High Cycle Fatigue of Electroactive Membranes

Interim Design Review

March 17, 2015

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Project Scope

Need Statement: There is a lack of information on the fatigue of electroactive membranes.

- Electroactive membranes are being studied for application onto robots.
- There is insufficient data on the fatigue behavior for electroactive membranes [1]
- The purpose of this project is the design and implementation of a fatigue mechanism for electroactive membranes

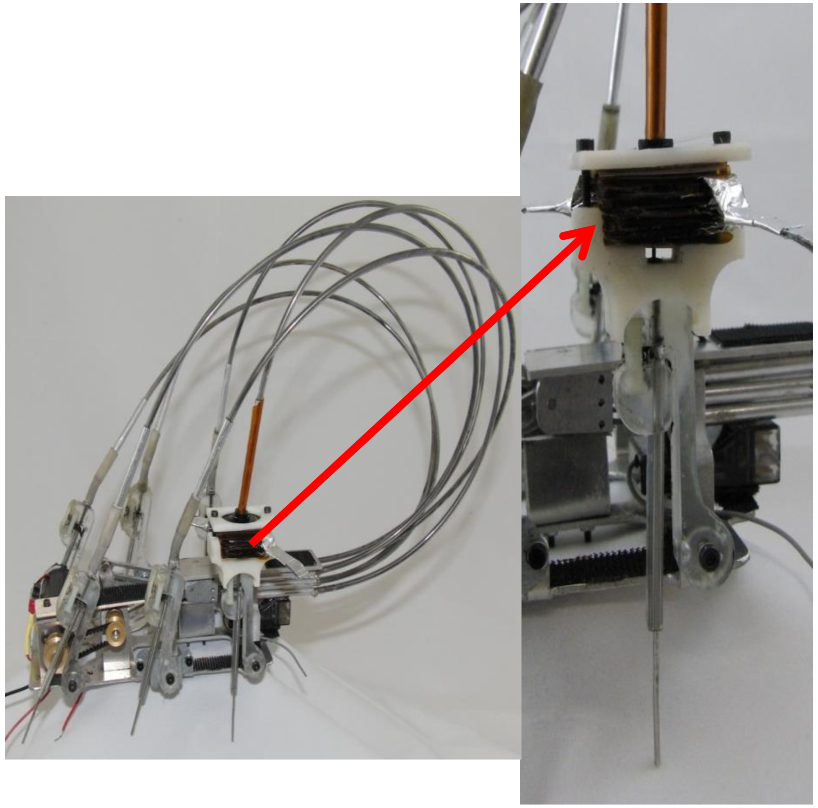


Figure 1. iSprawl Robot with VHB membrane stack[2]

[1] Oates, William and Jonathan Clark. "High Cycle Fatigue of Electroactive Membranes." Florida A&M/Florida State University, 2014. Print.
[2] Newton, Jason. "Design And Characterization Of A Dielectric Elastomer Based Variable Stiffness Mechanism For Implementation Onto A Dynamic Running Robot." Thesis. Florida State University - College Of Engineering, 2014. Print

Project Scope

Goal Statement: Design and build a device that produces high cycle sinusoidal mechanical fatigue of electroactive membranes.

Objectives:

- Accurately measure the fatigue placed on the specimen
- Produce various frequencies of cycling
- Produce varying stroke distances to displace the membrane
- Allow for tracking of the displacements controlled by the fatigue machine
- Measure the load associated with the stroke by implementing with the MTS machine

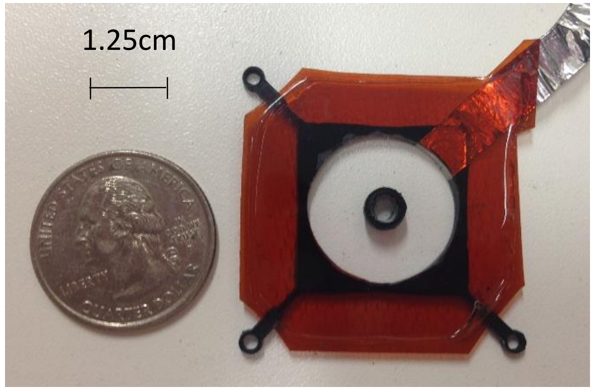


Figure 2. VHB membrane specimen

Project Scope

Constraints

- System should be a tabletop mechanism that is mounted to the MTS machine
- Vary stroke - 2.5mm, 5mm, 7.5mm
- Vary frequency from 0 to 25 Hz
- Implement LVDT (Linear Variable Differential Transducer)
- Produce consistent functionality for various specimens
- Test 1 to 5 specimens at a time
- Complete within the budget

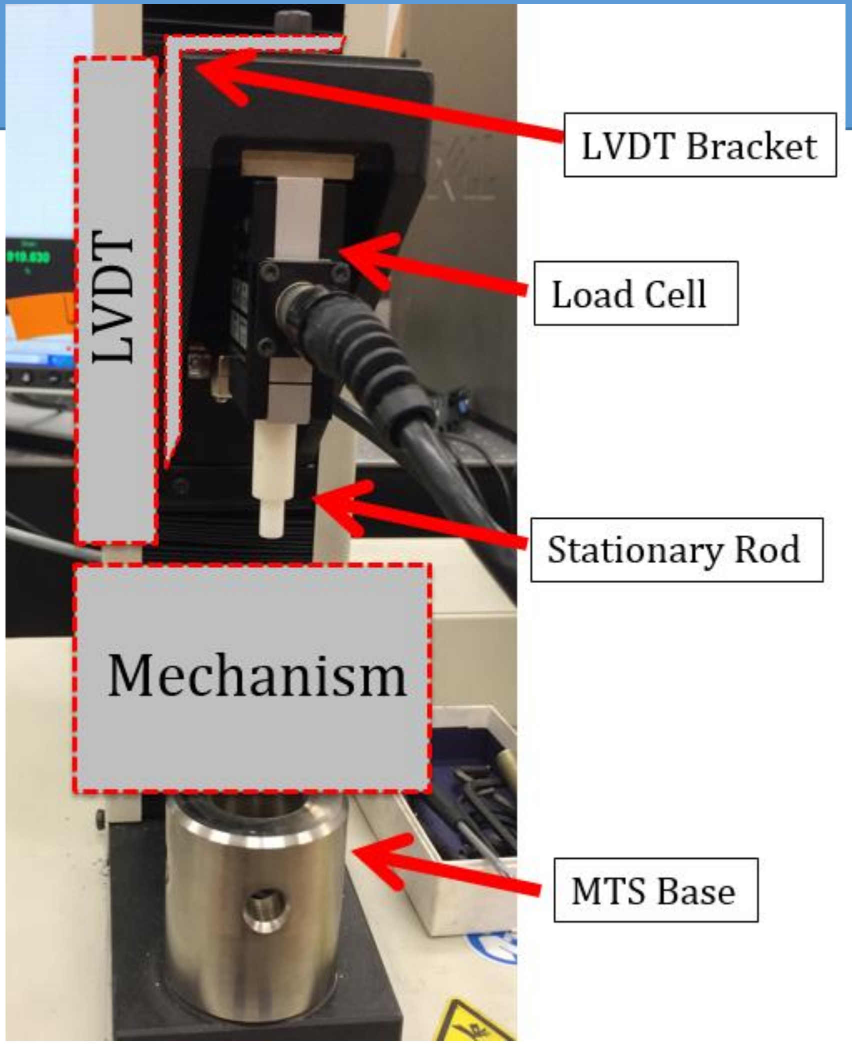


Figure 3. MTS machine

Selected Design - Crank Slider Mechanism

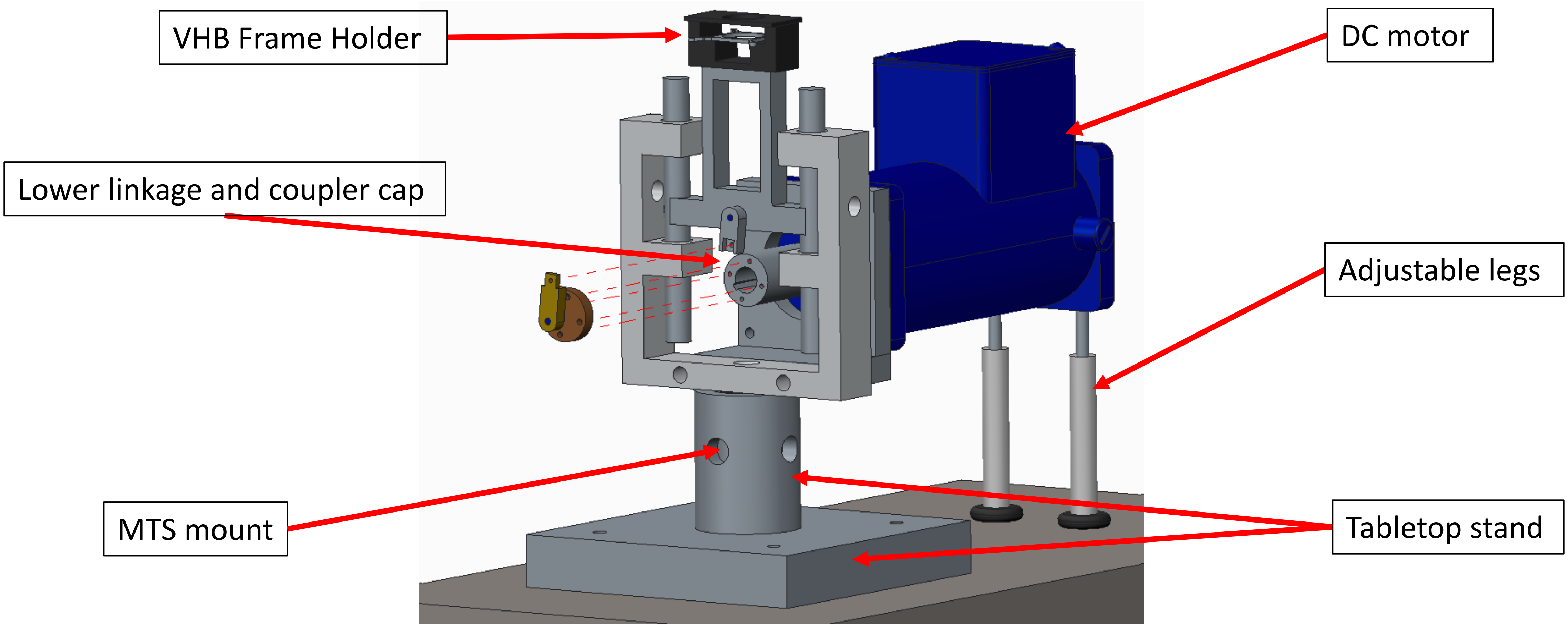
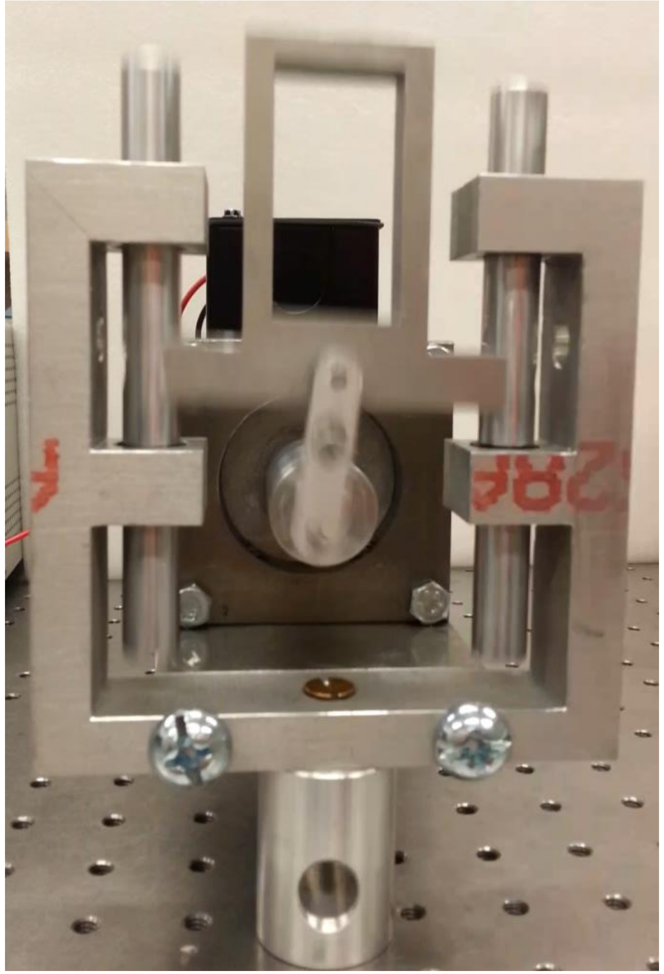


Figure 5. Mechanism with removable linkage

Figure 4. Assembled mechanism

Nicholas Dawkins

Assembled Mechanism



Remaining Assembly

- Safety shield
- ABS frame holder
- LVDT mount

Selected Motor & Controller

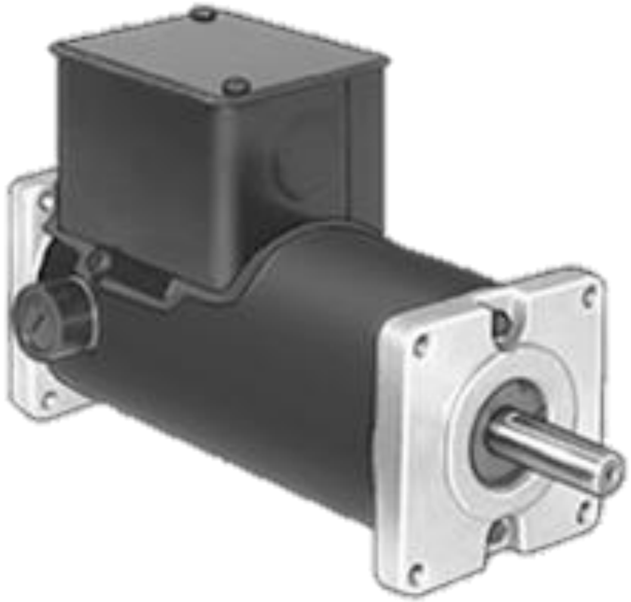


Figure 8. Compact DC Motor [3]

Figure 9. Motor Controller[4]

Motor Requirements

- 1500 rpm
- 0.7Nm

Compact Face Mount DC Motor

- 24V
- 13A
- 3500 rpm @ 0.72 Nm

RoboClaw Motor Controller

- USB or serial
- 2 channel
- 60A

[3] http://www.mcmaster.com/#59835k63/=vjpspd
[4] https://www.pololu.com/product/2393

Approach to Assembly - Control

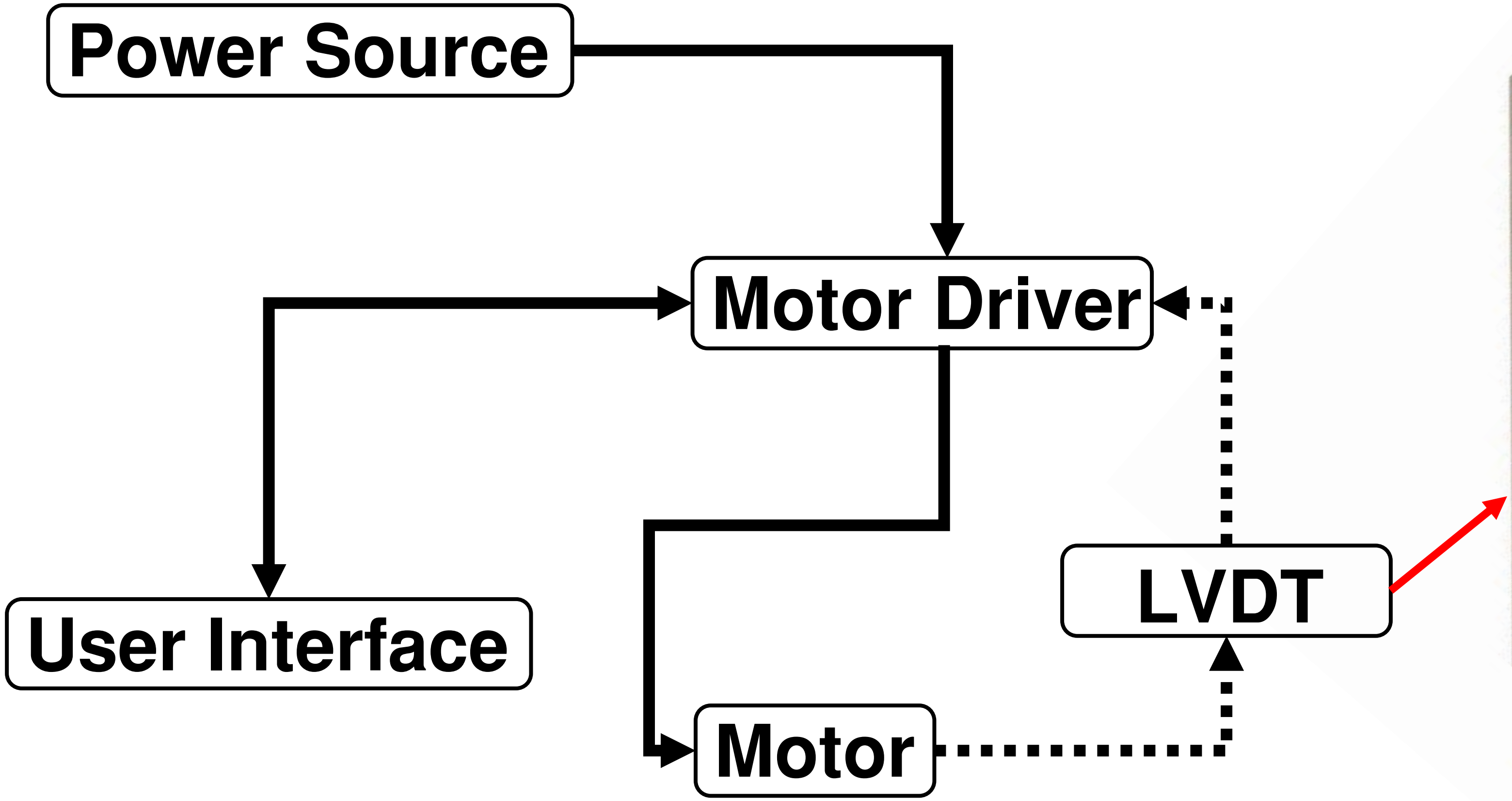


Figure 8. LVDT [5]

LD630-10

- 0 to10mm travel length
- 20 to 4 mA output
- 0.2% Linearity

[5] http://www.omega.com/Pressure/pdf/LD630.pdf

Testing

Completed

- Power needed to operate at 25 Hz with no load measured using stroboscope
  - 1.82 A @ 9.6V

Future

- Variable stroke distances using LVDT
  - Data acquisition to standardize produced displacement
- Frequency using LVDT
  - Measure time between peaks of sine wave

Challenges Faced

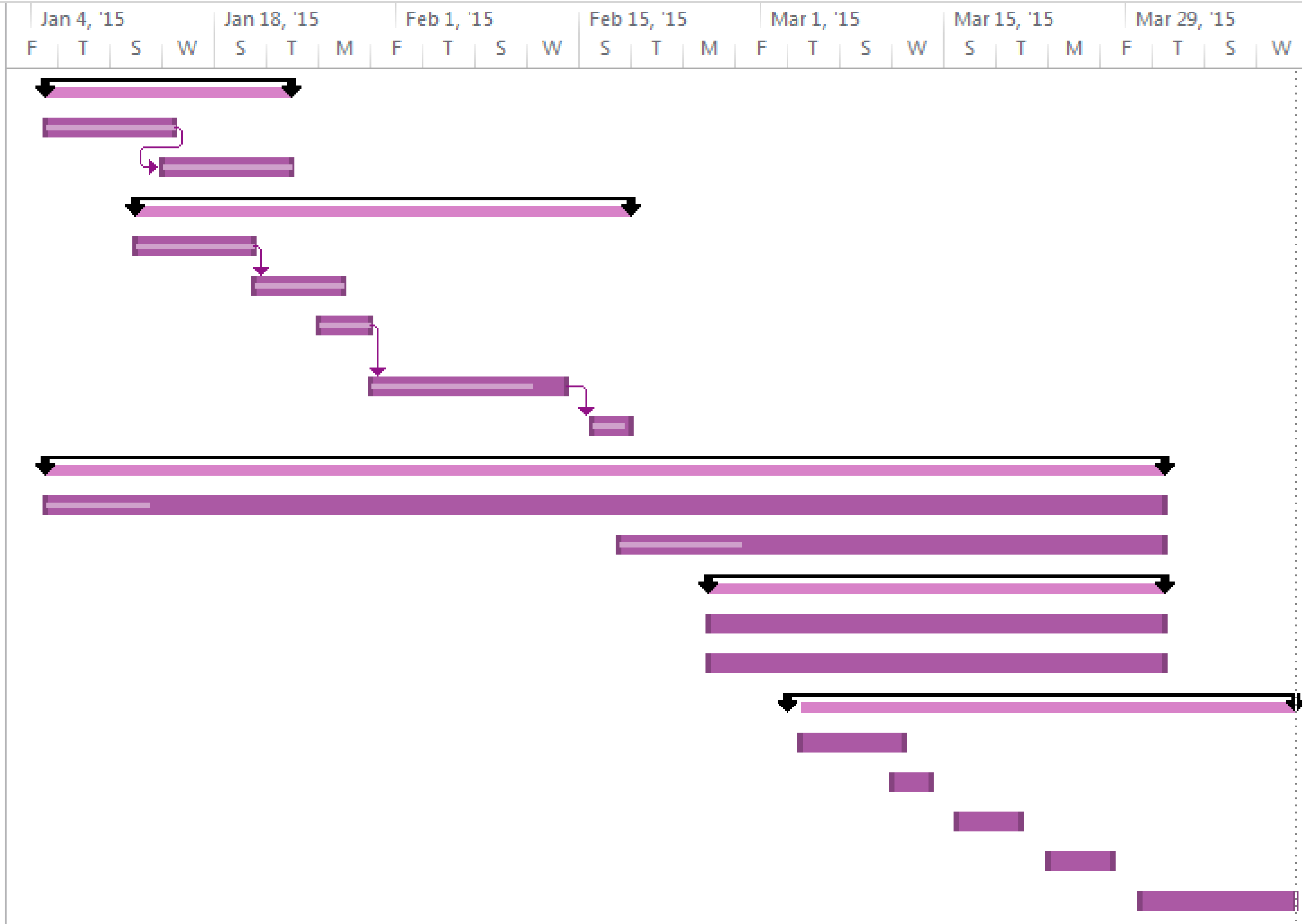
- Assembly
  - Guide rod alignment, friction
- Implementation of LVDT
  - Placement between MTS frame and mechanism
  - Wiring to BNC board for data acquisition
- Possible hardware damage on controller
- Controller use
  - Implementing code through PC

Future Work

- Improve current mechanism
  - Minimize friction
- Reliability testing of mechanism (precise data)
- Open loop testing now priority over control
- Return controller for repair
- Continuation/Integration of user interface to the mechanism
- FMEA
- Machining of final components
  - Lower linkage and coupler cap for 2.5 mm and 5 mm
  - Tabletop stand, frame holder, safety shield

Schedule

Task Name	Start	Finish
Material Procurement	**Mon 1/5/15**	**Fri 1/23/15**
Finalize materials list	Mon 1/5/15	Wed 1/14/15
Order materials and components	Wed 1/14/15	Fri 1/23/15
Production of Mechanism	**Mon 1/12/15**	**Wed 2/18/15**
Finalize all part drawings	Mon 1/12/15	Tue 1/20/15
Submit drawings to machine shop	Wed 1/21/15	Tue 1/27/15
Submit raw materials to shop for production - (subject to change due to	Mon 1/26/15	Thu 1/29/15
Machining and production of mechanisı	Fri 1/30/15	Fri 2/13/15
Assembly of mechanism	Mon 2/16/15	Wed 2/18/15
User Interface	**Mon 1/5/15**	**Tue 3/31/15**
Develop user interface	Mon 1/5/15	Tue 3/31/15
Integrate user interface with mechanism	Wed 2/18/15	Tue 3/31/15
Testing	**Wed 2/25/15**	**Tue 3/31/15**
Verify cyclic loading	Wed 2/25/15	Tue 3/31/15
Verify variable frequency	Wed 2/25/15	Tue 3/31/15
Redesign (if needed)	**Tue 3/3/15**	**Fri 4/10/15**
Redesign part drawings	Wed 3/4/15	Wed 3/11/15
Order materials	Wed 3/11/15	Fri 3/13/15
Machining and production of redesignec	Mon 3/16/15	Fri 3/20/15
Reassemble new mechanism	Mon 3/23/15	Fri 3/27/15
Implement and test redesigned mechani:	Mon 3/30/15	Fri 4/10/15



Budget & Procurement

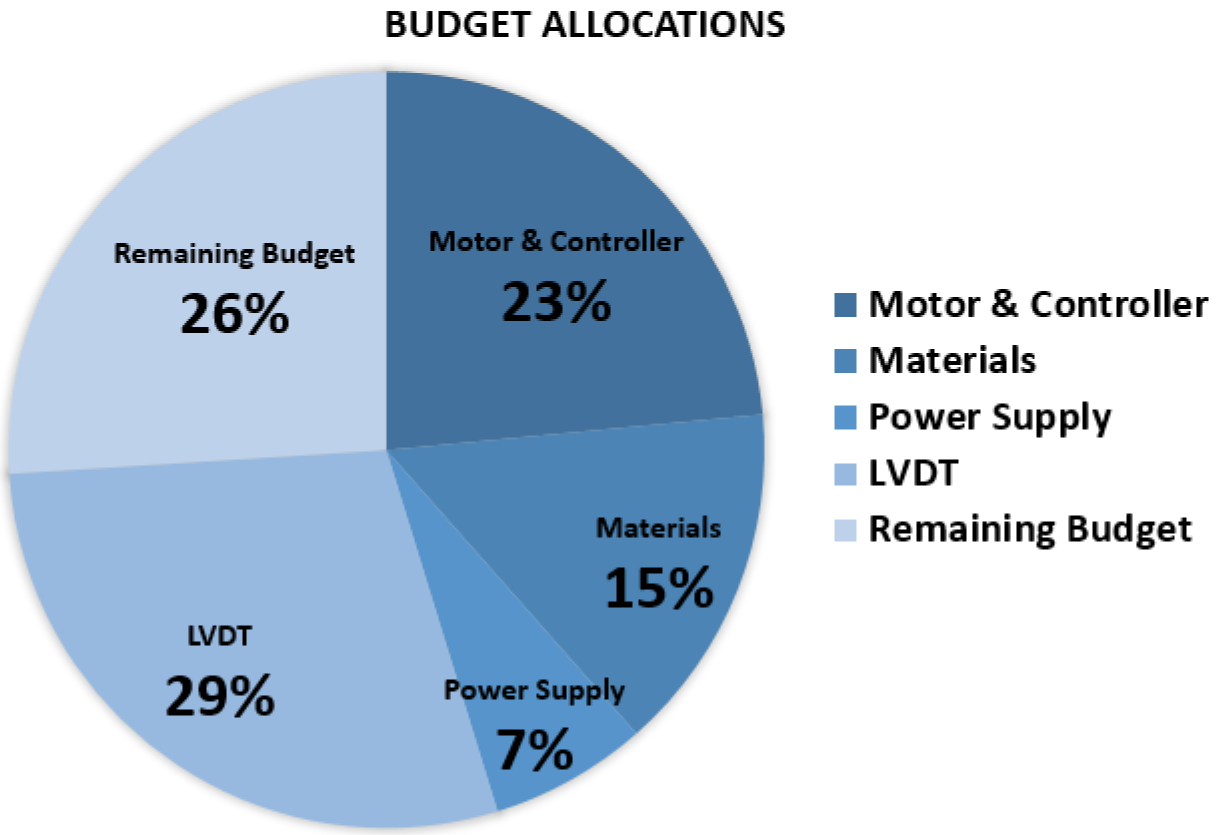


Figure 10. Pie Chart of Budget Allocation

Motor & Controller	$ 470.00
Materials	$ 300.00
Power Supply	$ 135.00
LVDT	$ 575.00
Remaining Budget	$ 520.00
Total	$2,000.00

Purchase of new controller:
Roboclaw 2x30A

- $124 (6.2%)

Summary

Need Statement: There is a lack of information on the fatigue of electroactive membranes.

Goal Statement: Design and build a device that produces high cycle sinusoidal mechanical fatigue of electroactive membranes.

- Vary frequency - 0 to 25 Hz
- Vary stroke - 2.5mm, 5mm, 7.5mm

Mechanism Design: Crank Slider

Latest Achieved Milestone: Assembly of second prototype

Key Next Step: Connect LVDT (record data) and integration of motor controller

References

[1] Oates, William and Jonathan Clark. “High Cycle Fatigue of Electroactive Membranes.” Florida A&M/Florida State University, 2014. Print.

[2] Newton, Jason. "Design And Characterization Of A Dielectric Elastomer Based Variable Stiffness Mechanism For Implementation Onto A Dynamic Running Robot." Thesis. Florida State University - College Of Engineering, 2014. Print

[3] http://www.mcmaster.com/#59835k63/=vjpspd

[4] https://www.pololu.com/product/2393

[5] http://www.omega.com/Pressure/pdf/LD630.pdf

Questions?

For more information visit our website:
www.eng.fsu.edu/me/senior_design/2015/team20/

Updated Motor Requirements

Most Extreme Conditions

Displacement, **x = 7.5mm**

Radius, r = 3.75mm

Frequency, f = 25 Hz

Mass, **m ~ 0.5 kg**

Acceleration: $\ddot{x} = x_o \omega^2 \sin(\omega t)$

Total Force: $F = m * a = m * \ddot{x}$

Max. Allowable Force (F.S. of 2) = **185N**

Minimum Required Torque

$$Torque = F_{max} \cdot r = 185N \cdot 3.75mm$$

$$\boxed{\boldsymbol{Torque = 0.7\ N \cdot m}}$$

Minimum Required Angular Velocity

$$\omega = \ 2\pi \cdot f = 2\pi \cdot 25Hz \cdot \frac{60s}{1\ min} \cdot \frac{1\ rev}{2\pi}$$

$$\boxed{\omega = 1500\ rpm}$$

Key Mechanical Changes

Linkage Update

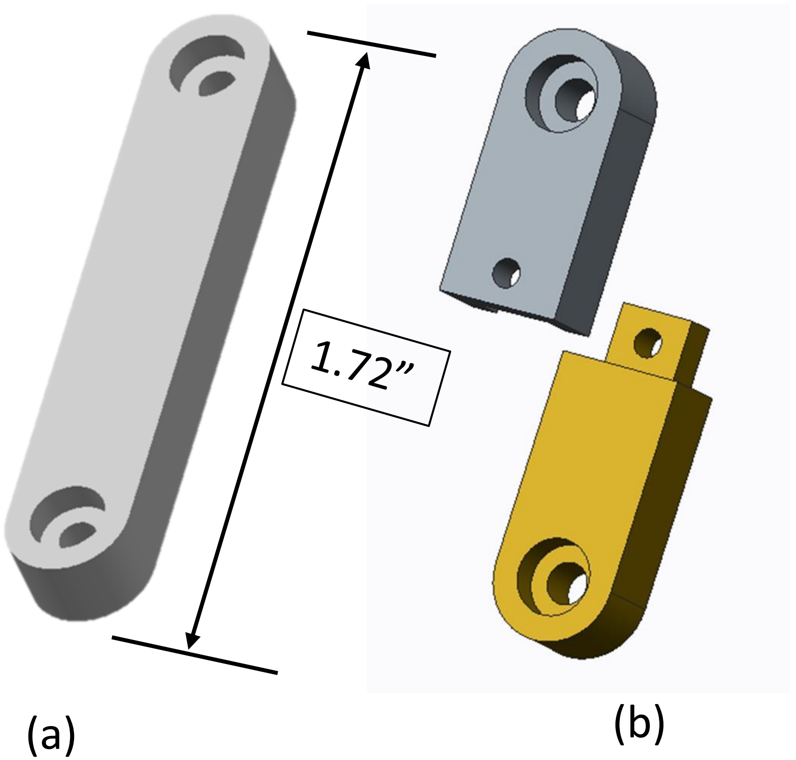


Figure 6. (a)Original linkage & (b) redesigned linkage.

Coupler Update

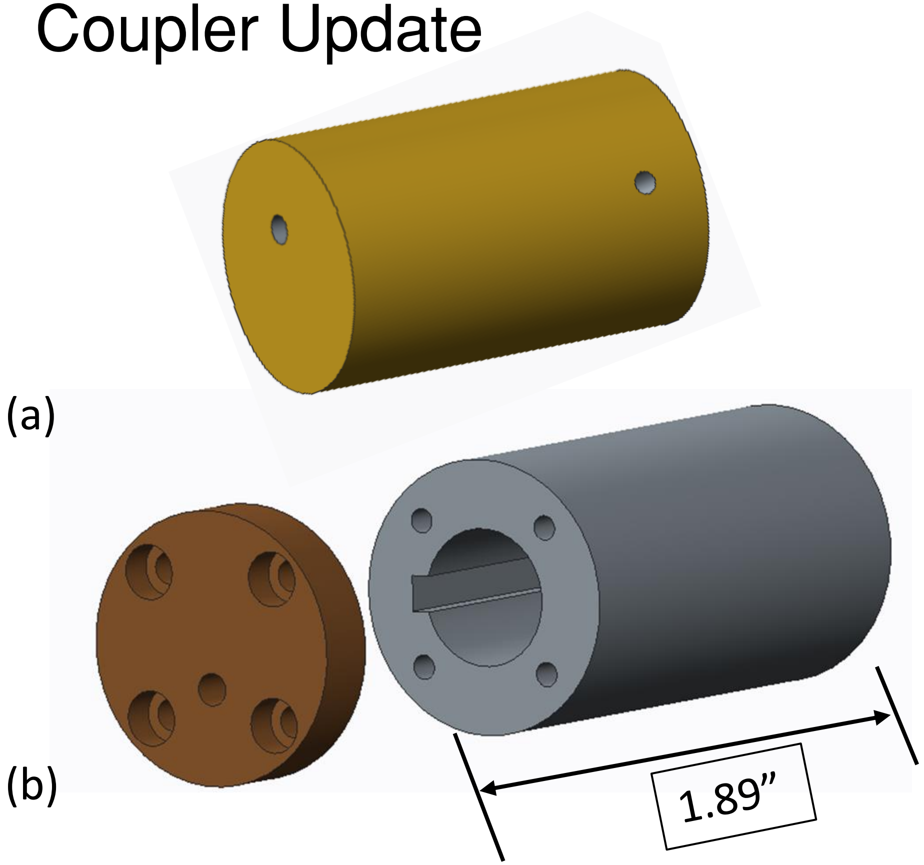
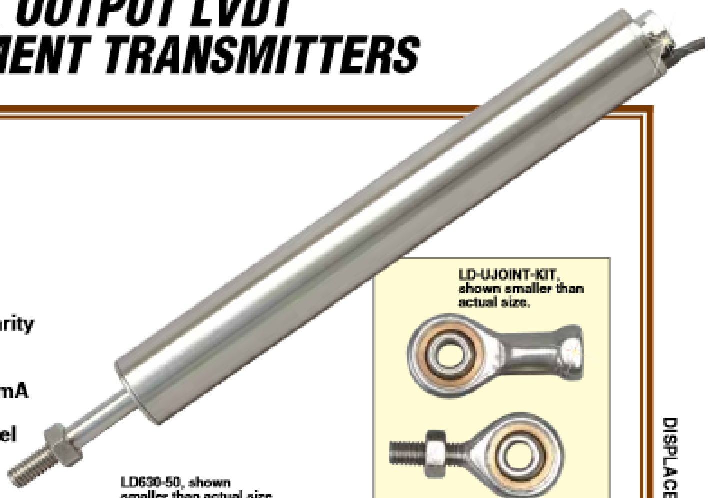


Figure 7. (a)Original coupler & (b) redesigned coupler.

4 TO 20 mA OUTPUT LVDT DISPLACEMENT TRANSMITTERS



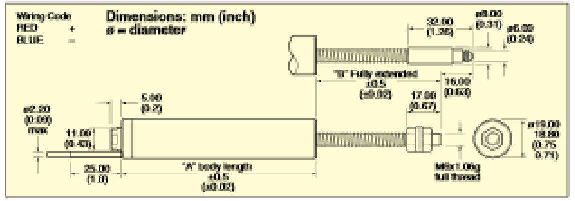
LD630-50, shown smaller than actual size.

LD630 Series

LD-UJOINT-KIT, shown smaller than actual size.

- Less Than 0.2% Linearity
- 5 to 300 mm Travel Lengths Available
- 4 to 20 mA or 20 to 4 mA Versions Available
- Rugged Stainless Steel Body Construction
- Guided Core with Removable Spring
- IP67 Environmental Rating

The LD630 Series current output displacement transmitters have improved IP67-rated sealing, coupled with polymer guides with rigid carriers. These transmitters are accurate and reliable, especially in wet and corrosive conditions. Output options are either direct-acting 4 to 20 mA or reverse-acting 20 to 4 mA. The direct-acting model will have 4 mA output when the guided core is fully out, and the output will increase to 20 mA when fully in.



SPECIFICATIONS

Linearity: <0.2% FSO
Excitation Voltage: 10 to 30 Vdc
Output: 4 to 20 mA
Output Ripple: 0.02% FSO
Bandwidth: 500 Hz (-3 dB)
Storage Temp: -20 to 85°C (-4 to 185°F)
Operating Temp: 0 to 65°C (32 to 149°F)
Vibration (Sinusoidal Frequency):
  10 to 50 Hz: 1 to 10 g rms linear amplitude
  50 Hz to 1 kHz: 10 g rms amplitude
Shock:
  Drop Testing: 1 m (3') onto hard surface
  Topple Testing: 10 times each end onto hard surface
Cable: PFA, 2 m (6') long
Core Material: Nickel-iron

To Order *Visit omega.com/ld630 for Pricing and Details*

MODEL NO.	RANGE: mm (inch)	"A" DIM mm (inch)	"B" DIM mm (inch)
LD630-5	0 to 5 (0 to 0.2)	94.0 (3.7)	35.3 (1.4)
LD630-10	0 to 10 (0 to 0.4)	113.5 (4.5)	46.3 (1.8)
LD630-15	0 to 15 (0 to 0.6)	120.7 (4.8)	50.3 (2.0)
LD630-20	0 to 20 (0 to 0.8)	135.0 (5.3)	61.3 (2.4)
LD630-30	0 to 30 (0 to 1.2)	149.4 (5.9)	79.3 (3.1)
LD630-50	0 to 50 (0 to 2.0)	170.9 (6.7)	102.3 (4.0)
LD630-100	0 to 100 (0 to 3.9)	228.5 (9.0)	160.3 (6.3)
LD630-150	0 to 150 (0 to 5.9)	278.7 (11.0)	231.3 (9.1)
LD630-200	0 to 200 (0 to 7.9)	336.2 (13.2)	291.2 (11.5)
LD630-300	0 to 300 (0 to 11.8)	450.9 (17.8)	457.3 (18.0)

To order reverse-acting version (20 to 4 mA), add suffix "-R" to model number, no additional charge.

Ordering Example: ***LD630-10-R****, 0 to 10 mm (0 to 0.4") displacement transmitter with reverse 20 to 4 mA output.*

ACCESSORIES

MODEL NO.	DESCRIPTION
LD-TIP	Tip adaptor/ball tip
LD-UJOINT-KIT	U-joint retro fit kit

TECHNICAL DATA:

Input

PARAMETER	DESCRIPTION/CONDITION	
Input voltage range	Universal Input	90 - 264 Vac 120 – 390 Vdc
Input frequency range	47-63 Hz	
Input surge current	230 Vac (cold start)	65 A max.
Safety ground leakage current	230 Vac	300 µA max
Input current	120 Vac @ 200 W 230 Vac @ 200 W	3.2 A 1.65 A

Output

PARAMETER	DESCRIPTION/CONDITION	
Voltage Adjustment	V1	± 3%
Transient Response	Main output 50 to 100% load change, 50 Hz, 50% duty cycle, 0.1 A / uSec, 50/60 Hz.	< 10%, recovery time < 5 mSec
Over Voltage Protection	V1	110 to 150% rated max
Over Current Protection	Rated output current	110 to 150% Typical
Short Circuit Protection	Automatic recovery	
Over Temperature Protection	Automatic recovery	110° C primary heatsink
Set point tolerance	± 1%	
Rise Time	<100 mSec	

Ordering Information

PRODUCT FAMILY	VOLTS (VDC)	MAX LOAD CONVECTION (2)	MAX LOAD 300 LFM (2)	MINIMUM LOAD (A)	RIPPLE & NOISE (4)	CONNECTOR	TOTAL REGULATION
ABC300-1T05G	5	28.0 A	40.0 A	0	2%	Screw Terminal	± 2.5%
ABC300-1T12G	12	15.0 A	25.0 A	0	2%	Screw Terminal	± 2.5%
ABC300-1T15G	15	12.0 A	20.0 A	0	2%	Screw Terminal	± 2.5%
ABC300-1T24G	24	7.5 A	13.54 A	0	2%	Screw Terminal	± 2.5%
ABC300-1T30G	30	6.0	10.83 A	0	2%	Screw Terminal	± 2.5%
ABC300-1T48G	48	3.75 A	6.77 A	0	2%	Screw Terminal	± 2.5%
Vfan (all models)	**12**	**0.5 A**	**0.6 A**	**0**			**± 20%**
V s/b (all models)	**5**	**2.0 A**	**2.0 A**	**0**			**± 5%**

Notes:

1. Peak current rating of 120% of max, < 30 Sec with max of 10% duty cycle.
2. Combined power from main output, Vfan and Vs/b should not exceed total power rating.
3. Fan output tolerance is ± 20%. When V1 full load, Vfan needs 20 mA load to be within regulation specification. Peak current for fan output is 1 A.
4. Ripple is 2% up to 20% load and less then 1% above 20% load. Output noise measurement is made with a 20 MHz bandwidth using a 6" twisted pair, terminated with a 10 uF tantalum capacitor in parallel with a 0.1 uF ceramic capacitor.
5. Specifications are for nominal input voltage, 25°C and max load unless otherwise stated.

6. Class 1 models have Earthing tab J4. Class 2 models (-2 suffix) have no Earthing tab.
7. Derate power linearly to 80% from 90 Vac to 80 Vac input.
8. Power supply shipped with J3 pin 1 and 2 shorted to enable main output
9. Specifications subject to change without notice.
10. Air flow over long edge (either direction) required for air flow rating. See mechanical drawing below.
11. Warranty 2 years.

General Specifications

PARAMETER	DESCRIPTION/CONDITION	
Hold Up Time	120 Vac 230 Vac	10 mSec 10 mSec
MTBF	>250 khrs	Bellcore TR-332
Switching Frequency	PFC converter 80 kHz typical	Resonant converter: Variable 35 to 250 kHz, 90 kHz typical
Isolation Voltage	Min 5900 Vdc	Input to Output
Weight	450 g (0.99 lbs)	

Environmental

PARAMETER	DESCRIPTION/CONDITION	
Operating Temperature	-20 to 70 C	See derating charts below
Altitude	Operating 10,000 ft.	Non-operation 40,000 ft.
Conducted emissions:	EN55022, FCC part 15 Level B	
Radiated Emissions	EN55022, FCC part 15 Level B	To be controlled in end system
Electromagnetic Susceptibility	EN61000-4 3	2, 3, 4, 5 level 3
Harmonic Current	EN61000-3-2, Class D	

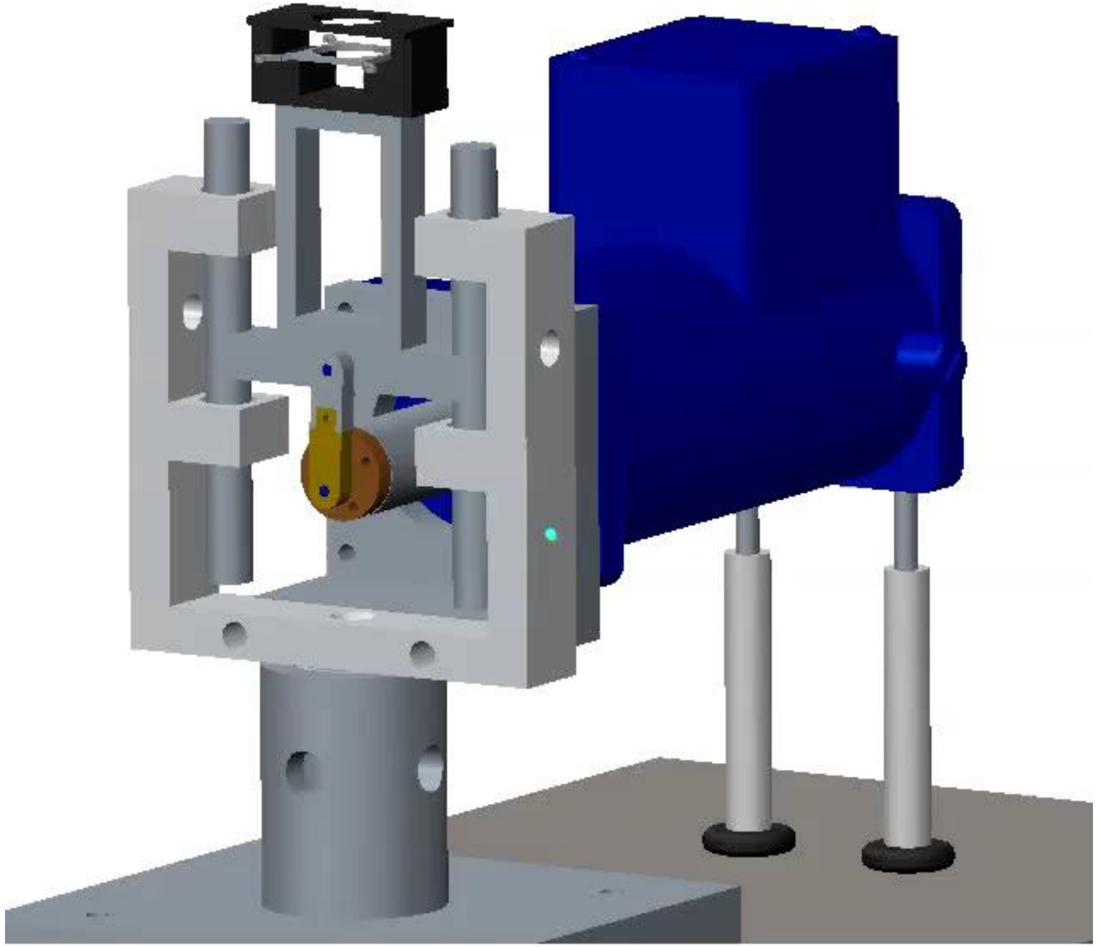
Signals

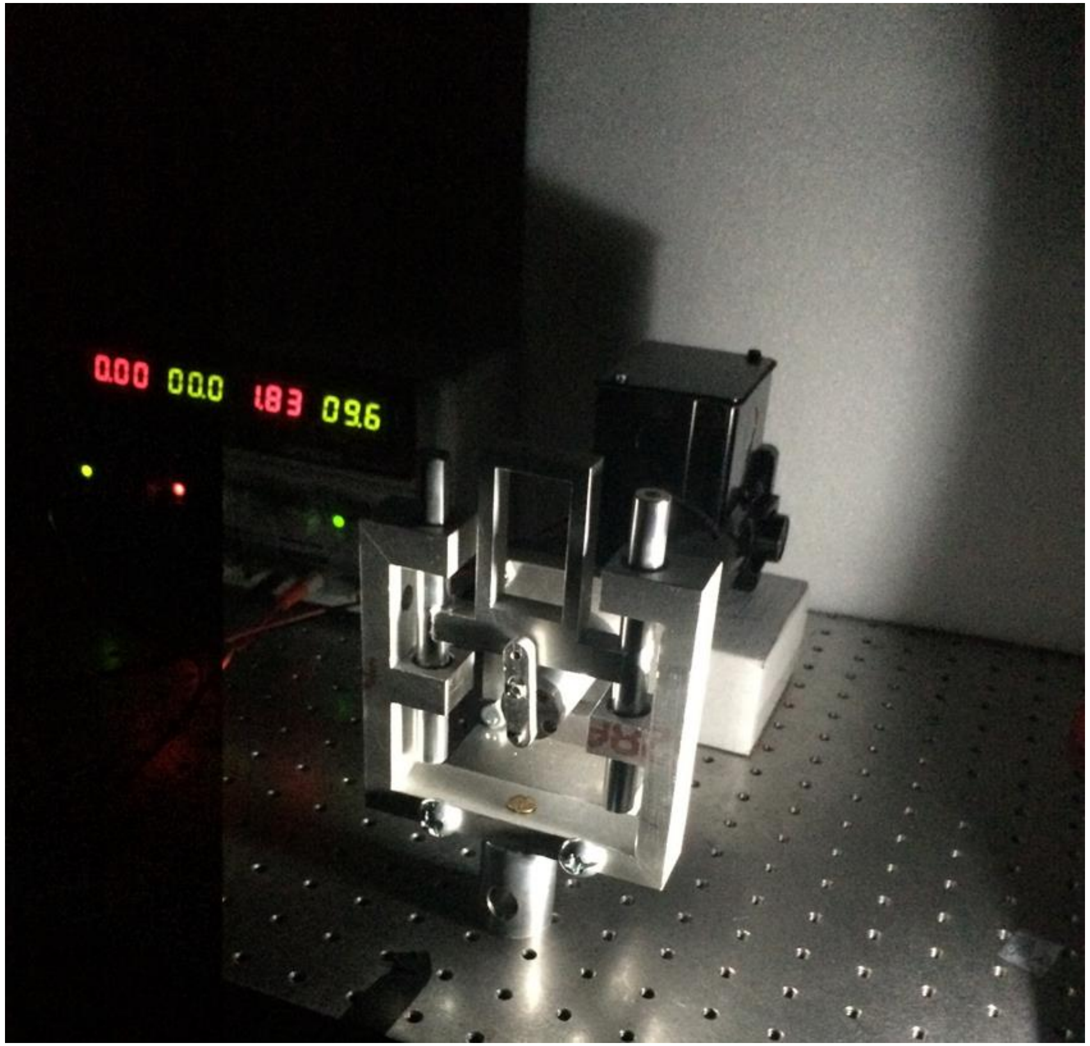
PARAMETER	DESCRIPTION/CONDITION
Power Good	TTL signal goes high after main output is within regulation, delay is 0.1 to 0.3 sec
Inhibit	To turn on power supply short J3 pin 1 to J3 pin 2 or J3 pin 7
Remote Sense	Compensates for 200 mV drop

Safety

PARAMETER	DESCRIPTION/CONDITION
EN / UL / CSA	EN60950-1+A12:2011, IEC60950-1 2nd+A1 2009, CSA-22.2 No 60950-01-07+ A1, UL60950-1-2011

Selected Design - Crank Slider Mechanism

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