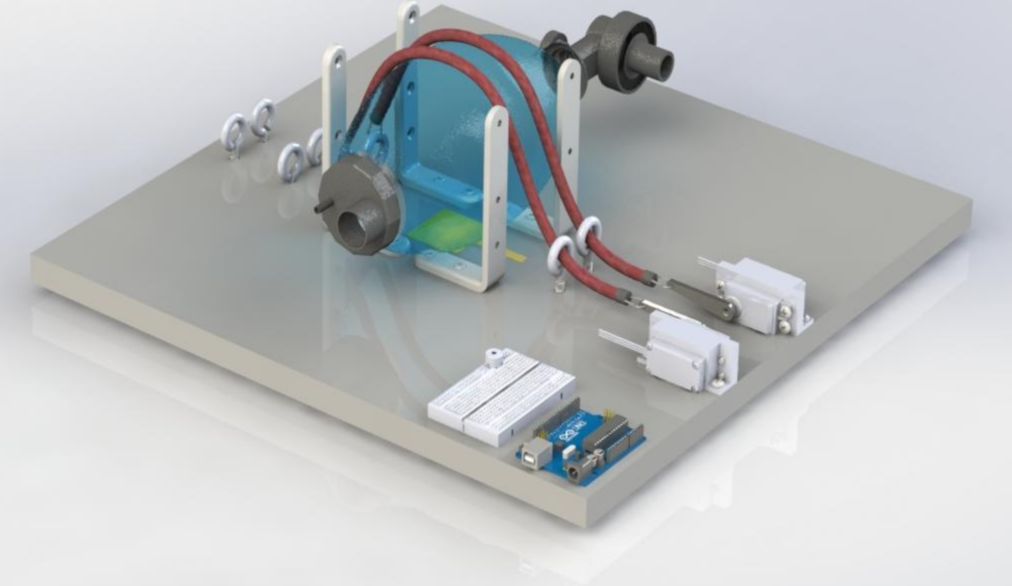
DIY Ventilator

Team RESVent



A. JAMES CLARK
SCHOOL OF ENGINEERING

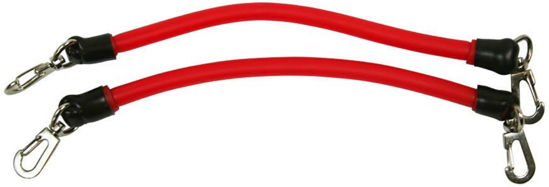
COLUMBIA | ENGINEERING
The Fu Foundation School of Engineering and Applied Science

Purpose

- Design ventilator using Ambubag with accessible tools and parts
  - Last resort for Ventilators if hospitals run out
- Avoid 3D printing or laser cutting.
  - Device becomes buildable much faster for majority of people

How it works

- Force on resistance bands deflate the ambu bag based on specified torque of the motors
- One side of the resistance band is secured in place, while the other side is attached to the servo arm
- Angle of the servo arm determines how much resistance bands are stretched and how much the ambu-bag is deflated underneath resistance band
- Speed of the servo arm determines rate of ambu-bag inflation and deflation



Members

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  - University of Maryland (Undergraduate Student)
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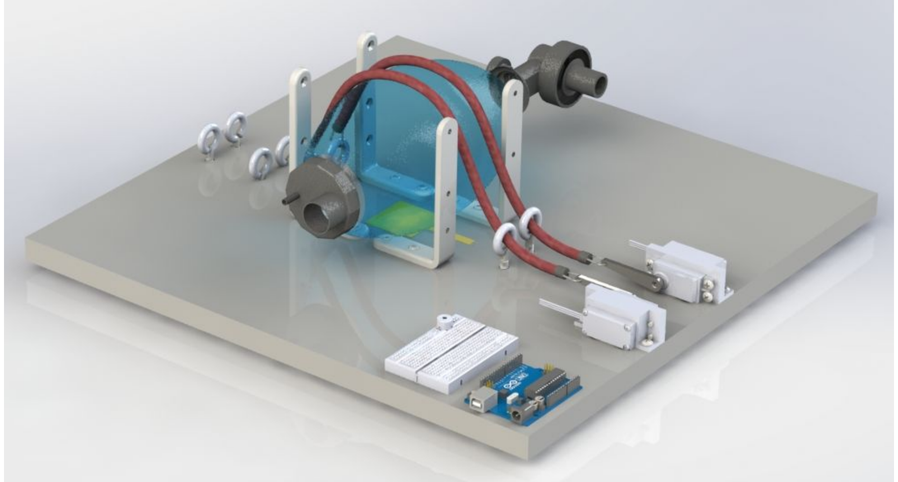
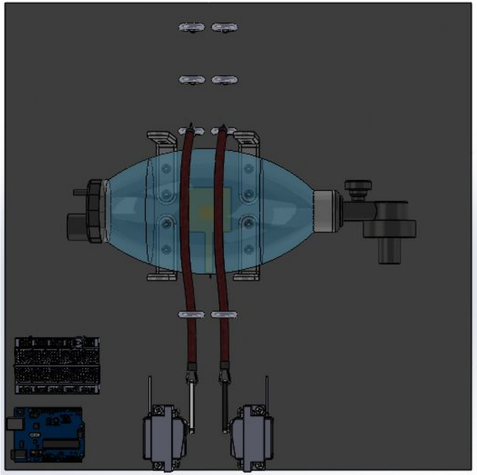
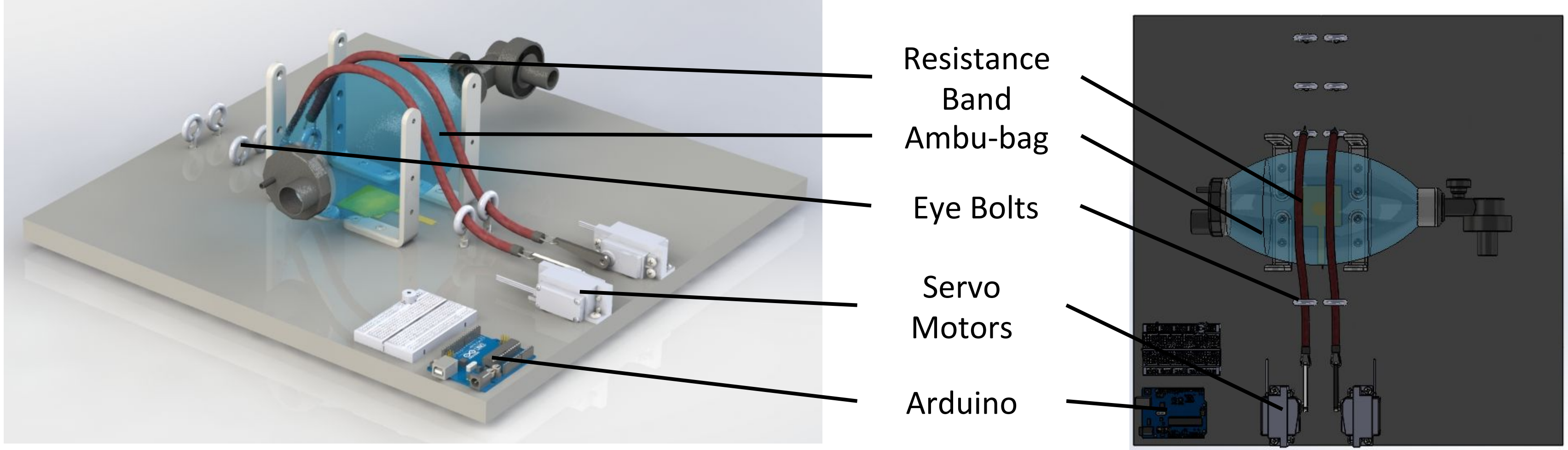
- Kimberly Ruth Kroupa
  - Columbia University (SEAS Graduate Student)
  - krk2153@columbia.edu, 914-610-9304

Design Renderings





Design Renderings



Resistance Band

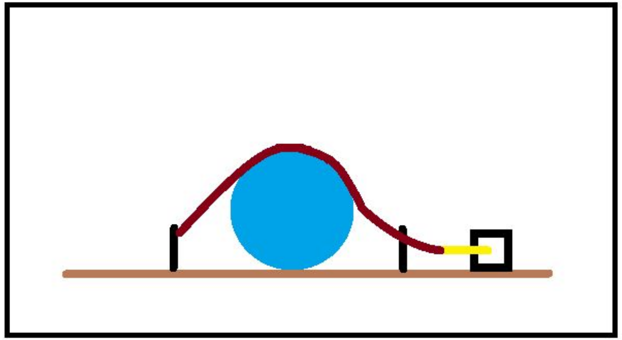
Ambu-bag

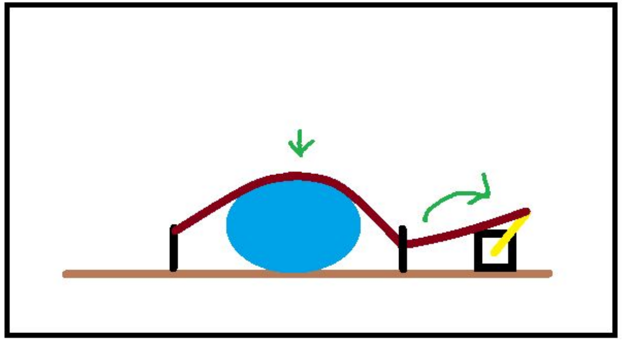
Eye Bolts

Servo Motors

Arduino

Mechanism Illustration





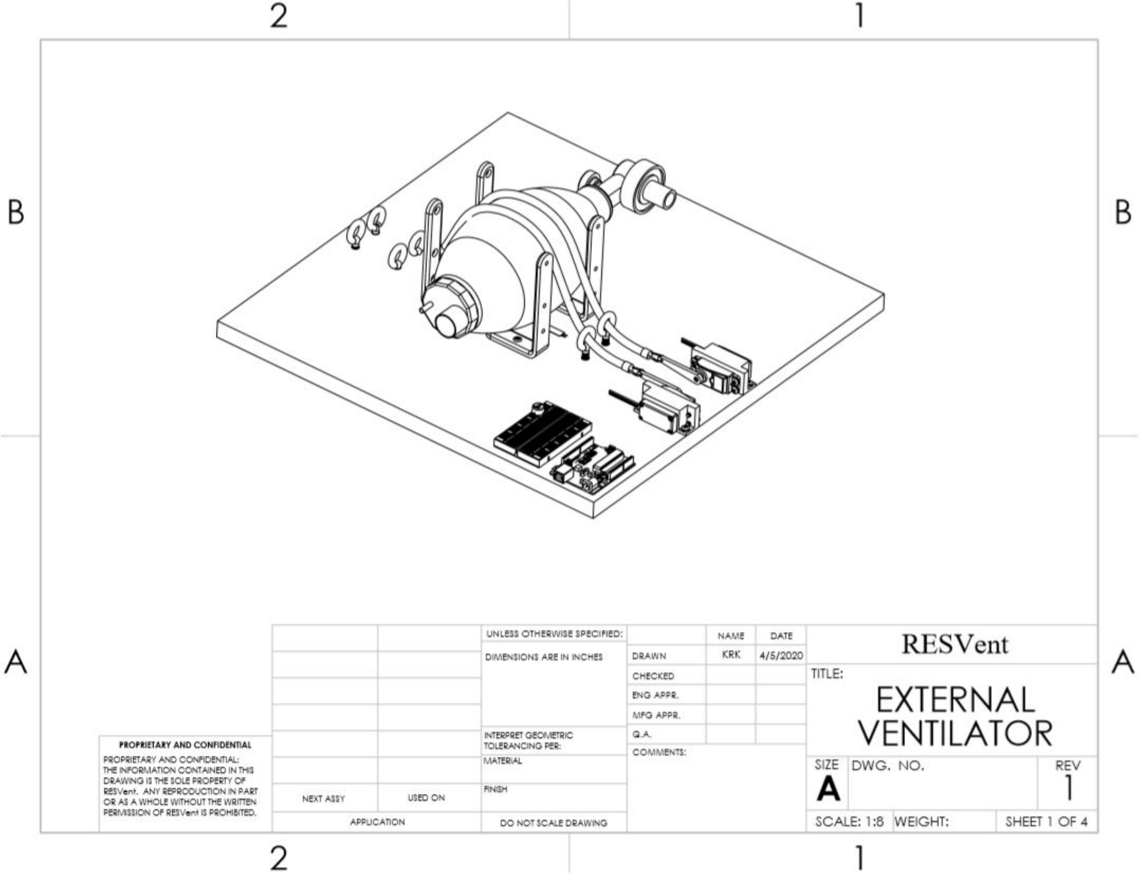
Inhale

1. Servos rotate 180° to pull resistance bands
2. Resistance bands tighten, press bag

Exhale

1. Servos rotate 180° back to pull resistance bands
2. Resistance bands relax and relax bag

Whole Assembly



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NEXT ASSY
USED ON
APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	KRK	4/5/2020
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

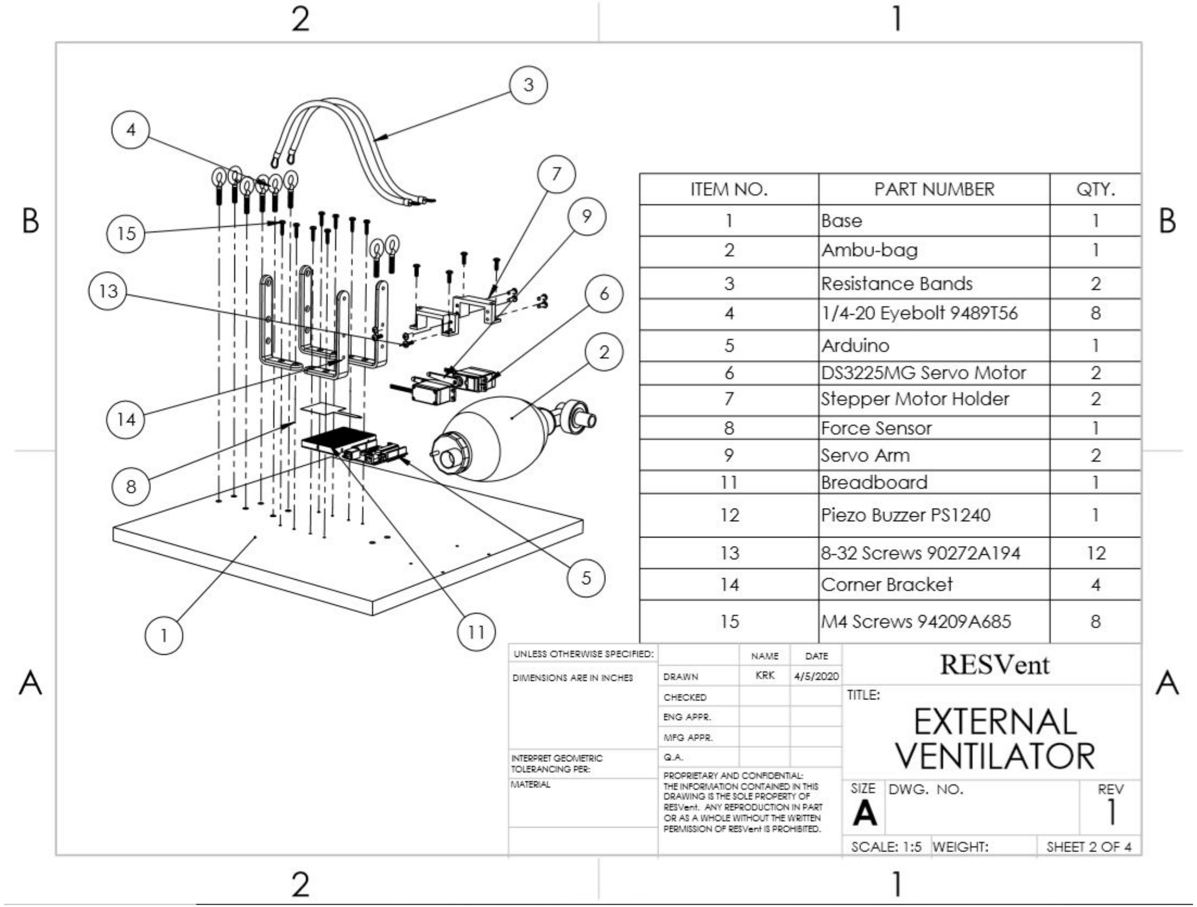
COMMENTS:

RESVent

TITLE: EXTERNAL VENTILATOR

SIZE A
DWG. NO.
REV 1
SCALE: 1:8
WEIGHT:
SHEET 1 OF 4

Exploded Assembly



ITEM NO.	PART NUMBER	QTY.
1	Base	1
2	Ambu-bag	1
3	Resistance Bands	2
4	1/4-20 Eyebolt 9489T56	8
5	Arduino	1
6	DS3225MG Servo Motor	2
7	Stepper Motor Holder	2
8	Force Sensor	1
9	Servo Arm	2
11	Breadboard	1
12	Piezo Buzzer PS1240	1
13	8-32 Screws 90272A194	12
14	Corner Bracket	4
15	M4 Screws 94209A685	8

UNLESS OTHERWISE SPECIFIED:
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INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL

	NAME	DATE
DRAWN	KRK	4/5/2020
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

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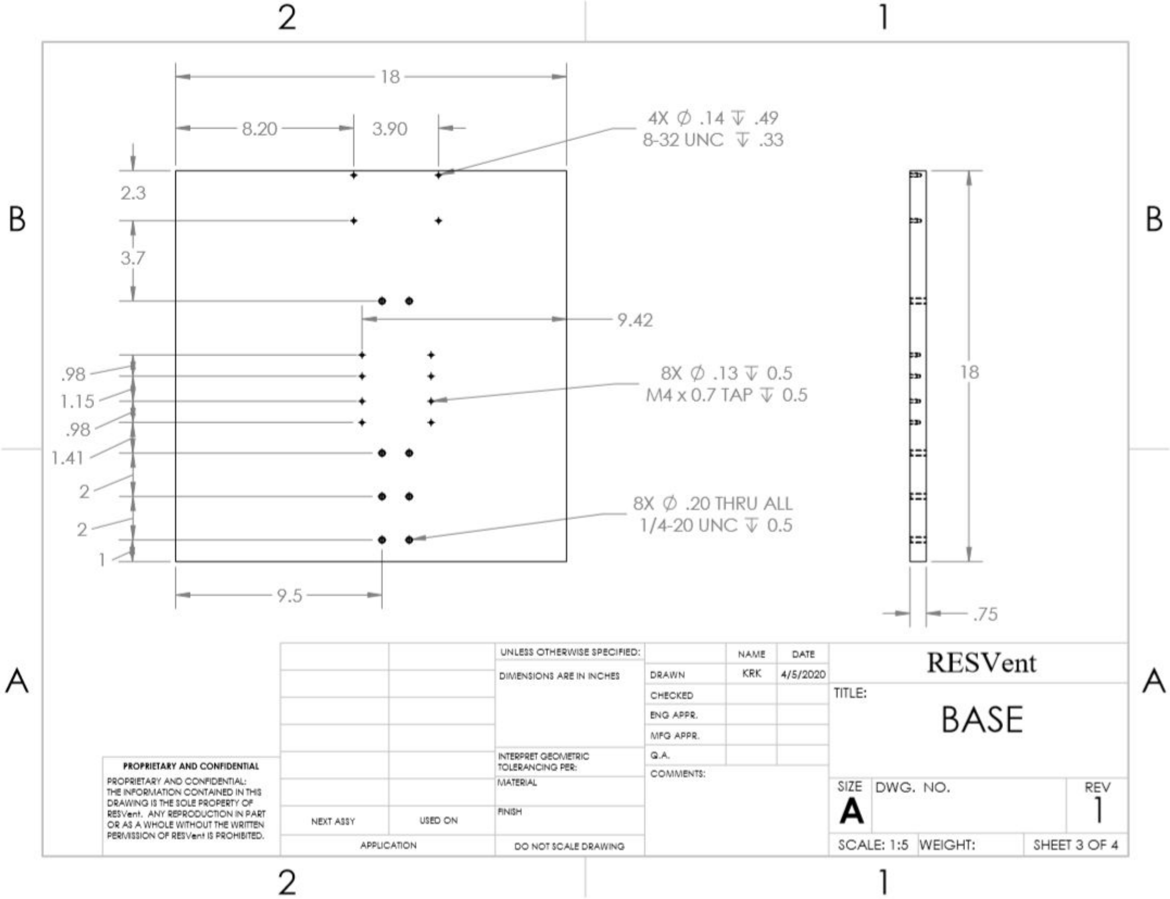
RESVent

TITLE:
EXTERNAL VENTILATOR

SIZE A
DWG. NO.
REV 1

SCALE: 1:5
WEIGHT:
SHEET 2 OF 4

Support Board


18
8.20
3.90
4X ∅ .14 ↧ .49
8-32 UNC ↧ .33
2.3
3.7
9.42
.98
1.15
.98
1.41
2
2
1
8X ∅ .13 ↧ 0.5
M4 x 0.7 TAP ↧ 0.5
8X ∅ .20 THRU ALL
1/4-20 UNC ↧ 0.5
9.5
18
.75
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
KRK
4/5/2020
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
RESVent
TITLE:
BASE
SIZE
A
DWG. NO.
REV
1
SCALE: 1:5
WEIGHT:
SHEET 3 OF 4
NEXT ASSY
USED ON
APPLICATION
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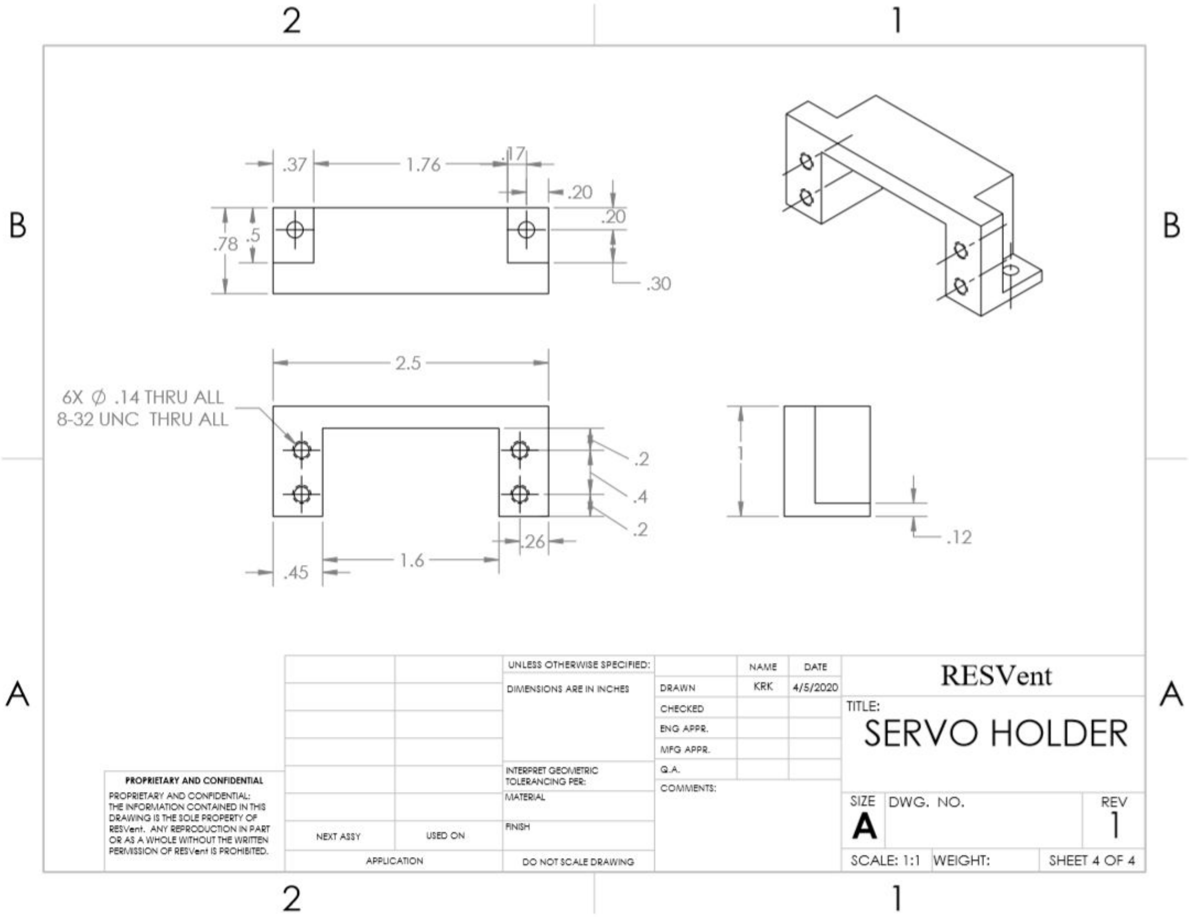
2
1
B
A

Servo Holder


2
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B
A
.37
1.76
.17
.20
.20
.78
.5
.30
2.5
6X ∅ .14 THRU ALL
8-32 UNC THRU ALL
.2
.4
.2
.26
1.6
.45
1
.12
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
FINISH
DO NOT SCALE DRAWING
NEXT ASSY
USED ON
APPLICATION
NAME
DATE
DRAWN
KRK
4/5/2020
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
RESVent
TITLE:
SERVO HOLDER
SIZE
A
DWG. NO.
REV
1
SCALE: 1:1
WEIGHT:
SHEET 4 OF 4
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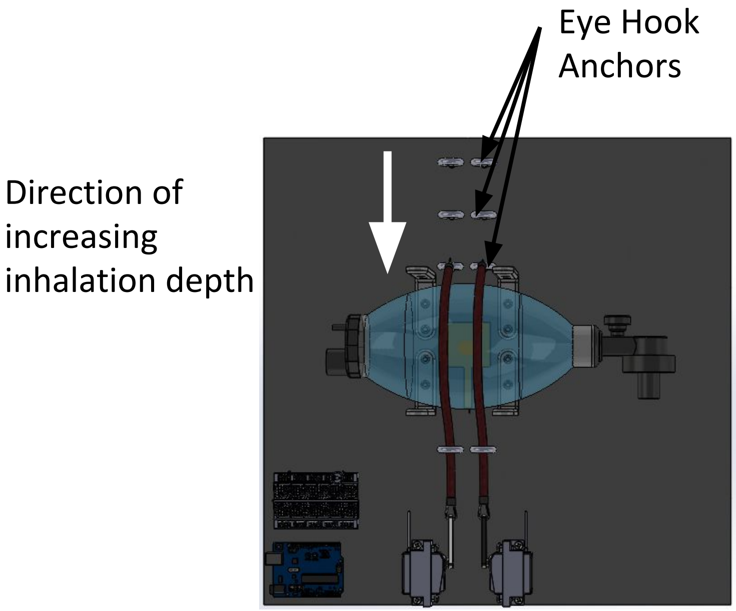
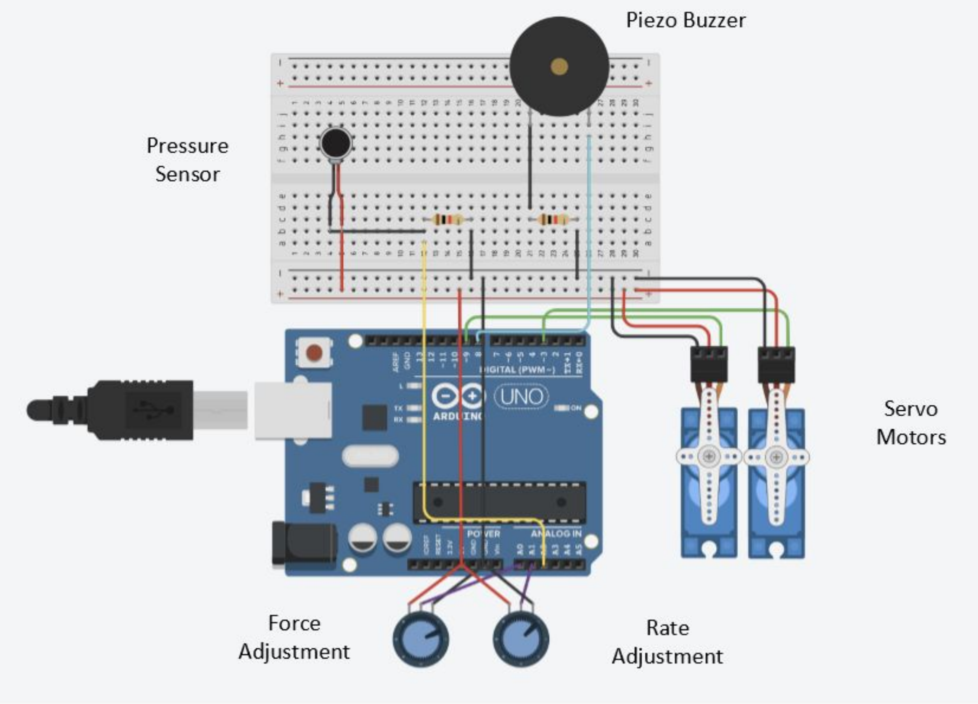
Variable Inhalation Mechanism


Eye Hook Anchors
Direction of increasing inhalation depth

- Resistance bands can be attached to different distance eyebolts to **vary inhalation depth** and **account for Ambubag size**

- The **range of motion** of servo can also be adjusted to **vary inhalation depth** (potentiometer knob)

Electronics Diagram


Piezo Buzzer
Pressure Sensor
UNO
ARDUINO
DIGITAL (PWM~)
POWER
ANALOG IN
Servo Motors
Force Adjustment
Rate Adjustment

Design Benefits

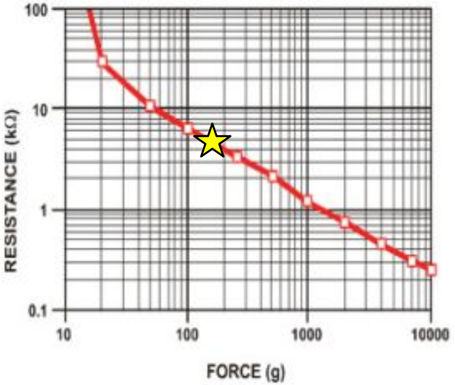
- Goal is to make the device “super” DIY and **avoid laser cutting and avoid 3d printing** to make materials more readily available.
- Low cost
- Working device should take less than **1-2 hours** for one to construct

Safety and Sense Conditions

- Variable rate: 10-30 pumps per minute (adjustable with potentiometer knob)
- Variable force on bag (adjustable with potentiometer knob)
- **Pressure sensor** to determine sudden drops in pressure (safety)
- **Buzzer sounds** to alert the user of the drops in pressure (safety)

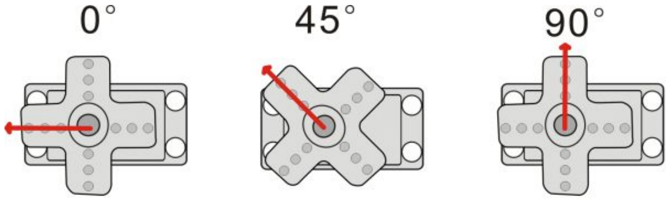
Alarm Mechanism

- **Pressure Sensor** will be calibrated to find resistance at which alarm should go off (where max pressure on inhale is too low, indicating a failure point)



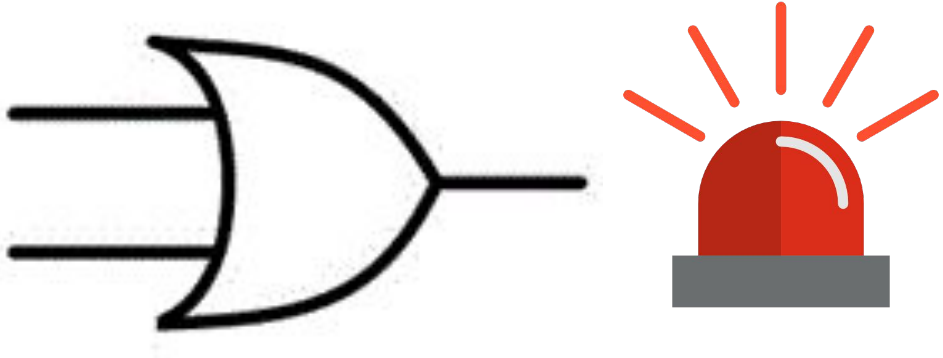
☆ - Calibrated threshold of max pressure for when to sound alarm

- **Angle of Servo** can be monitored to check if full range of motion is being used.



Alarm Mechanism

- If pressure sensor is out of range or servo is at incorrect position/frequency → alarm sounds

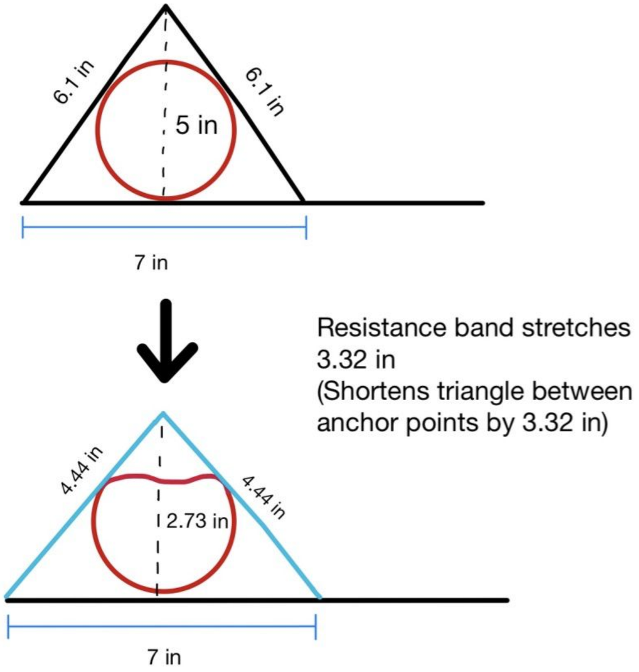


Pressure Sensor Issue

Servo Angle Issue

Stroke Length Calculation

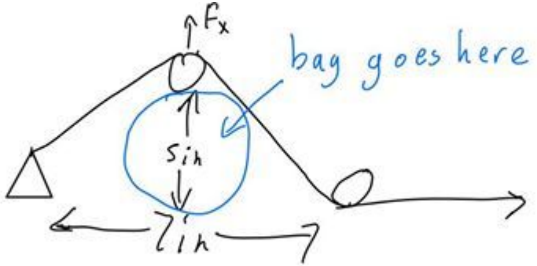
- Estimate the amplitude range of the bag using an ideal rope triangular model
- Assume that the servo motion stretches the resistance band by 3.32 in
- Height of the bag decreases by **2.27 in** on 5 in dia bag
- This length can be increased by changing servo horn



Resistance band stretches 3.32 in
(Shortens triangle between anchor points by 3.32 in)

Force Calculation

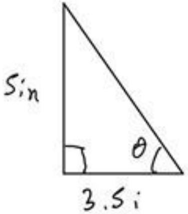
- Modeled as simple pulley problem
- Calculated force on bag: **191.1N**


F_x
bag goes here
5in
7in

Motor Torque = 25 Kg·cm

$r_{max} = 4.2$ cm

$F = \text{Torque} \cdot r_{max} \cdot 9.8\ m/s^2 = 58.33\ N$



$\tan(\theta) = \frac{5}{3.5} = 55°$

$58.33 \cdot \sin(55) = \frac{F_x}{2} = 47.78\ N$

1 servo's force on bag = 95.56 N

Total force on bag $= 2 \cdot 95.56\ N = \boxed{191.1}$

Potential Caveats

- Difficulty calibrating how much force can be applied (on resistance band) to make the bag go down the desired amount
- Bag is not as secure as it would be with 3d printed parts
- Possibly less reliable than more solid mechanism system
  - Solid pieces can more reliably press the ambu-bag

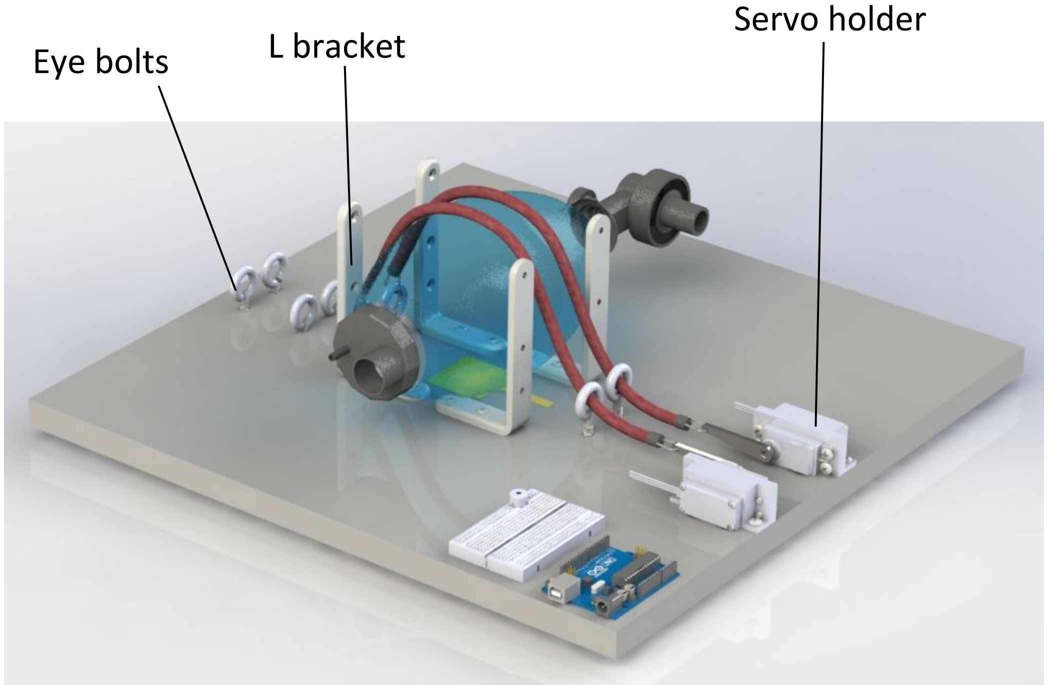
Materials

Name	Quantity	Price	# needed per build	Cost per build
Arduino Uno	1	$11.98	1	$11.98
Plywood	32	$17.52	2.25	$1.23
Eye bolts	100	$6.70	8	$0.54
Resistance Bands	1	$3.90	1	$3.90
High Torque Servo	6	$68.33	1	$11.39
Pressure Sensor	1	$11.25	1	$11.25
Alarm	1	$1.13	1	$1.13
Ambubag	1	$24.95	1	$24.95
solderable breadboard	4	$5.50	1	$1.38
Potentiometer	5	$0.91	1	$0.18
External Power Supply	1	$7.99	1	$7.99
Resistors	100	$6.28	2	$0.13
M/M wire	40	$1.00	10	$0.25
Servo bracket	1	$2.29	1	$2.29
Servo Horn	1	$7.80	1	$7.80
Screws	100	$3.24	12	$0.39
Corner Bracket	8	$15.99	4	$8.00
Soft Metal Screws	25	$8.56	8	$2.74
			Total Cost per Build	**$97.50**

Optional 3D Printed parts

Parts that can be 3D printed instead of bought

- L brackets
- Servo holder
- Eye bolts


Servo holder
Eye bolts
L bracket

Tools Needed

Name	**Price**
Toolbox tools (screwdrivers, screws, etc)	$20
Drill	$40
Solder, Soldering Iron	$40

Requested Funding

$1000 - To do thorough testing and make several prototypes of device

CAD Sources -via GradCAB

- https://grabcad.com/library/piezo-buzzer-ps1240-1/files?fbclid=IwAR0rINIB0iVYwq3c3NGdAxOF_Kqf_sqI1zerqSJYYDe_SE2NR-zQSZkSDVM
- https://grabcad.com/library/mountaineering-buckle-carabiner-1
- https://grabcad.com/library/breadboard-83x55mm-1
- https://grabcad.com/library/9g-servo-5
- https://grabcad.com/library/sen-09376-force-sensing-resistor-1
- https://grabcad.com/library/dsservo-ds3225mg-metal-gear-25kg-4-8-6-5v-servo-1?fbclid=IwAR0e3GIOecyUOhbzs_PHCXDnRS7tRFAk_UvNV2zHl-Yprp5_thjfbaTH14w
- https://grabcad.com/library/arduino-72
- https://grabcad.com/library/ventilator-ambu-bag-1

Parts Links

Name	Link
Arduino Uno	https://www.dhgate.com/product/uno-r3-electronic-components-uno-board-with/270589477.html#s1-1-1b;srp|4122845844
Plywood	https://www.homedepot.com/p/1-4-in-x-4-ft-x-8-ft-BC-Sanded-Pine-Plywood-235552/100063669?mtc=Shopping-B-F_D21-G-D21-21_1_PLYWOOD-Generic-NA-Feed-LIA-NA-NA-&cm_mmc=Shopping-B-F_D21-G-D21-21_1_PLYWOOD-Generic-NA-Feed-LIA-NA-NA--71700000044150928-58700004609752639-92700041149959771&gclid=CjwKCAjwg6b0BRBMEiwANd1_SKfT2OOnKipyEH4XybEtzsgRsueu5gmseMn7Ai1cm9uX5J5wEdpXlhoCOnoQAvD_BwE&gclsrc=aw.ds
Eye bolts	https://www.homedepot.com/p/Everbilt-216-Zinc-Plated-Steel-Screw-Eye-100-Piece-per-Pack-803262/204273865
Resistance Bands	https://www.amazon.com/Wacces-Fitness-Exercise-Resistance-Straps/dp/B0158PVX4I/ref=sr_1_16?dchild=1&qid=1586208252&refinements=p_n_feature_keywords_browse-bin:4811883011&s=exercise-and-fitness&sr=1-16&fbclid=IwAR33bx4JNa7PWaM2LNICn20FkuUmOevqgGKpk6ygeZGbJMzOhMFXZ6i56gI
High Torque Servo	https://usa.banggood.com/DSSERVO-DS3225-25KG-180-Degree-Metal-Gear-High-Torque-Waterproof-Digital-Servo-For-RC-Airplane-Robot-Car-6pcs-p-1621420.html?gmcCountry=US&currency=USD&createTmp=1&utm_source=googleshopping&utm_medium=cpc_bgs&utm_content=frank&utm_campaign=frank-ssc-us-all-1108&ad_id=395572890419&cur_warehouse=CN
Pressure Sensor	https://www.sparkfun.com/products/9376
Alarm	https://www.adafruit.com/product/160
Ambubag	https://www.amazon.com/Ambu-Adult-Bag-Mask-Each/dp/B009I2YS5E/ref=sr_1_3?dchild=1&keywords=ambu+bag&qid=1586130015&s=industrial&sr=1-3
solderable breadboard	https://www.allelectronics.com/item/sbb-4/snappable-breadboard/1.html
Potentiometer	https://h5.aliexpress.com/item/33045413226.html?spm=a2g0n.seo-amp-search.searchResult.33045413226
External Power Supply	https://www.amazon.com/dp/B01GCI99OG/ref=twister_B07WBY19CX?_encoding=UTF8&psc=1
Resistors	https://www.amazon.com/Projects-100EP51210K0-10k-Resistors-Pack/dp/B0185FIOTA
M/M wire	https://www.ebay.com/i/132882197909?chn=ps&norover=1&mkevt=1&mkrid=711-117182-37290-0&mkcid=2&itemid=132882197909&targetid=884652277561&device=c&mktype=pla&googleloc=9007733&poi=&campaignid=9426322279&mkgroupid=92907991862&rlsatarget=pla-884652277561&abcId=1141016&merchantid=6296724&gclid=CjwKCAjwg6b0BRBMEiwANd1_SMiKydpNs8RynFAxe9fQJzWL2dQLOoQV5Bv4JcuHoqD0bAnWmCd0BRoCcjcQAvD_BwE
Servo bracket	https://usa.banggood.com/Multifunction-Servo-Bracket-PTZ-Robotic-Manipulator-DIY-Robot-Mount-p-1067666.html?gmcCountry=US&currency=USD&createTmp=1&utm_source=googleshopping&utm_medium=cpc_bgcs&utm_content=frank&utm_campaign=frank-ssc-usg-toys-tool-ele-newcustom-ncv80-0116&ad_id=411440960076&gclid=CjwKCAjwpqv0BRABEiwA-TySwTh3ysRzMvvxl0YxoTDjEIii0XKcUVulq48H7TXy4HjB9w8OyyX2tRoCyDIQAvD_BwE&ID=224&cur_warehouse=CN
Servo Horn	https://www.savoxusa.com/products/savsh82-aluminum-servo-horn-25-spline?fbclid=IwAR2T9P6BV7McAf8MzQTbxY75VC6O91J2cJKHvyR7L_CD1iwx1mgN8jvozPU
Screws	https://www.mcmaster.com/90272A194
Corner Bracket	https://www.amazon.com/LuckIn-Brackets-Stainless-Furniture-Shelves/dp/B07CYX7GF1?ref_=fsclp_pl_dp_10
Soft Metal Screws	https://www.mcmaster.com/94209A685