Magnetostrictive Torque Motor

Concept Generation and Selection

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October 23, 2015

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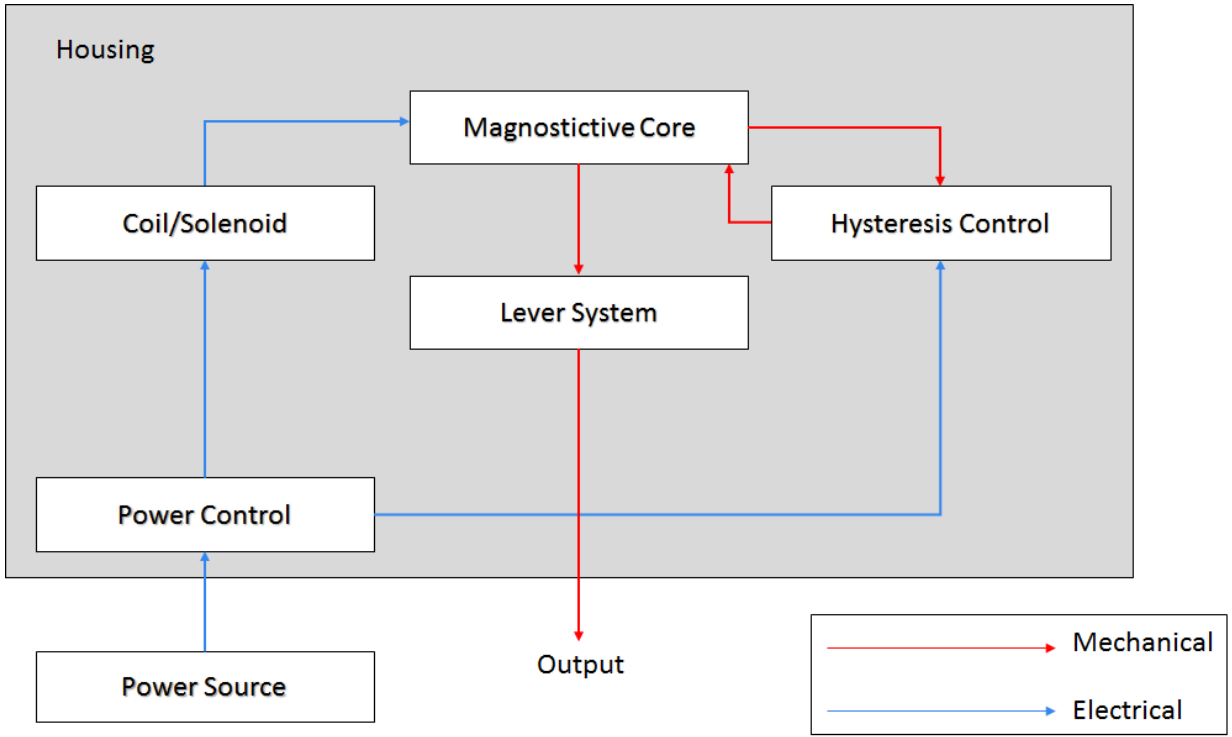
Overview

- Introduction
- Functional Diagram
- Criteria
- Relative Weights
- Relative Weights of Criteria
- Concept Generations
- Decision Matrices
- Updated Project Plan
- Conclusions

Introduction

- We are designing an actuator for Honeywell that incorporates Terfenol-D, a magnetostrictive material
- Need to determine feasibility of using Terfenol-D in aircraft valve systems
- Our goal is to design a feasible actuator that uses the magnetostrictive properties of Terfenol-D
- The main objectives are to minimize actuator size, increase stroke, and reduce effect of hysteresis,
- Constraints include a minimum output force and stroke, equivalent thermal expansions, budget, and temperature effects
- The Quality Function Deployment relates the customer needs to engineering requirements that we will use in the design

Functional Diagram



Criteria

Power Source
- Capacity
- Voltage
- Cost
- Weight
- Dimensions
- Current

Magnetostrictive Core
- Strain
- Cost
- Dimensions
- Output force
- Hysteresis
- Thermal expansion

Housing
- Compact
- Weight
- Strength
- Heat control
- Aesthetics/safe
- Non-magnetic

Power control
- Response
- Time
- Cost
- Accuracy
- Precision
- Voltage
- Current

Solenoid
- Conductive material
- Usable Magnetic Field
- Size
- Thermal coefficient
- Heat loss Dissipation
- Weight
- Cost

Hysteresis control
- Durability
- Force output
- Non-magnetic
- Thermal Effects
- Dimensions
- Cost

Lever
- Deformation
- Output stroke
- Fatigue Strength
- Coefficient of friction
- Non-magnetic
- Dimensions

Relative Weight: Power Source

Power source	Capacity	Voltage	Cost	Weight	Dimensions	Current
Capacity	1	5	3	1/3	1/3	3
Voltage	1/5	1	3	1/5	1/3	9
Cost	1/3	1/3	1	7	7	5
Weight	3	5	1/7	1	6	1/7
Dimensions	3	3	1/7	1/6	1	1/7
Current	1/3	1/9	1/5	7	7	1

Scale	
Extremely Preferred	9
Very Strongly Preferred	7
Stongly Preferred	5
Moderatly Preferred	3
Equally Preferred	1

Power source	Capacity	Voltage	Cost	Weight	Dimensions	Current	Overall
Capacity	0.0776	0.1740	0.1817	0.0778	0.0267	0.1632	0.1168
Voltage	0.0723	0.0790	0.1650	0.1005	0.1138	0.1672	0.1163
Cost	0.1573	0.2036	0.2080	0.2878	0.2441	0.2384	0.2232
Weight	0.2167	0.2010	0.1275	0.1290	0.2503	0.1030	0.1713
Dimensions	0.2080	0.1473	0.0544	0.0527	0.0634	0.0719	0.0996
Current	0.2681	0.1951	0.2635	0.3521	0.3017	0.2562	0.2728
							1.0000

Relative Weights of Criteria

Power Source Criteria	Weights
Capacity	0.117
Voltage	0.116
Cost	0.223
Weight	0.171
Dimensions	0.100
Current	0.273
Total:	1.000

Housing	Weights
Compact	0.205
Weight	0.220
Strength	0.157
Heat Control	0.158
Safety	0.058
Non-Magnetic	0.202
Total:	1.000

Hysteresis Control	Weights
Durablility	0.268
Force output	0.224
Non-magnetic	0.122
Thermal Effects	0.157
Dimensions	0.124
Cost	0.105
Total:	1.000

Solenoid	Weights
Conductive material	0.227
Usable Magnetic Field	0.217
Size	0.099
Thermal Coefficient	0.158
Heat Dissipation	0.095
Weight	0.122
Cost	0.083
Total:	1.000

Magnetostrictive Core	Weights
Strain	0.338
Cost	0.109
Dimensions	0.093
Output Force	0.128
Hysteresis	0.234
Thermal Expansion	0.097
Total:	1.000

Lever System	Weights
Deformation	0.194
Output Stroke	0.354
Fatigue Strength	0.146
Coefficient of Friction	0.097
Non-magnetic	0.135
Dimensions	0.074
Total:	1.000

Power Control	Weights
Response Time	0.237
Cost	0.168
Accuracy	0.161
Precision	0.171
Voltage	0.108
Current	0.156
Total:	1.000

Concept Generation: Power Supply

Car Battery

Wall Outlet

Fuel Generator

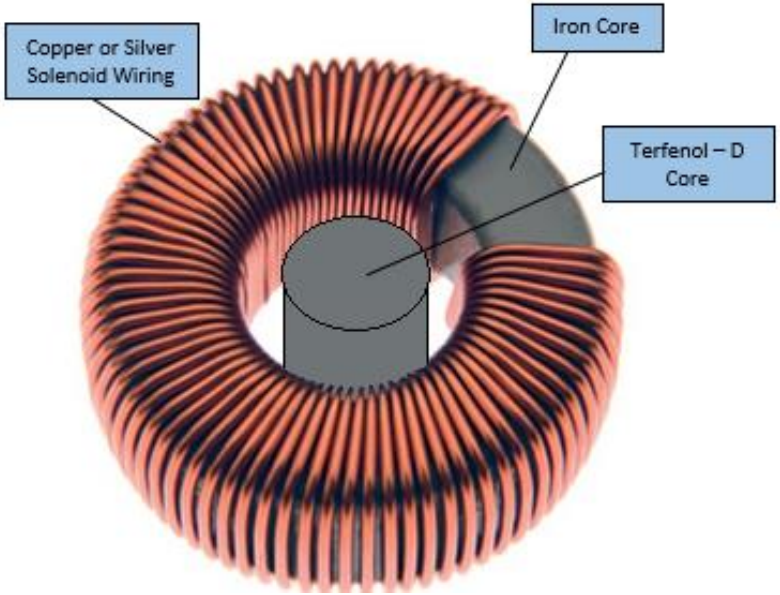
D-Cell Battery

Decision Matrix: Power Supply

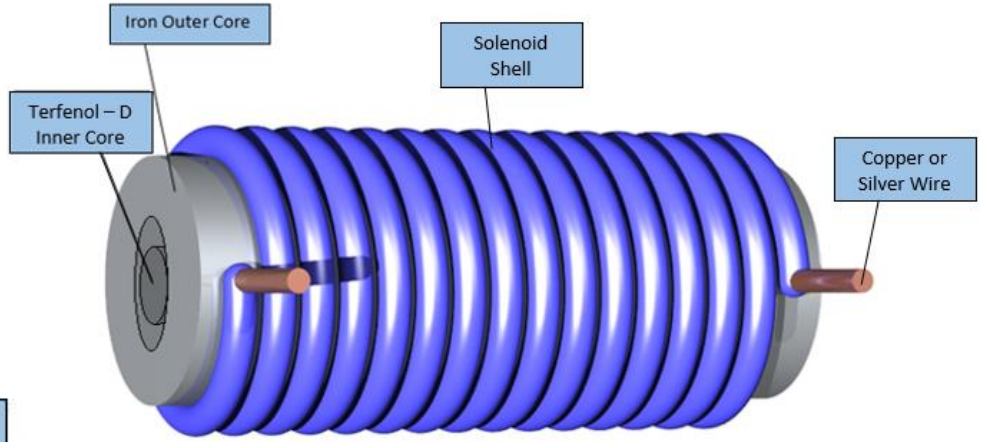
Power Source	Car Battery	D-Cell Batteries	Wall Outlet	Fuel Generator
Capacity	8	4	10	3
Voltage	7	2	10	10
Cost	5	10	10	1
Weight	3	8	7	1
Dimensions	4	9	7	2
Current	10	2	10	10

Power Source Criteria	Weights	Car Battery	D-Cell Batteries	Wall Outlet	Fuel Generator
Capacity	0.117	0.935	0.467	1.168	0.351
Voltage	0.116	0.814	0.233	1.163	1.163
Cost	0.223	1.116	2.232	2.232	0.223
Weight	0.171	0.514	1.370	1.199	0.171
Dimensions	0.100	0.399	0.897	0.697	0.199
Current	0.273	2.728	0.546	2.728	2.728
Total:	1.000	6.505	5.744	**9.187**	4.835

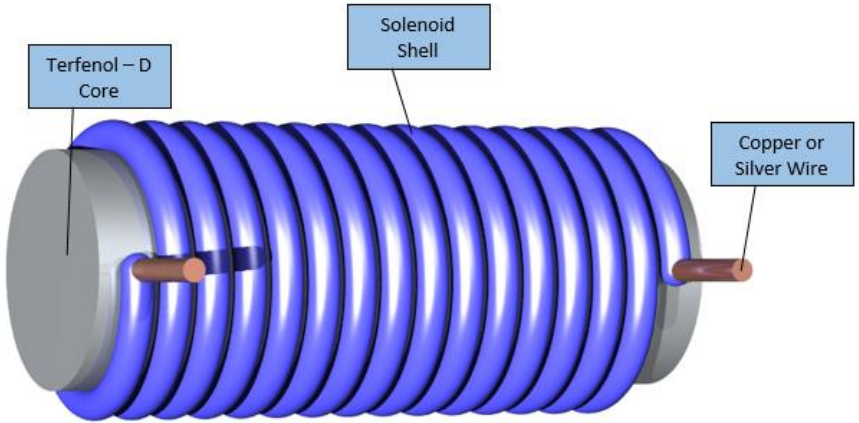
Concept Generation: Solenoid



Ring Solenoid



Coil Solenoid with Iron Core



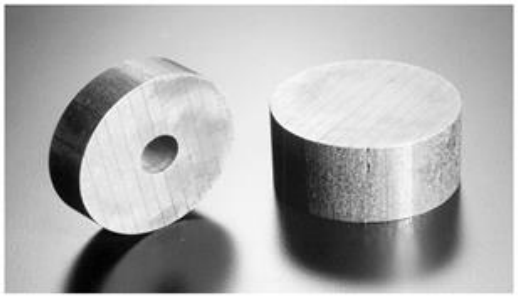
Coil Solenoid

Decision Matrix: Solenoid

Solenoid	Ring Solenoid (Silver Wire)	Ring Solenoid (Copper Wire)	Coil Solenoid (Silver Wire)	Coil Solenoid (Copper Wire)	Coil Solenoid (Silver Wire) with Iron Core	Coil Solenoid (Copper Wire) with Iron Core
Conductive material	10	8	10	8	10	8
Usable Magnetic Field	6	5	8	7	6	5
Size	4	4	6	6	3	3
Thermal Coefficient	5	6	5	6	4	5
Heat Dissipation	8	7	7	6	7	6
Weight	4	6	5	7	3	4
Cost	3	5	6	8	4	6

Solenoid	Weights	Ring Solenoid (Silver Wire)	Ring Solenoid (Copper Wire)	Coil Solenoid (Silver Wire)	Coil Solenoid (Copper Wire)	Coil Solenoid (Silver Wire) with Iron Core	Coil Solenoid (Copper Wire) with Iron Core
Conductive material	0.227	2.266	1.813	2.266	1.813	2.266	1.813
Usable Magnetic Field	0.217	1.304	1.086	1.738	1.521	1.304	1.086
Size	0.099	0.395	0.395	0.593	0.593	0.296	0.296
Thermal Coefficient	0.158	0.789	0.946	0.789	0.946	0.631	0.789
Heat Dissipation	0.095	0.759	0.664	0.664	0.569	0.664	0.569
Weight	0.122	0.487	0.730	0.608	0.852	0.365	0.487
Cost	0.083	0.249	0.415	0.498	0.665	0.332	0.498
Total:	1.000	6.248	6.050	**7.156**	6.958	5.858	5.538

Concept Generation: Magnetostrictive Core



Cylindrical

Square Bar

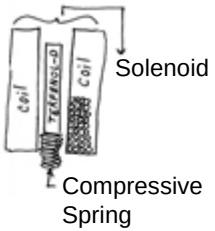
Powdered

Decision Matrix: Magnetostrictive Core

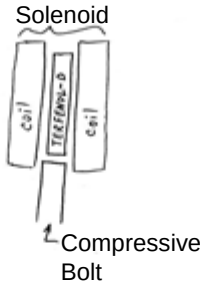
Magnetostrictive Core	Cylindrical	Square Bar	Powdered
Strain	7	7	1
Cost	5	5	8
Dimensions	8	6	10
Output Force	8	8	3
Hysteresis	4	5	6
Thermal Expansion	5	5	5

Magnetostrictive Core	Weights	Cylindrical	Square Bar	Powdered
Strain	0.338	2.367	2.367	0.338
Cost	0.109	0.546	0.546	0.873
Dimensions	0.093	0.745	0.559	0.931
Output Force	0.128	1.028	1.028	0.385
Hysteresis	0.234	0.936	1.170	1.404
Thermal Expansion	0.097	0.486	0.486	0.486
Total:	1.000	6.107	**6.155**	4.418

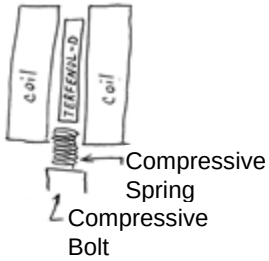
Concept Generation: Hysteresis Control



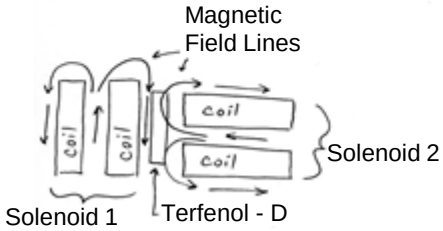
Spring



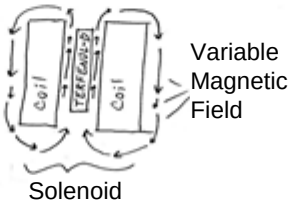
Bolt



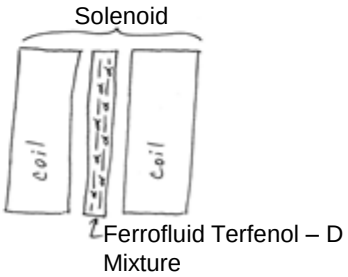
Spring and Bolt



Dual Magnetic Field



Randomizing Field



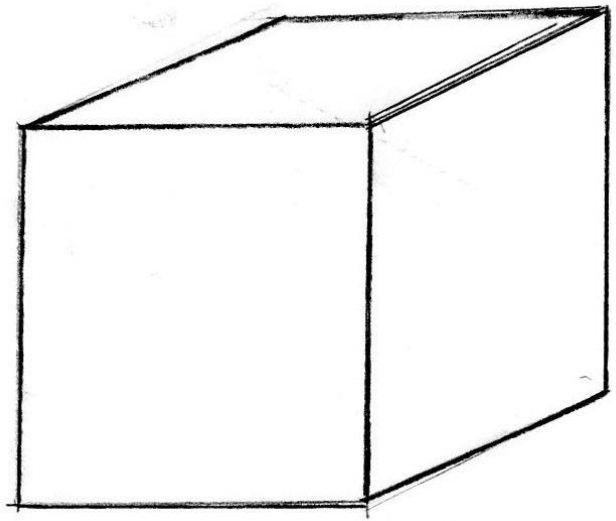
Ferrofluid Solution

Decision Matrix: Hysteresis Control

Hysteresis Control	Spring	Bolt	Spring and Bolts	Duel Magnetic Fields	Randomizing Field	Ferrofluid Solution
Durablility	6	9	7	10	10	9
Force output	7	8	9	6	1	3
Non-magnetic	9	9	9	2	2	1
Thermal Effects	7	4	6	1	3	8
Dimensions	8	9	7	2	10	5
Cost	10	10	9	3	5	3

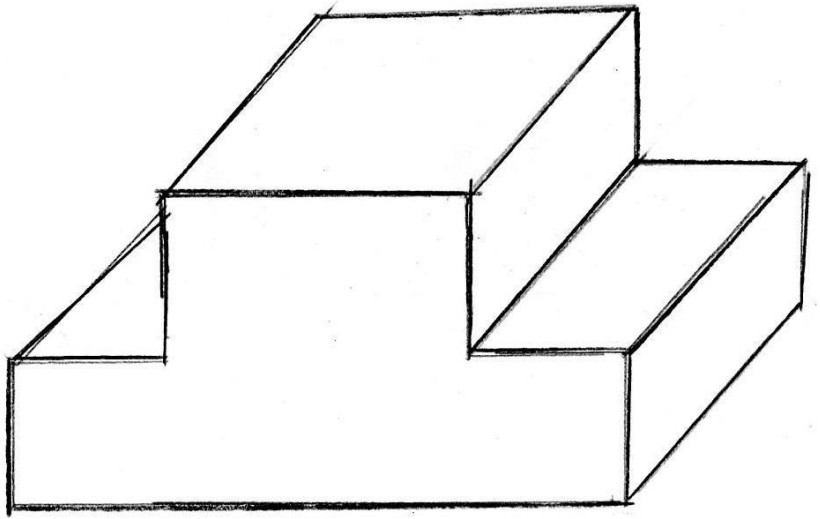
Hysteresis Control	Weights	Spring	Bolt	Spring and Bolts	Duel Magnetic Fields	Randomizing Field	Ferrofluid Solution
Durablility	0.268	1.610	2.416	1.879	2.684	2.684	2.416
Force output	0.224	1.570	1.794	2.018	1.345	0.224	0.673
Non-magnetic	0.122	1.095	1.095	1.095	0.243	0.243	0.122
Thermal Effects	0.157	1.099	0.628	0.942	0.157	0.471	1.256
Dimensions	0.124	0.989	1.113	0.865	0.247	1.236	0.618
Cost	0.105	1.051	1.051	0.946	0.315	0.525	0.315
Total:	1.000	7.414	**8.096**	7.745	4.992	5.384	5.399

Concept Generation: Housing



Can be made from:

- Metal
- Plastic
- Glass
- Wood



Can be made from:

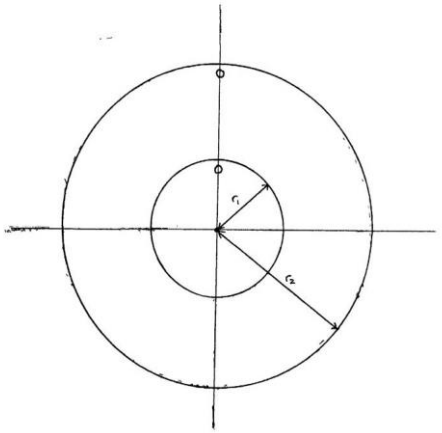
- Metal
- Plastic

Decision Matrix: Housing

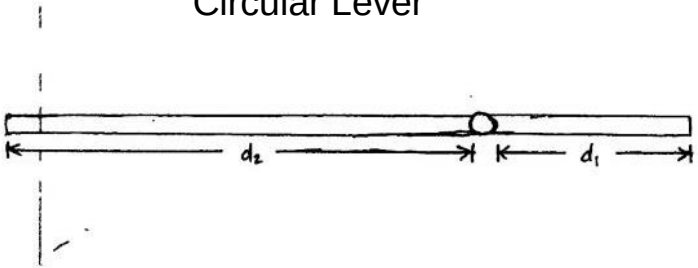
Housing	Sheet Metal Box	Sheet Metal Compact Casing	Glass Viewing Box	Wood Box	Wood Plate Mounted Parts	Plastic Box	Plastic Compact Casing
Compact	3	8	3	3	6	3	8
Weight	3	4	2	6	8	9	10
Strength	10	9	2	5	1	4	3
Heat Control	7	8	1	3	3	5	5
Safety	2	1	2	8	8	8	8
Non-Magnetic	2	2	8	8	8	8	8

Housing	Weights	Sheet Metal Box	Sheet Metal Compact Casing	Glass Viewing Box	Wood Box	Wood Plate Mounted Parts	Plastic Box	Plastic Compact Casing
Compact	0.205	0.615	1.641	0.615	0.615	1.230	0.615	1.641
Weight	0.220	0.660	0.880	0.440	1.320	1.760	1.980	2.200
Strength	0.157	1.569	1.412	0.314	0.784	0.157	0.627	0.471
Heat Control	0.158	1.108	1.267	0.158	0.475	0.475	0.792	0.792
Safety	0.058	0.115	0.058	0.115	0.461	0.461	0.461	0.461
Non-Magnetic	0.202	0.404	0.404	1.617	1.617	1.617	1.617	1.617
Total:	1.000	4.472	5.661	3.259	5.272	5.700	6.092	**7.181**

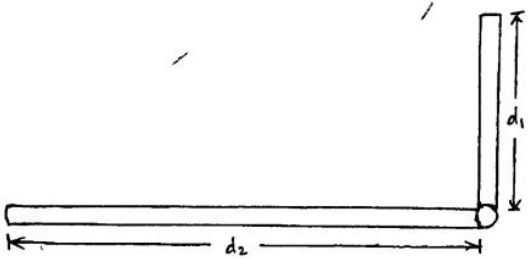
Concept Generation: Lever



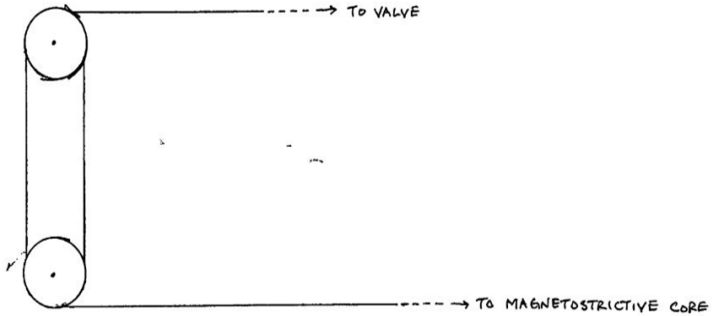
Circular Lever



Bar Lever



Angle Lever



Pulley System

Decision Matrix: Lever

Lever System	Angle Lever	Bar Lever	Pulley System	Circular Lever
Deformation	7	4	9	6
Output Stroke	5	5	4	5
Fatigue Strength	7	7	8	9
Coefficient of Friction	8	8	5	6
Non-magnetic	8	8	9	7
Dimensions	10	7	3	4

Lever System	Weights	Angle Lever	Bar Lever	Pulley System	Circular Lever
Deformation	0.194	1.360	0.777	1.748	1.166
Output Stroke	0.354	1.771	1.771	1.417	1.771
Fatigue Strength	0.146	1.019	1.019	1.164	1.310
Coefficient of Friction	0.097	0.773	0.773	0.483	0.580
Non-magnetic	0.135	1.082	1.082	1.217	0.946
Dimensions	0.074	0.742	0.520	0.223	0.297
Total:	1.000	**6.746**	5.941	6.252	6.069

Concept Generation: Power Control

Switch

Electromagnetic Relay

Solid State Relay

Reed Relay

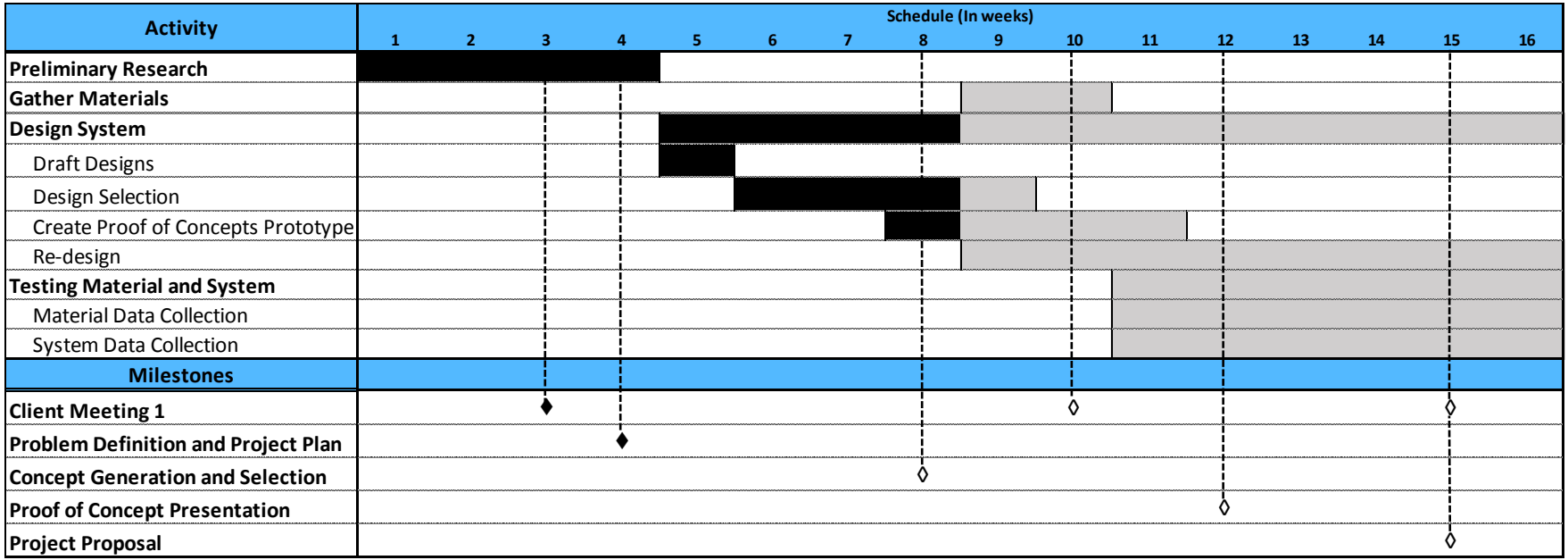
Digital Potentiometer

Decision Matrix: Power Control

Power Control	On/Off Switch	Electromagnetic Relay	Digital Potentiometer	Solid State Relay	Reed Relay
Response Time	1	5	7	6	6
Cost	9	7	10	6	8
Accuracy	3	6	5	7	6
Precision	6	7	8	7	7
Voltage	9	8	1	9	8
Current	9	8	1	9	8

Power Control	Weights	On/Off Switch	Electromagnetic Relay	Digital Potentiometer	Solid State Relay	Reed Relay
Response Time	0.237	0.237	1.183	1.656	1.420	1.420
Cost	0.168	1.509	1.173	1.676	1.006	1.341
Accuracy	0.161	0.484	0.967	0.806	1.129	0.967
Precision	0.171	1.025	1.196	1.367	1.196	1.196
Voltage	0.108	0.969	0.861	0.108	0.969	0.861
Current	0.156	1.404	1.248	0.156	1.404	1.248
Total:	1.000	5.627	6.629	5.769	**7.123**	7.033

Updated Project Plan



Conclusions

- We are assessing the feasibility of using Terfenol-D, a magnetostrictive material, in an actuator, for Honeywell
- The functional diagram shows how each component of the system transfers information to one another
- We determined criteria for each component of the system and weighted them relative to each other
- Sketches were generated and decision matrices apply the criteria to the concepts
- Based on the decision matrices, we found that wall outlet, angle lever, bolt, solid state relay, square Terfenol-D bar, silver coil solenoid, and plastic compact housing are the concepts that best fit the criteria for each component
- The updated Gantt chart displays the progress we have made so far, as well as upcoming tasks and deliverables

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