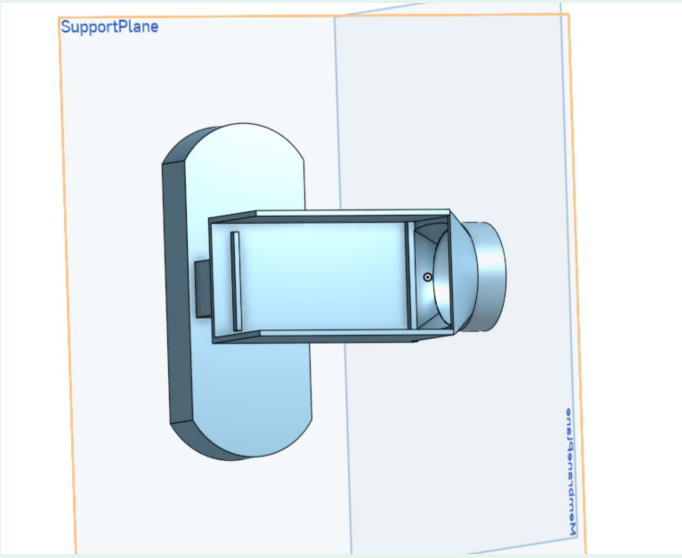
Excluding PCB studio, mechanical design has been finished with 3 different parts.

NO.	Name	Specification
Part 1	LSA Studio	LSA studio is the room for actuating system -Specific supporter inside- stability as LSA has fierce mechanical movement. -Not sealed(Back), for following assemble issues. -External supporter height: 70mm
Part 2	Connector 1: MT connector	A connector between LSA studio and Pneumotachometer. Functionalities: 1. Set up membrane- Squeezing method+ glue(if necessary). 2. Set up heating mat. 3. Air outlet for breathing.
Part 3	Connector 2: PS connector	A connector between pneumotachometer and mouthpiece, with second external supporter. - Connect with pressure sensing. - Set up temperature sensing PCB.

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	21/11/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	 Top  Removed rear, open top floor, add a shaci / flange is the best approach to set membrane. Report structure sketch/ ~~Code cannot be run(stuck in idle state~~)/ PCB doesn't work at this moment

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	22/11/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Week10 summary 1. Mechanical design(2 version) 2. Electronics Update, including temperature sensing board and main board(3v3 load current limit: 500mA) 3. BLE module test(Can work, but just send ASCII for 3 words per time, need further updates but not in a rush) 4. Structured Phase two report TODO: 1. Integrate all (sensor/MCU/Heating pad/LSA) ***TUE-WED*** - Actuating signal missing - The power port of LSA is not reliable - Collect new LSA studio 2. Test procedure ***WED-FRI*** Will think about what/ how should be tested, give a list or a table in the end. 3. Start data collection May require me to do some extra coding on different test modules. Impact/ Worldwide**; data** about COPD/reasons to cause Test Tidal breathing flow through Temperature control

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	23/11/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Test: - ***Git Set up*** Git is super useful when comes to a coding system of the complex system design(STM32CUBEIDE in this case), I was very stressful to back up STM32 files every time after I did updates. Sometimes it could easily get crushed with copy folder. For example, a common error, indicating" make file cannot find target", may be caused by just simply renaming the copy folder. To improve efficiency and ease my mental stress, learning how to use git as the tool to back every changes saved my life. It is also encouraged for every EEE student working on control system design to use this "CS" tool when there's heavy work required for coding and debugging. Useful tutorial: Git, GitHub, & GitHub Desktop for beginners - YouTube Learn Git In 15 Minutes - YouTube How to upload files/folders/projects on github | Upload Project folder on github (Simple Way) - YouTube The simplest procedure from my own experience: | Tool | Git+ GitHub | | Procedure | - Download both of them - Open working folder with Git Bash - Type" git init", create a repository under this path - Open GitHub, file->Add a local repository - Done | Test plan: See: https://uoemy.sharepoint.com/personal/s2134810_ed_ac_uk/Documents/learn/MEng/Phase2/Result/TestData.xlsx TODO: - Test Sensing function, collect data from ADC(download from work space?) - Populate temperature sensing PCB, verify the input of temperature sensors.

	Sensing test: Board works functionally, Original design is inappropriate. Problem: ***Negative voltage output from sensors.*** Offset voltage of pressure sensors are around 1.6V, DC part is removed after the bandpass filter, therefore, as this sensor is bi-direction, negative value possibly could be attained. However, STM32F4 series controller can only support positive input of ADCs. I ignored transit issue before and only cared about AC analysis. In fact, bandpass filter is unnecessary as only high frequency inside of the device could only generate by LSA. Therefore, modified original circuit to a **LPF**(Low pass filter to remove tidal breath(Normally 0.5-2Hz)) + **VD**(Voltage divider, add a 3.3/2=1.65V offset in the end.) Schematic and simulation result can be found through Phase2->LabData->SensingData As new PCB have been printed out☹ **Manual correction on new board** needs to be done on this part. (Not really, got a new design from Alan, still waiting for parts, new board will be populated at next semester)

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	24/11/2022

EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	*Actuating system Test* **Electronics Test: Done** **If PCB works functionally** Design: ~~Low side load switch circuit(Schematics & PCB)~~ Result: **Do pay attention on the enable port for each load switch** *Test1: Signal generator as input, fixed at 5Hz* Output and input out of phase, desired(Low-side switch circuit) Test2: MCU PWM as input, sweeping from 5Hz to 30Hz Collect data of actuating signals; Collect data of LSA power input in this case. **Programming Test: Done** **If actuating signals are generated properly** ~~Code related;~~ ~~Signal captured;~~ **Mechanical Test: Done but pics needed** **If all mechanisms are integrated properly** CAD 3d overview Practical pics(Focus on LSA studio and membrane set-up) Hold is not strong enough, LSA supporter needs to be held manually. ~~(Tape it?)~~ All data related has been collected to path: LabData->ActuatingData

SIGNATURE

Day book - MEng project

NAME	DATE
Peggy Pei	25/11/2022

EQUIPMENT

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

Actuating system+ Sensing system Test

TODO:

~~Fixed LSA~~/seal all gap

Actuator can function properly but it causes fierce vibration of other parts while actuator is on.

Problem	Solution
When restart and power the actuator, an overshot will power LSA initially at 12V.	It really depends on PCB and switch circuit. As my PCB is bare board design, all tracks are exposed outside, therefore, overshot happens occasionally. More reliable PCB manufacture is required.

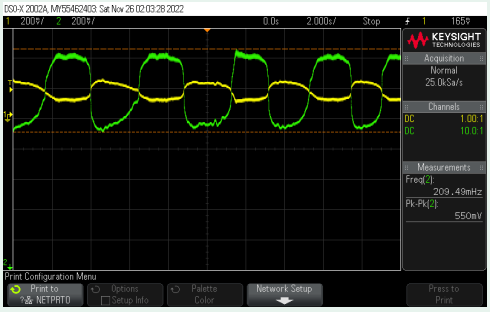
Data Request from:

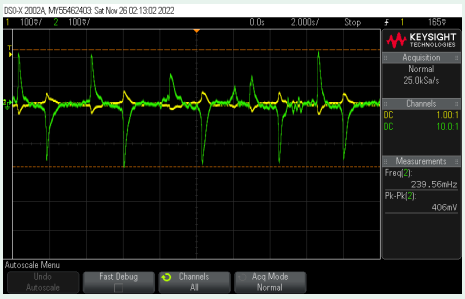
1. Tidal breath Measurement

   No need to use MCU, set up sensors on Bread board(Without filter) & PCB(With filter/adjust capacitor firstly), measure tidal breath with oscilloscope. (All parts can be sealed after this.)

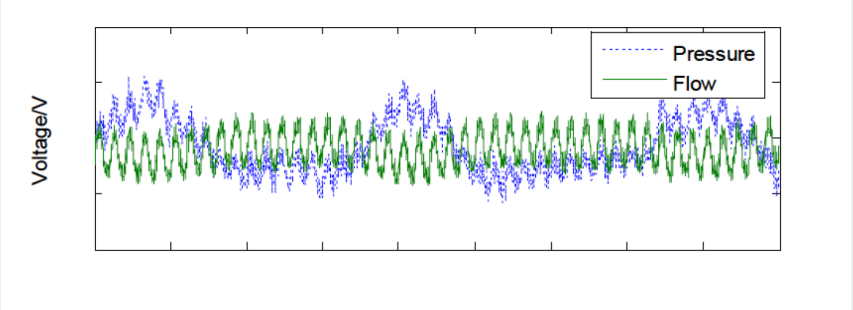
   Without AC;

   Without/With Bandpass filter (Y: Pressure / G:FlowRate)





Beautiful graph!! Exactly consistent with previous study :



	P and Q In Phase. 2. Actuating signal (in tube) Measurement Done. See file: Phase2->Result-> TestData->Test1-AC+Sensors

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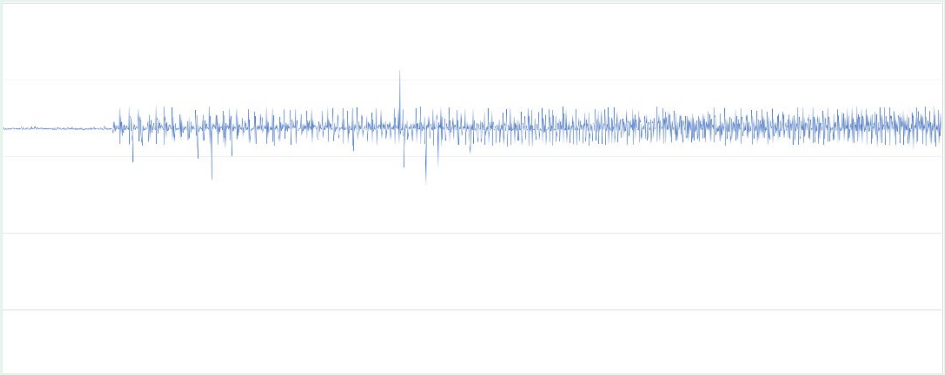
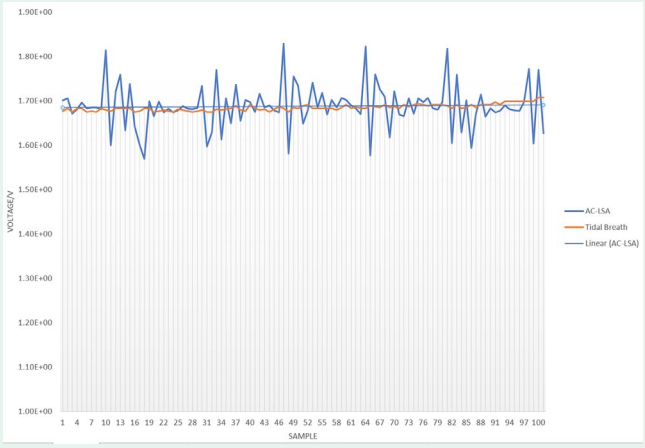
EQUIPMENT	Lab equipment
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	TODO: 1. Seal all parts, then measure the respiratory impedance without temperature control (3 times) 2. Temperature control Test - Populate Temperature Board(Manufacture problem; mismatch on connector- waiting for new board) - Collect data from temperature sensor - Collect data of respiratory impedance under temperature control Done: 1. Redo Test 1: Instead of calculating impedance, use sensors and oscilloscope to measure the ac signal without human. Overall:  Clearly shows that the frequency of actuating signal is increasing as it should be. Zoom in, pick a length of signal:  It is not a small amplitude signal compared to the tidal breath of human. Available approaches:

-Thicken the membrane;

- expand stoke length of LSA

2. Test 4:
   Measure respiratory impedance with temperature control
3. Test 5:
   Measure respiratory impedance under temperature control

Emergent situation:

One of sensors got burnt

Issue	Suspect cause	Conclusion & Solution
One of sensors got burnt	Mechanical damage: Pressure out of range	I did a few tests, thought electrical spike might be the main issue in this case. As I frequently switched on/off 12v power supply, and this PCB is almost bare board due to the limitation of PCB manufacture by ourselves. Lots of spikes were detected during my other tests. The supply current of this type of sensor is 3.3-5.8mA, I added a large resistor at the end of sensor output, restricting large current flowing through this, which will probably be helpful(Hopefully) . Do not long-time power whole system with 12V. **Solution:** **Add a large load resistors.** **Order two new sensors.**
	Electrical damage: Power supply spikes in circuit	

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EQUIPMENT

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

TODO:

-Waiting for New TC PCB

-Waiting for New sensors.

Summary of Output and Result

Output:

Electronics output: PCB

Mainboard - 3 versions

Version No.	Feature	Modification
1	-12 Power input -3V3 regulator as power input for the sensor system and MCU -Load switch circuit -Connectors and connection circuits between each subsystem -Ground pour and 12V pour layer. -Bandpass filter for sensing signal	None
2	-Same features as previous	1. Changed new **load switch IC** model on Altium(FPF2701MX instead of FPF2701MPX, as they are on the different package.) 2. Delete 12V pour layer, Ground pour was occasionally deleted (due to a manufacture issue.)
3	-Same features as previous version	1. Changed **3V3 regulator and its peripheral circuit**. (Current limit for previous regulator is 200mA, however, 250 mA is sinking from MCU and 10mA is sinking from sensors. Therefore, change a new 3V3 regulator with current limit up to 500mA) 2. Add vias for through whole connector. (Due to manufacture limit in the Uni, all vias and through whole components have to be manually soldered on both

		sides, which means through whole connectors were taken apart firstly and assemble back, causing noises and instability.) 3. Add ground pour layer back.(Manufacture) 4. Change band pass filter to high pass filter + voltage divider(avoid negative value input to the ADC)

Temperature sensing board: 2 Version

Version No.	Feature	Modification
1	-Temperature sensor field. -Low pass filter for temperature sensor output. -Connectors for power input and analogue output.	None
2	Same features as previous	1. Correct layer orientation. 2. Correct connector length.(2mm to 2.54mm)

Mechanical Output- Mechanism of the device

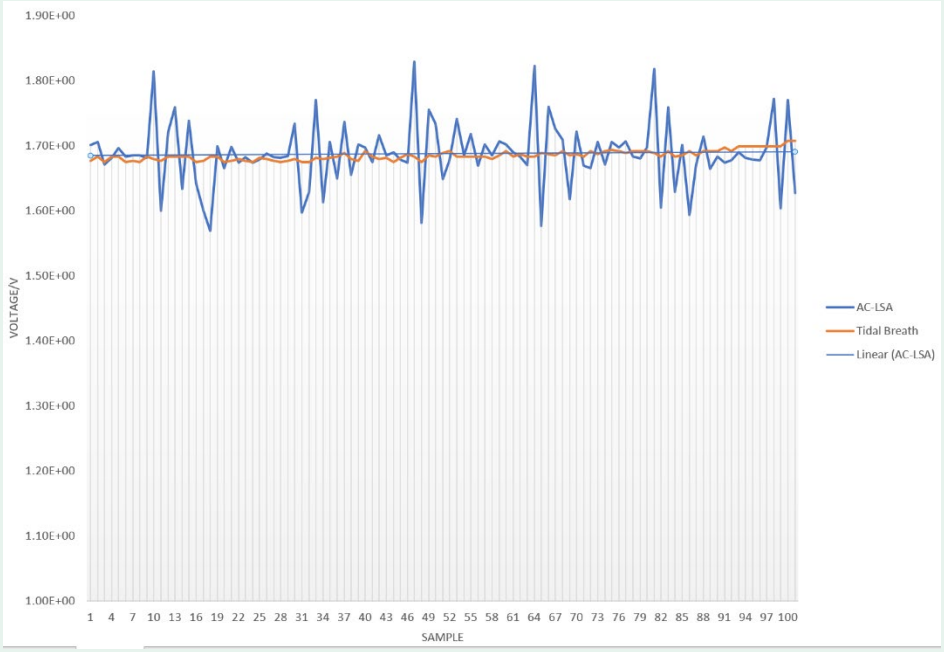
Version NO.	Feature	Modification
1	-Part 1: LSA studio -Part 2: Membrane connector(Connect Membrane+ Air outlet) -Part 3: Sensor connector (Connect pressure sensor and temperature sensor board)	Cut the edge of junction to fit in the mouthpiece. 0.2-0.4mm for strong squeezing connection
2	-Same features as previous	Part 1: 1.Opened top roof, providing more space for cable settlement. Reduced stoke length for LSA(12cm? to 14.3cm) 2.Changed the diameter of Membrane junction (Improvement: membrane flange/google it

Result:

Tidal breathing:

Actuating signal:

Discussion can be added here: How small the actuating signal can be?



Previous student COMCOUL model define the amplitude of actuating signal as 0.3kPa(Convert to voltage). From my experiment, this actuating signal generated by LSA is far bigger than tidal breathing, but what should the relationship be between them?
Talked about solutions to reduce amplitude of this actuating signal.

Another discussion: Why sensors got burnt.
Check daybook on 29,Nov

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EQUIPMENT

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

Temperature control Test

Offset Configuration Test:

Equation:

```
Temp_Vanalogue=(float)Temp_Vdigital*3/4096;
Temp=(Temp_Vanalogue-0.5)/0.01;
```

Scenario	Analogue reading/V	Real temperature/°	Converted Temperature/ °
Room-20°	0.884	22	38.4
Human- 37°	1.024	36	52.4

Offset=16

```
Temp_Vanalogue=(float)Temp_Vdigital*3/4096;
Temp=(Temp_Vanalogue-0.5)/0.01-16;

if(Temp<=35){
    HAL_GPIO_WritePin(GPIOA, GPIO_PIN_1, GPIO_PIN_SET);
}
else
    HAL_GPIO_WritePin(GPIOA, GPIO_PIN_1, GPIO_PIN_RESET);
```

PA1 should be connected with EN_HP

Real Time Control Test:

Generate a data array[512] record analogue temp output from workspace;
Measure the real-time digital output by using oscilloscope;
Overlap those two result.

Only for test:

Current sampling frequency :1/1ms=1kHz, change it to 1/100ms=10Hz
Assume measuring time is 20s, create the array[200];

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EQUIPMENT

EVENT

- ☐ *Reading materials*
- ☐ *Laboratory*
- ☐ *Design*
- ☐ *Others (Device test)*

Project summary – Test Part

No	Functionality	Procedure	Data Collection	Test Record	Progress
1	***Sensing Reading***	Connect sensor to MCU, check reading from ADC, DC reading range should be at ~2200.	Sensor offset/ P&V Tidal breath	Idle offset-1.65V / Changed PCB	Done
			Sensing data from HPF+ voltage Divider		No
2	***Actuating Signal Generate***	Check if actuating signal is generated properly from MCU. Check is LSA can be properly control through PCB interface. Check if signals generated by MCU can be used to control LSA. Check if membrane and mechanism related do their job.	Graph for actuating signal Signal generated by LSA through whole process		Done
3	***Temperature sensing and control***	Check if heating mat can be powered up through PCB interface. Check if MCU can read sensing value from Temperature sensing PCB. Check how distance between temperature sensor and heating pad affect the control result	Temperature reading Graph for actuating signal		Done
4	***Impedance Measurement***	Measure impedance without temperature control Measure impedance with temperature control	Impedance from workspace Impedance from UI graph		No

-Sensing Test:

Simulation:

- Changed original bandpass filter to a high pass filter + voltage divider(Remove tidal breath ~0.2-0.5Hz)

New PCB was not tested.(3v3 regulator hasn't been delivered)

-Actuating Test

Used oscilloscope to record how actuating signal look like

Can do- **But :**

Large amplitude/ High harmonics

Improvement:

How to reduce amplitude?

How to reduce harmonics?

(Membrane setting: Thickness of membrane/ Mechanism of membrane set up(tension))

Tidal breathing:

- ~~Without AC, Without Filter~~
- ~~Without AC, With Bandpass filter~~
- Without AC, With HPF+ Voltage divider - > New PCB Test
- With AC, With HPF+ Voltage divider -> Final impedance Measurement

Temperature control

-Record analogue reading from workspace
-Recorded digital output of TS control
-Aligned two of them, got reliable response.

Improvement:
Multistage control, set another TS board on heating mat, protecting mechanism surrounded from melting.
PID controller application further test

Dimension:
WHL:
W=90mm
H=100mm
L=279mm

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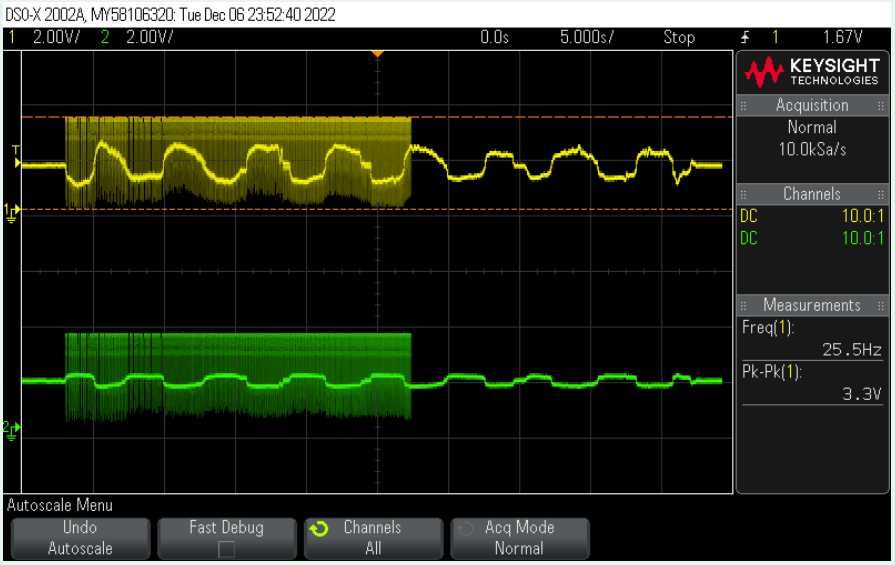
EQUIPMENT	
EVENT ☐ *Reading materials* ☐ *Laboratory* ☐ *Design* ☐ *Others (Device test)*	Test5- Impedance Calculation from MCU Not desired data Test6- Forced breathing signal measurement  Forced breathing signal VS Tidal breathing signal, Could be used to explain loads of things. Analyse why data from MCU is not desirable. Does the amplitude of actuating signal make difference? Is there any problem with impedance calculation logic? If FFT has been verified, can current data collecting method(Separately deal with data at each frequency) be the problem? Of Course, further repetitive tests need to be done.

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