Universidad de Costa Rica

2-Axis Balance and Yaw Turntable

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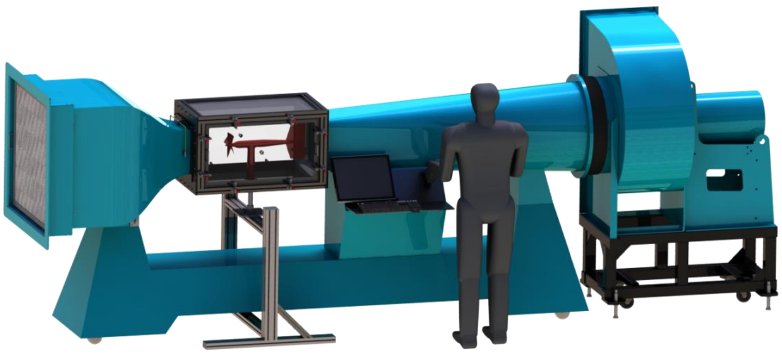

OWNERS MANUAL

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Version: 1.0
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Acronyms

Acronyms	Description
DAQ	Data Acquisition
in	Inch
MPS	Model Positioning System
NA	Not Applicable
NI	National Instruments
PC	Personal Computer
PTA	Pressure Transducer Array
V	Volt
VFD	Variable Frequency Drive
TBD	To Be Decided

Document Version Control

Version	Description	Date
1.0	Initial Release.	7/31/2017
2.0		

Software Version Control

Version	Description	Date
1.0	Aero-Ware	03/20/2017

Reference Documents

Version	Document	Description	Date
1.1	AeroWare User Manual	Aerolab Software User Manual	Mar 2017
1.0	CPT6100 Data Sheet.pdf	CPT 6100 Transducer Documentation	Jan 2015
1.0	DS_CPT6100Barometer_en_um_33331.pdf	CPT 6100 Barometric Transducer	Mar 2015
1.0	ACS550-User Manual.pdf	VFD User Manual	Nov 2016
1.0	ACS355-03U-46A2-2.pdf	ABB ACS355 Specifications	Nov 2016
1.0	MDR-60-16 Datasheet.pdf	60W Single Output Industrial DIN Rail Power Supply- MDR-60 series	Nov 2016
1.0	Centrifugal-Fans-ES-52.pdf	Centrifugal Fans -INSTALLATION, OPERATION & MAINTENANCE MANUAL	Aug 2014
1.0	HN2NSTA22 Data Sheet.pdf	Veris Industries HP/HN Digital RH and RH/T Transmitters	Nov 2016

1. 2-Component Floor Balance

1.1. Introduction

The 2-Component Floor balance was custom designed for a 36x48 inch Atmospheric Boundary Layer (ABL) Tunnel with a top end speed of 20 m/s. The balance measures drag and side force and additionally has a servo driven yaw table with a 160:1 harmonic drive and multi-turn absolute encoder, providing excellent torque capability and position repeatability with virtually no backlash.

High-quality, commercial-grade miniature tension/compression load cells permit simultaneous sensing of both Drag and Side Force.
This unique AEROLAB design incorporates several features to protect the delicate subcomponents:
A pair of toggle clamps on each side to lock the balance during model changes
4 sets of self-centering Linear Flexure Pivots provide frictionless, lubrication-free transformation of loads with infinite life when used within design limits

The balance requires a data acquisition system to operate.

1.2. Specifications and Load Limits

The balance has specific load limits. Do not exceed these limits or permanent damage will result. Allow 45 minutes for warm-up to permit optimal stabilization of the signals.

Table 1: Balance System Specifications

Parameter	Specification
Max Axial Force (Drag)	+/- 50 lbf
Max Side Force	+/- 50 lbf
Yaw Range	+/- 360 degrees
Max Model Weight	150 lbf
Axial Force Accuracy (FS %)	1.06
Side Force Accuracy (FS %)	1.48
Axial Force Sensitivity (mV/Vex-lb)	-13.39
Side Force Sensitivity (mV/ Vex-lb)	-23.08
Excitation Voltage (Vex)	5 V

1.3. Hardware

Only the Key component hardware for the Balance and Yaw Turn-Table is listed below. Please refer to the Appendices for additional information regarding hardware.

Table 2: Key Component Hardware

Model/Part Number	Description	Manufacturer
2479650	Linear Free Flex Pivot Assembly (QTY 8)	Riverhawk
779521-01	NI 9237 4-CH 50 kS/s per Channel. 24-Bit Bridge Analog Input Module	National Instruments
AKM21E-ANB2AB00	Servo Motor	Kollmorgen
AKD-P00306-NBEC-0000	3A, 120-240 VAC, ETHERCAT DRIVE	Kollmorgen
CSF-20-160-GH-J6-SP3832	Size 20, 160:1 Gearhead, Shaft Output W/ key	Harmonic Drive
LCM300	50 lb , Tension & Compression Load Cell (QTY 2)	Futec

1.4. Calibration

The balance was calibrated (first-order calibration with linear interaction compensation) at AEROLAB prior to delivery. The calibration was performed with all channels excited at 5 VDC.
The calibration was performed following American Institute of Aeronautics and Astronautics (AIAA) standards. The AIAA published these standards in: "Calibration and Use of Internal Strain-Gage Balances with Application to Wind Tunnel Testing" publication R-091-2003. The AEROLAB calibration uses the nomenclature from this document. This document is available directly from the Institute at http://www.aiaa.org/.

1.1.1. Loading Schedule

The balance was applied with a series of incremental loads for each axis. The loading included increasing and decreasing loads to capture any hysteresis effects. There were different incremental loads applied depending on which component of the balance was being tested. In addition a coupled load was applied. The plots below outline the calibration loading schedules used and model verification study that was conducted.

Figure 1 below illustrates the Drag (Axial) and Side Force loading schedule that was conducted. A tabular version of this loading schedule can be found in

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Appendix A: Loading Schedule and Raw Readings. The same loading schedule was repeated with different model weights to ensure performance under vertical load. Model weights were simulated by simply placing a series of evenly distributed weights on top of the yaw table.

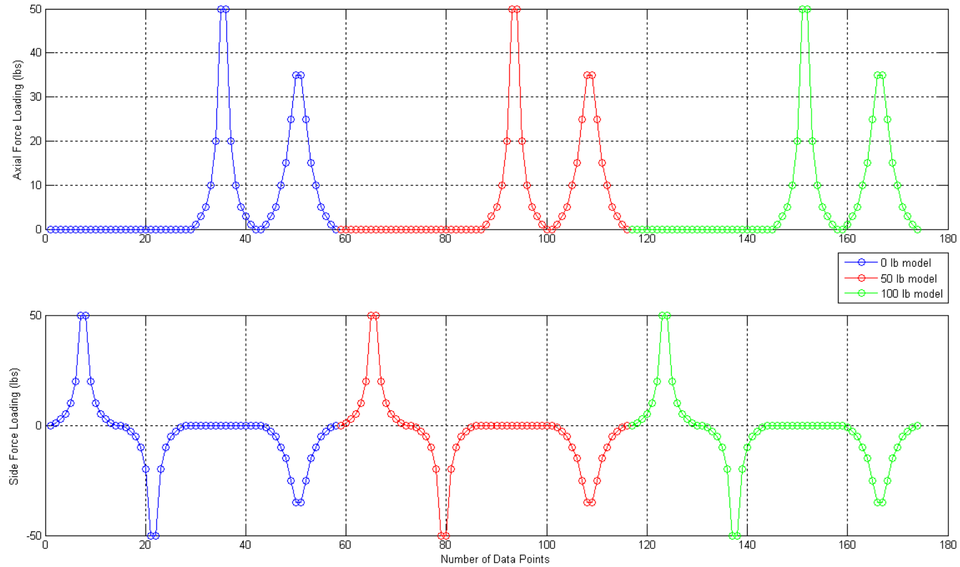

Figure 1: Calibration Loading Schedule

Figure 2 illustrates the Voltage Read by the Acquisition Equipment for each loading. This plot also captures the linearity of the balance response. Note, non-linearity around 35 lbf in the Drag simulation is actually due to the coupled loadings that were performed. It will be interesting to see if the derived calibration matrices will capture coupling effects.

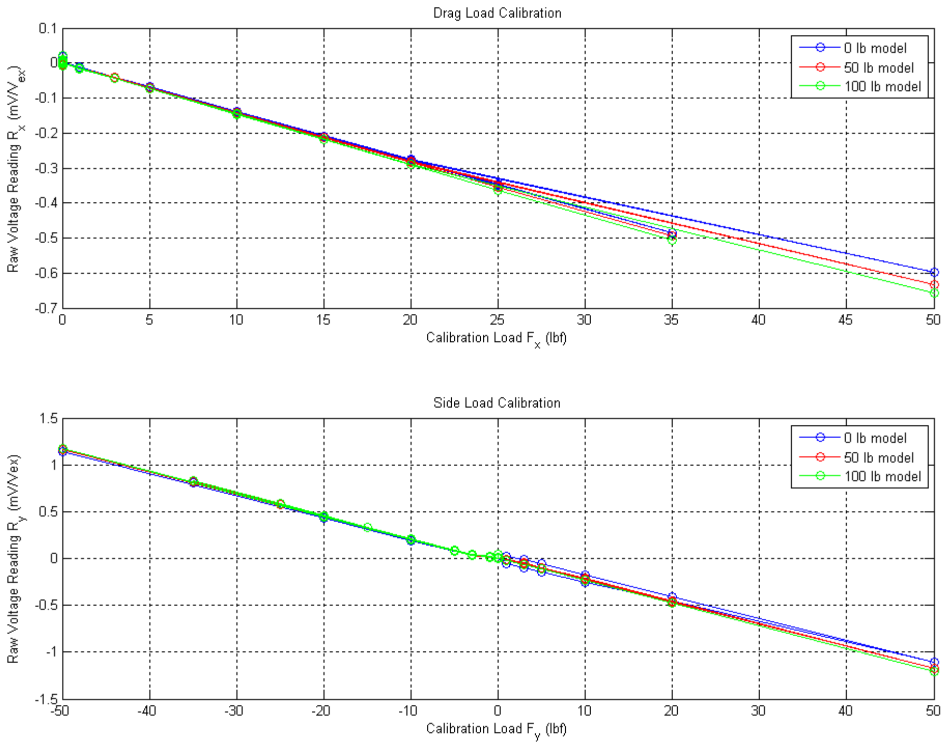

Figure 2: Raw Voltage Reading Vs Calibration Load

1.1.2. Regression Analysis

The raw voltage data acquired from the loading schedule was used to perform a Multiple Regression Analysis. Only data from the 50 lb model loading schedule was used, as this best represents the realistic model weight expected during use of the balance with the Wind Tunnel.

Derivation of the Regression Equations for the Balance:

$$\boldsymbol{X} = \begin{bmatrix} 1 & F_x & F_y & |F_y| & {F_x}^2 & {F_y}^2 & F_x F_y \end{bmatrix}$$

$$\boldsymbol{R_x} = [X][B_x]$$

$$\boldsymbol{R_y} = [\boldsymbol{X}][\boldsymbol{B_y}]$$

$$\boldsymbol{B_x} = (\boldsymbol{X^T X})^{-1}\boldsymbol{X^T R_x}$$

$$\boldsymbol{B_y} = (\boldsymbol{X^T X})^{-1}\boldsymbol{X^T R_y}$$

- $\boldsymbol{X}$ = nxp design matrix with rows corresponding to observations and columns to predictor variables. The first column is set to 1's to permit a constant (intercept) in the regression analysis.
- $\boldsymbol{R_x}$ and $\boldsymbol{R_y}$ = nx1 vectors and are the Raw Measurement Outputs from the Balance Load Cells.
- $\boldsymbol{F_x}$ and $\boldsymbol{F_y}$= nx1 vectors and are the Applied Forces to the Load Cells.
- $\boldsymbol{B_x}$ **and** $\boldsymbol{B_y}$ = px1 vectors that comprises the regression coefficients. These coefficients will ultimately comprise the inverse of the Calibration Matrix.

Once the regression coefficients are determined, an estimate of the raw voltage readings can easily be derived as follows:

$$\boldsymbol{R_x} = B_{x,1} + B_{x,2}\boldsymbol{F_x} + B_{x,3}\boldsymbol{F_y} + B_{x,4}|\boldsymbol{F_y}| + B_{x,5}\boldsymbol{F_x}^2 + B_{x,6}\boldsymbol{F_y}^2 + B_{x,7}\boldsymbol{F_x}\boldsymbol{F_y}$$

$$\boldsymbol{R_y} = B_{y,1} + B_{y,2}\boldsymbol{F_x} + B_{y,3}\boldsymbol{F_y} + B_{y,4}|\boldsymbol{F_y}| + B_{y,5}\boldsymbol{F_x}^2 + B_{y,6}\boldsymbol{F_y}^2 + B_{y,7}\boldsymbol{F_x}\boldsymbol{F_y}$$

Figure 3 illustrates the results of a multi-variable regression analysis, used to derive the calibration coefficients. At this point, a verification of the regression was conducted and it appears that the model is able to properly calculate the raw voltage readings

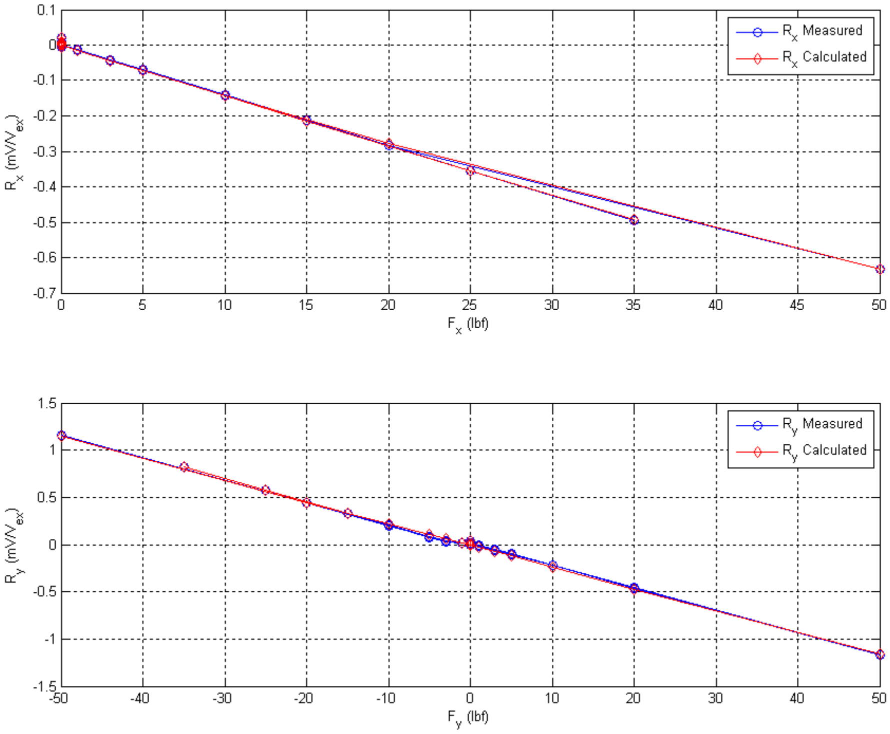

Figure 3: Regression Analysis Verification

The equations above can be re-arranged into Matrix notation:

$$\begin{bmatrix} \boldsymbol{R_x} \\ \boldsymbol{R_y} \end{bmatrix} = \boldsymbol{C_1} \begin{bmatrix} \boldsymbol{F_x} \\ \boldsymbol{F_y} \end{bmatrix} + \boldsymbol{C_2} \begin{bmatrix} |\boldsymbol{F_y}| \\ \boldsymbol{F_x}^2 \\ \boldsymbol{F_y}^2 \\ \boldsymbol{F_x F_y} \end{bmatrix}$$

$$[\boldsymbol{R}] = \boldsymbol{C_1}[\boldsymbol{F}] + \boldsymbol{C_2}[\boldsymbol{H}]$$

Where,

$$\boldsymbol{C_1} = \begin{bmatrix} B_{x,2} & B_{x,3} \\ B_{y,2} & B_{y,3} \end{bmatrix}$$

$$C_2 = \begin{bmatrix} B_{x,4} & B_{x,5} & B_{x6} & B_{x,7} \\ B_{y,4} & B_{y,5} & B_{y,6} & B_{y,7} \end{bmatrix}$$

Lastly, $\boldsymbol{C_1^{-1}}$ can be multiplied across the above equation to derive the final calibration equation

$$\boldsymbol{C_1^{-1}[R] = C_1^{-1}C_1[F] + C_1^{-1}C_2[H]}$$

$$\boldsymbol{F} = C_1^{-1}\boldsymbol{R} - C_1^{-1}C_2\,\boldsymbol{H}$$

$\boldsymbol{C_1}$ and $\boldsymbol{C_2}$ are the calibration matrices, but it is actually $\boldsymbol{C_1^{-1}}$ and $C_1^{-1}C_2$ that we are interested in

1.1.3. Calibration Matrix

The following first order equation is used to derive the forces on the balance from the voltage readings on the balance.

$$\boldsymbol{F} = C_1^{-1}\boldsymbol{R} - C_1^{-1}C_2\,\boldsymbol{H}$$

$$\begin{bmatrix} \boldsymbol{F_x} \\ \boldsymbol{F_y} \end{bmatrix} = \begin{pmatrix} C_{1_{1,1}} & C_{1_{1,2}} \\ C_{1_{2,1}} & C_{1_{2,2}} \end{pmatrix}^{-1} \begin{bmatrix} \boldsymbol{R_x} \\ \boldsymbol{R_y} \end{bmatrix} - \begin{pmatrix} C_{1_{1,1}} & C_{1_{1,2}} \\ C_{1_{2,1}} & C_{1_{2,2}} \end{pmatrix}^{-1} \begin{pmatrix} C_{2_{1,1}} & C_{2_{1,2}} & C_{2_{1,3}} & C_{2_{1,4}} \\ C_{2_{2,1}} & C_{2_{2,2}} & C_{2_{2,3}} & C_{2_{2,4}} \end{pmatrix} \begin{bmatrix} |\boldsymbol{F_y}| \\ \boldsymbol{F_x}^2 \\ \boldsymbol{F_y}^2 \\ \boldsymbol{F_xF_y} \end{bmatrix}$$

$$\boldsymbol{C_1^{-1}} = \begin{bmatrix} \boldsymbol{-68209.01000} & \boldsymbol{-784.95788} \\ \boldsymbol{1031.17199} & \boldsymbol{-43402.58455} \end{bmatrix}$$

$$\boldsymbol{C_1^{-1}C_2} = \begin{bmatrix} \boldsymbol{-0.018875} & \boldsymbol{-0.0027414} & \boldsymbol{0.000177} & \boldsymbol{-0.0014236} \\ \boldsymbol{0.059378} & \boldsymbol{-0.0010193} & \boldsymbol{-0.0011411} & \boldsymbol{0.0005577} \end{bmatrix}$$

Where:

- F is the derived load applied to the balance (lbs)
- R is the load measured by the balance (µV/V_{ex})
- H is the non-linear combinations and absolute values of the component loads, F
- $[C_1]^{-1}$ is the first order square matrix that relates load cell voltage outputs to the component loads
- C_2 is the interaction matrix that relates load cell voltage outputs to the component load absolute values, and non-linear combinations of the component loads.

- $[C1]^{-1}[C2]$ is given below

1. Data readings are ratio metric to the excitation. This means at full load, the raw balance reading should be 2.000, or with units 2.000 mV/V. The NI 9237 senses both the bridge potential AND the excitation voltage simultaneously so that even with excitation drift, noise, or any other unsteady variation, the numerical output is always correctly scaled. It makes the output value independent from the excitation voltage potential.
2. As a result, if anyone using the balance were to ever decide to apply a different excitation voltage FROM THE CONFIG FILE, nothing would change and the calibration would be valid.
3. If anyone decided to use their own excitation source, NOT FROM THE NI 9237 CARD, then this calibration is invalidated. This is because the card has no way to measure the excitation being output and would then scale the reading according to whatever excitation value was currently in the config file. Essentially, the card would still be outputting and measuring the excitation and applying that ratio to the output, but the user would not be using that excitation and thus would not have a ratio metric measurement.
4. It would theoretically be possible to use an external excitation and still get a modestly accurate answer under the following conditions:
   - External excitation is used
   - Internal excitation is known
   - Config file is set to scale the signal to compensate for the ratio metric math already done on the card

It is not recommended to use external excitation.

1.1.4. Model Verification

Figure 4 illustrates the full model verification by plotting the calculated response (in lbf) to ground truth (actual loading). For the derived calibration, only the 50 lb model data was used as this is most representative of realistic tests that will be conducted in the tunnel. The Full scale error is plotted as well to illustrate where errors are largest. Unsurprisingly, errors were highest where the side force crosses zero load.

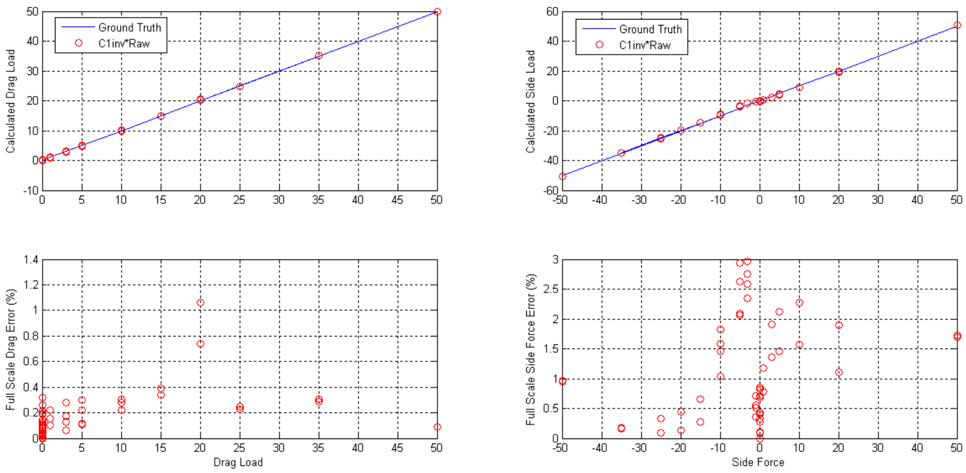

Figure 4: Calibration Model Verification

Figure 5 is another representation of the errors for the complete loading schedule for the 50 lb model case.

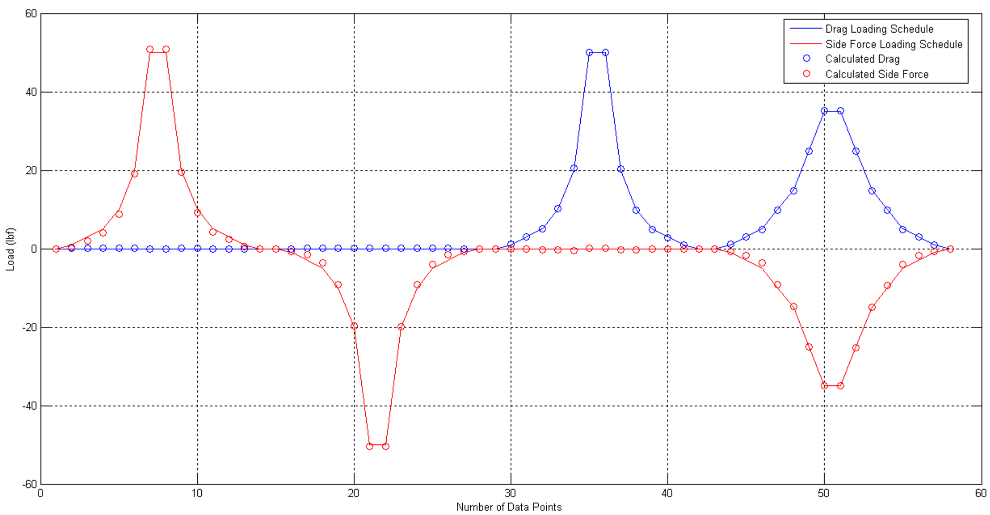

Figure 5: Calibration Model Verification

1.1.5. Sensitivity

The following chart provides a summary of the resolution sensitivity for each component load of the balance. The load cells themselves are rated for 2 mV/V_{ex} at a nominal load of 50 lbs. Therefore the sensitivity of the load cell is 40 µV/(V_{ex}-lb). The balance as a full system, however, has a unique sensitivity that must be characterized. Based on the raw readings of each axis across the full loading schedule, the response and sensitivity of the balance is characterized in the table below

Table 3: Sensitivity Characterization

Force/Moment	Excitation Voltage (V)	Output at Nominal Load (mV/ Vex)	Response (µV/lb)	Sensitivity (µV/(Vex-lb))
Axial Force	5	-0.6695	-66.95	-13.39
Side Force	5	1.154	-115.42	-23.08

1.1.6. Accuracy

An analysis on the first order calibration was performed to determine the calibration accuracy. The Full Scale Accuracy illustrates the worst case error divided by the Full Scale (FS) Range. The Mean FS Accuracy illustrates the average FS error across the full range of load.

Load Range
Axial Force = 0 to 50 lbs **(50 lbs)**
Side Forcer = -50 to + 50 lbs **(100 lbs)**

FS Accuracy
Maximum Full Scale Axial Force Error = 0.53 lbs = **1.06%** (Highlighted in red below)
Maximum Full Scale Side Force Error = 1.48 lbs = **1.48 %** (Highlighted in red below)

Mean FS Accuracy
Mean FS Axial Force Error = **0.16 %** (Highlighted in red below)
Mean FS Side Force Error = **0.49 %** (Highlighted in red below)

Table 4: Regression Error Analysis

Fx (lbs)	Fy (lbs)	Fx_calc (lbs)	Fy_calc (lbs)	Fx_error (lbs)	Fy_error (lbs)	FS Fx_error (%)	FS Fy_error (%)
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	1.00	0.04	0.41	0.04	-0.59	0.07	0.59
0.00	3.00	0.04	2.04	0.04	-0.96	0.08	0.96
0.00	5.00	0.05	3.94	0.05	-1.06	0.10	1.06

0.00	10.00	0.07	8.86	0.07	-1.14	0.15	1.14
0.00	20.00	0.11	19.05	0.11	-0.95	0.21	0.95
0.00	50.00	-0.03	50.86	-0.03	0.86	0.06	0.86
0.00	50.00	-0.02	50.85	-0.02	0.85	0.04	0.85
0.00	20.00	0.06	19.45	0.06	-0.56	0.12	0.56
0.00	10.00	0.01	9.21	0.01	-0.79	0.01	0.79
0.00	5.00	-0.03	4.27	-0.03	-0.73	0.06	0.73
0.00	3.00	-0.05	2.32	-0.05	-0.68	0.10	0.68
0.00	1.00	-0.05	0.61	-0.05	-0.39	0.10	0.39
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	-1.00	0.00	-0.64	0.00	0.36	0.01	0.36
0.00	-3.00	0.02	-1.52	0.02	1.48	0.03	1.48
0.00	-5.00	0.03	-3.53	0.03	1.47	0.06	1.47
0.00	-10.00	0.09	-9.21	0.09	0.79	0.19	0.79
0.00	-20.00	0.13	-19.78	0.13	0.22	0.26	0.22
0.00	-50.00	0.02	-50.48	0.02	-0.48	0.03	0.48
0.00	-50.00	0.01	-50.47	0.01	-0.47	0.02	0.47
0.00	-20.00	0.16	-19.93	0.16	0.07	0.32	0.07
0.00	-10.00	0.10	-9.09	0.10	0.91	0.19	0.91
0.00	-5.00	0.10	-3.96	0.10	1.04	0.19	1.04
0.00	-3.00	0.06	-1.62	0.06	1.38	0.13	1.38
0.00	-1.00	-0.01	-0.72	-0.01	0.28	0.02	0.28
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.00	0.00	1.08	-0.05	0.08	-0.05	0.15	0.05
3.00	0.00	3.06	-0.14	0.06	-0.14	0.13	0.14
5.00	0.00	5.05	-0.21	0.05	-0.21	0.11	0.21
10.00	0.00	10.11	-0.35	0.11	-0.35	0.22	0.35
20.00	0.00	20.53	-0.43	0.53	-0.43	1.06	0.43
50.00	0.00	49.96	0.16	-0.04	0.16	0.09	0.16
50.00	0.00	49.96	0.16	-0.05	0.16	0.09	0.16
20.00	0.00	20.37	-0.41	0.37	-0.41	0.74	0.41
10.00	0.00	9.89	-0.34	-0.11	-0.34	0.22	0.34
5.00	0.00	4.85	-0.20	-0.15	-0.20	0.30	0.20
3.00	0.00	2.86	-0.14	-0.14	-0.14	0.28	0.14

1.00	0.00	0.89	-0.05	-0.11	-0.05	0.22	0.05
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.00	-1.00	1.05	-0.74	0.05	0.26	0.10	0.26
3.00	-3.00	2.97	-1.83	-0.03	1.17	0.06	1.17
5.00	-5.00	4.94	-3.69	-0.06	1.31	0.12	1.31
10.00	-10.00	9.86	-9.27	-0.14	0.73	0.28	0.73
15.00	-15.00	14.83	-14.68	-0.17	0.32	0.34	0.32
25.00	-25.00	24.89	-25.05	-0.11	-0.05	0.23	0.05
35.00	-35.00	35.15	-34.91	0.15	0.09	0.31	0.09
35.00	-35.00	35.14	-34.92	0.14	0.08	0.29	0.08
25.00	-25.00	24.88	-25.17	-0.12	-0.17	0.24	0.17
15.00	-15.00	14.80	-14.86	-0.20	0.14	0.39	0.14
10.00	-10.00	9.85	-9.48	-0.15	0.52	0.31	0.52
5.00	-5.00	4.89	-3.97	-0.11	1.03	0.22	1.03
3.00	-3.00	2.91	-1.71	-0.09	1.29	0.17	1.29
1.00	-1.00	0.92	-0.82	-0.08	0.18	0.15	0.18
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
					Average	0.16	0.49

1.1.7. Confidence Interval

An analysis on the first order calibration was performed to determine the standard error and 95% confidence interval. This is a measure of how much trust one can put into the experimental measurements.

$$SE = \sqrt{\frac{\sum_{i=1}^{n}(E_i^2)}{(n-p-1)}}$$

$$95\%\ C.I. = 1.96(SE)$$

- SE = Standard Error
- E = Actual Load – Calculated Load
- n = number of samples
- p = number of degrees of freedom (2 in this case)
- i = i^{th} sample
- C.I. = Confidence Interval

Table 5: Confidence Interval

Axis	Standard Error (lbf)	95% Confidence Interval (lbf)
Axial Force	0.1234	+/- 0.2418
Side Force	0.6786	+/- 1.3301

Appendix A: Loading Schedule and Raw Readings

Normal Force (lb)	Drag Force Load (lb)	Side Force Load (lb)	Drag Force Reading (mV)	Side Force Reading (mV)	Tared Drag Reading (mV)	Tared Side Reading (mV)
0	0	0	0.000019	-0.000009	0	0
0	0	1	-0.000007	-0.019805	0.0006075	-0.05088
0	0	3	0.000314	-0.06405	0.0009285	-0.095125
0	0	5	0.000988	-0.109659	0.0016025	-0.140734
0	0	10	0.002759	-0.227698	0.0033735	-0.258773
0	0	20	0.007055	-0.426743	0.0076695	-0.457818
0	0	50	0.018695	-1.075144	0.0193095	-1.106219
0	0	50	0.018583	-1.074672	0.0191975	-1.105747
0	0	20	0.007064	-0.380906	0.0076785	-0.411981
0	0	10	0.00304	-0.146358	0.0036545	-0.177433
0	0	5	0.001037	-0.029119	0.0016515	-0.060194
0	0	3	0.000311	0.018707	0.0009255	-0.012368
0	0	1	-0.00067	0.051281	-0.0000555	0.020206
0	0	0	-0.001248	0.062159	0	0
50	0	0	-0.013475	-0.005186	0	0
50	0	1	-0.013199	-0.016483	-0.000304	-0.010021
50	0	3	-0.012385	-0.056253	0.00051	-0.049791
50	0	5	-0.011494	-0.102233	0.001401	-0.095771
50	0	10	-0.009257	-0.220646	0.003638	-0.214184
50	0	20	-0.00485	-0.461772	0.008045	-0.45531
50	0	50	0.00837	-1.179392	0.021265	-1.17293
50	0	50	0.008235	-1.179135	0.02113	-1.172673
50	0	20	-0.003978	-0.47094	0.008917	-0.464478
50	0	10	-0.008105	-0.228959	0.00479	-0.222497
50	0	5	-0.010115	-0.110151	0.00278	-0.103689
50	0	3	-0.010902	-0.062839	0.001993	-0.056377
50	0	1	-0.011824	-0.021374	0.001071	-0.014912
50	0	0	-0.012315	-0.007738	0	0
100	0	0	-0.01458	-0.011622	0	0
100	0	1	-0.014436	-0.029187	-0.000808	-0.018367
100	0	3	-0.013576	-0.073103	0.000052	-0.062283

Normal Force (lb)	Drag Force Load (lb)	Side Force Load (lb)	Drag Force Reading (mV)	Side Force Reading (mV)	Tared Drag Reading (mV)	Tared Side Reading (mV)
100	0	5	-0.012325	-0.124595	0.001303	-0.113775
100	0	10	-0.009858	-0.246769	0.00377	-0.235949
100	0	20	-0.005549	-0.488918	0.008079	-0.478098
100	0	50	0.008441	-1.213172	0.022069	-1.202352
100	0	50	0.008364	-1.212874	0.021992	-1.202054
100	0	20	-0.004517	-0.489316	0.009111	-0.478496
100	0	10	-0.008619	-0.245776	0.005009	-0.234956
100	0	5	-0.010735	-0.122625	0.002893	-0.111805
100	0	3	-0.011465	-0.077358	0.002163	-0.066538
100	0	1	-0.012211	-0.029529	0.001417	-0.018709
100	0	0	-0.012676	-0.010018	0	0
0	0	0	-0.000055	0.000002	0	0
0	0	-1	-0.000073	0.007696	0.001287	0.0062485
0	0	-3	-0.00064	0.035047	0.00072	0.0335995
0	0	-5	-0.000998	0.077769	0.000362	0.0763215
0	0	-10	-0.00186	0.195001	-0.0005	0.1935535
0	0	-20	-0.004073	0.43749	-0.002713	0.4360425
0	0	-50	-0.008336	1.146212	-0.006976	1.1447645
0	0	-50	-0.008285	1.145617	-0.006925	1.1441695
0	0	-20	-0.005117	0.438587	-0.003757	0.4371395
0	0	-10	-0.004217	0.203265	-0.002857	0.2018175
0	0	-5	-0.003208	0.082498	-0.001848	0.0810505
0	0	-3	-0.003406	0.038945	-0.002046	0.0374975
0	0	-1	-0.002847	0.012314	-0.001487	0.0108665
0	0	0	-0.002665	0.002893	0	0
50	0	0	-0.013103	-0.012027	0	0
50	0	-1	-0.012927	0.003362	5.80E-05	0.013916
50	0	-3	-0.013193	0.022368	-0.000208	0.032922
50	0	-5	-0.013384	0.066243	-0.000399	0.076797
50	0	-10	-0.014353	0.191277	-0.001368	0.201831
50	0	-20	-0.015554	0.428384	-0.002569	0.438938
50	0	-50	-0.019243	1.150316	-0.006258	1.16087
50	0	-50	-0.019139	1.150163	-0.006154	1.160717

Normal Force (lb)	Drag Force Load (lb)	Side Force Load (lb)	Drag Force Reading (mV)	Side Force Reading (mV)	Tared Drag Reading (mV)	Tared Side Reading (mV)
50	0	-20	-0.015972	0.431852	-0.002987	0.442406
50	0	-10	-0.014395	0.188553	-0.00141	0.199107
50	0	-5	-0.014329	0.075547	-0.001344	0.086101
50	0	-3	-0.013893	0.024652	-0.000908	0.035206
50	0	-1	-0.012798	0.005104	0.000187	0.015658
50	0	0	-0.012867	-0.009081	0	0
100	0	0	-0.011513	-0.01586	0	0
100	0	-1	-0.011359	0.001546	0.0007365	0.0157265
100	0	-3	-0.012283	0.027757	-0.0001875	0.0419375
100	0	-5	-0.012675	0.059944	-0.0005795	0.0741245
100	0	-10	-0.013688	0.180881	-0.0015925	0.1950615
100	0	-20	-0.015583	0.430952	-0.0034875	0.4451325
100	0	-50	-0.018983	1.158351	-0.0068875	1.1725315
100	0	-50	-0.018964	1.158252	-0.0068685	1.1724325
100	0	-20	-0.015397	0.434952	-0.0033015	0.4491325
100	0	-10	-0.014131	0.188296	-0.0020355	0.2024765
100	0	-5	-0.013696	0.067142	-0.0016005	0.0813225
100	0	-3	-0.013689	0.024525	-0.0015935	0.0387055
100	0	-1	-0.012849	0.008699	-0.0007535	0.0228795
100	0	0	-0.012678	-0.012501	0	0
0	0	0	0.000076	0	0	0
0	1	0	-0.014118	0.000601	-0.0157325	0.0020055
0	3	0	-0.042256	0.001375	-0.0438705	0.0027795
0	5	0	-0.070282	0.002286	-0.0718965	0.0036905
0	10	0	-0.138972	0.003616	-0.1405865	0.0050205
0	20	0	-0.276435	0.005385	-0.2780495	0.0067895
0	50	0	-0.595631	0.044369	-0.5972455	0.0457735
0	50	0	-0.595562	0.044305	-0.5971765	0.0457095
0	20	0	-0.274005	0.004816	-0.2756195	0.0062205
0	10	0	-0.136217	0.001467	-0.1378315	0.0028715
0	5	0	-0.066733	-0.000544	-0.0683475	0.0008605
0	3	0	-0.038821	-0.00123	-0.0404355	0.0001745
0	1	0	-0.010799	-0.002407	-0.0124135	-0.0010025

Normal Force (lb)	Drag Force Load (lb)	Side Force Load (lb)	Drag Force Reading (mV)	Side Force Reading (mV)	Tared Drag Reading (mV)	Tared Side Reading (mV)
0	0	0	0.003153	-0.002809	0	0
50	0	0	-0.013638	-0.011963	0	0
50	1	0	-0.02795	-0.011119	-0.0157195	0.0006325
50	3	0	-0.056762	-0.009601	-0.0445315	0.0021505
50	5	0	-0.085289	-0.008225	-0.0730585	0.0035265
50	10	0	-0.156395	-0.005065	-0.1441645	0.0066865
50	20	0	-0.296497	0.000722	-0.2842665	0.0124735
50	50	0	-0.64457	0.02771	-0.6323395	0.0394615
50	50	0	-0.644554	0.027724	-0.6323235	0.0394755
50	20	0	-0.2944	0.000337	-0.2821695	0.0120885
50	10	0	-0.15336	-0.005326	-0.1411295	0.0064255
50	5	0	-0.082377	-0.008502	-0.0701465	0.0032495
50	3	0	-0.053814	-0.009601	-0.0415835	0.0021505
50	1	0	-0.025223	-0.010868	-0.0129925	0.0008835
50	0	0	-0.010823	-0.01154	0	0
100	0	0	-0.013596	-0.011844	0	0
100	1	0	-0.028303	-0.010849	-0.015594	0.0014705
100	3	0	-0.057744	-0.009454	-0.045035	0.0028655
100	5	0	-0.086901	-0.008314	-0.074192	0.0040055
100	10	0	-0.159972	-0.005546	-0.147263	0.0067735
100	20	0	-0.302811	0.001176	-0.290102	0.0134955
100	50	0	-0.670799	0.033721	-0.65809	0.0460405
100	50	0	-0.67074	0.03386	-0.658031	0.0461795
100	20	0	-0.30165	-0.001187	-0.288941	0.0111325
100	10	0	-0.157476	-0.006987	-0.144767	0.0053325
100	5	0	-0.084887	-0.009398	-0.072178	0.0029215
100	3	0	-0.055969	-0.010611	-0.04326	0.0017085
100	1	0	-0.026584	-0.012159	-0.013875	0.0001605
100	0	0	-0.011822	-0.012795	0	0
0	0	0	0.0001	-0.000118	0	0
0	1	-1	-0.015301	0.009442	-0.0154105	0.0082675
0	3	-3	-0.043297	0.041969	-0.0434065	0.0407945
0	5	-5	-0.071367	0.087731	-0.0714765	0.0865565

Normal Force (lb)	Drag Force Load (lb)	Side Force Load (lb)	Drag Force Reading (mV)	Side Force Reading (mV)	Tared Drag Reading (mV)	Tared Side Reading (mV)
0	10	-10	-0.140672	0.208941	-0.1407815	0.2077665
0	15	-15	-0.211419	0.331653	-0.2115285	0.3304785
0	25	-25	-0.347649	0.57301	-0.3477585	0.5718355
0	35	-35	-0.483821	0.814087	-0.4839305	0.8129125
0	35	-35	-0.483686	0.813859	-0.4837955	0.8126845
0	25	-25	-0.34712	0.573808	-0.3472295	0.5726335
0	15	-15	-0.209026	0.332102	-0.2091355	0.3309275
0	10	-10	-0.139655	0.211969	-0.1397645	0.2107945
0	5	-5	-0.070417	0.094573	-0.0705265	0.0933985
0	3	-3	-0.042334	0.046382	-0.0424435	0.0452075
0	1	-1	-0.014013	0.016079	-0.0141225	0.0149045
0	0	0	0.000119	0.002467	0	0
50	0	0	-0.013938	-0.014264	0	0
50	1	-1	-0.028423	0.002234	-0.015374	0.0158075
50	3	-3	-0.056294	0.025362	-0.043245	0.0389355
50	5	-5	-0.084825	0.065811	-0.071776	0.0793845
50	10	-10	-0.155625	0.189606	-0.142576	0.2031795
50	15	-15	-0.226452	0.313026	-0.213403	0.3265995
50	25	-25	-0.367316	0.559838	-0.354267	0.5734115
50	35	-35	-0.507335	0.808122	-0.494286	0.8216955
50	35	-35	-0.507213	0.80821	-0.494164	0.8217835
50	25	-25	-0.367289	0.562642	-0.35424	0.5762155
50	15	-15	-0.226133	0.317259	-0.213084	0.3308325
50	10	-10	-0.155448	0.194326	-0.142399	0.2078995
50	5	-5	-0.084096	0.071962	-0.071047	0.0855355
50	3	-3	-0.055475	0.022719	-0.042426	0.0362925
50	1	-1	-0.026555	0.004008	-0.013506	0.0175815
50	0	0	-0.01216	-0.012883	0	0
100	0	0	-0.013184	-0.016853	0	0
100	1	-1	-0.028086	0.002692	-0.015437	0.018167
100	3	-3	-0.057159	0.031409	-0.04451	0.046884
100	5	-5	-0.086475	0.062966	-0.073826	0.078441
100	10	-10	-0.159103	0.1916	-0.146454	0.207075

Normal Force (lb)	Drag Force Load (lb)	Side Force Load (lb)	Drag Force Reading (mV)	Side Force Reading (mV)	Tared Drag Reading (mV)	Tared Side Reading (mV)
100	15	-15	-0.231663	0.315732	-0.219014	0.331207
100	25	-25	-0.375744	0.568028	-0.363095	0.583503
100	35	-35	-0.518603	0.818427	-0.505954	0.833902
100	35	-35	-0.51853	0.81838	-0.505881	0.833855
100	25	-25	-0.376086	0.57009	-0.363437	0.585565
100	15	-15	-0.231445	0.32084	-0.218796	0.336315
100	10	-10	-0.158704	0.194753	-0.146055	0.210228
100	5	-5	-0.085647	0.069136	-0.072998	0.084611
100	3	-3	-0.056466	0.030322	-0.043817	0.045797
100	1	-1	-0.0267	0.006076	-0.014051	0.021551
100	0	0	-0.012114	-0.014097	0	0

Appendix B: Load Cell Calibrations

FUTEK
ADVANCED SENSOR TECHNOLOGY, INC.

10 Thomas, Irvine, CA 92618 USA
Tel: (949) 465-0900
Fax: (949) 465-0905

Certificate of Calibration

Certificate Number: **1608160060**

Sensor Info:

S/N: 680495	**Model**: LCM300
Item #: FSH03884	**Capacity**: 50 lb

Description: LCM300, 50 lb, Tension & Compression Load Cell (Miniature/Inline Threaded), RoHS Compliant, Material - 17-4 PH S.S., M6x1-Thread, 28 Awg 4 Conductor Braided Shielded Clear PVC, 10 ft Long

Calibration Procedure OP1000

CALIBRATION EQUIPMENT USED

Digital Multimeter:
HP Model: 34401A, **S/N:** MY44001975

Dead Weight(s):
1-10 lb, ***Traceability No:*** 678784

This certifies that the following sensor has been calibrated using equipment traceable to NIST. Supporting documentation relative to traceability is on file and is available for examination upon request. This certificate shall not be reproduced except in full, without the written approval of FUTEK

Calibration Technician: *Angel Mendoza*	
Issue Date: 8/16/2016	**Re-Calibration Date:** One Year After Issue Date

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ADVANCED SENSOR TECHNOLOGY, INC.

10 Thomas, Irvine, CA 92618 USA
Tel: (949) 465-0900
Fax: (949) 465-0905

Certificate Number: **1608160060**

Single Channel Item

CALIBRATION DATA

Test Temp: 74 ºF (23 ºC)	**Relative Humidity**: 47 %	**Excitation**: 9.99 Vdc
Input Resistance: 743 Ω	**Output Resistance**: 743 Ω	**Zero Balance**: -0.0024 mV/V

Tension

Load (lb)	Output (mV/V)	Non-Lin. Error (% R.O.)
0	0.0000	0.000
10	0.4218	0.060
20	0.8436	0.120
30	1.2644	0.132
40	1.6836	0.068
50	2.1027	0.000
0	0.0005	

SHUNT CALIBRATION

Direction	Shunt Value (KΩ)	Shunt Connection	Output Value (mV/V)	Equivalent Load (lb)
Tension	100	(-Exc) & (-S)	1.8513	44

FUTEK
ADVANCED SENSOR TECHNOLOGY, INC.

10 Thomas, Irvine, CA 92618 USA
Tel: (949) 465-0900
Fax: (949) 465-0905

Certificate of Calibration

Certificate Number: **1608160061**

Sensor Info:

S/N: 680496 **Model**: LCM300
Item #: FSH03884 **Capacity**: 50 lb

Description: LCM300, 50 lb, Tension & Compression Load Cell (Miniature/Inline Threaded), RoHS Compliant, Material - 17-4 PH S.S., M6x1-Thread, 28 Awg 4 Conductor Braided Shielded Clear PVC, 10 ft Long

Calibration Procedure OP1000

CALIBRATION EQUIPMENT USED

Digital Multimeter:
HP Model: 34401A, **S/N:** MY44001975

Dead Weight(s):
1-10 lb, *Traceability No:* 678784

This certifies that the following sensor has been calibrated using equipment traceable to NIST. Supporting documentation relative to traceability is on file and is available for examination upon request. This certificate shall not be reproduced except in full, without the written approval of FUTEK

Calibration Technician: *Angel Mendoza*
Issue Date: 8/16/2016 **Re-Calibration Date:** One Year After Issue Date

FUTEK
ADVANCED SENSOR TECHNOLOGY, INC.
10 Thomas, Irvine, CA 92618 USA
Tel: (949) 465-0900
Fax: (949) 465-0905

Certificate Number: 1608160061

Single Channel Item

CALIBRATION DATA

Test Temp: 74 ºF (23 ºC)	**Relative Humidity**: 47 %	**Excitation**: 9.99 Vdc
Input Resistance: 742 Ω	**Output Resistance**: 743 Ω	**Zero Balance**: -0.0021 mV/V

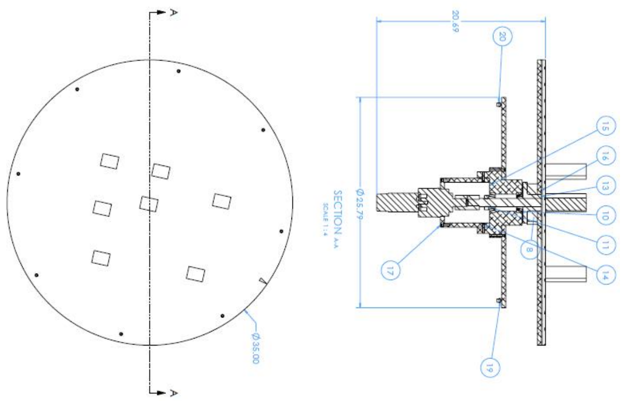
Tension

Load (lb)	Output (mV/V)	Non-Lin. Error (% R.O.)
0	0.0000	0.000
10	0.4424	0.080
20	0.8868	0.251
30	1.3271	0.235
40	1.7685	0.270
50	2.2032	0.000
0	0.0012	

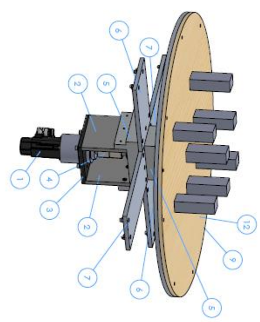
SHUNT CALIBRATION

Direction	Shunt Value (KΩ)	Shunt Connection	Output Value (mV/V)	Equivalent Load (lb)
Tension	100	(-Exc) & (-S)	1.8494	42

Appendix C: Turn-Table Schematic



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	MPS Motor and Drive Subassembly_13-33		1
2	MPS Yaw Actuator Holder Sides_13-33	SEE SHEET 2	2
3	MPS Yaw Actuator Holder Bottom_13-33	SEE SHEET 2	1
4	MPS McMaster Metric Shaft Coupler 2469K32_13-33	McMaster- Carr- One-Piece Clamp-on Rigid Shaft Coupling without Keyway for 25mm x 20mm Diameter Shaft, Type 303 Stainless Steel	1
5	MPS Yaw Box Top_2_13-33	SEE SHEET 4	1
6	BalanceSupportArm1	SEE SHEET 2	2
7	BalanceSupportArm_long	SEE SHEET 2	2
8	YawTableConnect	SEE SHEET 5	1
9	TestArticle_assem1	SEE SHEET 6	1
10	5709K19	McMaster- Carr- Steel Tapered-Roller Bearing for 1" Shaft Dia, Trade NO. 15100, 2-7/16" OD	2
11	6438K61	McMaster-Carr- Threaded-Bore One-Piece Clamp-on Shaft Collar with 1"-14 Thread, Type 303 Stainless Steel	1
12	Quarter Plate	SEE SHEET 7	1
13	MPS Trunk Coupler Assembly		1
14	91771A544 0.25-20 Length 1.25	18-8 Stainless Steel Flat Head Phillips Machine Screw, 1/4"-20 Thread, 1-1/4" Length	6
15	91771A550 0.25-20 Length 2 in	18-8 Stainless Steel Flat Head Phillips Machine Screw, 1/4"-20 Thread, 2" Length	12
16	91771A628 .375-16 Length 1.5	18-8 Stainless Steel Flat Head Phillips Machine Screw, 3/8"-16 Thread, 1-1/2" Length	8
17	91771A542 0.25-20 Length 1.0 in	18-8 Stainless Steel Flat Head Phillips Machine Screw, 1/4"-20 Thread, 1" Length	6
18	92196A540 0.25-20 Length 0.75in	18-8 Stainless Steel Socket Head Screw, 1/4"-20 Thread Size, 3/4" Long	8
19	91771A541	18-8 Stainless Steel Flat Head Phillips Machine Screw, 1/4"-20 Thread, 7/8" Length	8
20	21.2261_2 QUARTER-20 SQUARE NUT POS FXG		8



Appendix D: Harmonic Drive Information

CSF - 20 - 100 - GH - F0 - Motor Code

Model Name	Size	Reduction Ratio	Model	Output Configuration	Input Configuration
HarmonicDrive® CSF Standard	14	50, 80, 100	GH: Gearhead	F0: Flange output J2: Shaft output without key J6: Shaft output with key and center tapped hole	This code represents the motor mounting configuration. Please contact us for a unique part number based on the motor you are using.
	20	50, 80, 100, 120, 160			
	32				
	45				
	65	80, 100, 120, 160			

Motor assembly procedure HPGP HPG CSG-GH CSF-GH HPN

To properly mount the motor to the gearhead, follow the procedure outlined below, refer to figure 3-1

(1) Turn the input shaft coupling and align the bolt head with the rubber cap hole.

(2) With the speed reducer in an upright position as illustrated in the figure below, slowly insert the motor shaft into the coupling of speed reducer. Slide the motor shaft into the input shaft coupling by guiding the motor shaft into it without letting it drop down. If the speed reducer cannot be positioned upright, slowly insert the motor shaft into the coupling of speed reducer, then tighten the motor bolts evenly (little by little) until the motor flange and gearhead flange are in full contact. Exercise care to avoid tilting the motor when inserting it into the gear head.

(3) Tighten the input shaft coupling bolt to the recommended torque specified in the table below. The bolt(s) or screw(s) is (are) already inserted into the input shaft coupling when delivered. Check the bolt size on the confirmation drawing provided.

Bolt tightening torque

Table 3-1

Bolt size		M3	M4	M5	M6	M8	M10	M12
Tightening torque	Nm	2.0	4.5	9.0	15.3	37.2	73.5	128
	kgfm	0.20	0.46	0.92	1.56	3.8	7.5	13.1

Caution: Always tighten the bolts to the tightening torque specified in the table above. If the bolt is not tightened to the torque value recommended slippage of the motor shaft in the shaft coupling may result. The bolt size will vary depending on the size of the gear and the shaft diameter of the mounted motor. Check the bolt size on the confirmation drawing provided.

Note: Two setscrews need to be tightened on size 11. Tighten the screws to the tightening torque specified below.

Table 3-2

Bolt size		M3
Tightening torque	Nm	0.69
	kgfm	0.07

(4) Fasten the motor to the gearhead flange with bolts.

Bolt* tightening torque

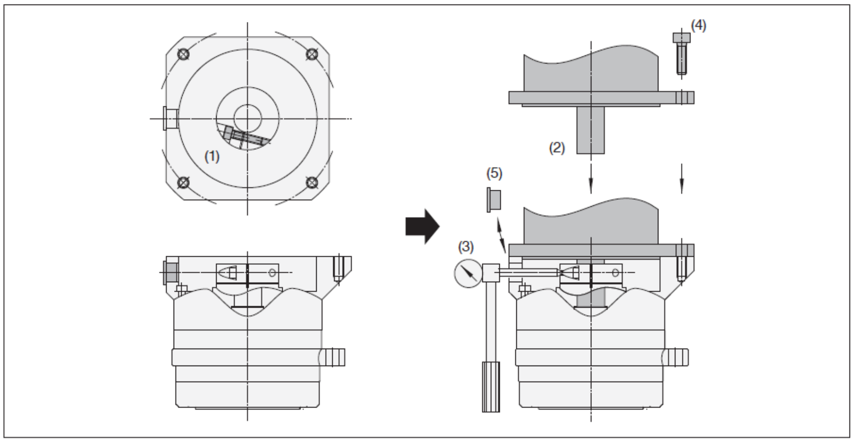
Table 3-3

Bolt size		M2.5	M3	M4	M5	M6	M8	M10	M12
Tightening torque	Nm	0.59	1.4	3.2	6.3	10.7	26.1	51.5	89.9
	kgfm	0.06	0.14	0.32	0.64	1.09	2.66	5.25	9.17

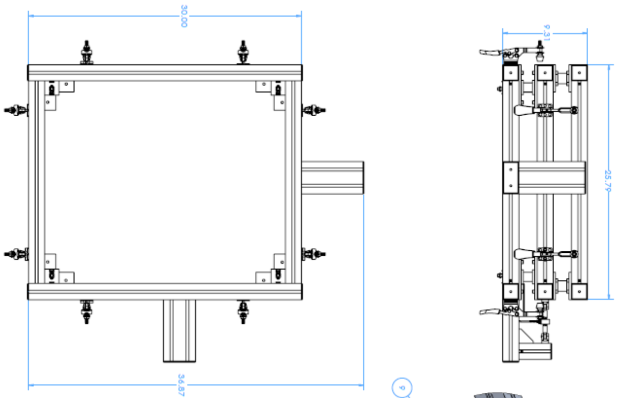
* Recommended bolt: JIS B 1176 Hexagon socket head bolt, Strength: JIS B 1051 12.9 or higher
Caution: Be sure to tighten the bolts to the tightening torques specified in the table.

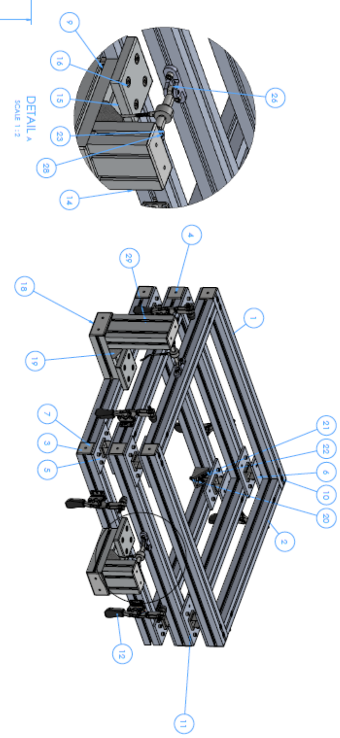
(5) Insert the rubber cap provided. This completes the assembly. (Size 11: Fasten screws with a gasket in two places)

Figure 3-1



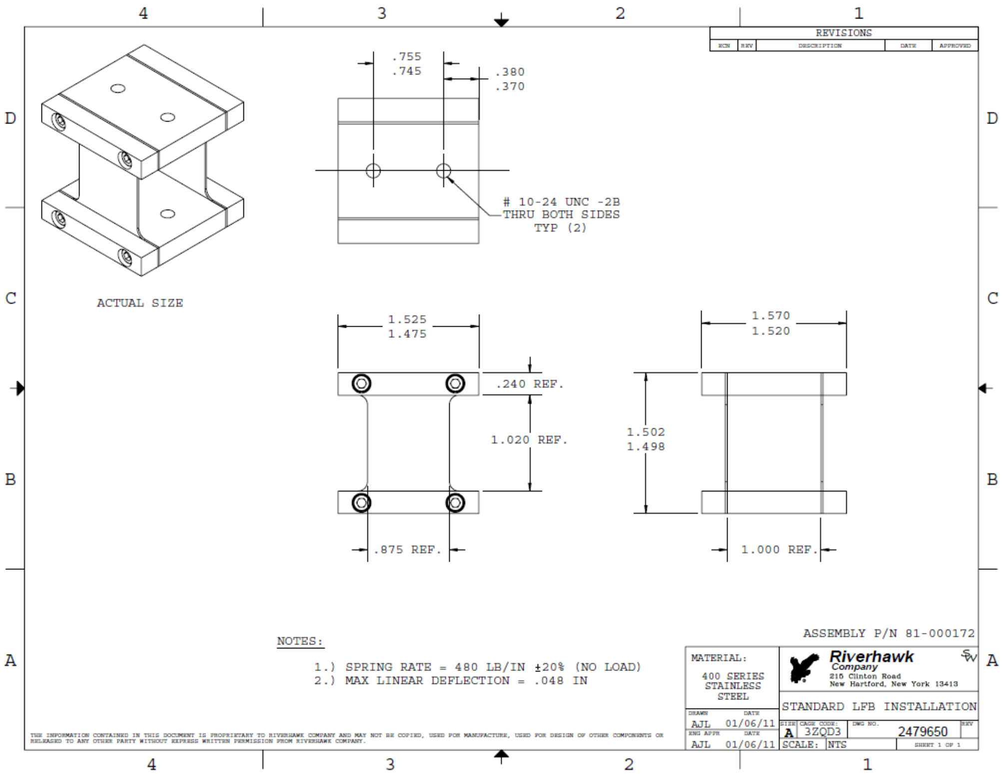
Appendix E: Balance Assembly Schematic



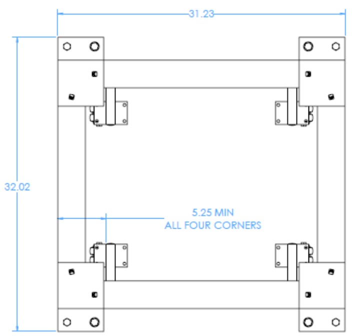


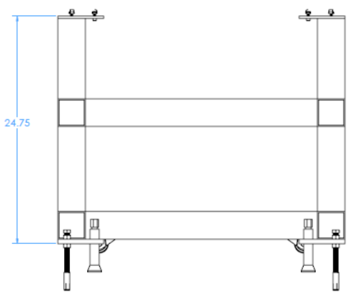
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	20.1063 45X45 UL_30.0L	MiniTec Part no. 20.1063; Cut to Length: 30.0in	6
2	20.1063 45X45 UL_22.25L	MiniTec Part no. 20.1063; Cut to Length: 22.25in	6
3	22.1004_1 END CAP 45X45 GRAY		12
4	END CAP DOWEL GRAY		20
5	Flexure Base		16
6	Riverhawk Linear Flexure Bearing		8
7	21.1018 POWER-LOCK BODY		20
8	21.1492 POWER-LOCK SF TORX SCREW		20
9	21.1301 M8X16 SET SCREW FLAT DIN 913		20
10	21.2261_2 QUARTER-20 SQUARE NUT POS FXG		77
11	91251A540		64
12	5128A220_LOW-PROFILE HOLD-DOWN TOGGLE CLAMP		8
13	20.1067 45X90 UL 6.75 inch		2
14	20.1067 45X90 UL 3.5inch		1
15	21.1473 CONNECTING PLATE 90X90		2
16	21.1202_M8x20		8
17	21.1351_2 M8 SQUARE NUT POS FXG		8
18	22.1007_1 End Cap 45x90 Gray		4
19	21.1349 ANGLE 45 GD-Z		8
20	21.1351 M8 SQUARE NUT		16
21	21.1127 M8 ROUND WASHER		16
22	21.1280 M8X22		16
23	Rod End Bracket V2.0		4
24	59935K72		2
25	LCM300		2
26	59935K512		2
27	90710A038 M6x1		4
28	97355A300		4
29	20.1067 45X90 UL 7.25inch		1

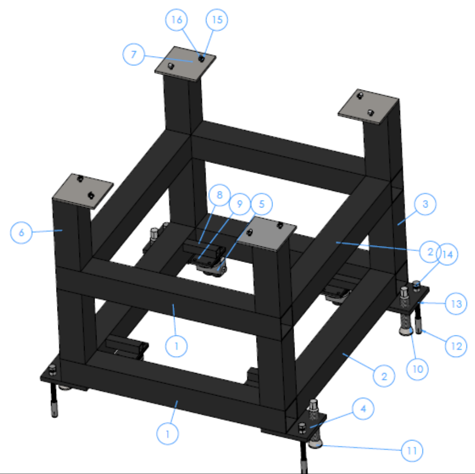
Appendix F: Flexure Schematic



Appendix G: Balance Base Assembly







ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	3 X 3 X 27.02L		4
2	3 X 3 X 25.23L		4
3	3 X 3 X 9.25L		4
4	AdjustmentBase1		4
5	2455T31	Cart-King Dual Wheel Caster, Swivel, 2" x 7/8" Neoprene Rubber Wheel, 250 lb Capacity	4
6	3 X 3 X 8.75L		4
7	Component Balance Support Plate		4
8	1 X 1 X 4L		4
9	Caster Support Plate		4
10	Standard Leveling Screw		4
11	Standard Foot Pad		4
12	97095A131	Internally Threaded Anchor for Concrete, Type 316 Stainless Steel, 1/2"-13 Screw Size, 2" Length	4
13	92240A732	18-8 Stainless Steel Hex Head Cap Screw, 1/2"-13 Thread, 5" Long, Fully Threaded	4
14	91845A310	18-8 Stainless Steel Hex Nut, 1/2"-13 Thread Size	8
15	21.2261_2 QUARTER-20 SQUARE NUT POS FXG	1/4-20 Square Nut With Position Fixing	8
16	92196A540 0.25-20 Length 0.75in	18-8 Stainless Steel Socket Head Screw, 1/4"-20 Thread Size, 3/4" Long	8

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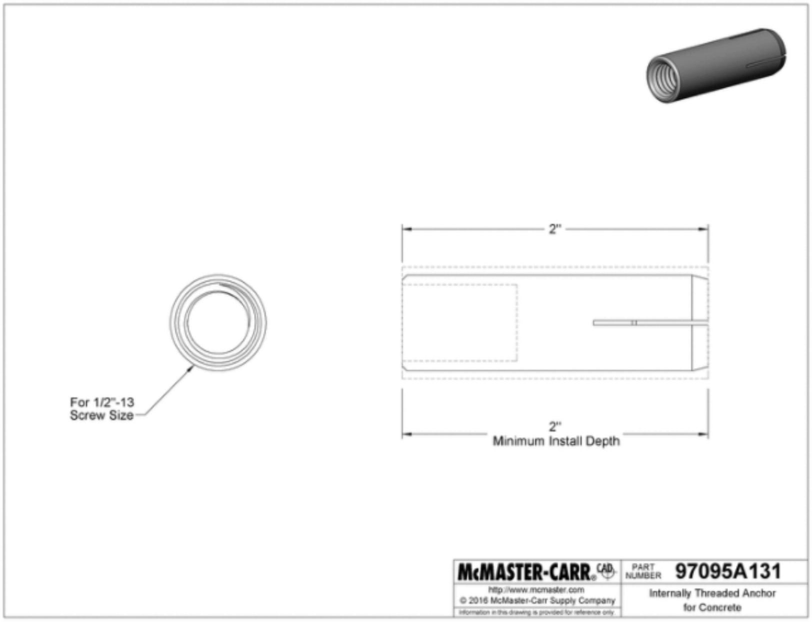
8291 Patuxent Range Rd
Jessup, MD 20794
Phone: (301) 658-3570
Email: contact@aerolab.com
Website: www.aerolab.com

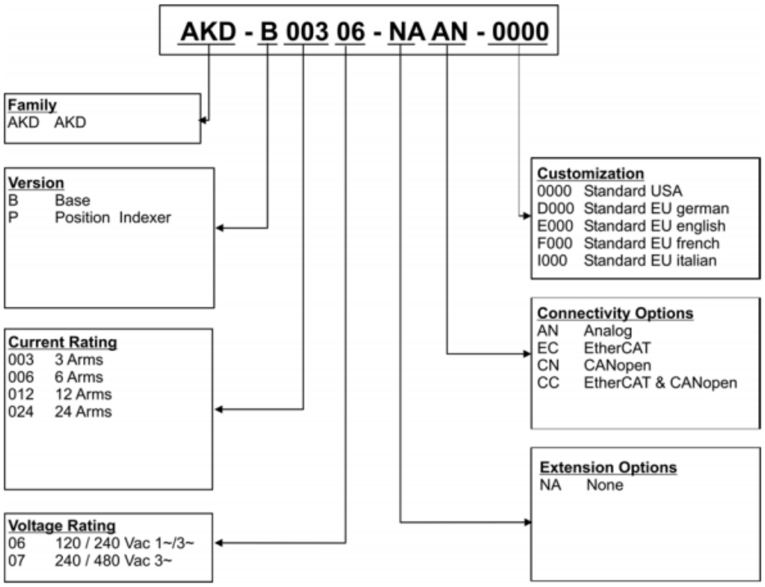

2"
For 1/2"-13
Screw Size
2"
Minimum Install Depth
McMASTER-CARR
PART NUMBER 97095A131
http://www.mcmaster.com
© 2016 McMaster-Carr Supply Company
Internally Threaded Anchor
for Concrete

Appendix H: Kollmorgen AKD Brushless Servo Drive Information

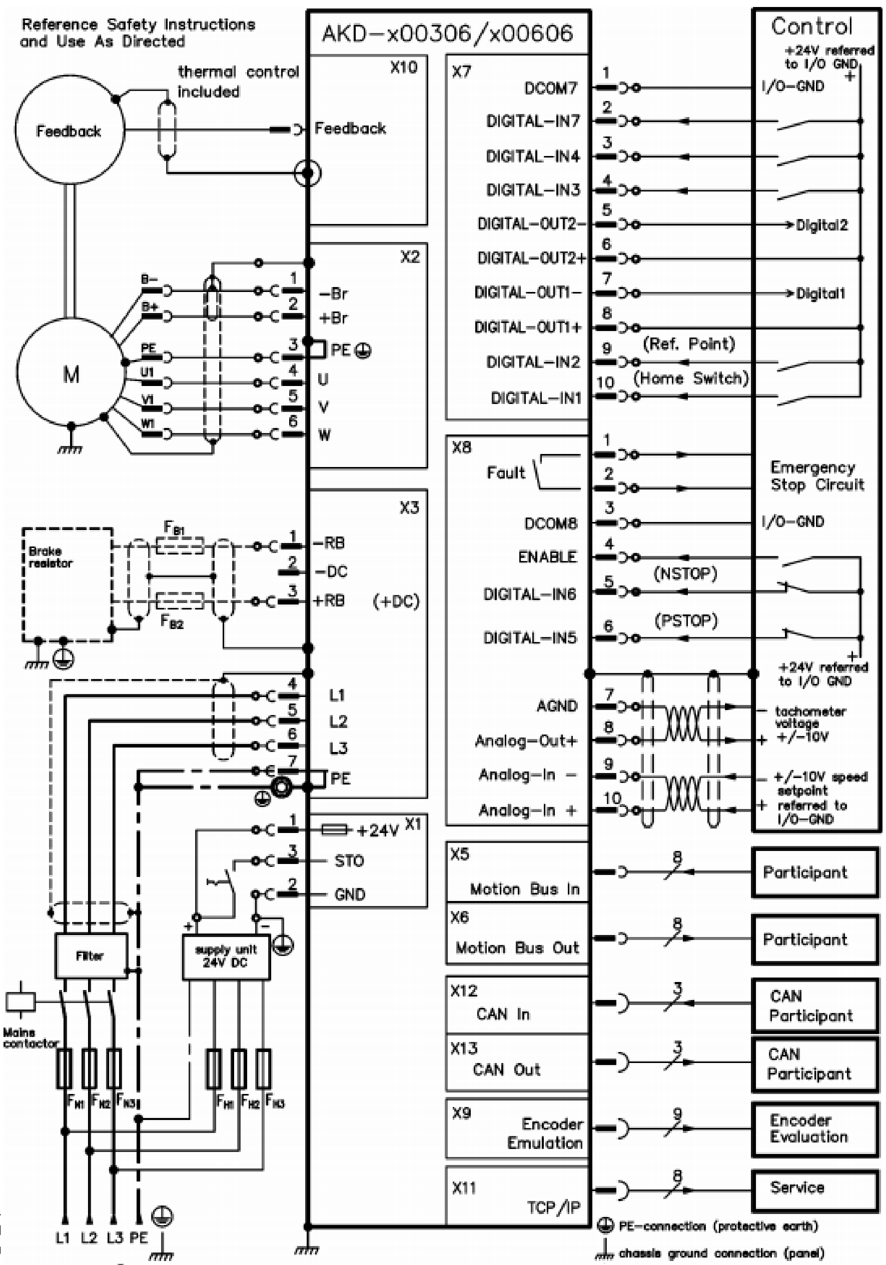

KOLLMORGEN
AKD
X1
X2
X3
X5
X6
X9
X10

AKD drive models are available in a variety of combinations of features. The part number identifies the features included in your model.

The figure below shows part number identification for drive features:

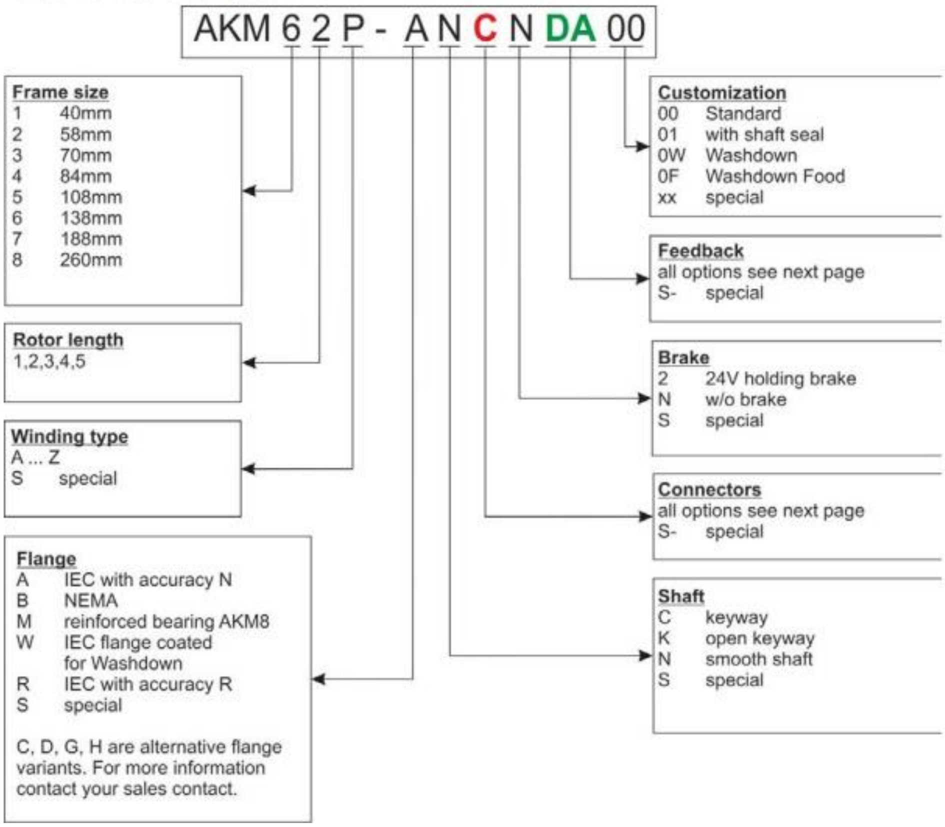


19.6 Connection Diagram, AKD-x00306 to x00606



Appendix G: Kollmorgen AKM Brushless Servo Information

1.3.3 Model number description



Trouble Shooting

The following table is to be seen as a “First Aid” box. There can be a large number of different reasons for a fault, depending on the particular conditions in your system. The fault causes described below are mostly those which directly influence the motor. Peculiarities which show up in the control loop behaviour can usually be traced back to an error in the parameterization of the servo amplifier. The documentation for the servo amplifier and the setup software provides information on these matters.

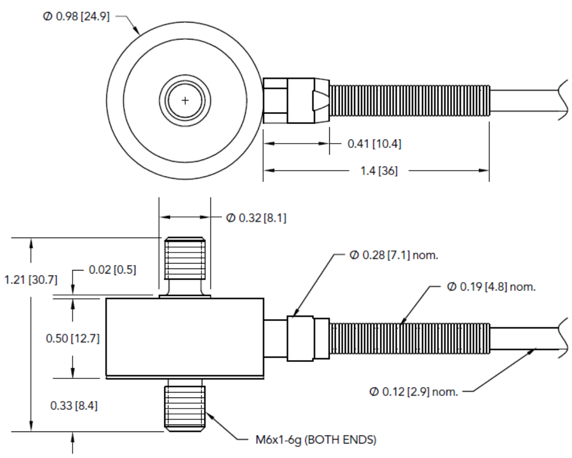
For multi-axis systems there may be further hidden reasons for faults.

Fault	Possible cause	Measures to remove the cause of the fault
Motor doesn't rotate	— Servo-amplifier not enabled — Break in setpoint lead — Motor phases in wrong sequence — Brake not released — Drive is mechanically blocked	— Supply ENABLE signal — Check setpoint lead — Correct the phase sequence — Check brake controls — Check mechanism
Motor runs away	— Motor phases in wrong sequence	— Correct the phase sequence
Motor oscillates	— Break in the shielding of the resolver cable — amplifier gain to high	— Replace resolver cable — use motor default values
Error message: brake	— Short-circuit in the supply voltage lead to the motor holding brake — Faulty motor holding brake	— Remove the short-circuit — Replace motor
Error message: output stage fault	— Motor cable has short-circuit or earth short — Motor has short-circuit or earth short	— Replace cable — Replace motor
Error message: resolver	— Resolver connector is not properly plugged in — Break in resolver cable, cable crushed or similar	— Check connector — Check cables
Error message: motor temperature	— Motor thermosensor has switched — Loose resolver connector or break in resolver cable	— Wait until the motor has cooled down. Then investigate why the motor becomes so hot. — Check connector, replace resolver cable if necessary
Brake does not grip	— Required holding torque too high — Brake faulty — Motor shaft axially overloaded	— Check the dimensioning — Replace motor — Check the axial load, reduce it. Replace motor, since the bearings have been damaged

Appendix J: LCM 300 Load Cells Dimensions and Wiring Colors

Model LCM300

DIMENSIONS inches [mm]



WIRING CODE (WC1)	
RED	+ EXCITATION
BLACK	– EXCITATION
GREEN	+ SIGNAL
WHITE	– SIGNAL
SHIELD	FLOATING

CAPACITIES

ITEM #	lb	N	Natural Frequency (kHz)
FSH03884	50	223	7.5
FSH03885	100	445	10.2
FSH03886	250	1112	16.2
FSH03887	500	2224	22.9
FSH03888	1000	4448	30.1

2. Warranty & Contact Information

(a) Equipment and Services Warranty. Aerolab warrants that Equipment (excluding Software, which is warranted as specified in paragraph (d) below) shall be delivered free of defects in material and workmanship and that Services shall be free of defects in workmanship. The Warranty Remedy Period for Equipment (excluding Software, Spare Parts and Refurbished or Repaired Parts) shall end twelve (12) months after installation or eighteen (18) months after date of shipment, whichever first occurs. The Warranty Remedy Period for new spare parts shall end twelve (12) months after date of shipment. The Warranty Remedy Period for refurbished or repaired parts shall end ninety (90) days after date of shipment. The Warranty Remedy Period for Services shall end ninety (90) days after the date of completion of Services.

(b) Equipment and Services Remedy. If a nonconformity to the foregoing warranty is discovered in the Equipment or Services during the applicable Warranty Remedy Period, as specified above, under normal and proper use and provided the Equipment has been properly stored, installed, operated and maintained and written notice of such nonconformity is provided to Aerolab promptly after such discovery and within the applicable Warranty Remedy Period, Aerolab shall, at its option, either (i) repair or replace the nonconforming portion of the Equipment or re-perform the nonconforming Services or (ii) refund the portion of the price applicable to the nonconforming portion of Equipment or Services. If any portion of the Equipment or Services so repaired, replaced or re-performed fails to conform to the foregoing warranty, and written notice of such nonconformity is provided to Aerolab promptly after discovery and within the original Warranty Remedy Period applicable to such Equipment or Services or 30 days from completion of such repair, replacement or re-performance, whichever is later, Aerolab will repair or replace such nonconforming Equipment or re-perform the nonconforming Services. The original Warranty Remedy Period shall not otherwise be extended.

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(ii) has been subjected to misuse, negligence or accident; (iii) has been used in a manner contrary to Aerolab's instructions; (iv) is comprised of materials provided by or a design specified by Purchaser; or (v) has failed as a result of ordinary wear and tear. Equipment supplied by Aerolab but manufactured by others is warranted only to the extent of the manufacturer's warranty, and only the remedies, if any, provided by the manufacturer will be allowed.

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3. References

- Barlow, J.B., Rae, W.H. Jr. and Pope, A. (1999) Low-Speed Wind Tunnel Testing, 3rd edn, John Wiley and Sons, New York

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