BME Design-Fall 2021 - Sammie Gilarde
Complete Notebook

PDF Version generated by

Sammie Gilarde (gilarde@wisc.edu)

on

Dec 15, 2021 @01:15 PM CST

Table of Contents

Team contact Information

Frankie Szatkowski - Oct 19, 2021, 1:13 PM CDT

Last Name	First Name	Role	E-mail	Phone	Office Room/Building
Skala	Melissa	Advisor	mcskala@wisc.edu		
Reuter	Mitchel	Client	mlreuter@wisc.edu		
Gilarde	Sammie	Leader	gilarde@wisc.edu	781-707-6695	
Norman	Riley	Communicator	rnorman4@wisc.edu	(612)462-9812	
Mohlke	Kasey	BSAC	kmohlke@wisc.edu	(612)865-6606	
Silver	Mateo	BWIG	mnsilver@wisc.edu	(608)622-5392	
Finn	Sophia	BWIG	svfinn@wisc.edu	(414)426-4592	
Szatkowski	Frank	BPAG	fszatkowski@wisc.edu	(262)-441-0300	

Project description

KASEY MOHLKE - Sep 15, 2021, 8:19 PM CDT

Course Number: BME 200/300

Project Name: Arterial Line Simulator

Short Name:

Project description/problem statement:

Currently only expensive and high tech medical manikins have the ability to show variability in arterial line monitoring. However, being accustomed to variation in arterial blood pressures and waveforms is an important skill for those in medical school. Given this, our device should be able to simulate the various waveforms by pressing a syringe plunger at different speeds and pressures. This device should be programmable in order to properly simulate a wide variety of conditions.

About the client:

Mr. Mitchel Reuter works in the Emergency Education Center as well as the Clinical Simulation Program for UW Hospital and Clinics associated with UW School of Medicine and Public Health.

9/20/2021 - Client Meeting 1

Sammie Gilarde (gilarde@wisc.edu) - Sep 23, 2021, 12:38 PM CDT

Title: Client Meeting 1

Date: 9/20/2021

Content by: Sammie Gilarde

Present: Kasey, Sophia, Riley, Mateo

Goals: ask client questions that we have prepared and begin to prepare for the PDS

Content:

- Should the device be able to accommodate 5 mL to 50 mL or we should just pick a size to make our design around?
  - Generally they are standardized size diameter might vary by a millimeter or two
  - We will be designing around a 10 mL syringe
- Approximate budget?
  - 500-1000
- Is it supposed to be an external device that attaches to the syringe?
- Anticipated materials? When to pick them up?
  - Syringes and transducer set up
  - Not sure what else would be needed
- Size and specifications of device?
  - Depends very variable - kind of unsure, maybe a VHS tape
  - Currently do it manually
- Elaborate on the device as a whole and the most important features.
- Pre-existing devices to give us an idea of where to go.
  - ONly mannequins that do it
  - No low fidelity equipment to make it work
- End goal of usage? Is it for simulating a condition and diagnosing it or more the set up and usage of an arterial line monitor.
  - Want to replicate the regular wave form for an artery - if they could even get a normal looking wave it would be good
  - Variable speed motor from 30rpm - 200rpm
  - Maybe a roller belt that could just roll and bump the plunger
    - Then other roller options would create different waveforms
    - Never needs to pull the plunger back up
- How would we replicate the various waveforms, ex over and under dampening?
  - Under - Same waveform as regular but with more pressure - might not directly work by just applying more pressure
  - Over - One rounded

Meeting notes:

- Sterility isn't that important
- Pressing harder is higher blood pressure - not necessary but good

Conclusions/action items:

The team was able to ask the client questions which provided clarification on the project. Above are the questions the team had prior to the meeting and any notes taken based on the clients response. Next, the team will begin working on the PDS.

12/5/2021 - Client Meeting 2

Frankie Szatkowski - Dec 11, 2021, 3:05 PM CST

Title: Client Meeting 2

Date: 12/5/2021

Content by: Frankie

Present: Sammie, Frankie, Riley, Mateo, Kasey

Goals: To hook our prototype up to the portable transducer and gather data on waveforms produced

Content:

See Testing and Results Folder for quantitative data

Qualitative

- vibrations produced lots of artifact
- transducer link should be directly mounted to housing (prevent separation between machine and system)
- Motor torque struggled with high cam changes
- Small amounts of saline leaked from the syringe, warping HDF
- Allowing syringe-mounted box to move from cam produced better transducer pressures.

Conclusions/action items: Meeting with our client allowed us to determine future work for the project as well as what would require minor tweaks versus complete reworks.

9/17/2021 - Advisor Meeting #1

Sammie Gilarde (gilarde@wisc.edu) - Sep 20, 2021, 11:22 AM CDT

Title: Advisor Meeting #1

Date: 9/17/2021

Content by: Sammie Gilarde

Present: Whole team

Goals: Introductions, take team photo

Content:

1. team met with advisor and introduced ourselves
2. team took team photo for website

Conclusions/action items:

The team's first meeting with their advisor was used for introductions and to set expectations for the semester. In addition the team was able to take a team photo that will be added to the team's website. Next steps are to meet with the client to better understand their needs for the project.

9/24/2021 -Advisor Meeting #2

KASEY MOHLKE - Sep 27, 2021, 10:35 PM CDT

Title: Advisor Meeting #2

Date: 9/27/21

Content by:

Present: Whole Team

Goals: Discuss upcoming project deadlines

Content:

- Went over progress report
- Next week the team must determine design matrix criteria and have three designs
- The design matrix will be used in the preliminary presentation which will take place in person in two weeks

Conclusions/action items:

Everyone is going to come up with design ideas, then we will meet to fill out the design matrix. Next advisor meeting on October 1st.

10/1/2021 - Advisor Meeting #3

Sammie Gilarde (gilarde@wisc.edu) - Oct 05, 2021, 3:59 PM CDT

Title: Advisor Meeting #3

Date: 10/1/2021

Content by: Sammie Gilarde

Present: Whole team

Goals: share current project status with advisor

Content:

1. discussed our 3 designs and design matrix
2. discussed preliminary presentation date change
3. began thinking about structure of preliminary presentation

Conclusions/action items:

The team will begin working on the preliminary presentation. In addition the team will begin the process of finalizing a design. The team's next advisor meeting is on 10/8.

10/8/2021 - Advisor Meeting #4

KASEY MOHLKE - Oct 18, 2021, 11:13 PM CDT

Title: Advisors Meeting #4

Date: 10/8/2021

Content by:

Present: Whole Team

Goals: Discuss progress report, upcoming goals.

Content:

We are at a good place in our project. We have started the preliminary presentation but since they were moved to next week, we still have plenty of time to work on it. Dr. Skala won't be there during the presentations so another advisor will be grading us. The presentation should be about 10 minutes long and will take place on 2nd floor of EHall. Preliminary deliverables will be due the Wednesday following the presentations which include the report, the notebook, and peer/self evaluations.

Conclusions/action items:

Continue work on preliminary presentation, begin preliminary report.

10/22/2021 - Advisor Meeting #5

Sammie Gilarde (gilarde@wisc.edu) - Oct 25, 2021, 4:19 PM CDT

Title: Advisor Meeting #5

Date: 10/22/2021

Content by: Sammie Gilarde

Present: Whole team

Goals: discuss progress and next steps

Content:

- received feedback on preliminary presentation
  - overall good, some areas to improve
- project is on task - next steps are to order materials

Conclusions/action items:

The team is on track and the project has been going well so far. The team received positive feedback on their preliminary presentation. The next steps are to finalize the materials and purchase them in order to begin fabrication.

11/19/2021 - Advisor Meeting #6

Sammie Gilarde (gilarde@wisc.edu) - Nov 19, 2021, 1:12 PM CST

Title: Advisor Meeting #6

Date: 11/19/2021

Content by: Sammie Gilarde

Present: Whole team

Goals: discuss project updates with advisor

Content:

- discussed materials being ordered
- concerns about testing being scheduled - email client to try to find a time to meet
- concerns about being reimbursed for material costs - suggested to be persistent and email him again

Conclusions/action items:

The team is going to 3D print and laser cut while the materials are being shipped. The team emailed the client to set up a time for testing once Thanksgiving break is over. After break the team will begin assembling the device.

12/3/2021 - Advisor Meeting #7

Sammie Gilarde (gilarde@wisc.edu) - Dec 11, 2021, 5:32 PM CST

Title: Advisor Meeting #7

Date: 12/3/2021

Content by: Sammie Gilarde

Present: Whole Team

Goals: discuss with advisor fabrication process and testing plans

Content:

- the team discussed testing plans with their advisor
    - meeting with client on Sunday December 5th
    - emphasize quantitative data
- poster should be printed in advance (contact advisor if having trouble printing)

Conclusions/action items:

Next the team will test the device with their client. If needed, the team will make adjustments to the device after testing. Additionally, the team will work on their final poster and complete it in time for the final poster presentation.

10/1/2021 - Design Matrix

Sammie Gilarde (gilarde@wisc.edu) - Oct 07, 2021, 3:21 PM CDT

Title: Design Matrix

Date: 10/1/2021

Content by: Sammie Gilarde

Present: Team

Goals: come up with 3 designs and create a design matrix in order to evaluate the 3 designs

Content:

see attached document on design matrix and criteria for selection

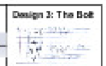
Conclusions/action items:

The team worked together to come up with 3 designs as well as the design matrix. The criteria was discussed and each design was evaluated as a team. Currently the final design is The Cam. Next the team will work on their preliminary presentation.

Sammie Gilarde (gilarde@wisc.edu) - Oct 07, 2021, 3:21 PM CDT

Design Matrix Criteria:

- Cost
    - The device should cost less than the client's budget of $500-$1000.
- Functionality
    - Consistency
        - The device should be able to replicate the requested waveform identically every time it is in use.
    - Range of Use
        - The device should maximize the amount of waveforms it is capable of simulating.
- Ease of fabrication/development
    - The device should be easy to physically fabricate and/or program to create our desired waveform.
- Ease of use
    - The device should be simple to learn how to use by the instructors who need this as a demonstration tool.
- Durability
    - The device should be able to withstand normal daily use for the next five years.
- Safety
    - The device should not pose any harm to the instructors using it or the students observing it.

Criteria	Design 1: The Cam 	Design 2: The Piston 	Design 3: The Bolt 
Consistency (25)	5/5 * 25 = 25	5/5 * 25 = 25	4/5 * 25 = 20
Range of Use (25)	4/5 * 25 = 20	2/5 * 25 = 10	3/5 * 25 = 15
Ease of Use (20)	5/5 * 20 = 20	5/5 * 20 = 20	4/5 * 20 = 16
Ease of Fabrication (10)	3/5 * 10 = 6	2/5 * 10 = 4	2/5 * 10 = 4
Safety (10)	5/5 * 10 = 10	5/5 * 10 = 10	4/5 * 10 = 8
Durability (5)	3/5 * 5 = 3	3/5 * 5 = 3	4/5 * 5 = 4
Cost (5)	5/5 * 5 = 5	4/5 * 5 = 4	4/5 * 5 = 4
Total = 100	89 / 100	76 / 100	71 / 100

Design_Ideas_and_Matrix.pdf(207.2 KB) - download

11/26/2021 - Bipolar Stepper Controller

Frankie Szatkowski - Dec 15, 2021, 2:08 AM CST

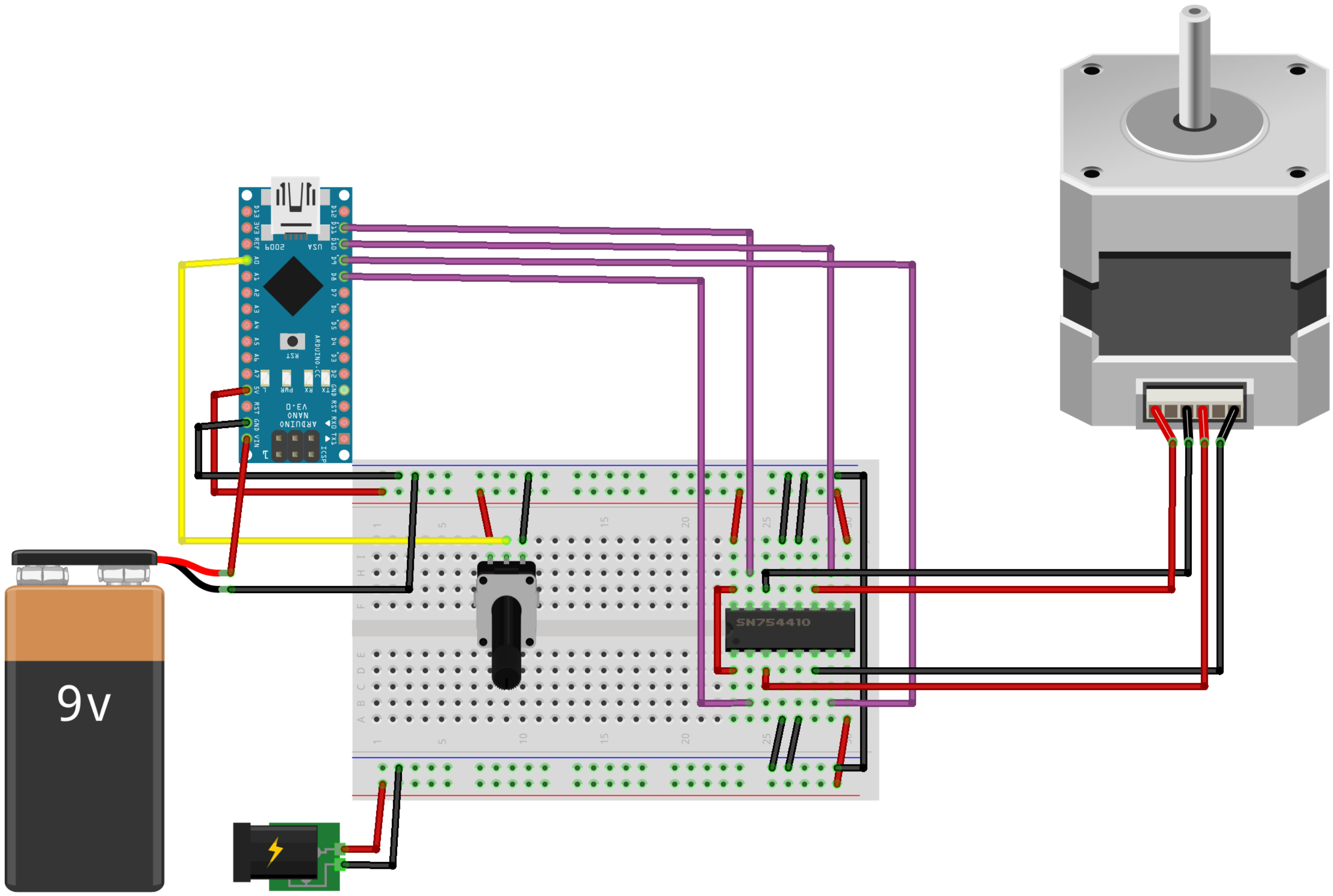
Title: Arduino Controller for Stepper Motor

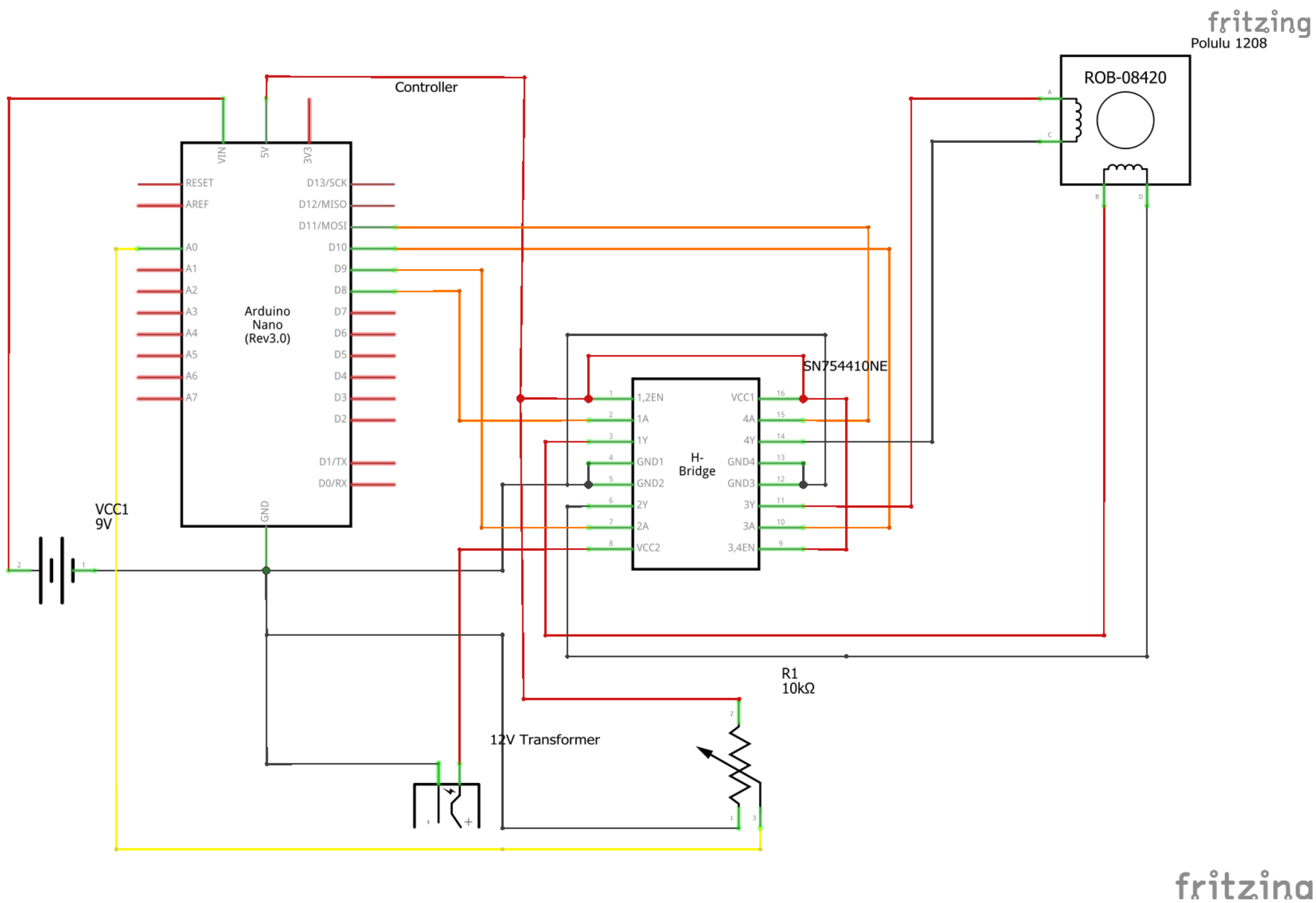
Date: 11/26/2021

Content by: Frankie

Goals: To control a bipolar stepper motor using an Arduino and a stepper driver

Content:


SN754410
9v


fritzing
Polulu 1208
ROB-08420
Controller
VIN
5V
3V3
RESET
AREF
A0
A1
A2
A3
A4
A5
A6
A7
D13/SCK
D12/MISO
D11/MOSI
D10
D9
D8
D7
D6
D5
D4
D3
D2
D1/TX
D0/RX
Arduino
Nano
(Rev3.0)
GND
VCC1
9V
SN754410NE
1,2EN
1A
1Y
GND1
GND2
2Y
2A
VCC2
H-
Bridge
VCC1
4A
4Y
GND4
GND3
3Y
3A
3,4EN
R1
10kΩ
12V Transformer
fritzing

Conclusions/action items:

The final schematic for the Arduino powered controller is shown above. This accurately controls the speed of the stepper motor for the client utilizing the rotary potentiometer attached to the board.

2021/12/07- Material Expenses

Frankie Szatkowski - Dec 11, 2021, 1:59 PM CST

Title: Material Expenses

Date: 12/07/2021

Content by: Frankie Szatkowski (BPAG)

Goals: To accurately log materials and expenses for this project

Content:

Items Purchased	Cost ($)
Arduino, Breadboard, Wires, Battery	$23.10
10k Ohm Potentiometer (2)	$0.52
Hex Adaptors (2)	$10.31
SN754410NE Driver (2)	$17.42
Polulu 1208 Stepper Motor	$22.50
Arduino Wires	$7.37
12V Wall Adaptor	$13.70
Bolts, Shrink Wrap, Battery, Additional Hardware	$3.19
Full Sheet HDF	$3.30
3D Prints (3)	$10.25
Total:	**$111.66**

Conclusions/action items: Our prototype ended up costing around $115 to produce. We were well under our $500 budget which leaves space for future adjsutments if the future bdget remains stable.

12/3/2021 - Final Device

Sammie Gilarde (gilarde@wisc.edu) - Dec 14, 2021, 4:02 PM CST

Title: Final Fabricated Device

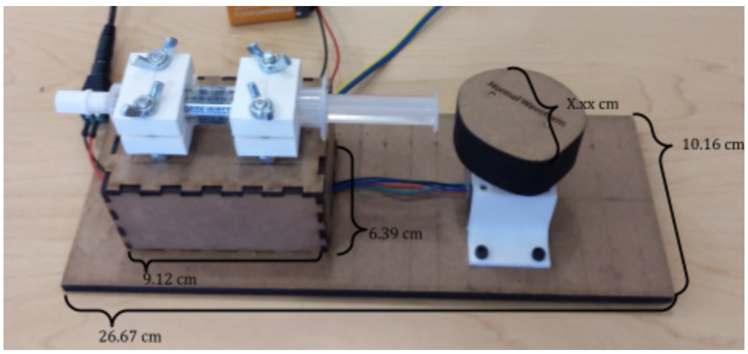
Date: 12/3/2021

Content by: Sammie Gilarde

Present: Whole team

Goals: complete fabrication of device

Content:



The final fabricated device is shown above. The base platform, box to house the circuitry and cams were laser cut from HDF. The motor mount and syringe clamps were 3D printed. The device is powered using a 9V battery and wall power. The box allows for the syringe to align with the cam which is raised due to the height of the motor. The syringe clamps hold the syringe in place while allowing for the position of the syringe to be adjusted depending on the cam being used. See additional entries for specifics on circuitry.

Conclusions/action items:

The device is now fully fabricated. Next the team is able to begin testing. After testing, the team will analyze the test results and determine any changes that need to be made to the device as a result.

12/4/21 - Testing Protocol

Riley Norman - Dec 11, 2021, 12:57 PM CST

Title: Testing Protocol

Date: 12/4/21

Content by: Riley Norman

Present: Riley Norman

Goals: To establish our groups testing protocol.

Content:

In order to test our device we met with our client to use an actual arterial line monitor to see how our device will perform in real world use. With our client we followed the following protocol.

1. Set up device and arterial line transducer
2. Pick one of the cam shapes and sizes, big or small, normal or overdamped
3. Place the syringe plunger at the lowest point on the cam
4. Test the device for the entire range of motor speed (~30 - 200 rpm)
5. Take pictures of the waveforms generated by the cam
6. Turn off the motor
7. Move the plunger to the middle height of the cam
8. Repeat 4-6
9. Move the plunger to the farthest part of the cam
10. Repeat 4-6
11. Repeat 2-10 for the three remaining cam sizes

Using this protocol we were able to test all speeds that the device is capable of producing for all cams. The data we collected i.e. the waveforms that we were able to produce could then be analyzed in matlab and compared to the true waveforms that we were attempting to reproduce.

Conclusions/action items:

To finish the report and all other final deliverables.

Riley Norman - Dec 11, 2021, 12:59 PM CST

IMG_6574.HEIC(1.1 MB) - download

12/5/2021 - Testing Data

Sammie Gilarde (gilarde@wisc.edu) - Dec 13, 2021, 7:48 PM CST

Title: Testing Data

Date: 12/5/2021

Content by: Sammie Gilarde

Present: Whole team

Goals: test device to determine waveform accuracy

Content:

The team was able to meet with their client to test the fabricated device for waveform accuracy. See attached document for results.

Conclusions/action items:

Now that the team has testing data for the device they will be able to quantify the results and determine accuracy of the waveforms produced. Future work will include adding rubber feet to the device to stabilize the platform. Additionally, the team will begin working on the final poster.

Sammie Gilarde (gilarde@wisc.edu) - Dec 13, 2021, 7:49 PM CST

Arterial_Line_Testing.pdf(2.5 MB) - download

12/5/2021 - MatLab Analysis

KASEY MOHLKE - Dec 14, 2021, 8:33 PM CST

Title: MatLab Analysis

Date: 12/14/2021

Content by: Kasey Mohlke

Present: Whole Team

Goals: Use MatLab to perform statistical analysis on the collected data.

Content:

The MatLab code (found below) was used to recreate the team's small and large normal cam waveforms. These were then compared to the ideal 120/60 mmHg normal arterial pulse waveform. The xcorr function in MatLab which computes the cross-correlation between two discrete time functions was used to determine that the small normal cam had correlation of 84% while the large normal cam had a correlation of 52% to the ideal waveform.

Conclusions/action items:

Include in final report, cite code in appendix.

KASEY MOHLKE - Dec 14, 2021, 8:33 PM CST

```
beatsPerMin = 80;

dur = beatsPerMin/60; %80 beats per minute (80/60)

fs = 12000; %%sampling rate

t = linspace(0,dur,fs);

theta = linspace(-pi,pi,fs);


%%%%%%


a = [0.9490, 0.5150, 0.2893, 0.2838, 0.1498, 0.1227, 0.1177, 0.0569, 0.0105, 0.0008, 0.0056];

b = [0, 0.05873, 0.1871, 0.0459, -0.0032, -0.1109, -0.0743, -0.0196, -0.0086, -0.043, -0.0007];

N = length(a);  %%number of fourier series coefficients

Sn = arterialW(a, b, N, theta);  %%arterial pulse waveform function

Sn = fft(Sn);

Tn = ifft(Sn,'symmetric');


figure  %%display arterial pulse waveform as function of time

hold on

plot(t,Tn*58); %%scale the waveform and plot against time

xlabel('Time (s)');

ylabel('Pressure (mmHg)');

title('Ideal Arterial Pulse Waveform');

hold off


%%%%%%


a2 = 0.96*[0.9490, 0.5150-.15, 0.289-0.08, 0.2838-0.075, 0.1498, 0.1227, 0.1177, 0.0569, 0.0105, 0.0008, 0.0056];

b2 = 2.1*[0, 0.05873, 0.1871, 0.0459, -0.0032, -0.1109, -0.0743, -0.0196, -0.0086, -0.043, -0.0007];

N = length(a2);  %%number of fourier series coefficients

Sn2 = arterialW(a2, b2, N, theta);  %%arterial pulse waveform function

Sn2 = fft(Sn2);

Tn2 = ifft(Sn2,'symmetric');


figure  %%display arterial pulse waveform as function of time

hold on

plot(t,Tn2*51);
```

```
xlabel('Time (s)');

ylabel('Pressure (mmHg)');

title('Small Normal Cam Waveform');

hold off



[r,c] = xcorr(Tn*58, Tn2*51);


figure

hold on

stem(c,r)

title('Ideal vs Small Normal Cam')

hold off


rmean = mean(r);

correlationW = rmean/4.543973457992685e+06


%%%%%%%


a3 = 0.48*[0.9490, 0.5150-.25, 0.289-0.18, 0.2838-0.075, 0.1498, 0.1227, 0.1177, 0.0569, 0.0105, 0.0008, 0.0056];

b3 = 0.34*[0, 0.05873, 0.1871, 0.0459, -0.0032, -0.1109, -0.0743, -0.0196, -0.0086, -0.043, -0.0007];

N = length(a2);  %%number of fourier series coefficients

Sn3 = arterialW(a3, b3, N, theta);  %%arterial pulse waveform function

Sn3 = fft(Sn3);

Tn3 = ifft(Sn3,'symmetric');


figure  %%display arterial pulse waveform as function of time

hold on

plot(t,Tn3*63);

xlabel('Time (s)');

ylabel('Pressure (mmHg)');

title('Big Normal Cam Waveform');

hold off



[r2,c2] = xcorr(Tn*58, Tn3*63);
```

```
figure

hold on

stem(c2,r2)

title('Ideal vs Big Normal Cam')

hold off


r2mean = mean(r2);

correlationW2 = r2mean/4.543973457992685e+06


figure  %%display arterial pulse waveform as function of time

hold on

subplot(3,2,1);

plot(t,Tn*58); %%scale the waveform and plot against time

xlabel('Time (s)');

ylabel('Pressure (mmHg)');

title('Ideal Arterial Pulse Waveform(120/60)');


%%display arterial pulse waveform as function of time

subplot(3,2,3);

plot(t,Tn2*51);

xlabel('Time (s)');

ylabel('Pressure (mmHg)');

title('Small Normal Cam Waveform(96/72)');


subplot(3,2,4);

stem(c,r)

title('     Ideal vs Small Normal Cam')

legend('Correlation= 0.8442')

ax.FontSize = 8;


%%display arterial pulse waveform as function of time

subplot(3,2,5);

plot(t,Tn3*63);

xlabel('Time (s)');

ylabel('Pressure (mmHg)');
```

```
title('Big Normal Cam Waveform(48/19)');


subplot(3,2,6)

stem(c2,r2)

title('     Ideal vs Big Normal Cam')

legend('Correlation= 0.5214')

ax.FontSize = 8;

hold off
```

KASEY MOHLKE - Dec 14, 2021, 8:34 PM CST

```
function [Sn] = arterialW(a,b,N,theta)

%arterial pulse waveform function

a0 = a(1)/2;

Sn = 0;

for n = 2:N

    Sn = Sn + (a(n).*cos((n-1)*theta)) + (b(n).*sin((n-1)*theta));

end

Sn = a0 + Sn;

end
```

9/24/2021- PDS

KASEY MOHLKE - Oct 18, 2021, 11:04 PM CDT

Title: PDS

Date: 9/24/2021

Content by: Whole Team

Present:

Goals: Determine specifications of the arterial line simulator device.

Content:

See attached document

Conclusions/action items:

Use PDS in the design process in order to meet required specifications.

KASEY MOHLKE - Oct 18, 2021, 11:04 PM CDT

BME Design Courses
The Product Design Specification (PDS)
9/24/2021

Arterial Line Simulator (Section 308):
Mitch Reuter (Client)
Sammie Gilarde (Team Leader)
Riley Norman (Communicator)
Kasey Mohlke (BSAC)
Frankie Stalkowski (BPAG)
Sophia Finn (Co-BWIG)
Mateo Silver (Co-BWIG)

Function:

Medical students need to be able to practice a wide variety of different techniques and skills on representative models to improve their skills without putting a living patient at risk. One such technique is arterial line monitoring. This technique involves placing an arterial line in the patient's artery to monitor their blood pressure and arterial waveform. Our device should be able to attach to a syringe of saline and replicate the waveforms expected from arterial line monitoring of a living patient. The device should be able to have adjustable heart rate, blood pressure, and ideally arterial line waveform. Finally, it should be affordable and allow for an experience that is comparable to the real world.

Client requirements (itemize what you have learned from the client about his / her needs):

A device that:

- Can replicate regular wave form for an artery
- Has variable speeds of 30 - 200 rpm
- Is about the size of a VHS tape
- Ideally can replicate both overdamped and underdamped wave forms
- Can be reused and attached to any 10mL syringe

Design requirements:

1. Physical and Operational Characteristics

a. *Performance requirements:* This device should be able to withstand small but consistent amounts of pressure, repeatedly, and ideally on a daily basis. It should be compatible with the monitor and transducer that the client plans to pair with our device. It should replicate accurate results on demand.

b. *Safety:* This device is entirely for instructional purposes. Ease of sanitization is a plus, but is not required.

c. *Accuracy and Reliability:* Given that this device is meant to minimize human error in replicating waveforms, it must measure up to a high degree of accuracy. This degree of accuracy needs to be

PDS_Arterial_Line.pdf(83.5 KB) - download

10/15/2021- Preliminary Presentation

KASEY MOHLKE - Oct 18, 2021, 11:07 PM CDT

Title: Preliminary Presentation

Date: 10/15/2021

Content by: Whole Team

Present:

Goals: Shared progress on the design project with class, advisor, and client.

Content:

See attachment

Conclusions/action items:

Write preliminary report!

KASEY MOHLKE - Oct 18, 2021, 11:07 PM CDT

Preliminary_Presentation.pdf(664.4 KB) - download

10/20/2021- Preliminary Report

KASEY MOHLKE - Oct 20, 2021, 1:04 PM CDT

Title: Preliminary Report

Date: 10/20/2021

Content by: Whole Team

Present:

Goals: Complete preliminary report and send to advisor and client.

Content:

See attached document

Conclusions/action items:

Follow report outline as the project progresses.

KASEY MOHLKE - Oct 20, 2021, 1:04 PM CDT

Department of Biomedical Engineering
UNIVERSITY OF WISCONSIN–MADISON

ARTERIAL LINE SIMULATOR
PRELIMINARY REPORT
BME 200/300
10/20/21

Client: Mr. Michael Renier
Advisor: Dr. Melissa Skala
Team Members:
Sammie Gilade - Team Leader
Kasey Mohlke - BSAC
Riley Norman - Communicator
Frank Szatkowski - BPAG
Sophia Finn - BWIG
Mateo Silver - BWIG

1

Preliminary_Report.pdf(651.5 KB) - download

12/12/21 - Poster

MATEO SILVER - Dec 12, 2021, 4:11 PM CST

Title: Preliminary Presentation

Date: 12/12/2021

Content by: Whole Team

Present:

Goals: Presented final design to client, advisor, and other groups.

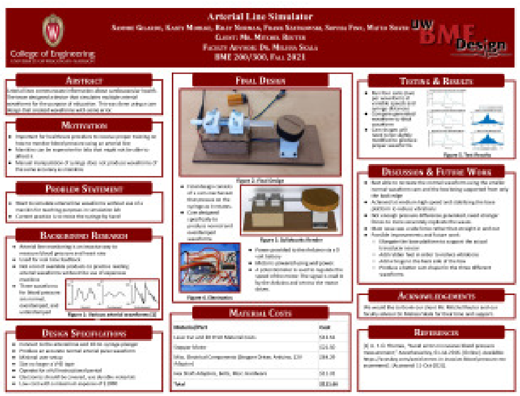
Content:

See attachment

Conclusions/action items:

Finish final report.

MATEO SILVER - Dec 12, 2021, 4:10 PM CST



Arterial_Line_Poster.pdf(1.4 MB) - download

9/15/2021 - Arterial Line Research

Sammie Gilarde (gilarde@wisc.edu) - Sep 23, 2021, 1:10 PM CDT

Title: Arterial Line Background

Date: 9/15/2021

Content by: Sammie Gilarde

Present: Sammie Gilarde

Goals: gain a better understanding of what an arterial line is

Content:

[1]

1. arterial line - small catheter inserted into an artery
2. arteries bring blood (with oxygen) to organs and tissues
3. have the highest blood pressure
4. arterial lines most common in critical care
    1. draw blood
    2. close blood pressure monitoring

[2]

1. blood pressure monitoring using an arterial line may be necessary during infection or post surgery
2. blood gas measurements
3. how to insert:
    1. check blood flow through branching arteries to ensure the arterial line will not block flow
    2. clean site
    3. inject local anesthetic to site
    4. insert needle through the artery, this is used to guide the catheter and then removed once the catheter is in place
    5. cover site with bandage
    6. hook up line to continuous flow saline
    7. line will then be hooked up to a monitor

Sources:

[1] “Arterial Line | LHSC.” https://www.lhsc.on.ca/critical-care-trauma-centre/arterial-line (accessed Sep. 23, 2021).

[2] “Arterial Line Placement,” *Saint Luke’s Health System*. http://www.saintlukeskc.org/health-library/arterial-line-placement (accessed Sep. 23, 2021).

Conclusions/action items:

These sources provided an overview of what an arterial line is and how it is set up. The most important function of arterial lines that relate to the project is the ability to read blood pressure. Next steps include researching blood pressure waveforms.

9/19/2021 - Blood Pressure Waveforms

Sammie Gilarde (gilarde@wisc.edu) - Sep 24, 2021, 12:09 PM CDT

Title: Blood Pressure Waveforms

Date: 9/19/2021

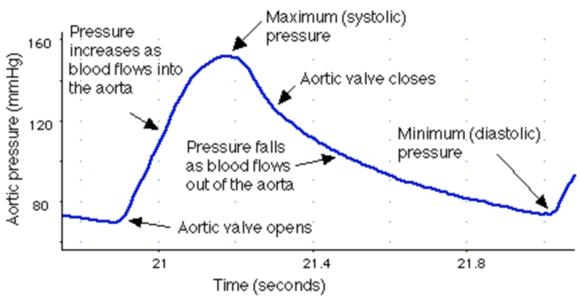
Content by: Sammie Gilarde

Present: Sammie Gilarde

Goals: research blood pressure waveforms and understand the different patterns

Content:

[1]

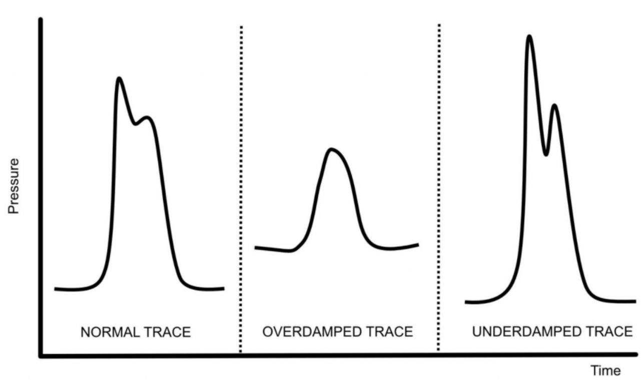


1. Maximum pressure (systolic) is the peak of the wave

2. minimum pressure (diastolic) is the lowest point of the wave

3. the wave represents the aorta opening, blood flowing in, an increase of pressure, and then the aortic valve closing and blood flowing out of the artery, decreasing pressure

[2]

1. transducer must be zeroed in order to be the most accurate reading
2. height of the transducer must be at the phlebostatic axis
   1. every 10 cm below this will add 7.4mmHg of pressure
3. overdamped vs. underdamped
4. 

[1]

"Arterial Pressure Waveforms." http://www.dynapulse.com/educator/webcurriculum/chapter%203/arterial%20pressure%20waveforms.htm (accessed Sep. 23, 2021).

[2]

"Arterial Lines – Intensive Care in a Flash." http://iciaf.com/?page_id=118 (accessed Sep. 24, 2021).

Conclusions/action items:

These sources gave a better understanding of blood pressure readings. They give an overview of what the waveforms are and what they mean. This will be helpful for when the team tests the product in order to understand the results that will show on the monitor.

9/25/2021 - Arterial Line Simulator

Sammie Gilarde (gilarde@wisc.edu) - Oct 19, 2021, 4:27 PM CDT

Title: Arterial-line Monitoring System Simulation

Date: 9/25/2021

Content by: Sammie Gilarde

Present: Sammie Gilarde

Goals: research any competing designs

Content:

- objective: simulate monitoring an arterial line
- MedSim simulator - arterial blood pressure is ideal, lacks variability
- their new system is compatible with the MedSim manikan
- hardware and software system
- different stop cock positions
- height of transducer
- new waveform delayed from ECG, varies with respiration, realistic diastolic pressures (hypotension and hypertension)

Conclusions/action items:

The design above is similar to the team's project in the way that it is intended for use in a lab to simulate arterial waveforms. However because it is dependent on the use of a MedSim manikan, the team's project goal seems to be independent of this competing design. The team's design will not be used with any type of manikan and will be able to simulate the arterial line waveforms on its own.

Sammie Gilarde (gilarde@wisc.edu) - Oct 19, 2021, 4:27 PM CDT

ARTERIAL-LINE MONITORING SYSTEM SIMULATION

David M. Feinstein, MD,[1] and Daniel B. Raemer, PhD[2]

KEY WORDS. Simulation, monitoring.

INTRODUCTION

Feinstein-Raemer2000_Article_Arterial-LineMonitoringSystemS.pdf(178.2 KB) - download

12/14/2021 - Global Impact

Sammie Gilarde (gilarde@wisc.edu) - Dec 14, 2021, 8:44 PM CST

Title: Motivation and Global Impact of the Device

Date: 12/14/2021

Content by: Sammie Gilarde

Present: Sammie Gilarde

Goals: describe the global impact for the device

Content:

Although the team is building the device for one specific client, there is a larger potential global impact. It is necessary for healthcare professionals to receive adequate training on how to read arterial line waveforms. This is used for applications that need real-time blood pressure monitoring such as during a surgery or in emergency care situations. While there are expensive manikins th at can be purchased by a teaching lab, some of these facilities may not be able to afford the manikins. Therefore it is necessary to have a device that can still act as a way to teach healthcare professionals how to read the waveforms while maintaining waveform accuracy. The teams device will be able to serve as the alternative option to expensive manikins for healthcare professionals in training.

Conclusions/action items:

It is important to recognize the global impact of the device. While the client's needs are ultimately the first priority, the device has the potential to be used beyond the scope of this project and semester.

10/1/2021 - Rotating Wheel Design

Sammie Gilarde (gilarde@wisc.edu) - Oct 19, 2021, 2:27 PM CDT

Title: Rotating Wheel Design

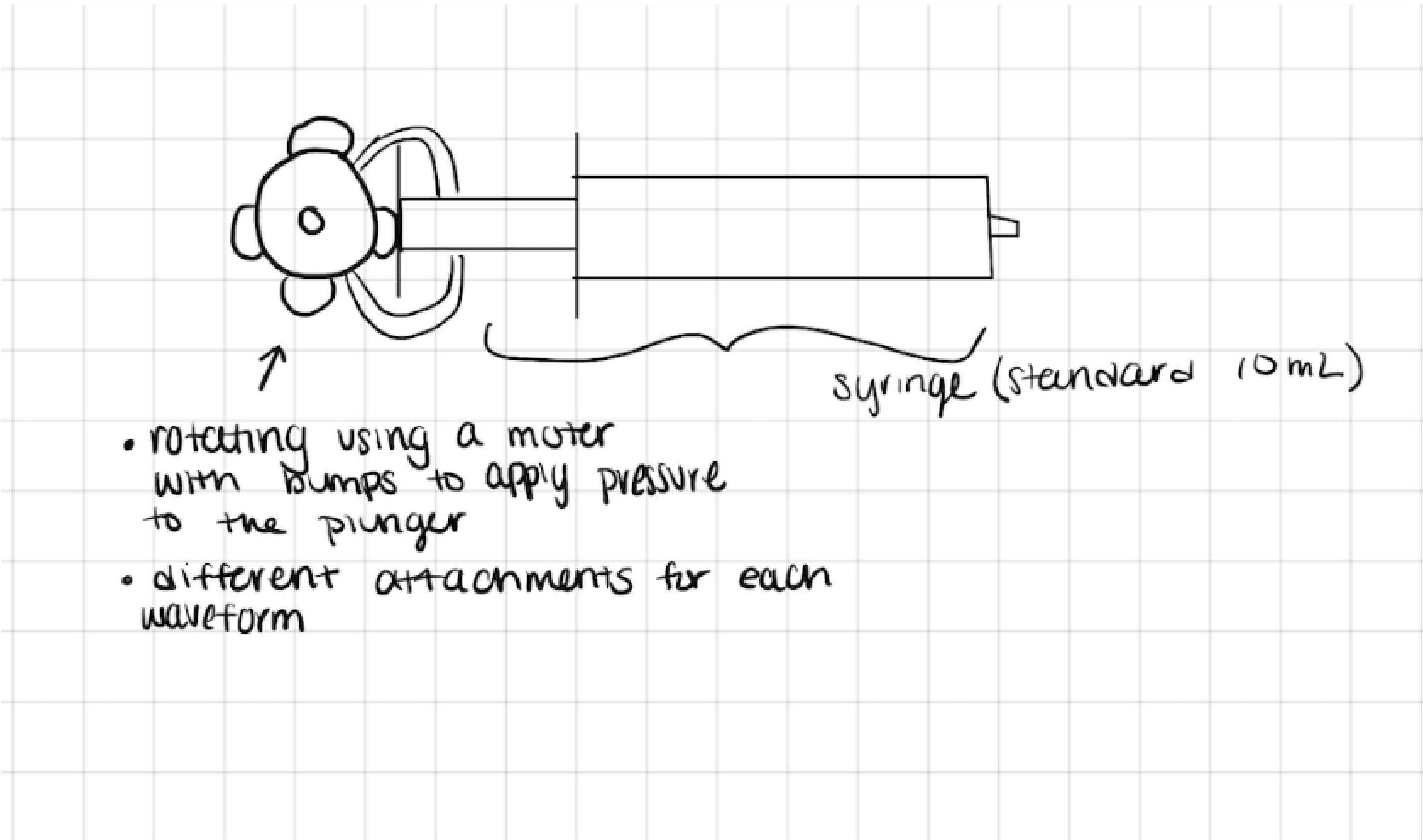
Date: 10/1/2021

Content by: Sammie Gilarde

Present: Sammie Gilarde

Goals: brainstorm preliminary design ideas

Content:



This design is a rotating wheel that would be attached to the syringe plunger. The wheel would be attached to a motor which would allow it to move at a consistent rate (yet to be determined). The wheel would be interchangeable with different bump patterns. The bumps are intended to push into the plunger, apply pressure, and simulate the different waveforms. There would need to be calculations made that would determine the appropriate pattern of bumps in order to simulate each of the desired waveforms.

Conclusions/action items:

This is a preliminary design that will be discussed as a group before creating our design matrix. The next steps are to meet as a group and share our individual preliminary designs. Additionally the group will work to complete a design matrix to determine the best preliminary design to move forward with.

11/5/2021 - Motor Research

Sammie Gilarde (gilarde@wisc.edu) - Dec 15, 2021, 10:17 AM CST

Title: Motor Research

Date: 11/5/2021

Content by: Sammie Gilarde

Present: Sammie Gilarde

Goals: research stepper motors

Content:

- full torque at standstill
- rotation angle of the motor is proportional to input pulse
- good speed control
- precise positioning
- repeatability of movement
- reliable - no contact brushes in motor
- minimizes mechanical failure
- maximize operational lifespan

source:

[1] M. C. O. M. Team | 02/12/2019, “The Best Applications for Stepper Motors,” *Automate*. https://www.automate.org/blogs/what-kinds-of-applications-are-best-for-stepper-motors (accessed Nov. 5, 2021).

Conclusions/action items:

Above is research done on the benefits and uses for stepper motors. This is most likely the best route to take for our project as the motors have good speed control, and repeatability of movement. Next, the team will order the motor and begin fabrication.

12/1/2021 - Materials Research

Sammie Gilarde (gilarde@wisc.edu) - Dec 15, 2021, 10:26 AM CST

Title: Materials Research

Date: 12/1/2021

Content by: Sammie Gilarde

Present: Sammie Gilarde

Goals: research materials for laser cutting cam

Content:

- POM - thermoplastic
  - endure large amounts of strain and friction
  - weatherproof, waterproof
  - not aesthetic
- acrylic
  - aesthetic
  - limited technical applications
  - comes in a variety of colors
  - can be expensive
- MDF/HDF
  - technical and decorative wood
  - laser engraving possible
  - not very expensive
  - technical purposes and aesthetic purposes
  - variety of thickness

source :

[1] "Which laser cutting material for which applications?," *3D Printing Blog: Tutorials, News, Trends and Resources | Sculpteo*. https://www.sculpteo.com/blog/2019/07/30/which-laser-cutting-material-for-which-application-2/ (accessed Dec. 1, 2021).

Conclusions/action items:

Above are some options for materials to laser cut the cams out of. While acrylic may be good because the cams would be smooth and not have a lot of friction, it is very expensive. The team has decided on HDF as the material to cut the cams out of because it is functional and cheap. The team will purchase this from the MakerSpace and begin fabrication.

2021/9/15-16: Background Info

SOPHIA FINN - Oct 20, 2021, 9:59 AM CDT

Title: Background Information

Date: 9/15-16

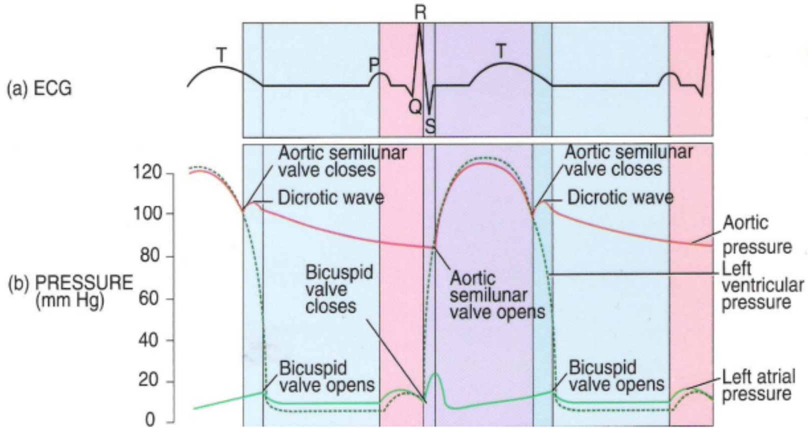
Content by: Sophia Finn

Present: Sophia Finn

Goals: To establish a solid base of knowledge for the arterial line project.

Content:

An arterial line is a cannula that can measure the blood pressure in an artery by direct placement inside of the artery (this is an invasive method). It will provide information on both systolic and diastolic pressure, as well as mean arterial pressure. It works using pressure tubing, rigid tubing, and a transducer in conjunction with the arterial cannula. The cannula works to sense both flow of blood and blood pressure using mechanical pressure, which is then converted into kinetic energy in the transducer. This kinetic energy is shown in a waveform display to be read and interpreted.



Arterial waveforms are, in essence, a response to the electrical activity of the heart through mechanical responses.

Sources: https://aci.health.nsw.gov.au/__data/assets/pdf_file/0012/221214/haemodynamic_monitoring_LP_2008.pdf

Conclusions/action items: Arterial lines are composed of several parts that all work to show a waveform.

2021/9/25: Competing Designs

SOPHIA FINN - Oct 20, 2021, 10:10 AM CDT

Title: Competing Designs

Date: 2021/9/25

Content by: Sopphia Finn

Present: N/A

Goals: To understand other designs on the market.

Content:

Amplitudes of arterial waveforms can vary beat-to-beat. In addition, competing products that use this design improve the realism of practice scenarios.

Other competing designs only simulate the insertion part of the design and the arm of a patient. They are typically designed to be compatible with in-hospital techniques for the accuracy and practical application of the medical students using them. The one from the Cuningham paper used “21 gauge needle, 0.018” guidewire and a 5 French catheter”. They did have to prepare replacement skin for the realistic patient arm.

https://digital.wpi.edu/downloads/v692t804c

https://pubmed.ncbi.nlm.nih.gov/12580215/

Conclusions/action items:

Although there are other arterial line simulators on the market, they don't quite accomplish what we are trying to.

2021/10/04 Design Ideas

SOPHIA FINN - Oct 20, 2021, 10:19 AM CDT

Title: Design Ideas

Date: 2021/10/04

Content by: Sophia Finn

Present: N/A

Goals: To brainstorm a workable design.

Content:

Using a servo motor, we could program a small “button pusher” to push the syringe down when we need. I found a few resources (linked below) that show ways to control server motors and write code to adjust the ways in which they press the desired button.

It seems to me that the simplest way to do this would be to write several methods, each for a waveform type, that all have a program in them along the lines of rotating the servo to hit the syringe, rotating back, waiting a given amount of time, and essentially repeating for the next pattern we hope to achieve.

https://www.youtube.com/watch?v=58Qqh60FrMU

https://create.arduino.cc/projecthub/akshayjoseph666/control-servo-motor-with-arduino-uno-and-pushbutton-18613f

ted.com/tutorials/arduino-button-servo-motor

Conclusions/action items:

We could use a servo and simple program to press the syringe plunger.

11/4/21 Motor Research DC

SOPHIA FINN - Dec 14, 2021, 1:52 PM CST

Title: Motor Research DC

Date: 11/4

Content by: Sophia Finn

Present: Sophia Finn

Goals: To research motor options for our design

Content:

Dc motors

- Converts energy electrical → mechanical
- Electrical through direct circuit
- Electric currents generate magnetic field, powering rotor on shaft
- Input of electricity varies speed
- Can be very small or large
- Parts:
    - Stator
        - Stationary part with rotating magnetic field
    - Armature
        - Rotated by stator
- Insulator wire winded to commutator, providing current
- Creates toque
- Types:
    - Brushless
        - No commutator, instead servomechanism adjusts angle
    - Brushed
        - “Classic” Dc motor
    - Shunt
        - Field windings parallel to armature
    - Series
        - Field windings in series

References:

https://ie.rs-online.com/web/generalDisplay.html?id=ideas-and-advice/dc-motors-guid

Conclusions/action items: Compare this with the stepper motor to find the ideal one for our design.

11/5/21 Motor Research Stepper

SOPHIA FINN - Dec 14, 2021, 2:11 PM CST

Title: Motor research stepper

Date: 11/5/21

Content by: Sophia Finn

Present: Sophia Finn

Goals: To compare stepper motor specs with dc motor specs.

Content:

Stepper motors

- High precision motor
- Permanent magnets at center
- Magnetized rotor on stator
- Higher speeds if rotor not magnetized but stator is
- Operated on Dc
- High torque and precision = ideal for small robotics
- Have coils grouped in “phases”
- Maximum torque at low speed
- Tend to run hot
- Less torque at high speeds

References:

https://www.moleymagneticsinc.com/what-you-should-know-about-stepper-motors/

https://learn.adafruit.com/all-about-stepper-motors

Conclusions/action items:

This definitely seems like a better option than the Dc, as we don't need a ton of speed but we do need precision.

11/19/21 Plastic research

SOPHIA FINN - Dec 14, 2021, 2:43 PM CST

Title: Plastic research

Date: 11/19/21

Content by: Sophia Finn

Present: Sophia Finn

Goals: To see what factors, if any, should influence which plastic we choose for the cam.

Content:

High-density plastic option for motor cams

- Commercial high-density polyethylene
- An increase in vibration amplitude → increased the effect on viscosity
- A lot of how plastics respond to vibrations has to do with the surrounding temperature
- Vibrates with higher frequency at lower temperatures
- Tensile strength of material increases with vibrational frequency
- Failure stress doesn’t increase that fast as vibrational frequency increases

References

https://www.researchgate.net/publication/230323359_Effect_of_vibration_extrusion_on_high-density_polyethylene

https://vibrationresearch.com/resources/fds-for-plastics/

https://www.stelray.com/reference-tables/

Conclusions/action items:

There really doesn't seem to be a ton of benefits to using a higher density plastic than the lower density cheaper option we can go with, as a lot of the factors that influence how plastic vibrates are minute and don't have a lot to do with our project.

Arterial Lines

KASEY MOHLKE - Sep 15, 2021, 9:23 PM CDT

Title: Arterial Lines

Date: 9/15/2021

Content by: Kasey Mohlke

Present: N/A

Goals: Learn the basics of how arterial lines are used and what their purpose is.

Content:

Arterial lines are catheters that are inserted into the lumen of an artery, often the radial or femoral artery. Arterial lines are used for continuous monitoring of arterial blood pressure as well as to take frequent blood samples [1]. The line contains a transducer (type of strain-gage) which allows blood pressure / heart rate waveforms to be monitored. The line also uses a hanging IV bag to fill the line and it is important for the patient and for proper monitoring that there are no air bubbles within the line [2]. Waveforms will vary based on the artery chosen for insertion, the patient, and the angle of insertion [2]. The insertion of the arterial line, called arterial cannulation, is very important. There are many contradictions concerning cannulation such as infection, coagulopathy, etc. [3]. The Seldinger and the catheter-over-needle techniques are most common for cannulation, and it is advised that a 20-ga catheter be used in adults and older children, while a 22-ga catheter for infants and pediatrics [3].

NU 213 (Medsurg 3) Week 2 (hemodynamic monitoring) Flashcards | Quizlet Fig: Arterial Line Setup and Components

Conclusions/action items:

Continue research on arterial lines and how the waveforms are generated.

[1] L. Pierre, “Arterial lines,” *StatPearls [Internet].*, 01-Aug-2021. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK499989/. [Accessed: 16-Sep-2021].

[2] C. Nickson, “Arterial line and Pressure Transducer,” *Life in the Fast Lane • LITFL*, 03-Nov-2020. [Online]. Available: https://litfl.com/arterial-line-and-pressure-transducer/. [Accessed: 16-Sep-2021].

[3] H. H. Hager, “Artery cannulation,” *StatPearls [Internet].*, 31-Jul-2021. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK482242/#:~:text=Arterial%20cannulation%20is%20a%20procedure,pressure%20than%20non%2Dinvasive%20means. [Accessed: 16-Sep-2021].

Arterial Pressure Monitoring and Waveforms

KASEY MOHLKE - Sep 15, 2021, 10:24 PM CDT

Title: Arterial Pressure Monitoring and Waveforms

Date: 9/15/2021

Content by: Kasey Mohlke

Present: N/A

Goals: Determine how blood pressure and heart rate affects the arterial line transducer and generates waveforms on the monitor.

Content:

"Each cardiac contraction exerts pressure, which results in mechanical motion of flow within the catheter. The mechanical motion is transmitted to a transducer via a rigid fluid-filled tubing. The transducer converts this information into electrical signals, which are transmitted to the monitor. The monitor displays a beat-to-beat arterial waveform as well as numerical pressures"[1]. The positioning of the transducer, damping, resonance, and zeroing are all important aspects of the arterial line. The amount of pressure that the fluid puts on the transducer varies with height, and "for every 2.5 cm, the transducer is above or below the catheter level, the pressure in the system changes by 1.877 mm". Additionally, to obtain accurate pressure readings the transducer must be exposed to atmospheric pressure. Finally, inadequate damping or over-damping (resonance in the system) leads to inaccurate systolic and diastolic pressures [1].

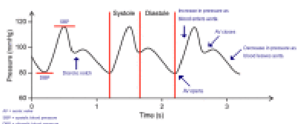


Fig. 1: Arterial waveforms [1]

The arterial waveform has many components from which information about the patient can be obtained including [2]:

- Heart rate
- Systolic pressure
- Diastolic pressure (coronary filling)
- Mean arterial pressure (systemic perfusion)
- Pulse pressure (high in AR, low in cardiac tamponade or cardiogenic shock)
- Changes in amplitude associated with respiration (pulse pressure variation)
- Slope of anacrotic limb associated with aortic stenosis

The arterial pulse has many components which form the waveform including [2]:

- Systolic upstroke
- Systolic peak pressure
- Systolic decline
- Dicrotic notch
- Diastolic runoff
- End-diastolic pressure

These components will all vary in magnitude and frequency from patient to patient. The arterial waveforms that the team's device must produce should display similarly to the following image, on a monitor.

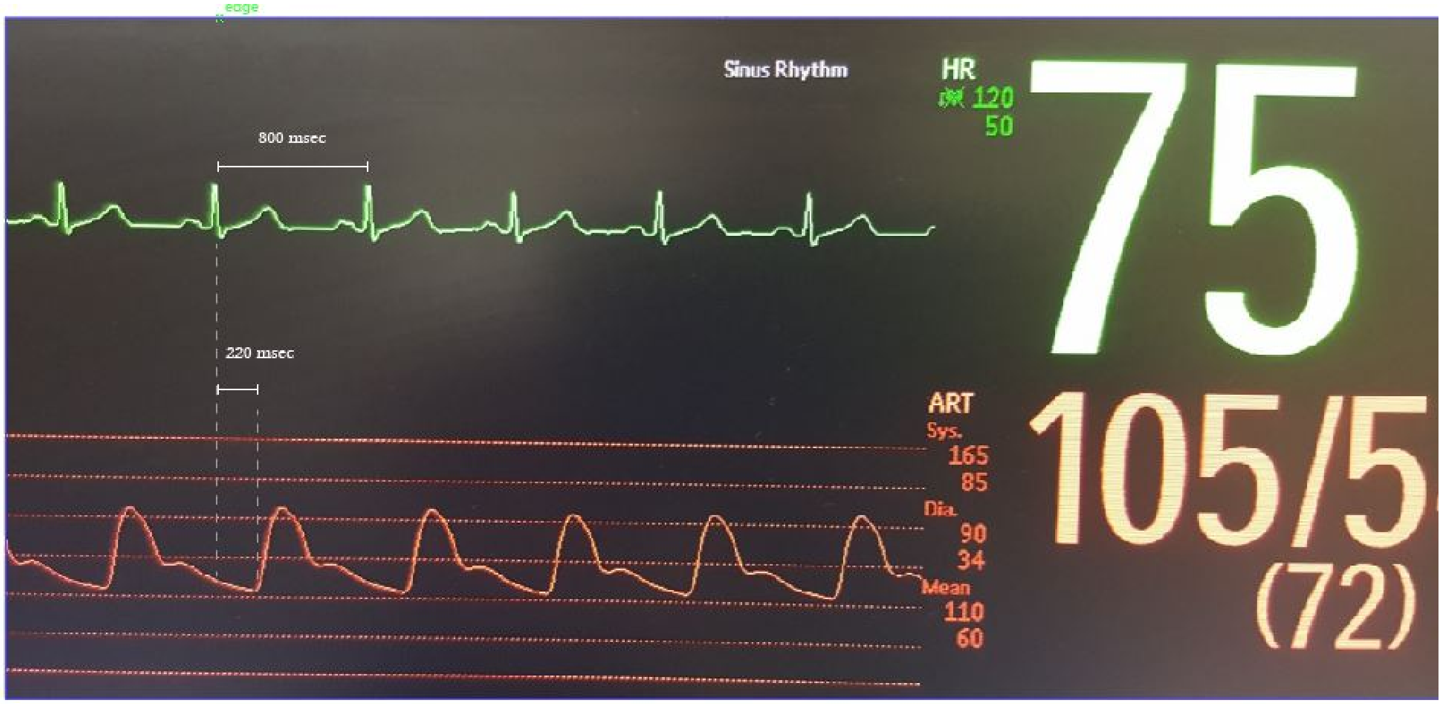


Fig. 2: Arterial waveform displayed on monitor [2]

Conclusions/action items:

Determine how the pressure and rates from blood affect the transducer from the arterial cannula.

[1] Y. Nguyen, “Arterial pressure monitoring,” *StatPearls [Internet].*, 04-May-2021. [Online]. Available: https://www.ncbi.nlm.nih.gov/books/NBK556127/. [Accessed: 16-Sep-2021].

[2] “Normal arterial line waveforms: Deranged physiology,” *Normal arterial line waveforms | Deranged Physiology*. [Online]. Available: https://derangedphysiology.com/main/cicm-primary-exam/required-reading/cardiovascular-system/Chapter%20760/normal-arterial-line-waveforms. [Accessed: 16-Sep-2021].

Arterial Pulse Waveforms

KASEY MOHLKE - Oct 18, 2021, 10:39 PM CDT

Title: Arterial Pulse Waveforms

Date: 10/11/21

Content by: Kasey Mohlke

Present: N/A

Goals: Determine how arterial pulse waveforms are read.

Content:

The arterial pulse waveform consists of the systolic upstroke, systolic peak, systolic decline, dicrotic notch, diastolic runoff, and end-diastolic pressure. These components of the arterial pulse waveform correspond to the ventricular ejection, systolic ejection, ventricular contraction, aortic valve closure, pressure decline due to valve closure, and the pressure exerted by the vascular tree on the aortic valve [1]. The monitor often displays the ECG as well, however the arterial pulse waveform is delayed by 160-180 ms compared to the ECG. From these waveforms, a lot of information can be gathered such as the systolic, diastolic, and mean arterial pressures, as well as heart rate and pulse pressure [1]. Normal systolic pressure is the range of 90-120 mmHg, diastolic pressure is in the range of 50-80 mmHg, and mean arterial pressure can range from 70-100 mmHg [2]. Monitoring systems are prone to interference and resonance causing amplitude distortion. Damping is introduced in order to decrease the distortion [3]. Insufficient and excessive damping is common, causing errors in pressure readings. Overdamping is associated with an incorrectly low systolic pressure and high diastolic pressure, along with an increased system response time [3]. This corresponds to a low systolic peak and a high end-diastolic pressure. Underdamping is associated with incorrectly high systolic pressures and low diastolic pressures, corresponding to high systolic peaks and low end-diastolic pressures [1].

Conclusions/action items:

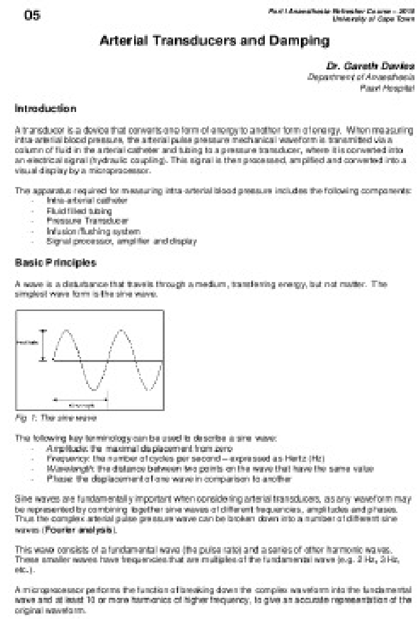
Use information to help determine shape of the cam.

[1] “Normal arterial line waveforms: Deranged physiology,” *Normal arterial line waveforms | Deranged Physiology*. [Online]. Available: https://derangedphysiology.com/main/cicm-primary -exam/required-reading/cardiovascular-system/Chapter%20760/normal-arterial-line-waveforms. [Accessed: 19-Oct-2021].

[2] “Arterial lines,” *Stephen Hadwiger Arterial Lines Comments*. [Online]. Available: http://shadwige.sites.truman.edu/hemodynamic-monitoring-front-page/arterial-lines/. [Accessed: 19-Oct-2021].

[3] G. Davies, “Arterial Transducers and Damping.” 2018.

KASEY MOHLKE - Oct 18, 2021, 10:43 PM CDT



05 Part I Anaesthesia Refresher Course – 2018
University of Cape Town

Arterial Transducers and Damping

Dr. Gareth Davies
Department of Anaesthesia
Paarl Hospital

Introduction

A transducer is a device that converts one form of energy to another form of energy. When measuring intra-arterial blood pressure, the arterial pulse pressure mechanical waveform is transmitted via a column of fluid in the arterial catheter and tubing to a pressure transducer, where it is converted into an electrical signal (hydraulic coupling). This signal is then processed, amplified and converted into a visual display by a microprocessor.

The apparatus required for measuring intra-arterial blood pressure includes the following components:
- Intra-arterial catheter
- Fluid filled tubing
- Pressure Transducer
- Infusion/flushing system
- Signal processor, amplifier and display

Basic Principles

A wave is a disturbance that travels through a medium, transferring energy, but not matter. The simplest wave form is the sine wave.

Fig. 1: The sine wave

The following key terminology can be used to describe a sine wave:
- *Amplitude*: the maximal displacement from zero
- *Frequency*: the number of cycles per second – expressed as Hertz (Hz)
- *Wavelength*: the distance between two points on the wave that have the same value
- *Phase*: the displacement of one wave in comparison to another

Sine waves are fundamentally important when considering arterial transducers, as any waveform may be represented by combining together sine waves of different frequencies, amplitudes and phases. Thus the complex arterial pulse pressure wave can be broken down into a number of different sine waves (**Fourier analysis**).

This wave consists of a fundamental wave (the pulse rate) and a series of other harmonic waves. These smaller waves have frequencies that are multiples of the fundamental wave (e.g. 2 Hz, 3 Hz, etc.).

A microprocessor performs the function of breaking down the complex waveform into the fundamental wave and at least 10 or more harmonics of higher frequency, to give an accurate representation of the original waveform.

Arterial_Transducers_and_Damping_G_Davies_.pdf(578.9 KB) - download

Arterial-Line Monitoring System Simulation

KASEY MOHLKE - Sep 21, 2021, 11:02 PM CDT

Title: Arterial-Line Monitoring System Simulation

Date: 09/21/21

Content by: Kasey Mohlke

Present: N/A

Goals: Although there are no directly-applicable competing designs, we can use information from similar models and simulations in order to improve our teams device.

Content:

The Arterial-Line Monitoring System Simulation describes adjustments made to the high-fidelity MedSim Advanced Simulation Ltd. manikin simulator in order to make it more realistic.

The project sought out to adjust the MedSim manikin so that it displays:

- the electromechanical delay between ECG and radial artery pressure
- beat to beat amplitude variability
- respiratory variation
- hypertensive and hypotensive states
- filtering characteristics

The team can use some of these ideas and try to implement them into our own device. Since the electromechanical delay between QRS wave of ECG and the appearance of a pulse wave is between 100-300ms, the research paper used a 200ms delay. They then randomized beat to beat variability up to 3% of the amplitude. This variability comes from filling volumes of cardiac chambers, the strength of cardiac contractions, and the tone of arterial vessels. The respiratory frequency was used with sinusoidal modulation of arterial pressure tracing at this frequency, with magnitudes of modulation under manual control displayed as a percentage of mean blood pressure. Respiratory variation stems from intrathoracic pressures transmitted to the lungs and heart, circulatory volume, and synchronous adrenergic discharge.

This project altered the stopcock and transducer of the arterial line. An amplifier was connected to an instrumentation amplifier and the resistance of the stopcock was altered using a potentiometer. Sinusoidal waves were generated using piece-wise segments converted to analog waveforms, and sampling was done at 100 Hz, buffered. A damping ratio of 0.5 and a natural frequency of 10 were used in the simulation.

Conclusions/action items:

Many of the alterations made to the MedSim manikin are unrealistic for our project, however a couple of them may be possible and all should be taken under consideration.

F. D. M. R. DB; “Arterial-line monitoring system simulation,” *Journal of clinical monitoring and computing*. [Online]. Available: https://pubmed.ncbi.nlm.nih.gov/12580215/. [Accessed: 22-Sep-2021].

KASEY MOHLKE - Sep 21, 2021, 11:02 PM CDT


ARTERIAL-LINE MONITORING SYSTEM SIMULATION

David M. Feinstein, MD,[1] and

Daniel. B. Raemer, PhD[2]

KEYWORDS. Simulation, monitoring.

INTRODUCTION

Arterial_Line_Competing_Design.pdf(178.2 KB) - download

Wheel with Bumps

KASEY MOHLKE - Sep 27, 2021, 10:47 PM CDT

Title: Wheel with Bumps Design

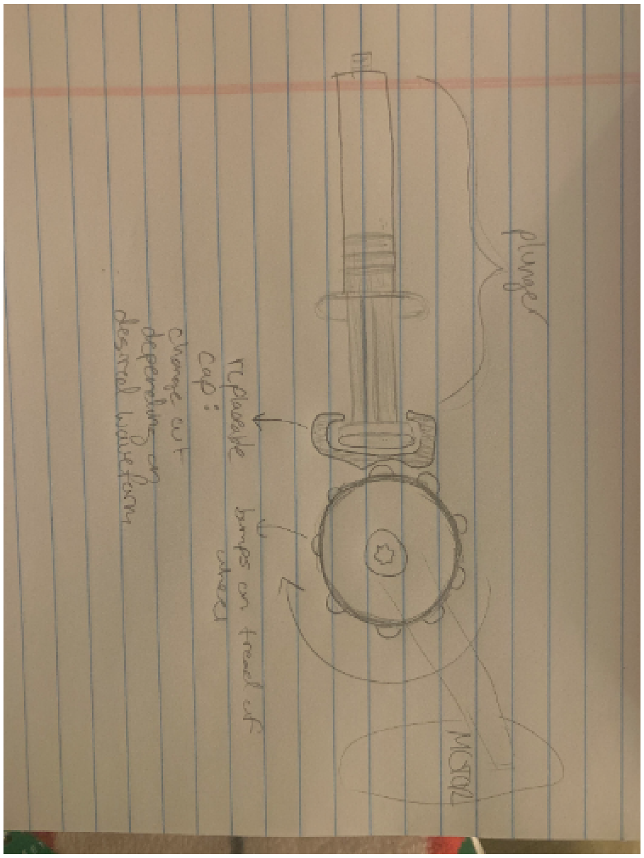
Date: 9/27/21

Content by: Kasey Mohlke

Present: N/A

Goals: Determine design logistics and feasibility.

Content:



This design incorporates a motor connected to a gear/wheel with a belt on it that has evenly spaced bumps on it. The plunger will have 3 different caps which will be used to simulate the normal arterial waveform, under-damping, and over-damping. The cap will have divots of different sizes so that as the wheel rotates, the bumps on the wheel will push down on the plunger cap in a pattern that simulates the peaks of the waveforms. The cap determines the amplitudes of the peaks while the motor speed determines the frequency.

Conclusions/action items:

Bring idea to team and consider using in the design matrix.

Cam Mechanics

KASEY MOHLKE - Sep 28, 2021, 10:44 PM CDT

Title: Cam Mechanics

Date: 9/28/21

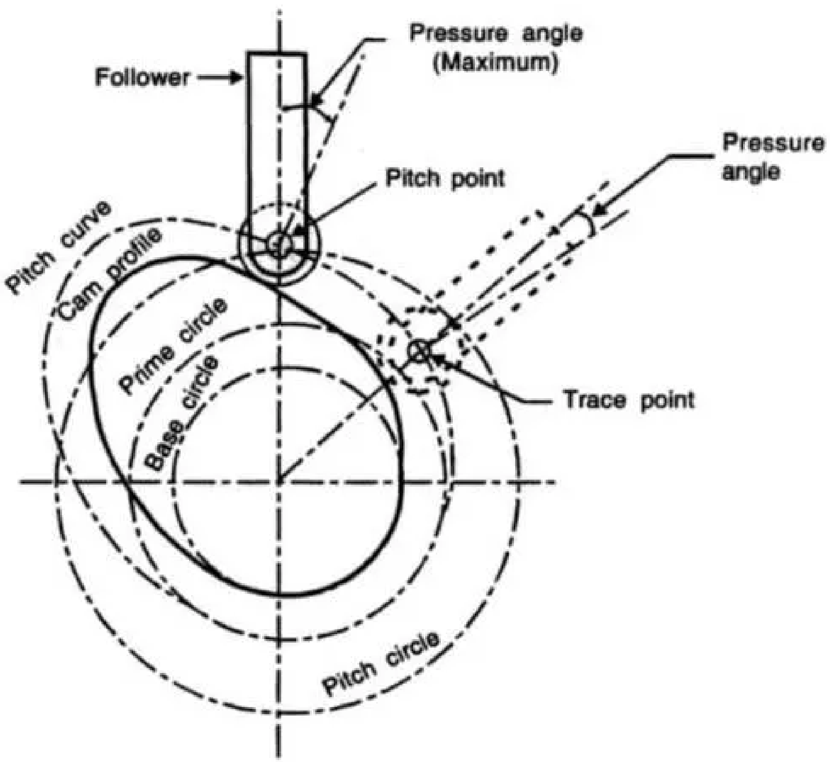
Content by: Kasey Mohlke

Present: N/A

Goals: Gain background knowledge of the potential cam design.

Content:

"A cam and follower mechanism is a profiled shape mounted on a shaft that causes a lever or follower to move" [1]. In our design, the plunger will act as the follower while the cam will be attached to a motor. As the cam rotates with the motor, the plunger will be pushed up and down. The shape of the cam will be dependent on the oscillations which should correlate to the sinusoid waveform of the desired signal. The key components of the cam shape to consider include the cam profile, the base circle, and the pitch curve [1]:



CAM TERMINOLOGY

We will be using a cam design that is as simple as possible. After determining the correct size, shape, and frequency at which the cam rotates, we must consider the follower. The follower should not jam against the cam and should be durable. Types of followers to consider are:

Knife-edge follower: sharp edge, simple, not used for fast application

Roller follower: smooth edge, used in high-speed operation, less wear and tear

Flat-faced follower: resists more side-thrust, used for precision application, wouldn't have to change plunger

Spherical follower: similar to flat-faced [1]

Conclusions/action items:

Discuss with team which type of follower will be best. I think spherical will be best because it is used for precision application and will most likely have less wear and tear than the flat-faced follower. Also discuss what type of motor will be used and what speed/speeds will be used.

[1] J. Sabhadiya, “Cam and follower: Definition, and types,” *Engineering Choice*, 24-Aug-2021. [Online]. Available: https://www.engineeringchoice.com/cam-and-follower/. [Accessed: 29-Sep-2021].

Motors

KASEY MOHLKE - Nov 03, 2021, 8:46 PM CDT

Title: Motors

Date: 11/3/2021

Content by: Kasey Mohlke

Present: N/A

Goals: Determine possible motors to be used in the device.

Content:

DC Brush Motor:

- Brushes are used to deliver power to the commutator
- Simple and low cost
- Good torque at low RPM
- Limited speed because brushes can overheat

Brushless Motor:

- Efficient and high speed
- Often needs specialized controller and gearbox
- Requires low starting loads

Stepper Motors:

- Uses poles to step positions
- High holding torque
- Position accuracy
- Small steps limited speed
- Draws maximum current

Linear Motors:

- High speed and efficient
- Expensive, not reasonable for the project

Conclusions/action items:

The team should determine if the torque and speed of a DC brush motor is sufficient. If not, we should look into the stepper motors.

In order to obtain the correct voltage and current, the team may need to an arduino (and possibly raspberry pi) with a battery pack, plus a breadboard with resistors and/or op-amps.

"Brushless vs brushed DC Motors: When and why to choose one over the other: Article: Mps," *Article* | *MPS*. [Online]. Available: https://www.monolithicpower.com/en/brushless-vs-brushed-dc-motors. [Accessed: 04-Nov-2021].

Testing Data

Title: Testing Data

Date: 12/21/2021

Content by: Kasey Mohlke

Present: N/A

Goals: Record quantitative data to be used for analysis.

Content:

While the rest of the team took notes, pictures, and made adjustments during testing with the client, I pulled the quantitative data from the monitor to use for my statistical analysis in MATLAB.

Team Data:

	Motor Speed	Syringe Distance	Performance	Notes	need more pressure, change directio
Small Normal	Slow	Almost touching at closest point	Bad (no waveform)		all the waveforms were more similar to u
	Slow	Touching at closest point	Bad (no waveform)	Stalling when the cam is touching the syringe. Friction moves plunger to side. New cam material?	
Big Normal	Slow				
	Medium (70-80)	Almost touching closest point	Better (small waveform)	Regular pulse, amplitude tiny (approx 67 mmhg at peak)	
	Medium (70-80)	Closer	Similar to last, but bigger amplitude	Letting box move a bit helps with the cam not getting stuck against the syringe	
	Medium (70-80)	Closer	Not what we were going for but we'll take it	Holding front of box gives underdamped; high amount of artifact	
Small Overdam	Medium	Further away	Bad (no waveform)	Low pressure values	
		Closer		Cannot clear the syringe	
Big overdamp		Further away (tipn on cam hits)	Small waveform, low pressure		

My Data:

A	B	C	D	E	F	G	H	
Cam	**Motor Speed (RPM)**	**Trial 1**	**Trial 1**	**Trial 2**	**Trial 2**	**Trial 3**	**Trial 3**	**Averag**
Small Normal	82	96	74	92	70	94	72	
Big Normal	91	46	17	51	20	47	21	
Small Overdamped	65	64	32	58	39	62	37	
Big Overdamped	74	44	31	46	25	48	29	

Conclusions/action items:

Analyze data in MATLAB.

MATLAB Analysis

KASEY MOHLKE - Dec 14, 2021, 7:36 PM CST

Title: MATLAB Analysis

Date: 11/23

Content by: Kasey Mohlke

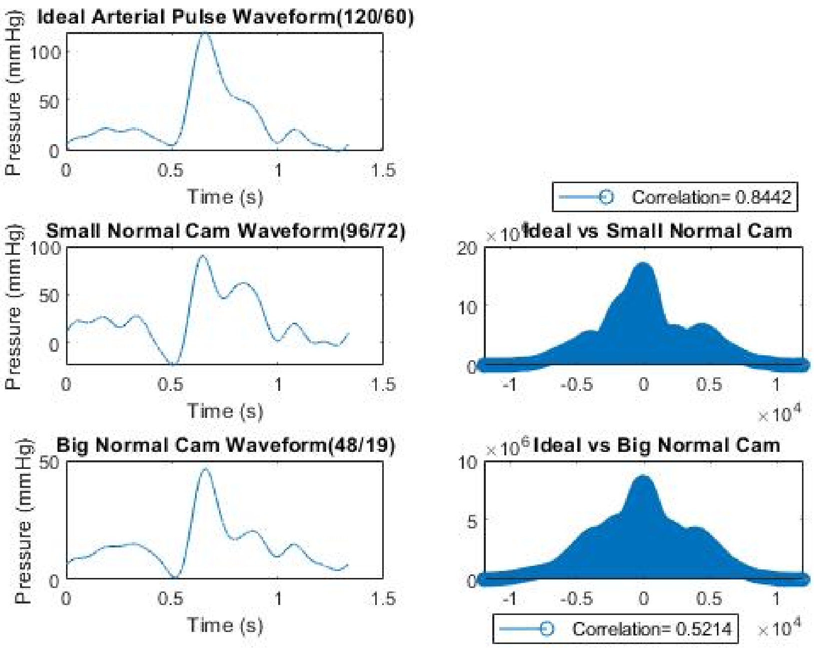
Present: N/A

Goals: Compare Normal Waveforms for Testing Data

Content: MATLAB Code and graphical results:

```
beatsPerMin = 80;
dur = beatsPerMin/60; %80 beats per minute (80/60)
fs = 12000; %%sampling rate
t = linspace(0,dur,fs);
theta = linspace(-pi,pi,fs);

%%%%%%

a = [0.9490, 0.5150, 0.2893, 0.2838, 0.1498, 0.1227, 0.1177, 0.0569, 0.0105, 0.0008, 0.0056];
b = [0, 0.05873, 0.1871, 0.0459, -0.0032, -0.1109, -0.0743, -0.0196, -0.0086, -0.043, -0.0007];
N = length(a);  %%number of fourier series coefficients
Sn = arterialW(a, b, N, theta);  %%arterial pulse waveform function
Sn = fft(Sn);
Tn = ifft(Sn,'symmetric');

figure  %%display arterial pulse waveform as function of time
hold on
plot(t,Tn*58); %%scale the waveform and plot against time
xlabel('Time (s)');
ylabel('Pressure (mmHg)');
title('Ideal Arterial Pulse Waveform');
hold off

%%%%%%

a2 = 0.96*[0.9490, 0.5150-.15, 0.289-0.08, 0.2838-0.075, 0.1498, 0.1227, 0.1177, 0.0569, 0.0105, 0.0008, 0.0056];
b2 = 2.1*[0, 0.05873, 0.1871, 0.0459, -0.0032, -0.1109, -0.0743, -0.0196, -0.0086, -0.043, -0.0007];
N = length(a2);  %%number of fourier series coefficients
Sn2 = arterialW(a2, b2, N, theta);  %%arterial pulse waveform function
Sn2 = fft(Sn2);
Tn2 = ifft(Sn2,'symmetric');

figure  %%display arterial pulse waveform as function of time
hold on
plot(t,Tn2*51);
xlabel('Time (s)');
ylabel('Pressure (mmHg)');
title('Small Normal Cam Waveform');
hold off


[r,c] = xcorr(Tn*58, Tn2*51);

figure
hold on
stem(c,r)
title('Ideal vs Small Normal Cam')
hold off
```

```
rmean = mean(r);
correlationW = rmean/4.543973457992685e+06

%%%%%%%

a3 = 0.48*[0.9490, 0.5150-.25, 0.289-0.18, 0.2838-0.075, 0.1498, 0.1227, 0.1177, 0.0569, 0.0105, 0.0008, 0.0056];
b3 = 0.34*[0, 0.05873, 0.1871, 0.0459, -0.0032, -0.1109, -0.0743, -0.0196, -0.0086, -0.043, -0.0007];
N = length(a2);  %%number of fourier series coefficients
Sn3 = arterialW(a3, b3, N, theta);  %%arterial pulse waveform function
Sn3 = fft(Sn3);
Tn3 = ifft(Sn3,'symmetric');

figure  %%display arterial pulse waveform as function of time
hold on
plot(t,Tn3*63);
xlabel('Time (s)');
ylabel('Pressure (mmHg)');
title('Big Normal Cam Waveform');
hold off


[r2,c2] = xcorr(Tn*58, Tn3*63);

figure
hold on
stem(c2,r2)
title('Ideal vs Big Normal Cam')
hold off

r2mean = mean(r2);
correlationW2 = r2mean/4.543973457992685e+06

figure  %%display arterial pulse waveform as function of time
hold on
subplot(3,2,1);
plot(t,Tn*58); %%scale the waveform and plot against time
xlabel('Time (s)');
ylabel('Pressure (mmHg)');
title('Ideal Arterial Pulse Waveform(120/60)');

%%display arterial pulse waveform as function of time
subplot(3,2,3);
plot(t,Tn2*51);
xlabel('Time (s)');
ylabel('Pressure (mmHg)');
title('Small Normal Cam Waveform(96/72)');

subplot(3,2,4);
stem(c,r)
title('     Ideal vs Small Normal Cam')
legend('Correlation= 0.8442')
ax.FontSize = 8;

%%display arterial pulse waveform as function of time
subplot(3,2,5);
plot(t,Tn3*63);
xlabel('Time (s)');
ylabel('Pressure (mmHg)');
title('Big Normal Cam Waveform(48/19)');

subplot(3,2,6)
stem(c2,r2)
title('     Ideal vs Big Normal Cam')
legend('Correlation= 0.5214')
ax.FontSize = 8;
hold off
```



Conclusions/action items:

Attempt overdamped waveform analysis using similar methods.

KASEY MOHLKE - Dec 14, 2021, 7:53 PM CST

12/05/2021

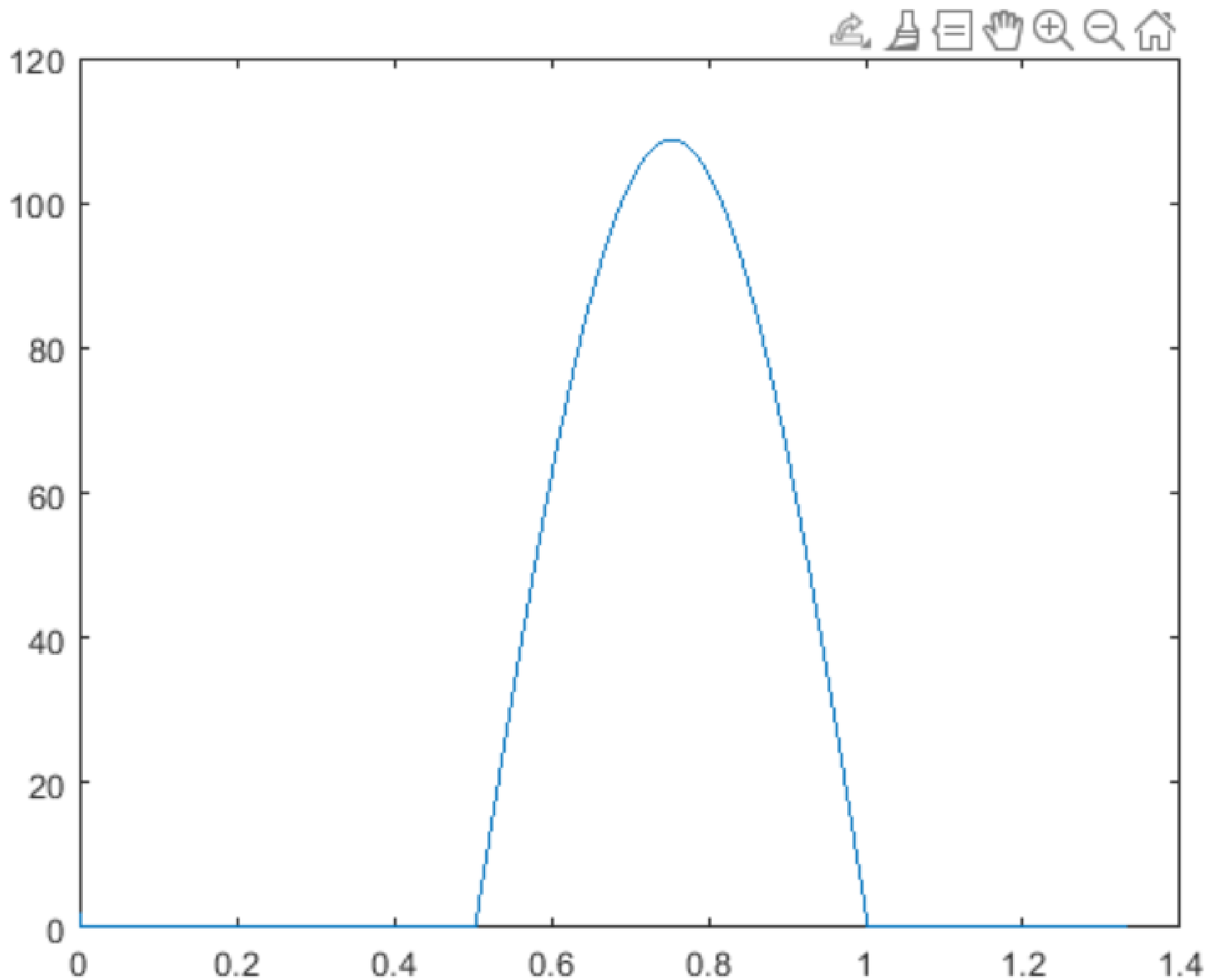
After extensive attempts, I was not able to produce an accurate overdamped arterial pulse waveform in MATLAB. The equation for the curve was very difficult to determine, below are some attempts to create it.

```
function [Sn] = arterialW(a,b,N,theta)
%UNTITLED2 Summary of this function goes here
%   Detailed explanation goes here
L = N/2;
a0 = a(1)/2;
Sn = 0;
for n = 2:N
   Sn = Sn + (a(n).*cos((n-1)*theta)) + (b(n).*sin((n-1)*theta));
end
Sn = a0 + Sn;
end

beatsPerMin = 80;

dur = beatsPerMin/60; %80 beats per minute (80/60)

fs = 12000; %%sampling rate

t = linspace(0,dur,fs);

theta = linspace(-pi,pi,fs);



a = [0.9490, 0.5150, 0.2893, 0.2838, 0.1498, 0.1227, 0.1177, 0.0569, 0.0105, 0.0008, 0.0056];

b = [0, 0.05873, 0.1871, 0.0459, -0.0032, -0.1109, -0.0743, -0.0196, -0.0086, -0.043, -0.0007];

N = length(a);  %%number of fourier series coefficients

over = oover(a,b,N, theta);  %%arterial pulse waveform function

over = fft(over);

Over = ifft(over,'symmetric');




figure  %%display arterial pulse waveform as function of time

hold on

plot(t,Over); %%scale the waveform and plot against time

xlabel('Time (s)');

ylabel('Pressure (mmHg)');

title('Ideal Arterial Pulse Waveform');

xlim([0 100]);
```

```
hold off


t = linspace(-pi/2, pi/2, 50);

%%a = genWaveform(t.*cos(t),t.*sin(t) , 50, -pi/2, pi/2);

x_param = t.*cos(t);

y_param = t.*sin(t);

d_param = 50;


% r(t) = <4cos(t), 3sin(t)> = <x,y>

    x = x_param;

    y = y_param;

    r = [x;y];


    % r'(t) = <-4sin(t), 3cos(t)> = <dx, dy>

    dx = diff(x);

    dy = diff(y);

    dr = [dx;dy;zeros(1,49)];


    % r''(t) = <ddx,ddy>

    ddx = diff(x,2);

    ddy = diff(y,2);

    ddr = [ddx 1;ddy 1;zeros(1,49)];


    %XX = [dr;0]

    %YY = [ddr;0]

    % curvature of function

    a = (norm(cross(dr,ddr)))/((norm(dr).^3)+0.000001)


    k = fft(a);

    kk = ifft(k, 'symmetric');
```

```
    figure

    plot(t,kk)


beatsPerMin = 80;

dur = beatsPerMin/60; %80 beats per minute (80/60)

fs = 12000; %%sampling rate

t = linspace(0,dur,fs);

x = 0;

for n = 2:11

x = x + (a(n)*cos(2*pi*dur)+b(n)*cos(2*pi*(dur*2.4)));

end


figure

plot(t, x)


beatsPerMin = 80;

dur = beatsPerMin/60; %80 beats per minute (80/60)

fs = 12000; %%sampling rate

t = linspace(0,dur,fs);

theta = linspace(-pi,pi,fs);


a = [0.9490, 0.5150, 0.2893, 0.2838, 0.1498, 0.1227, 0.1177, 0.0569, 0.0105, 0.0008, 0.0056];

b = [0, 0.05873, 0.1871, 0.0459, -0.0032, -0.1109, -0.0743, -0.0196, -0.0086, -0.043, -0.0007];

N = length(a);

x = overdamped(a,b,t,N);


figure

plot(t,subplus(x*70))



a2 = [0.9490, 0.5150-.1, 0.2893-.1, 0.2838/2, 0.1498, 0.1227, 0.1177, 0.0569, 0.0105, 0.0008, 0.0056];
```

```
b2 = [0, 0.05873, 0.1871, 0.0459, -0.0032, -0.1109, -0.0743, -0.0196, -0.0086, -0.043, -0.0007];

N = length(a);

x2 = overdamped(a2,b2,t,N);


figure

plot(t,subplus(x2*30))
```



Ethics & Global Impact

KASEY MOHLKE - Dec 14, 2021, 9:30 PM CST

Title: Ethics & Global Impact

Date: 12/14/2021

Content by: Kasey Mohlke

Present: N/A

Goals: Determine ompact of the device and ethical consideration for design.

Content:

This device has far reaching impacts when it comes to educational medicine. Functioning properly, this low cost device would be capable of helping train medical students to interpret arterial pulse waveforms which can definitely help to save lives. If mass produced, the device could be a fraction of the cost of the MedSim Manikin which would allow a greater amount of devices to be pruchased and therefore providing better access for medical students.

Ethical concerns extend do the environmental impact of the device and to the teachers and students who will be using the device. Environmentally, the device could be improved by running off of only wall power instead of wall power and batteries. For the users, the most important ethical component is that the device must be accurate. If not, the students will be taught poorly which would affect their patient care.

Conclusions/action items:

Consider these impacts when designing and making improvements to the device.

09/15/21 - Setting up an Arterial Line Transducer in a Clinic

Riley Norman - Sep 15, 2021, 4:04 PM CDT

Title: Setting up an Arterial Line Transducer in a Clinic

Date: 09/15/21

Content by: Riley Norman

Present: Riley Norman

Goals: To better understand how an arterial line simulator is set up and used in a real setting.

Content:

An arterial line transducer is an invasive for of blood pressure and heart rate monitoring. It is used by connecting the blood flow of a patient via an artery to a saline reservoir. As the heart presses blood around the body the pressure of the saline varies. This information is fed through various machines in order to calculate the patients blood pressure and heart rate.

Please see the attached video for a demonstration.

Conclusions/action items:

Continue research into arterial line transducers, meet with client to discuss project goals, and begin to brainstorm various ideas for a simulator that is cheap and functional.

09/15/21 - Arterial Pressure Monitoring General Information

Riley Norman - Sep 15, 2021, 4:38 PM CDT

Title: Arterial Pressure Monitoring General Information

Date: 09/15/21

Content by: Riley Norman

Present: Riley Norman

Goals: To get a sense of how these devices are used for teaching medical students and what important attributes we will need to replicate.

Content:

This type of vital monitoring is usually for the critically ill and pre-op patients. Intermittent monitoring of vitals is good but with critically ill or those with high risk of morbidity and mortality it is important to have a constant stream of information. Each contraction of the heart leads to a mechanical motion of fluid in the catheter, the mechanical motion is transmitted to a transducer by way of a rigid fluid filled tube. The transducer is able to covert the information into electrical signals which can be sent to a monitor in real time. Monitor displays beat to beat arterial waveform as well as numerical pressures. Provides critical information about the patients cardiovascular system.

Most commonly use the radial artery due to its ease of accessibility, can also use the brachial, femoral, or dorsals pedis arteries. Some complications can arise and therefore each patient should be carefully considered before using this invasive method. For example, infection, lack of circulation leading to vascular insufficiency, narrowing of the vessel, and blood loss.

Conclusions/action items:

Continue research into possible simulation methods, find competing designs, meet with client.

Citation:

Nguyen, Yenly. “Arterial Pressure Monitoring.” *StatPearls [Internet].*, U.S. National Library of Medicine, 4 May 2021, www.ncbi.nlm.nih.gov/books/NBK556127/.

10/11/21 - Competing Arterial Line Monitor Mannequin

Riley Norman - Oct 11, 2021, 7:52 PM CDT

Title: Blue Phantom Gen II Arterial Line Monitor Mannequin

Date: 10/11/21

Content by: Riley Norman

Present: Riley Norman

Goals: To document how expensive any model that meets the clients needs is.

Content:

The Blue Phantom II can do everything that the client is looking for our device to do and much more. This device helps students place ultrasound guided lines, arterial line placement, and peripheral IV placement. As well as helping with needle and guide wire placement in a variety of veins and arteries. Unfortunately, these many other features drastically increase the price to $2,699.00. Our device doesn't need to achieve all of these features so it should be easier to keep the price down.

Conclusions/action items:

To continue modeling our cam as well as practicing our preliminary presentation.

Citation:

"Blue Phantom™ gen II PICC W/IV & arterial line ultrasound training model arm: Aed Superstore - BPA304-hp," *AED Superstore*. [Online]. Available: https://www.aedsuperstore.com/bpa304-hp-blue-phantom-gen-ii-picc-iv-arterial-line-ultrasound-training-model-arm.html. [Accessed: 11-Oct-2021].

09/15/21 - Initial Client Meeting Questions

Riley Norman - Sep 15, 2021, 4:07 PM CDT

Title: Initial Client Meeting Questions

Date: 09/15/21

Content by: Riley Norman

Present: Riley Norman

Goals: To establish a good list of questions that we can review when meeting with our client for the first time.

Content:

- Should the device be able to accommodate 5 mL to 50 mL or we should just pick a size to make our design around?
- Approximate budget?
- Is it supposed to be an external device that attaches to the syringe?
- Anticipated materials? When to pick them up?
- Size and specifications of device?
- Elaborate on the device as a whole and the most important features.
- Pre-existing devices to give us an idea of where to go.
- End goal of usage? Is it for simulating a condition and diagnosing it or more the set up and usage of an arterial line monitor.

Conclusions/action items:

To continue creating possible questions and set up a time to meet with our client.

10/11/21 - Design and Matrix Meeting

Riley Norman - Oct 11, 2021, 7:58 PM CDT

Title: Design Ideas and Matrix Meeting

Date: 10/1/2021

Content by: Riley Norman

Present: Whole team

Goals: To fill out our design matrix with our three ideas and select a winning design based on the scoring.

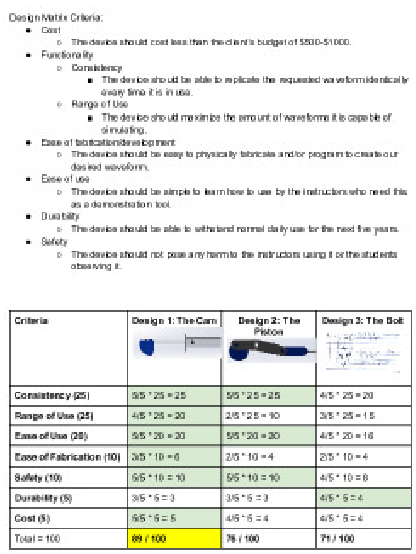
Content:

Please find the design matrix with criteria and design descriptions attached to this page. Our winning design was the cam design because of its ease of use for the client as well as how well it will be able to recreate the arterial waveforms. In the coming weeks we will decide how to attach the device to our syringe and what shapes will result in our desired waveforms.

Conclusions/action items:

Figure out what cam shapes will yield the desired waveforms.

Riley Norman - Oct 11, 2021, 8:12 PM CDT



Design Matrix Criteria:

- Cost
  - The device should cost less than the client's budget of $500-$1000.
- Functionality
  - Consistency
    - The device should be able to replicate the requested waveform identically every time it is in use.
  - Range of Use
    - The device should maximize the amount of waveforms it is capable of simulating.
- Ease of fabrication/development
  - The device should be easy to physically fabricate and/or program to create our desired waveform.
- Ease of use
  - The device should be simple to learn how to use by the instructors who need this as a demonstration tool.
- Durability
  - The device should be able to withstand normal daily use for the next five years.
- Safety
  - The device should not pose any harm to the instructors using it or the students observing it.

Criteria	Design 1: The Cam	Design 2: The Piston	Design 3: The Bolt
Consistency (25)	5/5 * 25 = 25	5/5 * 25 = 25	4/5 * 25 = 20
Range of Use (25)	4/5 * 25 = 20	2/5 * 25 = 10	3/5 * 25 = 15
Ease of Use (20)	5/5 * 20 = 20	5/5 * 20 = 20	4/5 * 20 = 16
Ease of Fabrication (10)	3/5 * 10 = 6	2/5 * 10 = 4	2/5 * 10 = 4
Safety (10)	5/5 * 10 = 10	5/5 * 10 = 10	4/5 * 10 = 8
Durability (5)	3/5 * 5 = 3	3/5 * 5 = 3	4/5 * 5 = 4
Cost (5)	5/5 * 5 = 5	4/5 * 5 = 4	4/5 * 5 = 4
Total = 100	89 / 100	76 / 100	71 / 100

Design_Ideas_and_Matrix.pdf(207.2 KB) - download

11/1/21 - Circuitry DC Motor Speed Control

Riley Norman - Nov 09, 2021, 2:16 PM CST

Title: DC Motor Speed Controller

Date: 11/9/21

Content by: Riley Norman

Present: Riley Norman

Goals: To first show a possible design that can control the speed of one of our potential motors.

Content:

This circuit digest article is an example of a circuit that uses a potentiometer to vary the speed of a DC motor. However, our group is unsure whether we will be using a stepper or DC motor in our project. This circuit is relatively simple and utilizes the varying resistances that potentiometers offer to control pulse width modulation that can then vary the speed of the motor. It requires simple components and code to run and would serve the purpose of varying speeds that we need. Please see the attached circuit diagram.

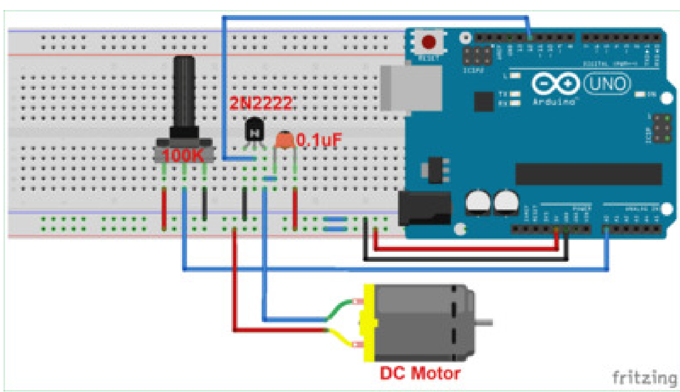
Conclusions/action items:

To decide what motor will be best suited to our group and buy materials.

Citation:

P. Khatri, “DC motor speed control using Arduino and potentiometer,” *Circuit Digest*, 26-Nov-2020. [Online]. Available: https://circuitdigest.com/microcontroller-projects/dc-motor-speed-control-using-arduino-and-potentiometer. [Accessed: 01-Nov-2021].

Riley Norman - Nov 09, 2021, 2:16 PM CST



DC-Motor-Speed-Control-circuit-diagram-using-Arduino-and-Potentiometer_0.png(64.2 KB) - download

11/5/21 - Circuitry Stepper Motor Speed Control

Riley Norman - Nov 09, 2021, 2:30 PM CST

Title: Circuitry for Stepper Motor Speed Control

Date: 11/6/21

Content by: Riley Norman

Present: Riley Norman

Goals: To document a possible circuit for controlling the speed of a stepper motor.

Content:

Our group has begun to lean towards a stepper motor rather than a DC motor because of its superior torque. The circuitry for the stepper motor is slightly more complex but it is still very achievable. This will allow our client to rotate the knob of the potentiometer and vary the speed of the stepper motor creating the range of rpm's that is desired. Please see the attached frizzing diagram for the circuitry we would use with a stepper motor.

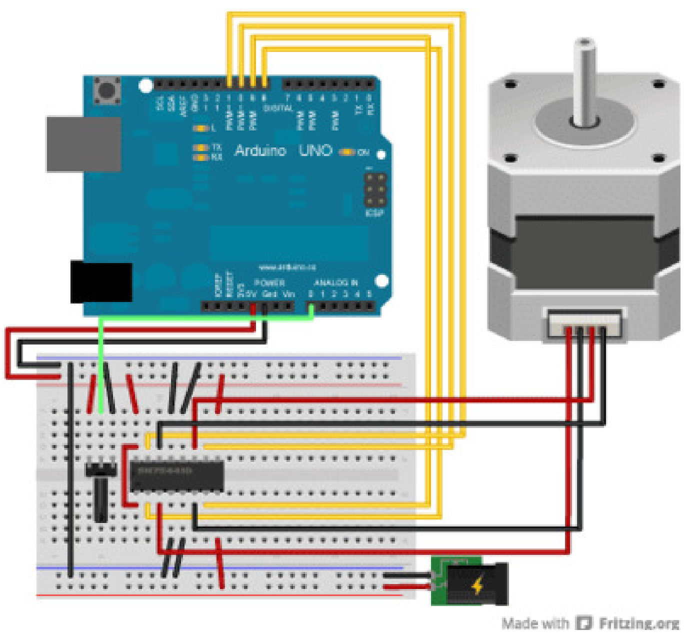
Conclusions/action items:

To finalize our materials list and order the necessary parts.

Citation:

> T. A. Team, "Stepper Speed Control," *Arduino*, 23-Aug-2018. [Online]. Available: https://www.arduino.cc/en/Tutorial/LibraryExamples/StepperSpeedControl. [Accessed: 05-Nov-2021].

Riley Norman - Nov 09, 2021, 2:31 PM CST



bipolarKnob_bbsm.png(14.2 KB) - download

12/4/21 - Cam Shapes

Riley Norman - Dec 04, 2021, 12:44 PM CST

Title: Cam Shapes

Date: 12/4/21

Content by: Riley Norman

Present: Riley Norman

Goals: To discuss how our cam shapes were chosen to give us our desired wave forms.

Content:

One of the most important aspects of our design was in the shape of the cams. The rotation of these shapes must give us our desired waveforms so their shapes greatly affect the accuracy and quality of our devices results. Because of the importance of these shapes we decided that we needed to generate the waveforms produced by a given shape on Matlab prior to cutting the cam shape out. In addition to testing the shapes on Matlab prior to fabricating them, we used the attached article to get us started with the shape of the cam for the normal waveform.

The article attached is a project that is quite similar to ours in that they were looking to reproduce arterial waveforms by varying pressures using a cam design. The researchers first collected and normalized the arterial waveforms of a young healthy adult male, they then generated a standard equation for these waves using a Fourier series. In order to convert this Fourier series representation of the waveform into a cam design the normalized period was set to 360° of rotation and a three peaked cam was developed. The researchers used this cam shape to vary the pressures of a fluid that would simulate blood in a model arm and thus generated their model arterial waveforms. Our device will differ slightly from this in that the cam will be used to press a syringe plunger in an arterial line transducer rather than in a model arm. This research was very helpful in establishing the shape of our normal waveform cam.

The over damped waveform cam shape was determined by Mateo Silver. Using Matlab to take polar equations representing different shapes and extrapolate the waveforms from these shapes. After trying a few different equations we found the best shape for the over damped cam. The underdamped cam shape was much more difficult as this waveform is far less predictable and harder to produce with a uniform shape. We tried a few different cam shapes but none seemed to be quite the desired waveform. Our group proceeded with the normal and over damped cam shapes and have the underdamped form as a future goal.

Conclusions/action items:

To complete testing and finalize our report.

Citation:

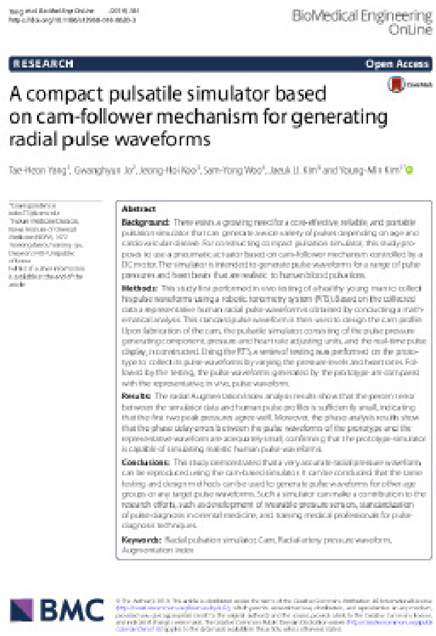
Paper :

T.-H. Yang, G. Jo, J.-H. Koo, S.-Y. Woo, J. U. Kim, and Y.-M. Kim, “A Compact Pulsatile Simulator based on Cam-follower mechanism for generating radial pulse waveforms,” *BioMedical Engineering OnLine*, vol. 18, no. 1, Jan. 2019.

Image:

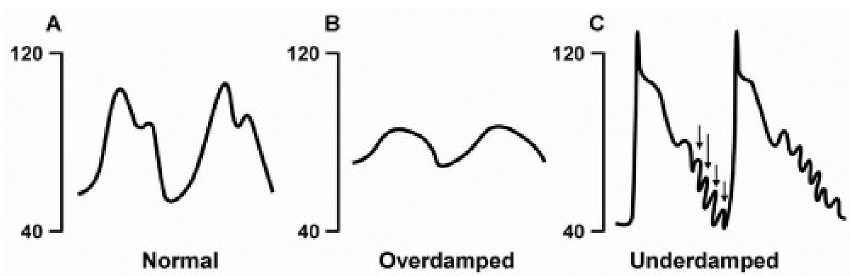
U. F. O. Themes, "Avoid errors in invasive blood pressure measurement," *Anesthesia Key,* 01-JUL-2016. [Online]. Available: https://aneskey.com/avoid-errors-in-invasive-blood-pressure-measurement/. [Accessed: 11-Oct-2021]

Riley Norman - Dec 04, 2021, 12:42 PM CST



s12938-018-0620-3.pdf(2.5 MB) - download

Riley Norman - Dec 04, 2021, 12:42 PM CST



C28-FF1.gif.png(43 KB) - download

12/11/21 - Material Decisions

Riley Norman - Dec 11, 2021, 2:08 PM CST

Title: Material Decisions

Date: 12/11/21

Content by: Riley Norman

Present: Riley Norman

Goals: To establish what materials we used for our final device and why.

Content:

We spent a decent amount of time trying to decide what materials to use for our device. While we knew that we wanted to laser cut most of the structural components, we were unsure of what material to make them out of. We ultimately went with HDF or high density fiberboard, this was a cheap, strong, and easy to laser cut material that would meet all of the needs of our device base board and support box. However, we didn't realize that there was a chance for water to leak out of the system during use. This small amount of leakage is not good for the HDF and at the very least the baseboard should be made out of a more water resistant material in the future. We decided that this material would also work well for our cams as it seemed to be relatively low friction on the syringe plunger, however after testing there may be materials that are even less likely to get stuck on the syringe plunger. Futher reseaarch would be needed to decide on a more suitable option. Finally, we decided to 3D print our motor mount and syringe clamps. 3D printing these pieces lent itself well to the less geometric shapes of these parts, and allowed us to quickly form strong pieces that could perform their desired task.

Conclusions/action items:

Finsish all final deliverables.

11/3/21 - Laser Cutter Upgrade

Riley Norman - Dec 02, 2021, 2:15 PM CST

Title: Laser Cutter Upgrade

Date: 11/3/21

Content by: Riley Norman

Present: Riley Norman

Goals: To get my laser cutter upgrade

Content:

Please see the attached upgrade.

Conclusions/action items:

Finish fabrication and testing.

Riley Norman - Dec 02, 2021, 2:16 PM CST

You have the following permits and upgrades:

Name	Date
Lab Orientation	11/09/2021
Red Permit	09/26/2019
Woodworking 1	10/25/2019
Laser 1	11/03/2021

Apply for a new/additional permit

Screen_Shot_2021-12-02_at_2.14.39_PM.png(91.2 KB) - download

11/19/21 - Laser Cutting Components

Riley Norman - Dec 04, 2021, 1:15 PM CST

Title: Laser Cutting Components

Date: 11/9/21

Content by: Riley Norman

Present: Riley Norman

Goals: To document the laser cut components and their fabrication.

Content:

For this project we decided that laser cutting a majority of the components was our best course of action. This was because of the precision, speed, and durability the laser cutter can provide. We used 1/4 inch HDF for the bottom plate and 1/8 inch HDF for the box. These materials were readily available in the scrap bin which allowed us free access to many different cuts. After some trial and error we got the cams to be the right size, the hex to fit inside of the cams, and the box to fit into the bottom plate. With these materials cut we could begin fabrication of our structural components. This required gluing the box together as well as drilling some holes and adding bolts to support the motor mount and the syringe clamps.

Conclusions/action items:

With the structural components of the device made we will focus on the circuitry, 3D printed components and final assembly of the device.

Riley Norman - Dec 04, 2021, 1:12 PM CST

IMG_6569.HEIC(1.2 MB) - download

11/29/21 - 3D Printing Components

Riley Norman - Dec 04, 2021, 1:19 PM CST

Title: 3D Printin Components

Date: 11/29/21

Content by: Riley Norman

Present: Riley Norman

Goals: To document the 3D printed parts of the device

Content:

With our structural components completed our group next focused on the 3D printed portions of our device. We 3D printed the motor mount and the syringe clamps because these parts were specific in shape and size to our motor and syringe respectively. 3D printing gave us the accuracy to pressure fit both the syringe and motor into place on our device. These tight fits in addition to some bolts and nuts will hold the syringe and motor firmly in place during usage. The CAD file for the syringe clamps was made from scratch based on the dimensions of our syringe, allowing two baths and wing nuts to be passed through the sides to tighten around the syringe. The motor mount CAD file was adjusted from a grab cab NEMA 17 stepper motor mount file. Our motor was a NEMA 14 so the dimensions had to be made smaller to accommodate our smaller motor. Please see the attached STL files which show the syringe clamp and motor mount.

Conclusions/action items:

To finalize our circuitry and complete assembly of our device.

Riley Norman - Dec 04, 2021, 1:20 PM CST

Stepper_Mount_3.STL(75.6 KB) - download

Riley Norman - Dec 04, 2021, 1:20 PM CST

Syringe_Clamp.STL(20 KB) - download

12/2/21 - Circuitry Components

Riley Norman - Dec 12, 2021, 2:56 PM CST

Title: Circuitry Components

Date: 12/2/21

Content by: Riley Norman

Present: Riley Norman

Goals: To document our groups circuit design for this device.

Content:

Our circuit was largely based on a predesigned circuit on the Arduino webpage. This page had circuitry for both a bipolar and unipolar stepper motor, given that we had a bipolar motor that is the circuit we used. Our main issues with the circuit were how we were going to power the device. Our group wanted to create a circuit that could use only one plug from the wall in order to eliminate the need to replace batteries and to keep it is simple as possible for our client. However, the Arduino Nano runs on 7-9 volts while the motor driver chip must run off of 12 volts. At first our group thought that the Arduino could run off of 12 volts from the wall outlet but after ruining our first Arduino Nano we realized that this wasn't an option.

Our next idea was to create a voltage divider with two resistors. This would allow us to take the 12 volts of wall power and convert it to something in the range of 7-9 volts. In order to achieve this we choose R1 to be 47 kOhms and R2 to be 22 kOhms. This would have us an output voltage of 8.1739 volts, which is within the operating voltage of the Arduino. Unfortunately, this did not work. We believe that it was an issue with the amperage being supplied to the Arduino as it would either not turn on at all or the LED's would be very faint. In order to increase we lowered the resistor values by a factor of 10, using a 4.7 and 2.2 kOhm resistors respectively. The same issue persisted so we again lowered the values by a factor of 10, using a 47 and 22 ohm resistor. This was still unsuccessful.

Without the voltage divider we could see no other way to power both the Arduino and the stepper driver with one power source. Our solution was to run the Arduino with a 9V battery and the motor driver with 12V from a wall outlet. With the power issues remedied we were ready to finalize our breadboard, soldering or hot glueing loose connections, organizing excess wire to fit nicely inside of the box, and creating ports in the box to allow for changing the battery and plugging in the wall power.

The circuit was one of the more difficult aspects of this project for our group and caused a few delays as we tried to trouble shoot the various issues we had. I was very confident in the voltage divider method to begin with and was disheartened when it failed.

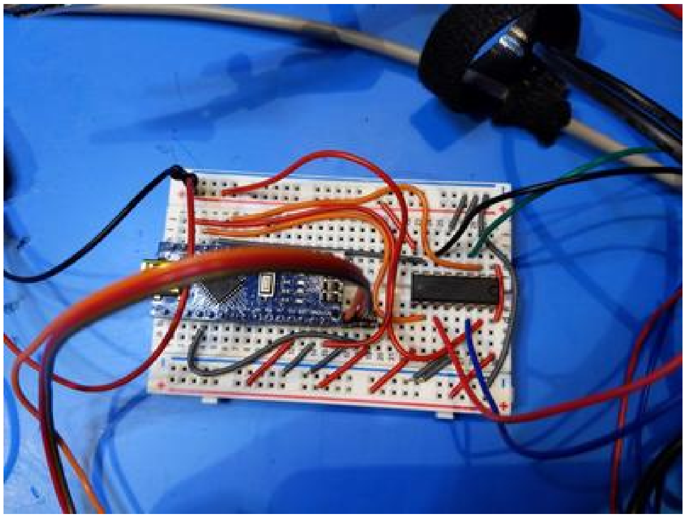
Conclusions/action items:

To test our device and finish final deliverables.

Citation:

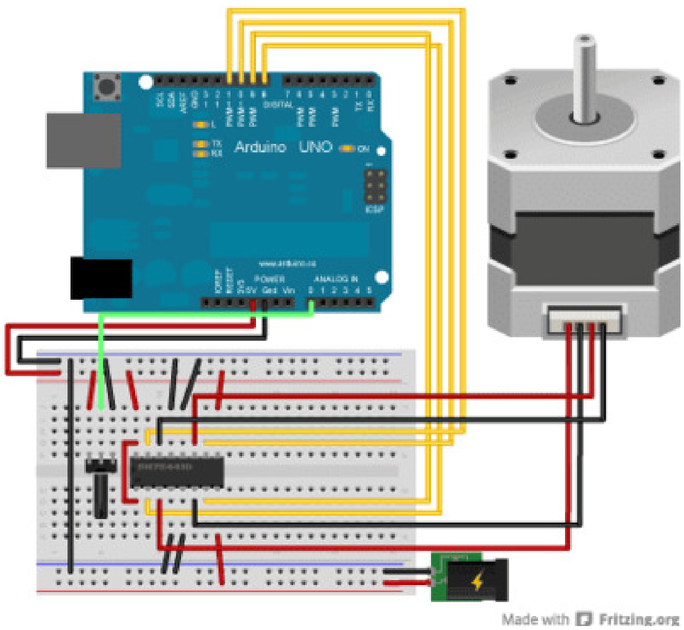
T. A. Team, “Stepper Speed Control,” *Arduino*, 05-Feb-2019. [Online]. Available: https://www.arduino.cc/en/Tutorial/LibraryExamples/StepperSpeedControl. [Accessed: 22-Nov-2021].

Riley Norman - Dec 12, 2021, 2:55 PM CST



Arterial_Line_Poster.pptx.jpg(401 KB) - download Circuitry implemented on a breadboard. Includes the Arduino, stepper motor driver, and the lead outs for the potentiometer.

Riley Norman - Dec 04, 2021, 2:08 PM CST



bipolarKnob_bbsm.png(14.2 KB) - download

12/4/21 - Projects Broader Significance

Riley Norman - Dec 11, 2021, 1:56 PM CST

Title: Project Broader Significance

Date: 12/11/21

Content by: Riley Norman

Present: Riley Norman

Goals: To present how this project has significance outside of BME 300.

Content:

This project was made for a client who works directly with upencoming EMT who are learning the many different important skills they will need in the field. One of these is being able to operate, place, read, and interpret an arterial line monitor. This gives them real time feedback about the patients cardiovascular system through blood pressure and heart rate measurements. This is a complex machine and is one of the first instruments placed in an emergency situation. Given the importance of this device it is vital that EMTs have thurough training and hands on practice with close supervision from an expert in the field. Without our arterial line simulator our client must simulate the arterial waveform by hand. This pulls him away from the students and ultimately affects their learning. Without proper instructor interaction these students could struggle in the high pressure situations they may face as active EMTs. By creating this device instructors everywhere would be able to devote their focus to their students entirely and leave the simulation of the arterial line waveform to our product.

In addition to instructors having more time to focus on their students. Our device is small and cheap compared to leading devices that carry out similar simulations. This makes it easy to ship all over the world and could give the power of arterial line monitor practice to thousands of people. By getting early and frequent exposure to arterial line monitors, indivduals can feel comfortable and prepared when they go to place and use the real device on a real patient, ultimately, improving patient care.

Conclusions/action items:

To finish all remaining final deliverables.

2021/09/16 - Arterial Line Transducer

Frankie Szatkowski - Oct 19, 2021, 1:27 PM CDT

Title: Arterial Line Transducer Use

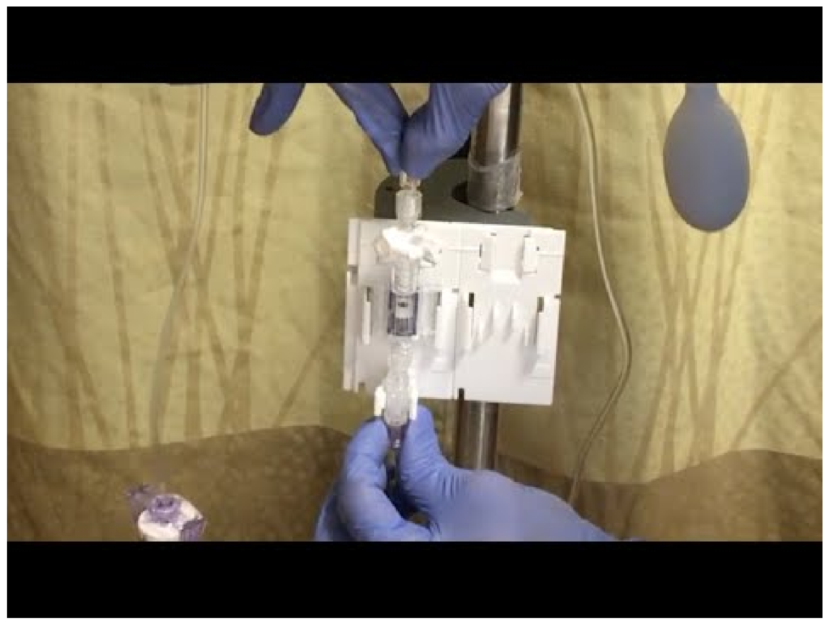
Date: 09/16/2021

Content by:

Present: N/A

Goals: To determine how an arterial line transducer works presently, enabling us to gain a better understanding of what is requested of the team.

Content:



- Device composed of syringe attached to stopcock, which splits into two lines.

- One line attached to output, other attached to saline bag.

- Transducer gets hooked up to Manikin and allows for "blood pressure" to appear in manikin.

- Client currently must depress the syringe by hand to develop the desired waveform(s)

Conclusions/action items: Our goal this semester is to design a device capable of depressing the transducer in certain frequencies and pressures to develop the desired arterial waveform for our client.

2021/09/23 - Arterial Line Monitoring System Simulation

Frankie Szatkowski - Oct 19, 2021, 1:50 PM CDT

Title: Arterial Line Monitoring System Simulation

Date: 09/23/2021

Content by: David M. Feinstein & Daniel B. Raemer

Present: N/A

Goals: To evaluate previous design/competition to learn what to avoid and what to strive for

Content:

- Hardware portion intended to simulate vitals in manikin.

- Software portion designed to simulate waveform components not observable through manikin.

- Electrical signal generated from stopcock position (measured via potentiometer)

UPDATE 10/19/2021 -- Article uploaded below for future reference.

Conclusions/action items: Current operation of arterial line simulation functions similarly to described above, except pressure is generated by hand. This enables a better understanding of what the team must do to provide ample simulation with minimal human interaction.

Frankie Szatkowski - Oct 19, 2021, 1:47 PM CDT

ARTERIAL-LINE MONITORING SYSTEM SIMULATION

David M. Feinstein, MD,[1] and Daniel B. Raemer, PhD[2]

Feinstein-Raemer2000_Article_Arterial-LineMonitoringSystemS.pdf(178.2 KB) - download

2021/10/11 - Design Matrix

Frankie Szatkowski - Oct 19, 2021, 1:37 PM CDT

Title: Arterial Line Simulator Design Matrix

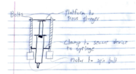
Date: 10/11/2021

Content by: Arterial Line Team

Present: Sammie Gilarde, Sophia Finn, Kasey Mohlke, Riley Norman, Frankie Szatkowski, Mateo Silver

Goals: To determine the best design to continue developing

Content:

Criteria	Design 1: The Cam 	Design 2: The Piston 	Design 3: The Bolt 
Consistency (25)	5/5 * 25 = 25	5/5 * 25 = 25	4/5 * 25 = 20
Range of Use (25)	4/5 * 25 = 20	2/5 * 25 = 10	3/5 * 25 = 15
Ease of Use (20)	5/5 * 20 = 20	5/5 * 20 = 20	4/5 * 20 = 16
Ease of Fabrication (10)	3/5 * 10 = 6	2/5 * 10 = 4	2/5 * 10 = 4
Safety (10)	5/5 * 10 = 10	5/5 * 10 = 10	4/5 * 10 = 8
Durability (5)	3/5 * 5 = 3	3/5 * 5 = 3	4/5 * 5 = 4
Cost (5)	5/5 * 5 = 5	4/5 * 5 = 4	4/5 * 5 = 4
Total = 100	**89 / 100**	**76 / 100**	**71 / 100**

- Our primary design, the cam, was best for majority of categories.

- Piston was close second but ultimately failed due to difficulty creating multiple waveforms

- Felt hardware (cam) beat software (piston rotation/direction) in terms of generating different waveforms

- Bolt had potential in most categories, but ultimately fell short due to complexity of design for simple result.

Conclusions/action items: The team will continue to develop the cam design, making use of different shaped cams to generate the desired waveforms. If success is found quickly and efficiently, look into designing an automated switcher for easy waveform conversion.

2021/11/05 - Stepper Motor Arduino Controller

Frankie Szatkowski - Dec 14, 2021, 9:10 PM CST

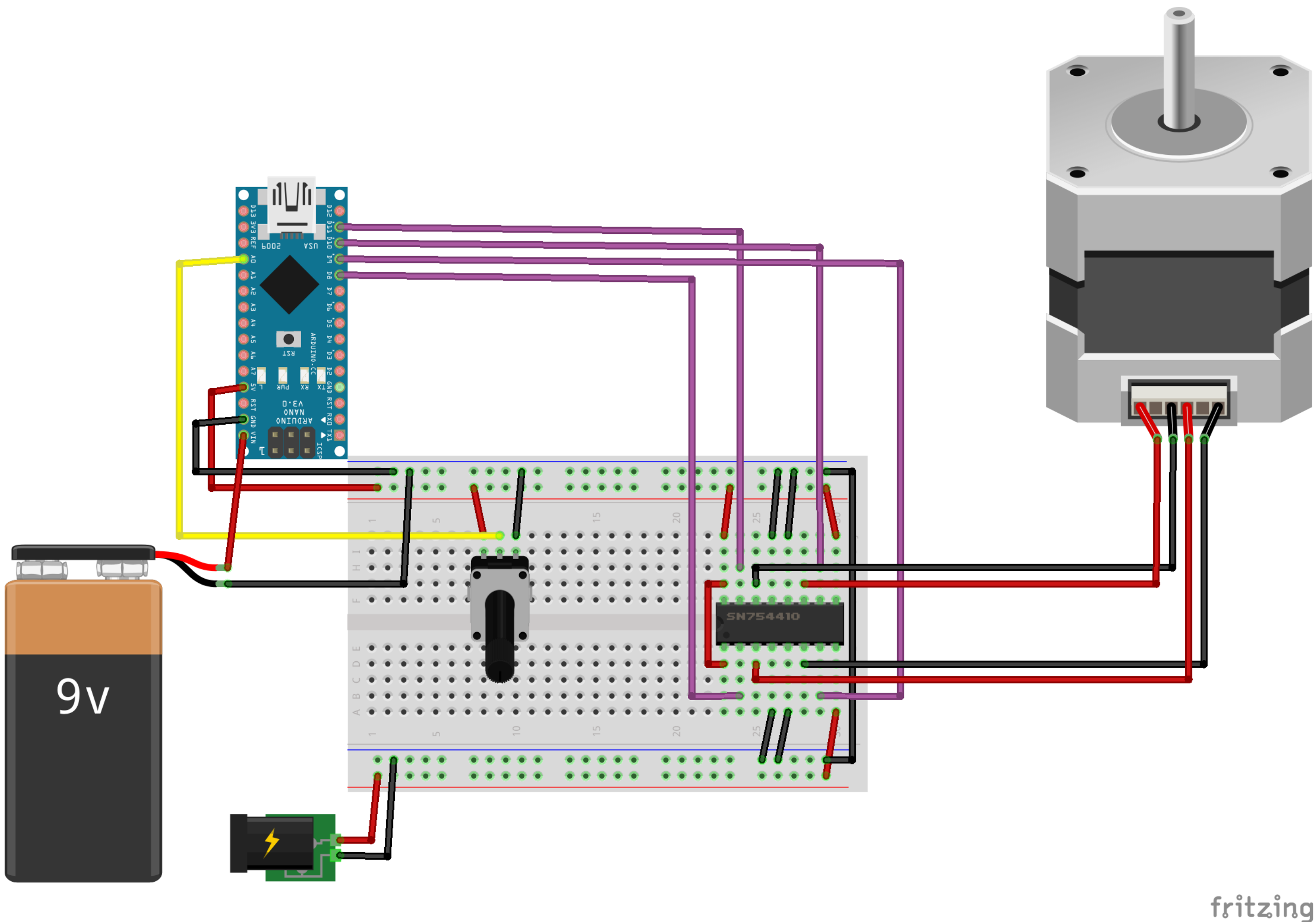
Title: Arduino Controller for Stepper Motor

Date: 11/5/2021

Content by: Frankie

Goals: To control a bipolar stepper motor using an arduino and a stepper driver

Content:



Conclusions/action items:

Using an Arduino Nano to control a bipolar stepper motor can be done as such. This schematic should allow full speed control of the motor utilizing a rotary potentiometer.

2021/12/10 - Future Material Selection

Frankie Szatkowski - Dec 15, 2021, 2:19 AM CST

Title: Future Cam Materials

Date: 12/10/2021

Content by: Frankie

Goals: To determine a better CAM material for future iterations

Content:

-HDF had high levels of friction with the syringe. This caused unwanted side effects including non-linear motion on the plunger.

- High Density Polyethylene and Polypropylene may be effective CAM materials for future.

- Impact resistance, lightweight and low friction against itself.

- Attaching a disk of HDPE to the end of the plunger will heavily reduce plunger-CAM friction and could potentially improve pressure gradients.

Conclusions/action items:

HDPE may be a viable solution for future CAMs to prevent high levels of friction that negatively impacted the CAM-plunger interaction.

2021/10/01 - BPAG Meeting 1

Frankie Szatkowski - Oct 19, 2021, 2:39 PM CDT

Title: BPAG Training

Date: 10/01/2021

Content by: John Puccinelli

Present: BPAGs

Goals: To establish our roles as BPAGs of our respective teams.

Content:

- Create spreadsheet for all transactions

- Put receipts in notebook (Team Activities > Materials and Expenses)

- Clear all purchases with client before purchasing

- Client specific: Purchases will be made through UW funds. Get client to pay if possible

- If going with reimbursement option, only BPAG receives reimbursement.

- Table should be put in report, team notebook and progress reports.

UPDATE 10/19/21 -- Uploaded PDF below for future reference.

Conclusions/action items: Stay on top of purchases and communicate with the client before doing anything. Maintain steady and careful logs to prevent any monetary problems, whether immediately or down the line.

Frankie Szatkowski - Oct 19, 2021, 2:02 PM CDT

BPAG_presentation.pdf(555.4 KB) - download Presentation from 10/01/2021 Meeting

9/15/21 - Background Research

MATEO SILVER - Sep 15, 2021, 10:14 PM CDT

Title: Background Research

Date: 2021/9/15

Content by: Mateo Silver

Present:

Goals: Begin research on background topics related to arterial lines.

Content:

Creating a realistic model of an arterial line monitor solves many problems in current clinical patient models. These include: accounting for other aspects of the simulated patient such as respiratory rate and blood pressure, familiarity with the same tools that students will see when practicing on real patients, and accounting for variability found in real patients due to differing physiology. [1]

Arterial line monitors can give a lot of useful information about a patient. Including: "heart rate, systolic [and diastolic] pressure, pulse pressure, and arterial pressure" Creating a model that is true to life assists clinicians in diagnosing cardiac problems when faced with a real patient. [2]

Conclusions/action items:

Realism in simulated arterial line monitors is of critical importance. A realistic model supports the transition from learning to making diagnoses on patients.

Sources:

[1] D. M. Feinstein and D. B. Raemer, “ Arterial-line monitoring system simulation,” Journal of Clinical Monitoring and Computing , vol. 16, no. 7, pp. 547–552, Sep. 2000.

[2] A. Yartsev, “Normal arterial line waveforms,” Normal arterial line waveforms | Deranged Physiology, 13-Aug-2021. [Online]. Available: https://derangedphysiology.com/main/cicm-primary-exam/required-reading/cardiovascular-system/Chapter%20760/normal-arterial-line-waveforms. [Accessed: 16-Sep-2021].

9/23/21 - Background Research

MATEO SILVER - Sep 23, 2021, 11:04 AM CDT

Title: Background Research

Date: 2021/9/23

Content by: Mateo Silver

Present:

Goals: Continuing research on solutions for actuating a syringe plunger.

Content:

- A similar project [1] which aimed to create a syringe actuator based on a servo motor utilized an Arduino as a microcontroller for their electronics. The Arduino used an lcd/button panel shield to show information and allow user control of the device. This is a solution that we could look into for incorporating user input of our product. This [2] product is similar to the one used.

- This project also made the decision to use a servo motor over the more commonly used (in this application) stepper motor. Using a servo allowed them to have more precise control over the movement of their actuator.

Conclusions/action items:

While going into the initial design phases of our project, it might be useful to consider some of the design choices (lcd, servo) that this project made. We will, of course, have to do our own research about specific components to use or avoid.

Sources:

[1] J. W. Ong, D. C. Chung, E. S. Lin, H. A. Abid, O. W. Liew, and T. W. Ng, “Syringe infusion pump with absolute piston displacement control,” Review of Scientific Instruments, vol. 90, no. 7, pp. 1–3, Jul. 2019.

[2] https://electropeak.com/1602-lcd-keypad-shield-for-arduino.

10/19/21 - Cam Shape Design

MATEO SILVER - Oct 19, 2021, 5:47 PM CDT

Title: Cam Shape Design

Date: 10/19/21

Content by: Mateo Silver

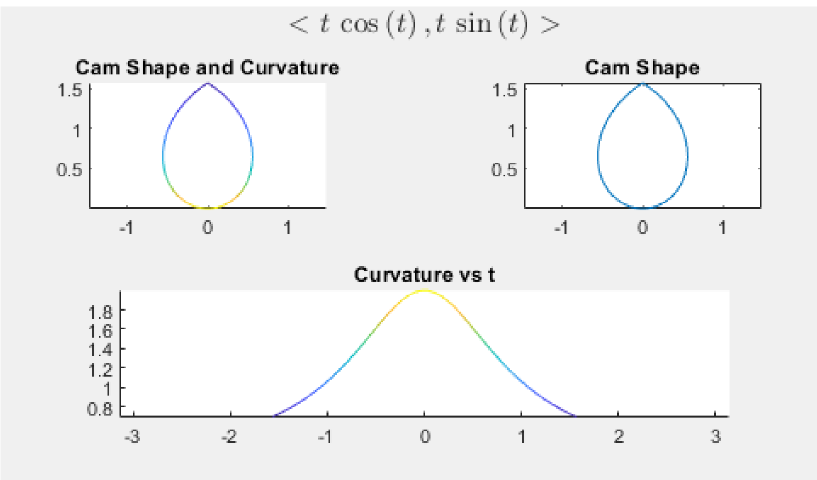
Present:

Goals:

Content:

In order to create a cam shape that consistently creates the waveform shape that we desire, it is necessary to model the cam shape before manufacturing.

To make the modeling process go more smoothly, I wrote up a program in Matlab to model the predicted waveform of any cam shape (as given by a parametric equation). For example, if given the parameterized equation <t*cos(t), t*sin(t)>, the program would output the following.



By building off of previous work, as well as using the cams generated by my program, it is possible to create models for the three cams that we need to create. The current code used to generate the output above can be found in this same LabArchives folder.

Conclusions/action items:

Wrote a Matlab program to predict waveform based on cam shape.

10/19/21 - Matlab Code

MATEO SILVER - Oct 19, 2021, 5:50 PM CDT

Title: Matlab Code

Date: 10/19/21

Content by: Mateo Silver

Present:

Goals:

Content:

```
syms t

% Known Functions
genWaveform(4*cos(t), 3*sin(t), 50, -pi, pi); % Oval Shaped Cam
genWaveform(cos(t), sin(t), 50, -pi, pi); % Circle Shaped Cam
genWaveform(t*cos(t),t*sin(t) , 50, -pi/2, pi/2); % Pear Shaped Cam
genWaveform(2*cos(t)-cos(2*t),2*sin(t)-sin(2*t) , 50, -2*pi, 2*pi); % Cardoid Shaped Cam
genWaveform((1+power(t,2))./(power(t,4)+power(t,2)+1),(t+power(t,3))./(power(t,4)+power(t,2)+1), 100, -4.58, 4.58); % Asteroid Function Cam

% Generates a cam waveform given a parameterized function
% representing the shape of the cam.
%
% @param x_param the x component of the parameterized function (e.g. 4*cos(t))
% @param y_param the y component of the parameterized function (e.g. 3*sin(t))
% @param d_param number of tangent vectors to use for approximated calculations.
% @param domain_start the beginning of the domain of the periodic function
% @param domain_end the end of the domain of the periodic function

function a = genWaveform(x_param, y_param, d_param, domain_start, domain_end)
t_num = linspace(domain_start, domain_end, d_param);
syms t;

% r(t) = <4cos(t), 3sin(t)> = <x,y>
x = x_param;
y = y_param;
r = [x;y];

% r'(t) = <-4sin(t), 3cos(t)> = <dx, dy>
dx = diff(x);
dy = diff(y);
dr = [dx;dy];

% r''(t) = <ddx,ddy>
ddx = diff(x,2);
ddy = diff(y,2);
ddr = [ddx;ddy];

% curvature of function
K = (norm(cross([dr;0],[ddr;0])))/((norm(dr).^3)+0.000001);

% Plot cam shape and curvature
figure;
```

```
chart = tiledlayout(3,2);
nexttile([1 1]);
hold on;
plot(subs(x,t,t_num),subs(y,t,t_num));
surface([subs(x,t,t_num); subs(x,t,t_num)],[subs(y,t,t_num); subs(y,t,t_num)], [zeros(size(subs(x,t,t_num))); zeros(size(subs(x,t,t_num)))],
[subs(K,t,t_num); subs(K,t,t_num)], "EdgeColor","interp");
axis equal;
title("Cam Shape and Curvature");

% Plot cam shape alone
hold off;
nexttile([1 1]);
plot(subs(x,t,t_num),subs(y,t,t_num));
axis equal;
title("Cam Shape");

% Plot curvature over t
nexttile([1 2]);
surface([t_num; t_num],[subs(K,t,t_num); subs(K,t,t_num)], [zeros(size(subs(x,t,t_num))); zeros(size(subs(x,t,t_num)))], [subs(K,t,t_num);
subs(K,t,t_num)], "EdgeColor","interp");
axis equal;
title("Curvature vs t");
title(chart,"$< "+latex(x_param)+ " , "+latex(y_param)+" >$",'interpreter', 'latex');

end
```

Conclusions/action items:

Code used to generate output found in "Cam Shape Design" LabArchives note

12/12/21 - Final Cam Shapes

MATEO SILVER - Dec 12, 2021, 4:27 PM CST

Title: Final Cam Shapes

Date: 12/12/21

Content by: Mateo Silver

Present:

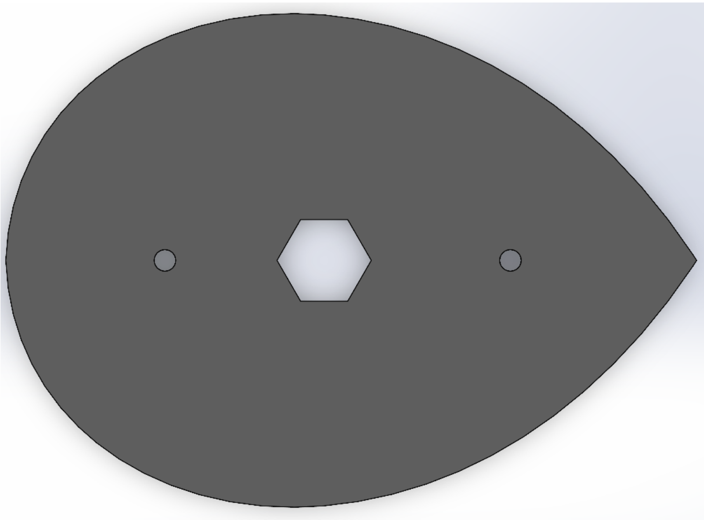
Goals:

Content:

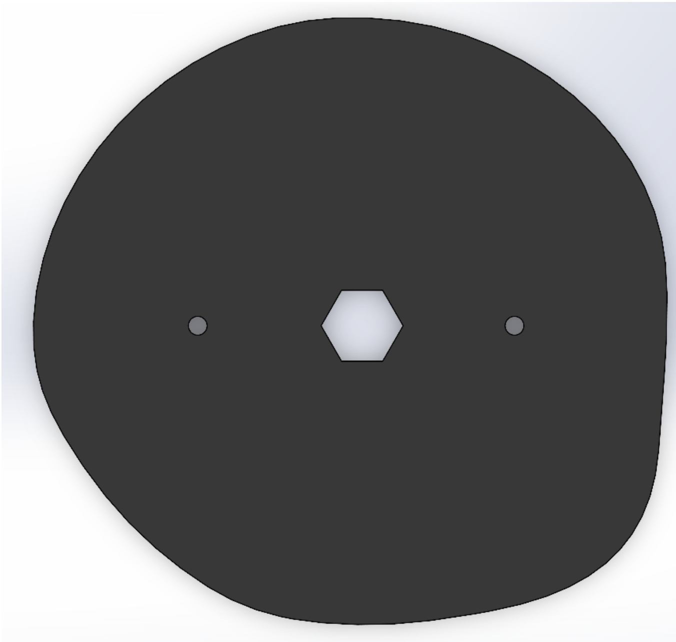
Below are the final two cam shapes that we used to create the overdamped and normal shaped waveforms. The normal shaped waveform is based on the shape calculated in this [1] paper. The overdamped one was designed using the MATLAB code that I had written, to estimate the waveform it would create when used. A hexagonal hole was cut in the cams to allow the motor shaft to drive the cam. There were also two smaller holes used to align the cams when they were assembled. For more information, see the "Cam Fabrication" entry.

[1] Yang, TH., Jo, G., Koo, JH. *et al.* A compact pulsatile simulator based on cam-follower mechanism for generating radial pulse waveforms. *BioMed Eng OnLine* **18,** 1 (2019). https://doi.org/10.1186/s12938-018-0620-3

Overdamped Cam:



Normal waveform Cam:



Conclusions/action items: Final cam shapes shown above.

10/1/21 - Preliminary Design 1

MATEO SILVER - Oct 01, 2021, 4:12 PM CDT

Title: Preliminary Design 1

Date: 2021/10/1

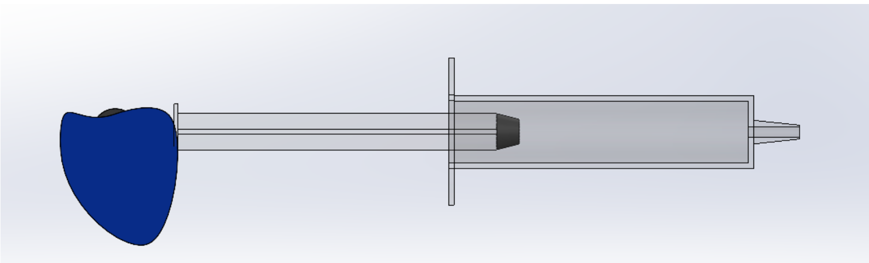
Content by: Mateo Silver

Present:

Goals:

Content:

Below is the first preliminary design that I created to press on the syringe. It consists of a cam wheel that rotates and compresses the plunger at varying pressures over the course of one revolution. To vary the waveform, we can change the shape of the cam.



Conclusions/action items:

Preliminary design one.

10/1/21 - Preliminary Design 2

MATEO SILVER - Oct 01, 2021, 4:15 PM CDT

Title: Preliminary Design 2

Date: 2021/10/1

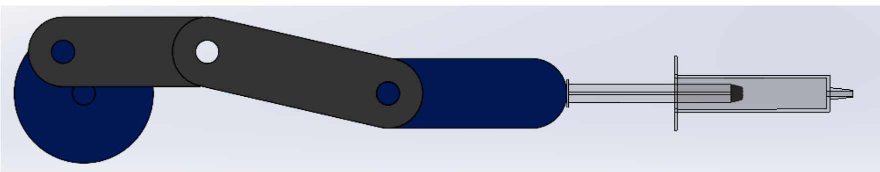
Content by: Mateo Silver

Present:

Goals:

Content:

This is the second preliminary design that I created. It consists of a crank that turns and creates a linear motion, that pushes the plunger in. With this design, it would be harder to vary the waveform, as the plunger would have to make an entire rotation before generating a new wave. The different waveforms would be dictated by the rate of the motor, controlled on the software side.



Conclusions/action items:

Preliminary design two.

10/1/21 - Preliminary Design 3

MATEO SILVER - Oct 01, 2021, 4:23 PM CDT

Title: Preliminary Design 3

Date: 2021/10/1

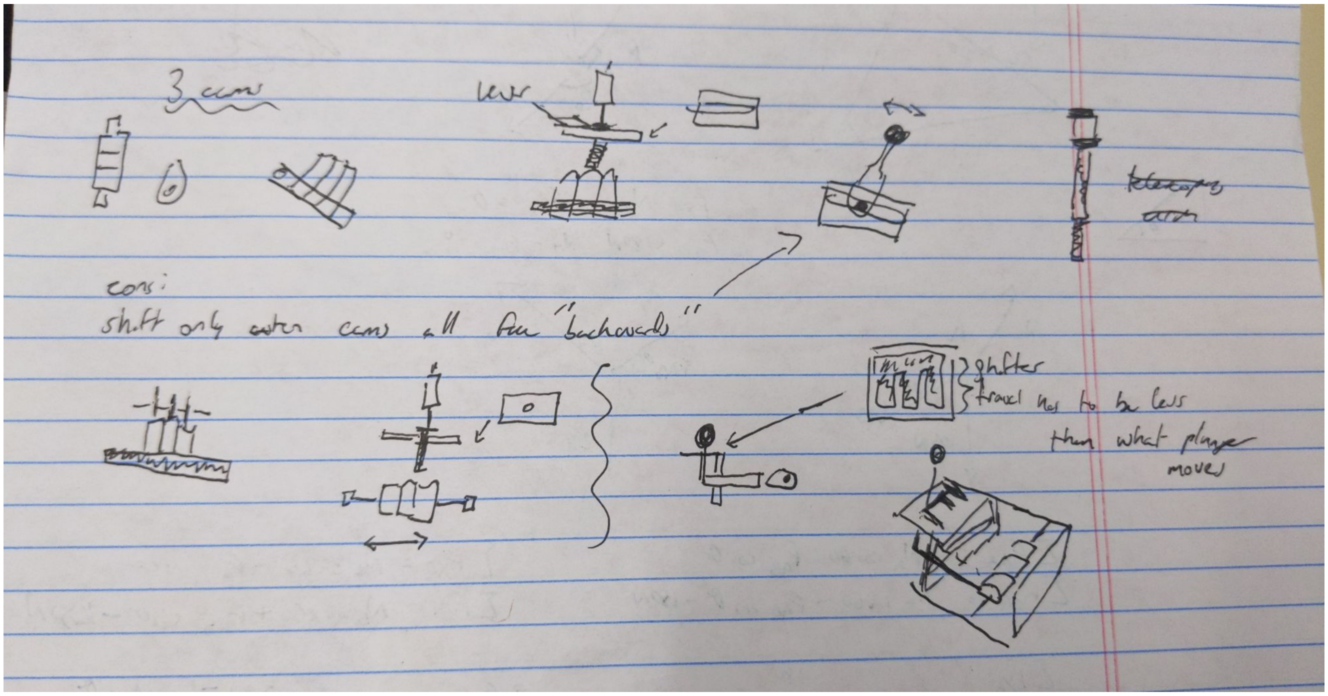
Content by: Mateo Silver

Present:

Goals:

Content:

Here are a few design ideas I sketched out that could resolve a few of the issues presented in preliminary design one. The biggest issue with that design was how challenging it would be to change cams, in order to vary the waveform. I present a mechanical "shifting mechanism" here, that would be able to change the cam used without having to open up the product. This design may be fleshed out in more detail as we iterate different designs.



Conclusions/action items:

Expansion on preliminary design one.

12/12/21 - Cam Fabrication

MATEO SILVER - Dec 12, 2021, 3:22 PM CST

Title: Cam Fabrication

Date: 12/12/21

Content by: Mateo Silver

Present:

Goals: Show fabrication process of cams.

Content:

After calculating the correct cam shapes that would produce our desired waveforms, it was time to manufacture the cams. The photos attached below demonstrate the assembly process of each cam.

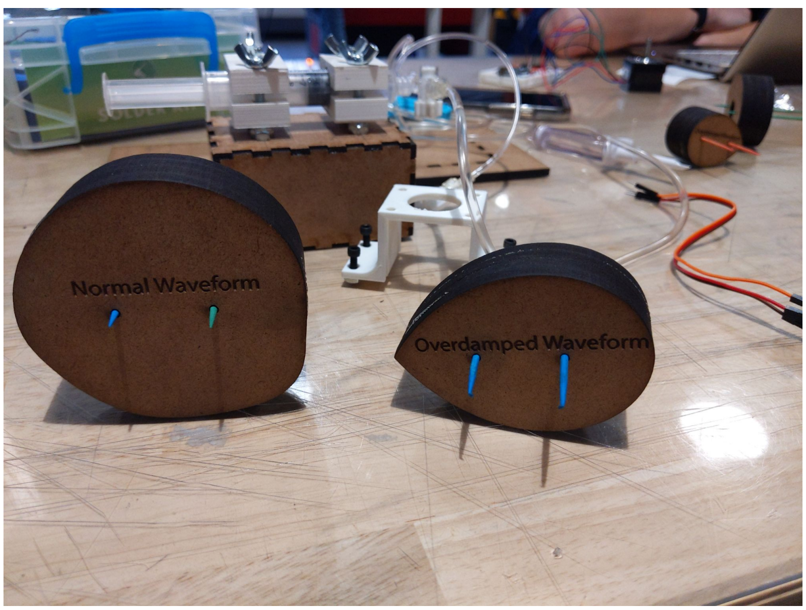
1. The first step after finding the correct shape of the cam was to create a model in solidworks with the same shape.

2. After the model was created, the design could be exported to an Adobe Illustrator file.

3. Next, some touching up was done in Illustrator to add the label to the cam.

4. In order to achieve enough contact between the plunger of the syringe and the face of the cam, multiple layers of material were stacked on top of each other. We ended up using four layers per cam.

5. After being laser cut, the layers could be glued up and assembled. To help align the cams while the glue dried, we added some holes to the face of the cam. Toothpicks were then inserted into the openings, which kept the cams from moving before the glue fully cured.



Conclusions/action items: Described how cams were fabricated.

12/12/21 - Base Fabrication

MATEO SILVER - Dec 12, 2021, 3:59 PM CST

Title: Base Fabrication

Date: 12/12/21

Content by: Mateo Silver

Present:

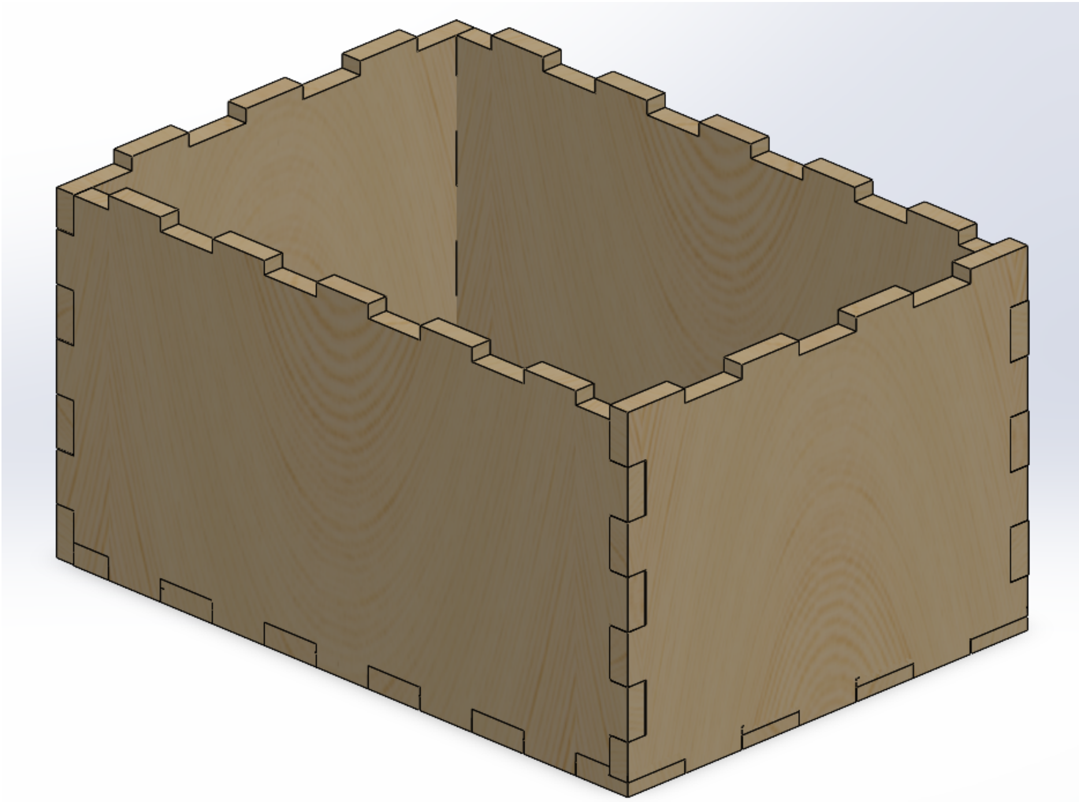
Goals: Show fabrication process of base plate and support box.

Content:

When fabricating the base plate and syringe support box, precision was key. The box was designed to mesh together, into itself and into the base plate using finger joints. The syringe mount also had to be placed at the correct height so that the cam would press up against it smootly.

To manufacture the support box, I first found a similarly designed box online on Grabcad. I then scaled the box appropriately so that the syringe would sit at the correct height. To get the box to sit nicely into the baseplate, I mated both of the objects in Solidworks, and subtracted the box from the base. All the solidworks files were then exported into Illustrator and laser cut.


NO TOOLS OR
CHEMICALS
ON THIS TABLE
JETBOIL
WILDLY VERSATILE
SMITH
SKI PATROL
IKON
PASS
DOUBLESHOT
ENERGY
SMITH



Conclusions/action items: Described how base plate and support box were fabricated.

12/12/21 - Motor and Syringe Mount Fabrication

MATEO SILVER - Dec 12, 2021, 4:07 PM CST

Title: Motor and Syringe Mount Fabrication

Date: 12/12/21

Content by: Mateo Silver

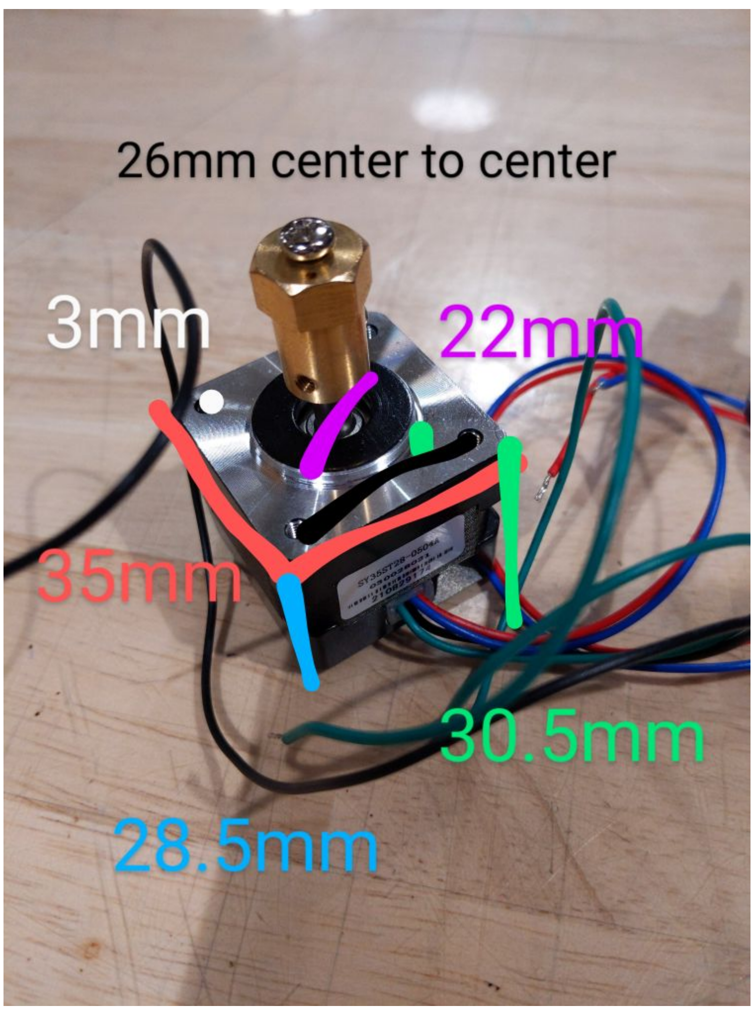
Present:

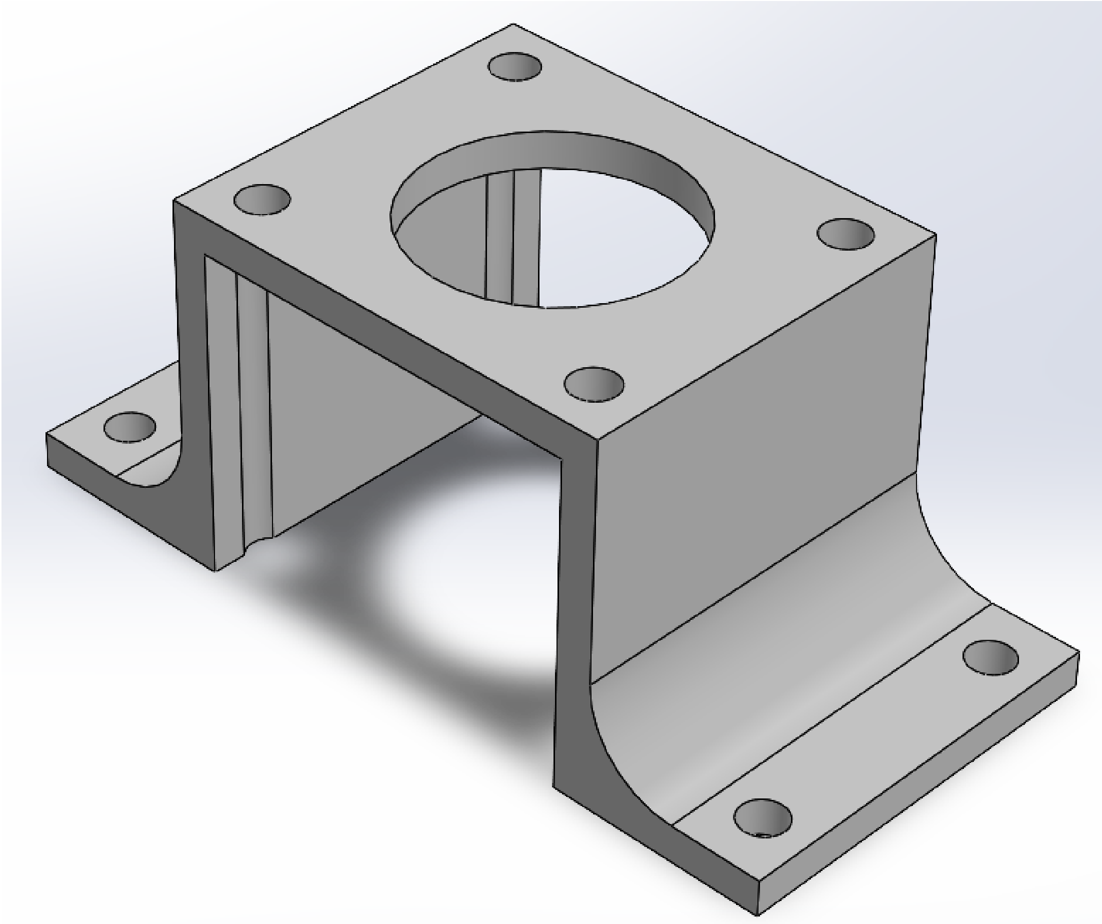
Goals: Show fabrication process of motor and syringe mounts.

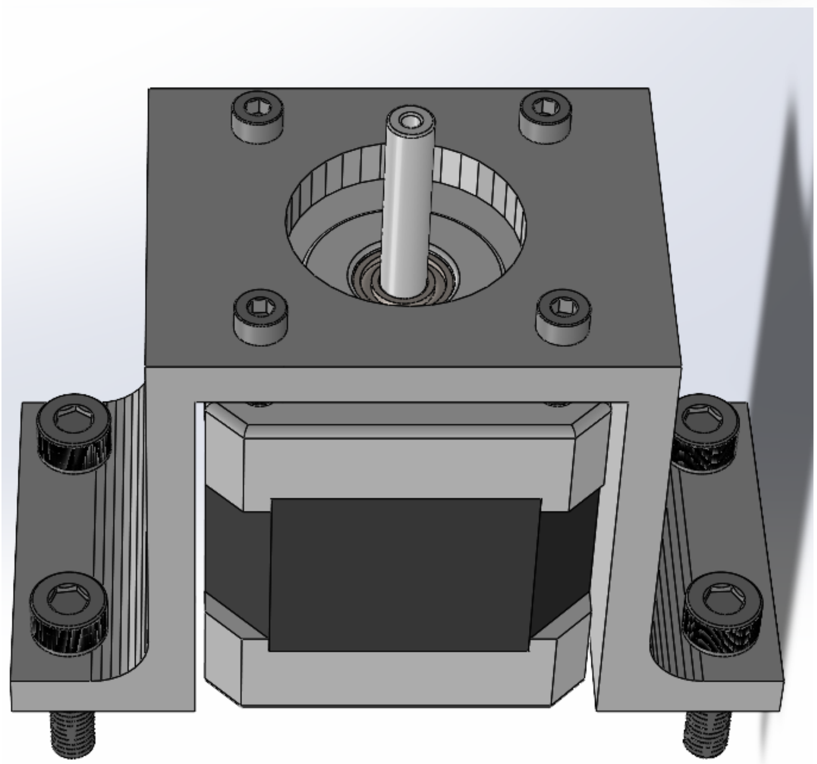
Content:

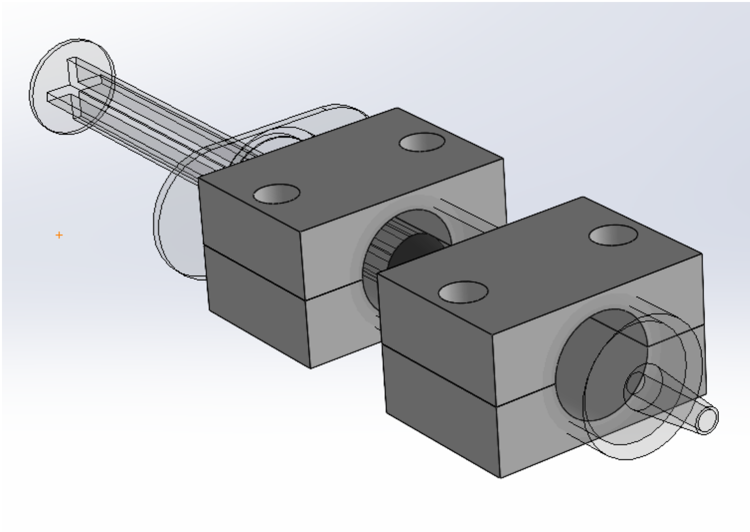
In order to minimize noise caused by vibration, it was very important that all of our components were securely mounted. This was achieved by using custom designed motor and syringe mounts. The first step in creating the motor mount was to carefully measure all the relevant dimensions using calipers. From there, I was able to go into Solidworks and create a design that would fit tightly around the motor. I also included four holes for mounting the motor to the base, and four more for securing the motor to the mount.

The syringe mount was created by Frankie. He designed it to fit the diameter of the syringe, and added in holes for securing the mount to the box and to keep the syringe from slipping.









Conclusions/action items: Described how motor and syringe mounts were fabricated.

2014/11/03-Entry guidelines

MATEO SILVER - Sep 15, 2021, 9:04 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

Title: Descriptive title (i.e. Client Meeting)

Date: 9/5/2016

Content by: The one person who wrote the content

Present: Names of those present if more than just you (not necessary for individual work)

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Content:

Contains clear and organized notes (also includes any references used)

Conclusions/action items:

Recap only the most significant findings and/or action items resulting from the entry.

2014/11/03-Template

John Puccinelli - Nov 03, 2014, 3:20 PM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items: