Esophageal Simulator

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Abstract

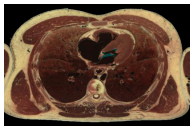
Eso-technologies is developing a new cardiac monitoring probe designed to read pressures within the esophagus. This probe is intended to replace the invasive Pulmonary Artery Catheter (PAC). Testing and development of the new probe is limited to a specific number of clinical trials set by the FDA.

Eso-technologies has asked our team to design an esophageal simulator that will enable the probe to be tested without the need for human or animal trials. This will allow for more testing and quicker refinement turnaround.

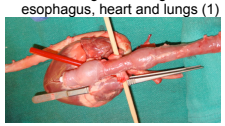
Background/Previous Work

Eso-Technologies Probe

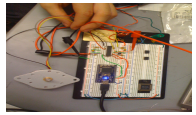
- New device designed to replace the Pulmonary Artery Catheter (PAC) which monitors heart function from within the pulmonary vein.
- New device is designed to monitor heart function via the esophagus.
- Pressure sensor designed with two saline filled balloons:
  - reference balloon - Reads respiratory pressure
  - recording balloon – Reads respiratory and atrial pressure
- Recording balloon – Reference balloon = left atrial pressure.



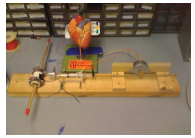
An image including the esophagus, heart and lungs (1)



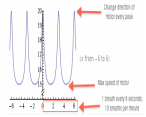
Anatomical representation of probe usage.



Motor Control Circuit



Complete Esophageal Simulator System



Motor control function

Previous Work

- Circuit with complete with stepper motor.
- Programmed function to produce sinusoidal waveform.
- Esophagus System made of PVC pipe, Penrose, O-rings and pipe clamps.
- Pressure generated by syringe moved by stepper motor and gear rotation.

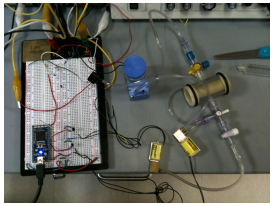
Bipolar Stepper Motor (3)

Final Design

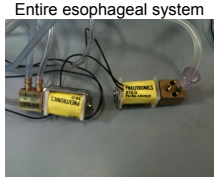
Design Requirements		
Anatomical Structure	**Pressure Range**	**Frequency**
Left Atrium	.8 – 2.93 kPa	40 – 140 per min
Chest Cavity	0 – 2.93 kPa	3 – 8 per min
Esophagus (static)	0 – 6.67 kPa	Constant

Left: The specified pressure ranges obtained from Eso-Technologies.

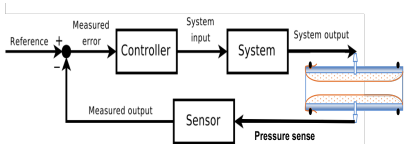
Below: Schematic of the simulator. A programmed input is continuously compared to the actual input; necessary corrections are made automatically.



Entire esophageal system



Valves: The left allows air into pressure compartment. The right lets air out.

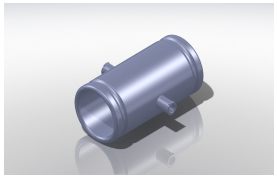


Valves

- Pneutronics solenoid valves
- Allow air in and out based on signal from the mBed.
- Improvements:
  - Much faster response time than stepper motor. Allows for rapid pressure waves such as the atrial pressure to be simulated.
  - Eliminates need for mechanical components such as gears and syringe.

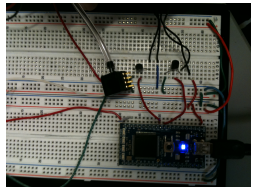
Pressure Compartment

- 3D printed to allow compatibility with Luer lock systems common in medical environments.
- Improvements:
  - Allows easier interchangeability of tubing/connections.
  - More air tight as compared to previous super glued PVC pressure compartment.



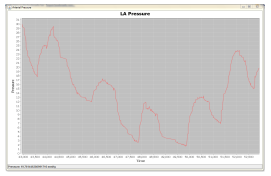
Major Circuit Components

- MPXV7025 Pressure Sensor
  - 25 – 25 kPa pressure range.
- LPC1768 mbed Microcontroller
  - Programmed using C++ language.
  - Provides feedback to make corrections.
- N-Channel MOSFET transistors
  - Send current to valves.



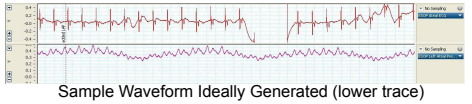
Testing

Right: The computer generated pressure output from the entire system.



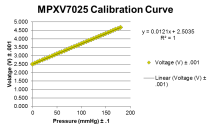
Other testing included:

- Oscilloscope voltage reading of pressure sensor and mBed output.
- Validation of air tight connections.



Sample Waveform Ideally Generated (lower trace)

Right: Calibration curve of the pressure sensor. The voltage resulting from this pressure conversion is fed into the microcontroller and necessary adjustments are made.



Future Work

Future improvements of the device include:

- User friendly interface that allows specific pressure ranges and frequencies to be chosen.
- Incorporate a periodic peristalsis waveform that can be encountered in real life situation.
- Reproducing the breadboard circuit on a circuit board to make the space requirements of the system smaller.

References

1. *Visible Human Server*. Web. 13 Oct. 2010. <http://visiblehuman.epfl.ch/>.
2. Widmaier, Eric P., Hershel Raff, and Kevin T. Strang. Vander's Human Physiology: the Mechanisms of Body Function. Boston: McGraw-Hill, 2006. Print.
3. http://www.cecs.csulb.edu/~hill/ee347/Bipolar_Stepper_Motor_Lab/images/djvnr2b_85dxjvr5gk_b.jpg

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