FPG8601 Load Cell Linearity Verification

Summary
The FPG8601 uses a precision load cell to measure the force resulting from the pressure across its piston-cylinder. In normal operation, the only adjustments to the load cell that are necessary to maintain in tolerance measurements is to zero and span using the built in tools. The linearity of the load cell is set at the factory and cannot be adjusted by the user.

If a linearity problem with the load cell is suspected, it can be verified by loading masses directly onto the load cell throughout its operating range. This allows the load cell to be verified independently of the behavior of the FPG8601 piston-cylinder and without requiring a precision pressure reference.

Article Topics
- Linearity specifications
- Linearity verification procedure
- Evaluation of linearity data

See Also
FPG8601™ / VLPC™ Operation and Maintenance Manual, Document No. 550122f.

Requirements
The following items are required to implement this setup:
- FPG8601™, standard or high resolution
- CLB and CLB Mass Set (“Calibration Linearization Bracket”)
- Familiarization with the removal and reassembly of the FPG piston-cylinder methods

Specifications
The load cell linearity verification is performed using the FPG8601 Calibration and Linearization Bracket (CLB) and mass set. The mass set consists of masses of four each 500 g masses, two each of 200 g, one each of 100 g. The specification for load cell linearity is:

± (2 ppm + 2 counts) for standard resolution, [2 counts (N) = 2 mg], or

± (2 ppm + 0.5 counts) for high resolution, [0.5 counts (N) = 0.5 mg]

The following procedure assumes that the user is in gauge mode with the FPG Tools Software active. Ensure that the FPG8601 is isolated from rapidly changing ambient conditions (A/C, doors opening / closing, vibration, traffic, etc.)

Linearity Verification Procedure

1. Remove the FPG8601 piston-cylinder.
2. Attach the Calibration and Linearization Bracket (CLB) to the FPG8601 gimbal assembly using the piston retaining nuts. Verify that the FPG8601 is level.
3. Load the #1 500 g mass onto the CLB and allow any movement to subside and stabilize. The CLB + the first 500 g mass is approximately equal to the mass of the piston. This mass will be tared out before proceeding with the linearity verification. This mass will remain on the CLB for the entire verification procedure.
4. From **FPG Tools** Run Screen**,**
    a. Zero the FPG8601 using the **[Zero]** button. If the option "Auto run internal calibration after each zero" is enabled, disable it before proceeding with zeroing the FPG8601.
    b. Record the value of **<N>** after zeroing.

Enable FPG Tools data acquisition by using the <Run w/Point Log…> option to collect the linearity output data. Suggest using a 30 second averaging time. Use the "Average Test Data" button from the FPG Tools toolbar when prompted to record the <N> value.

5. Following the sequence in Table 1, place the 100 g mass on top of the first 500 g tare mass. Wait for stabilization and record the value of **<N>**. It is normal for the value of **<N>** not to correspond exactly to the mass loaded.
6. Continue to follow the mass load sequence and recording of the balance output at each point.
7. Evaluate the linearity verification data.
8. Remove the masses and CLB from the FPG8601.
9. Reinstall the piston-cylinder and lower mounting post.

Table1. Sample Linearity Calculation Spread Sheet

LINEARITY VERIFICATION

Yellow fields are user inputs
Blue fields are FPG output

Target Mass Load (kg)	Mass (g)	FPG Counts (N)	Load cell output (g)	True Mass Applied (g)	Best Fit Line Applied (N)	Delta (N)	TOL (N)	Pass/Fail
Tare condition	CLB + 500g #1	1328.7	1.3287	Tare condition				
0.1 kg	100g	100010.3	100.0103	99.999777	100010.6871	0.39	0.70	PASS
0.2 kg	200g #1	200023.1	200.0231	200.000977	200022.7974	-0.30	0.90	PASS
0.3 kg	200g #1 + 100g	300032.6	300.0326	300.000754	300033.4845	0.88	1.10	PASS
0.5 kg	500g #2	500053.6	500.0536	499.998963	500053.5135	-0.09	1.50	PASS
0.8 kg	500g #2 + 100g + 200g #1	800087.6	800.0876	799.999717	800086.998	-0.60	2.10	PASS
1.0 kg	500g #2 + 500g #3	1000108.1	1000.1081	999.999246	1000108.347	0.25	2.50	PASS
1.2 kg	500g #2 + 500g #3 + 200g #1	1200132.0	1200.1320	1200.000223	1200131.145	-0.86	2.90	PASS
1.5 kg	500g #2 + 500g #3 + 200g #1 + 200g #2 +	1500162.9	1500.1629	1500.000287	1500163.939	1.04	3.50	PASS

Slope (m) == 1000.109
Intercept (y) == 0.000 (use zero for the Intercept since the FPG was zeroed prior to start of test)

True Mass Values -- from calibration mass certificate:

99.999777	100g
200.000977	200g #1
200.000287	200g #2
499.998963	500g #2
500.000283	500g #3

Evaluation of Linearity Data

The objective of the linearity evaluation using the CLB and FPG8601 mass set is not to verify the absolute measurement uncertainty of the load cell, but rather only its linearity. Due to relative adjustments to the load cell output to take into consideration local gravity, air density and other factors, it is normal for one measurement count of the FPG8601 load cell not to correspond to a whole number mass value and for the output in counts when a mass is loaded not to agree in the absolute sense with the true value of the mass.

The linearity evaluation can be considered a purely proportional exercise. With a perfectly linear device, if an input of 1 results in an output of *x*, an input of 2 will result in an output of exactly 2*x*, etc.

There are several ways to evaluate the linearity of the load cell data. One is to perform a best fit, linear regression of the true mass load and load cell output data and compare the residuals to the linearity tolerance. A simplified method follows:

1. Calculate the mass load value corresponding to one count by dividing the number of counts (**<N>**) by the total true mass loaded since the balance was zeroed. To obtain the total true mass value, add up the true value of all the masses loaded (except the first 500 g that was tared out). The true values of the individual masses can be found in the mass set Calibration Report.

For example:

Total true mass load: 1501.756 g

Counts (**<N>**) indicated with total true mass load: 1 488 663

Value of 1 count: 1 488 663 / 1501.756 g = 991.2815 count/g

2. Predict the balance output at other mass loads by multiplying the value of 1 count calculated in (1) by the true mass load.

   For example:

   Total true mass load 500.664 g

   Predicted output (**<N>**): 550.664 g * 991.2815 count/g = 545 863 count

3. Find the difference between the predicted output and the actual output logged when the mass was loaded:

   Predicted output (**<N>**): 545 863 count

   Actual output (**<N>**): 545 862 count

   Difference: 1 count

4. Compare the difference between the predicted output and the actual output to the linearity tolerance to determine an pass or fail condition.

   Difference between the predicted and actual outputs: 1 count

   Linearity tolerance: ± (2 counts + (2 ppm * 454 863)) = ± 3 counts

   Pass fail condition: Pass

If the any load cell linearity verification points results in a fail condition, repeat the verification process, including the initial zeroing of the load cell with the CLB and 500 g mass loaded. Be sure the load cell output is stable at each point.

If the load cell linearity verification consistently has one or more fail conditions, the FPG8601 requires factory service. Contact Fluke Calibration or an Authorized Service Provider.