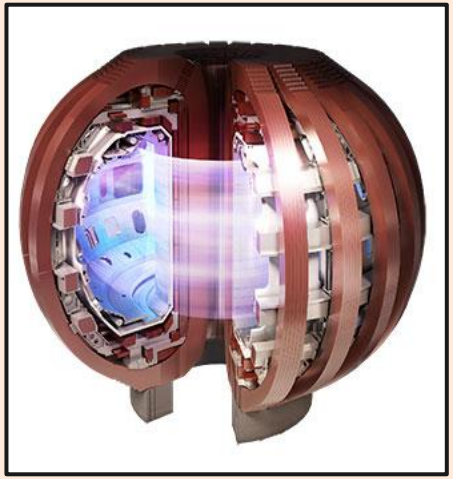
Equipment Testing Report

Eagle Harbor Tech ISP-16 Prototype Integrator



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June 12, 2024

Introduction

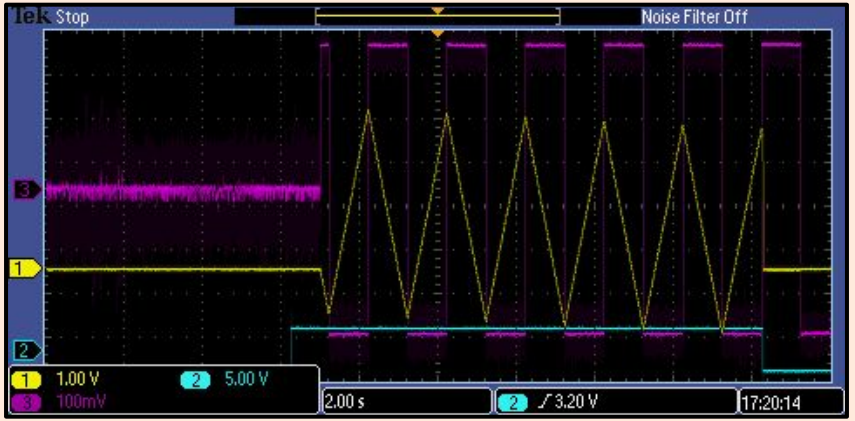
Integrator Testing Overview

- RC time is 33 us, factory set for all channels
- Integration output found over a 10 second intervals
  - Integration started 1 second after enable started to minimize initial drift
- Tests completed on a range of input/output channels
  - No discernible difference between channel results
- Plots are smoothed over every 0.16 seconds (100 data points)
  - R^2 values and linear fits calculated
  - RMS noise calculated with the difference between the smoothed and unsmoothed data

$$N_{rms} = \sqrt{\frac{\sum_i^n (S_i - \overline{S})^2}{n}}$$

Units

$$V_{OUT} = \frac{1}{RC}\int_0^T V(t)dt$$



Example: Test 2

- Oscilloscope input (V) is in purple
- Integrator output (V) is in yellow

Drift vs. Figure of Merit

Drift (D):

- D = [Output (V)] / [T (s)]
- Units: V/s

Figure of merit (F):

- F = D (V/s) * RC (s) = [True integration (V-s)] / [T (s)]
- Units: V-s/s → Rate of change of the true integration

Drift is used as the primary measure of integrator accuracy in these slides

Advertised Drift and Figure of Merit

The advertised F is ~4.50E-8 V-s/s, and D is ~1.49 mV/s

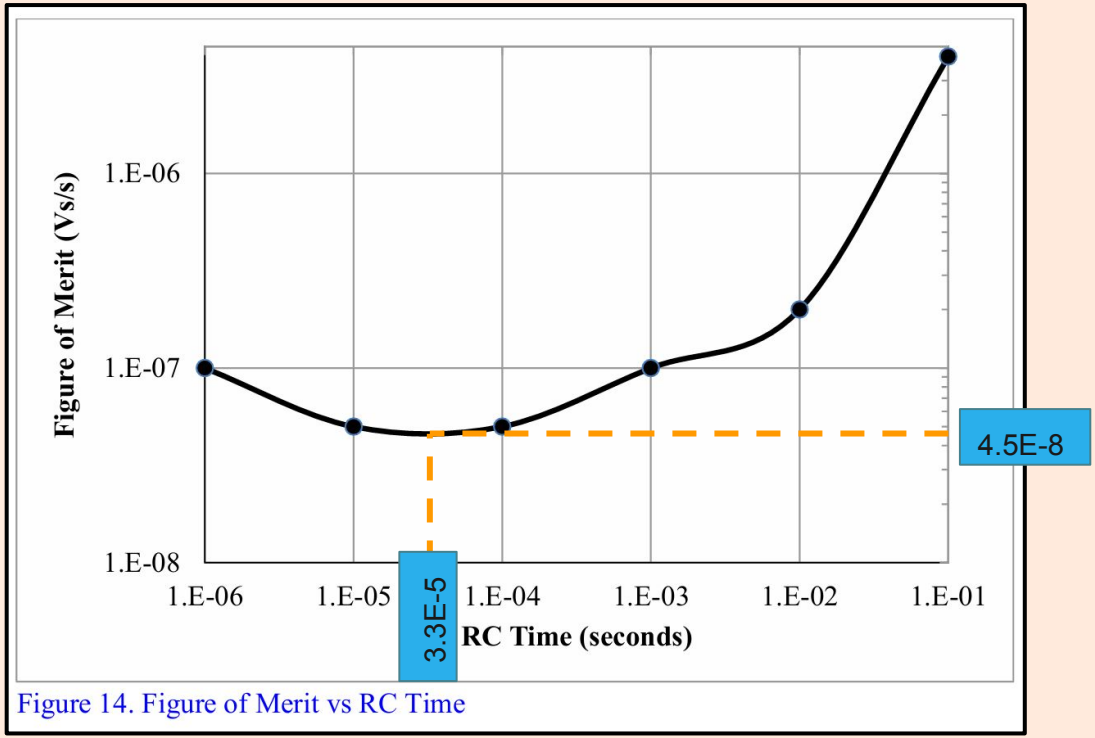


Figure 14. Figure of Merit vs RC Time

ISP16-Users-Manual-33us-10JUN2016.pdf (eagleharbortech.com)

Testing Outline

Test 1

Shorted integration

- ❏ Details
- ❏ Setup
- ❏ Graphs and data

Test 2

Square wave integration

- ❏ Details
- ❏ Setup
- ❏ Graphs and data

Test 3

AC integration

- ❏ Details
- ❏ Setup
- ❏ Graphs and data

Drift Comparisons

- ❏ Drift and Figure of Merit
- ❏ Example Waveforms

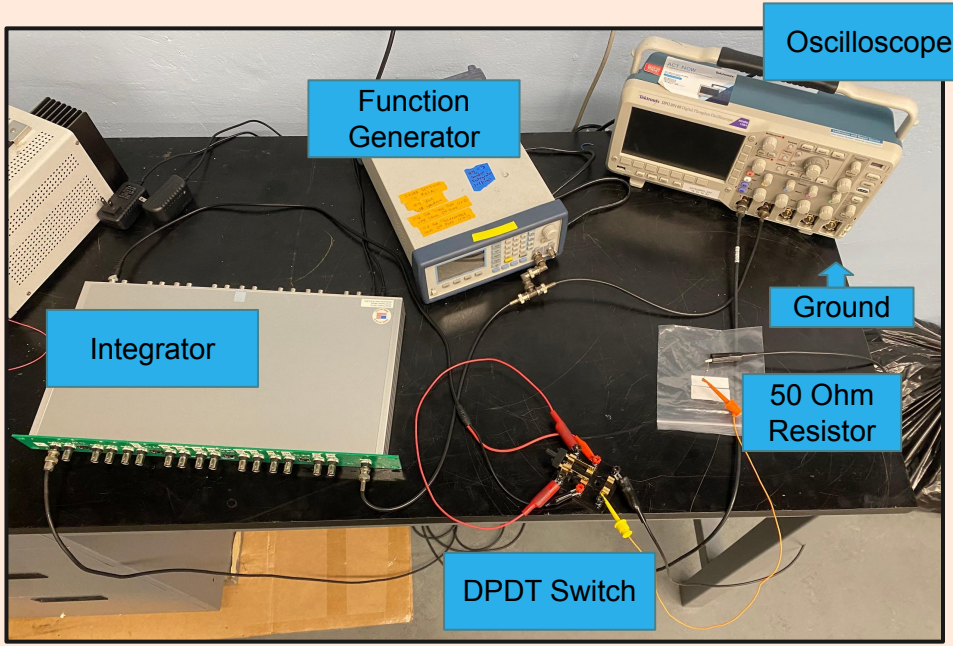
Test 1

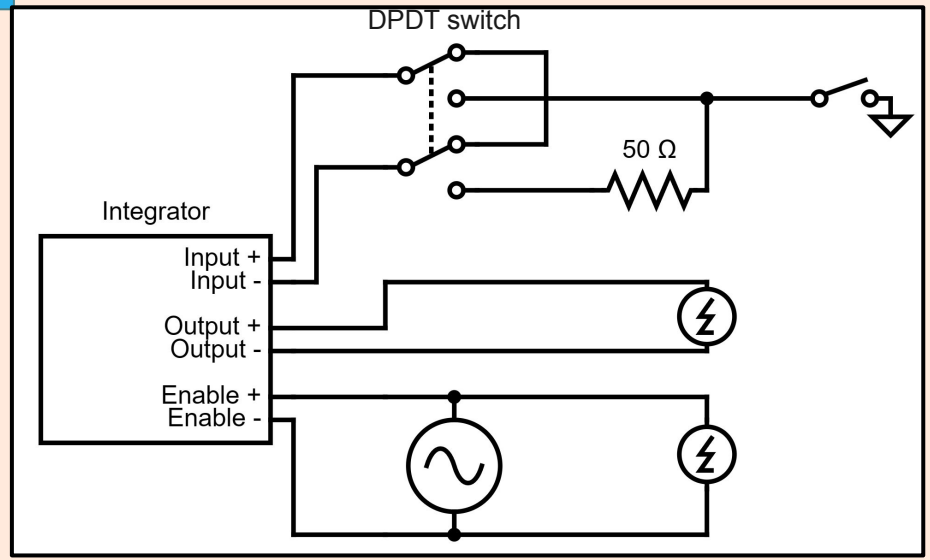
Shorted Circuit

Test 1 Overview

- Test 1 consisted of 6 subtests, all with a shorted integrator input through a:
  - Wire
  - Grounded wire
  - 50 Ohm resistor
  - Grounded 50 Ohm resistor
  - Switching halfway from wire to resistor
  - Switching halfway from resistor to wire
- Grounding was done on the oscilloscope
- First 4 subtests:
  - Measured mean and worst value for abs drift, R^2, and RMS noise.
- Switched subtests
  - Measured mean and worst value for abs drift before, and after test

Test 1 Setup


Oscilloscope
Function Generator
Integrator
Ground
50 Ohm Resistor
DPDT Switch

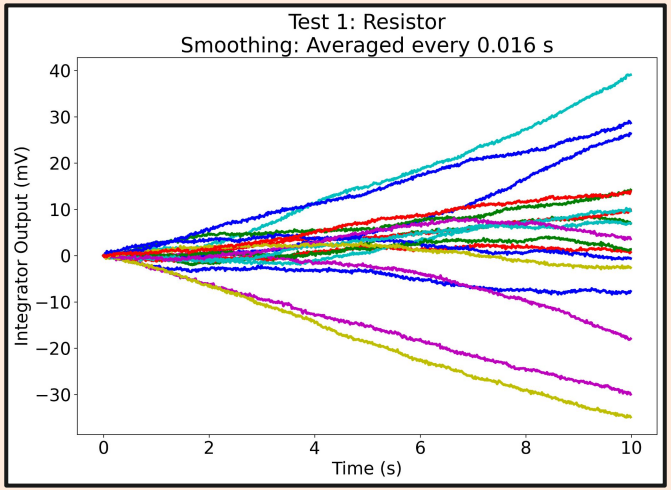

DPDT switch
50 Ω
Integrator
Input +
Input -
Output +
Output -
Enable +
Enable -

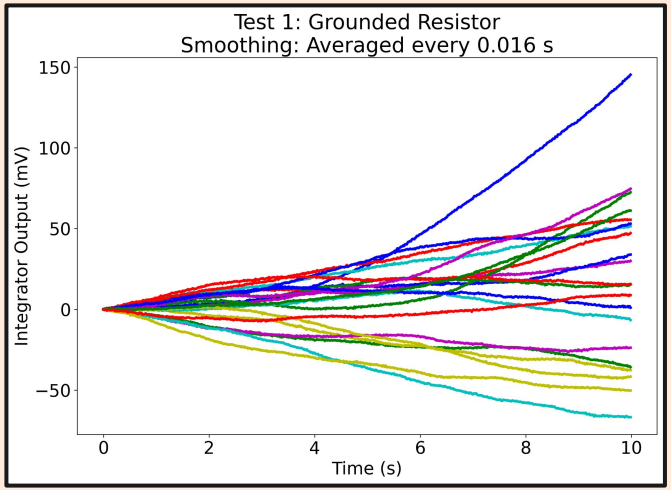
Test 1 Data

Not Grounded

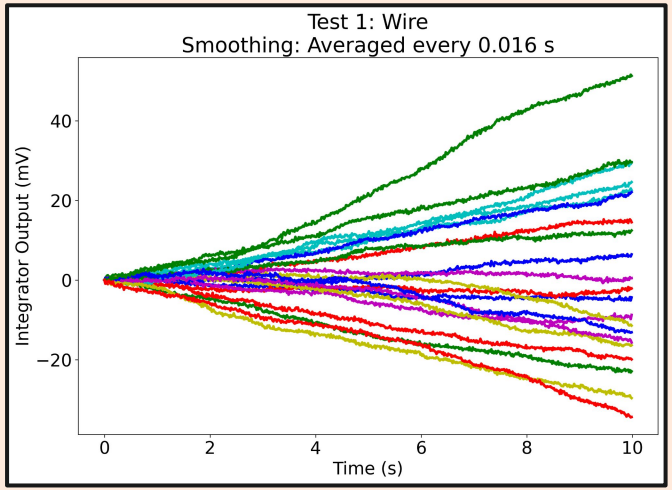
Grounded

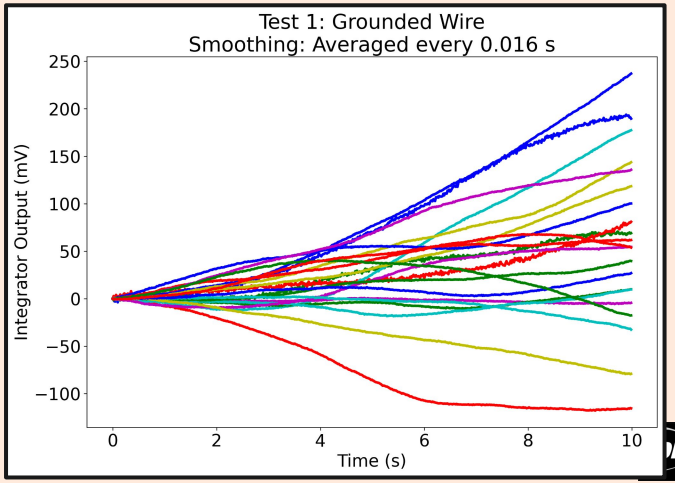
Resistor





Wire



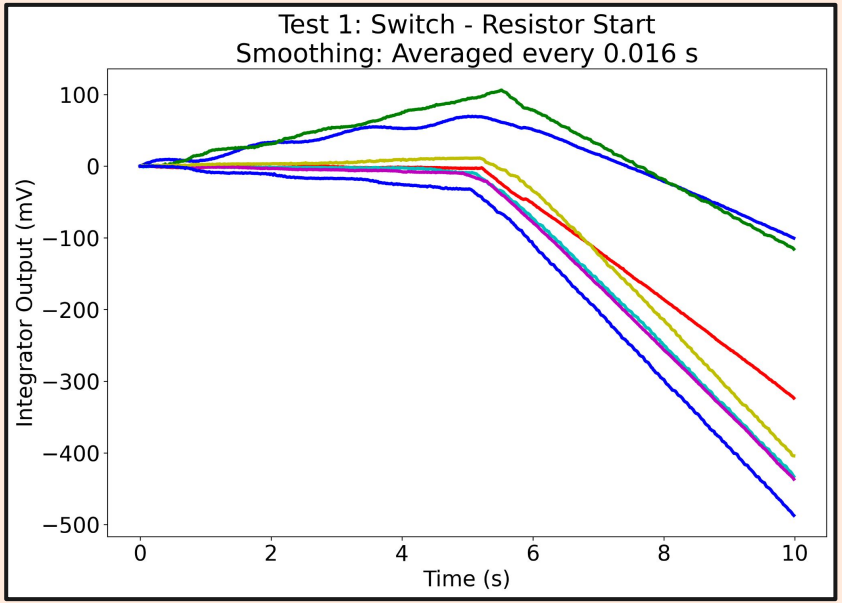


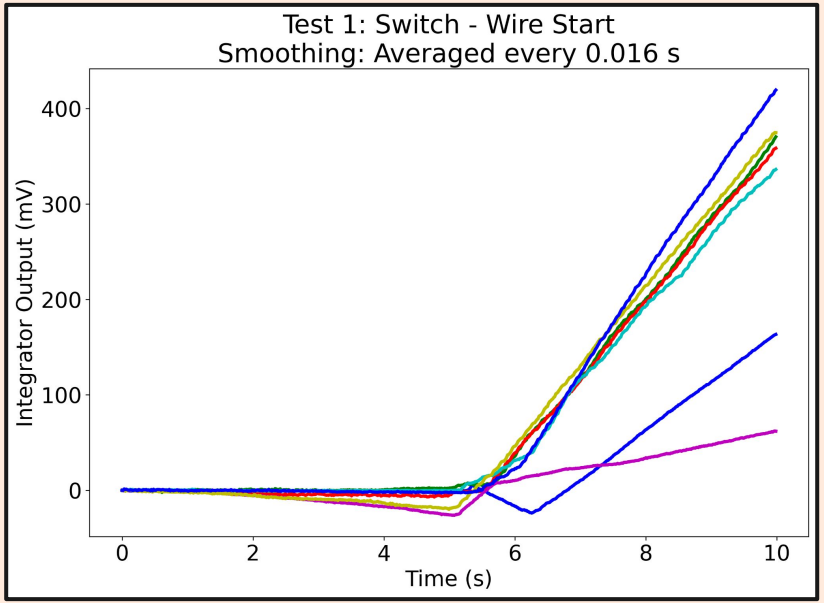
Test 1 Data

Trials	21	21	21	21	
Test 1 RC time: 33 us	Wire	Grounded Wire	50 Ohm Resistor	Grounded 50 Ohm Resistor	Advertised
Mean Abs Drift (mV/s)	1.96	8.24	1.34	4.45	1.49
Worst Abs Drift (mV/s)	4.97	23.79	3.97	14.48	
Mean R^2	0.874	0.758	0.836	0.776	
Worst R^2	0.0613	0.0323	0.426	0.000324	
Mean RMS noise (mV)	28.15	46.06	8.27	28.82	
Worst RMS noise (mV)	28.73	141.82	9.39	33.64	

Comparisons of F and Drift for all tests here

Test 1 Switch Data





Test 1 Switch Data

Trials	7	7	
Test 1 (Switch) RC time: 33 us	Resistor to wire	Wire to resistor	Advertised
Before switch			
Mean Abs Drift (mV/s)	6.58	1.63	1.49
Worst Abs Drift (mV/s)	18.75	5.14	
After Switch			
Mean Abs Drift (mV/s)	68.89	60.95	1.49
Worst Abs Drift (mV/s)	93.69	84.47	

Test 2

Square Wave Input

Test 2 Overview

0.5 Hz square wave integration:

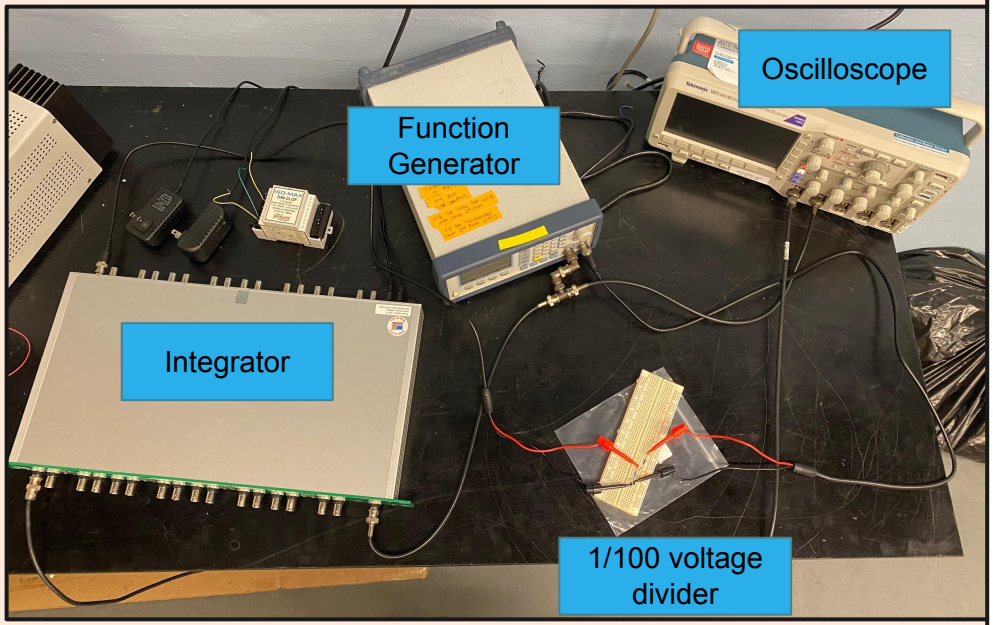
- Voltage divider brought voltage down by a factor of 100, and another factor of 21 due to the termination resistance according to this equation: $(R_s + R_T)/R_T = (1000 + 50)/50 = 21$
- Three different variations were performed:
  - 1.6E-5 V, with an output amplitude ~0.5 V
  - 1.6E-4 V, with an output amplitude ~5 V
  - 3.1E-4 V, with an output amplitude ~10 V
- For these tests the integrator was enabled 1 second before the input signal was started. A DPDT switch proved unreliable
- A minor offset in the function generator was accounted for in the output data by subtracting the integration of the mean of the input

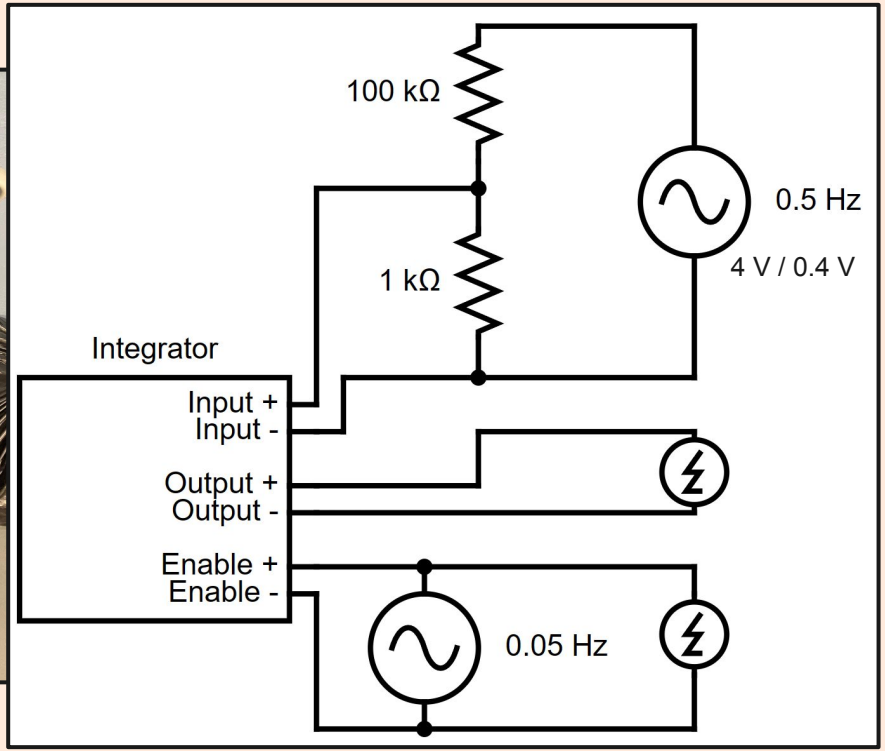
Test 2 Overview

For each subtest, a linear fit was performed on the peaks and troughs of the output. Also recorded was:

- The average and worst mean abs drift of linear fits, and R^2 values
- Mean abs drift of peaks minus mean abs drift of trough
- Average quadratic fit to linear fit ratio for full-amplitude segment
- Output to input full-amplitude ratio
- Clipping occurred past +-10 V outputs.
- Linear fits were also plotted on a separate graph, and were adjusted to start at 0,0.

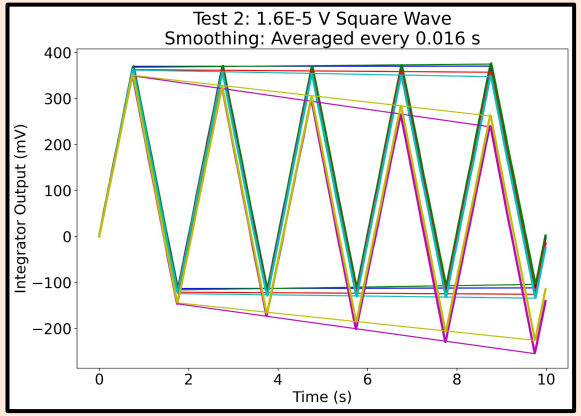
Test 2 Setup

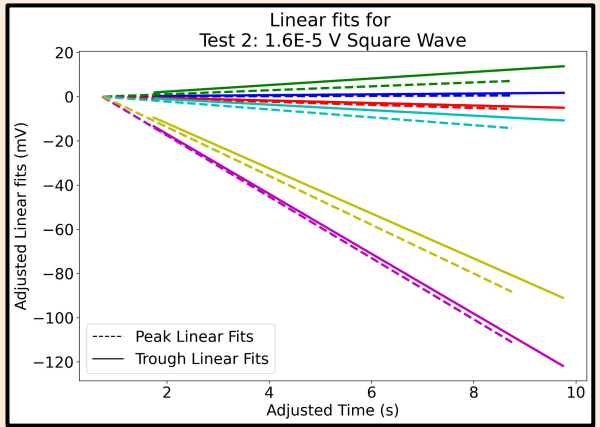

Oscilloscope
Function Generator
Integrator
1/100 voltage divider


100 kΩ
1 kΩ
0.5 Hz
4 V / 0.4 V
Integrator
Input +
Input -
Output +
Output -
Enable +
Enable -
0.05 Hz

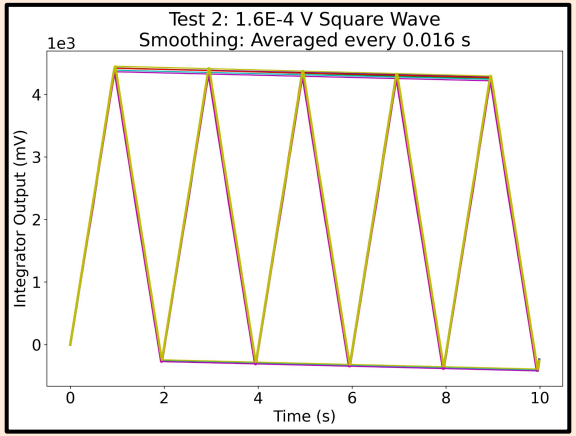
Test 2 Data: Input offset accounted for

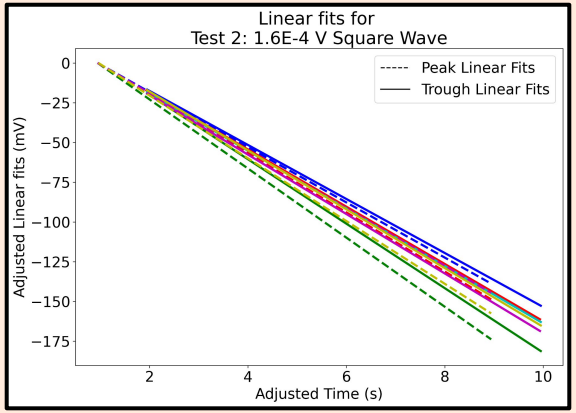
1.6E-5 V input: 0.5 V Amplitude



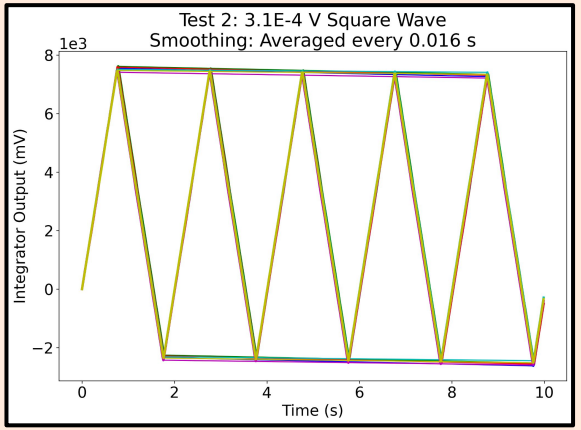


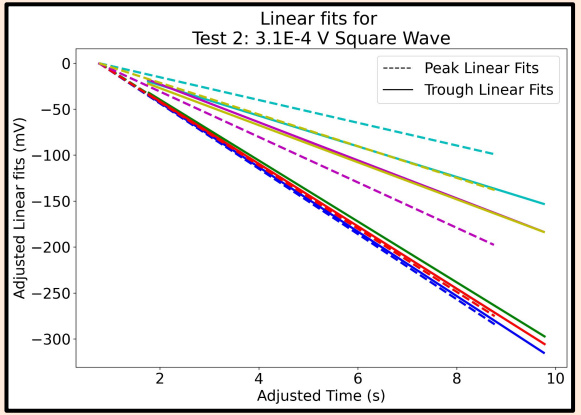
1.6E-4 V input: 5 V Amplitude





3.1E-4 V input: 10 V Amplitude

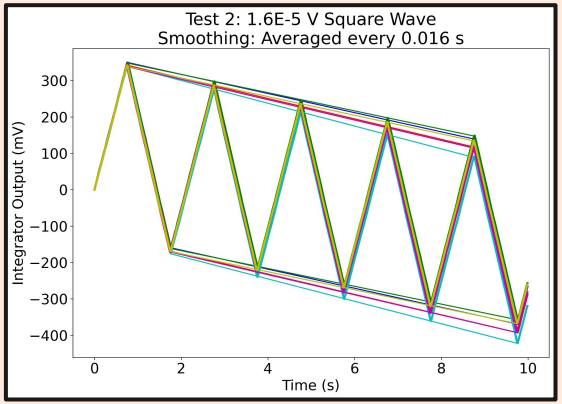


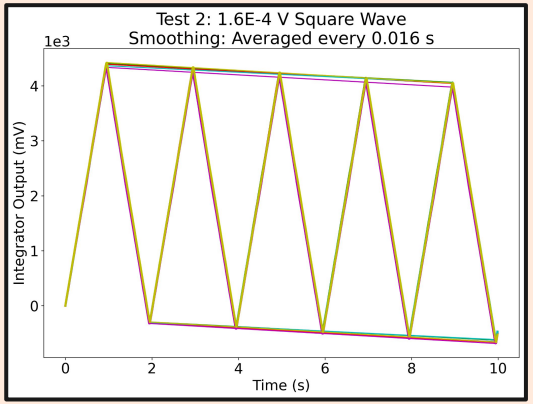


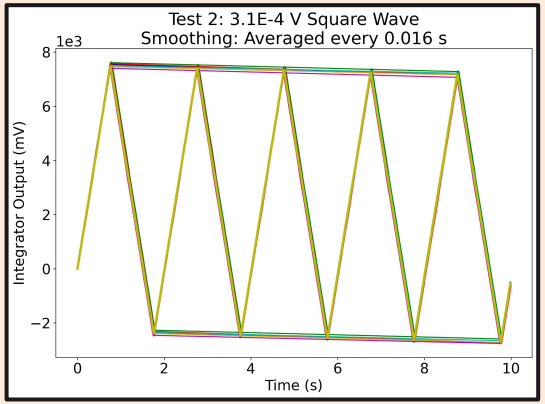
Test 2 Data

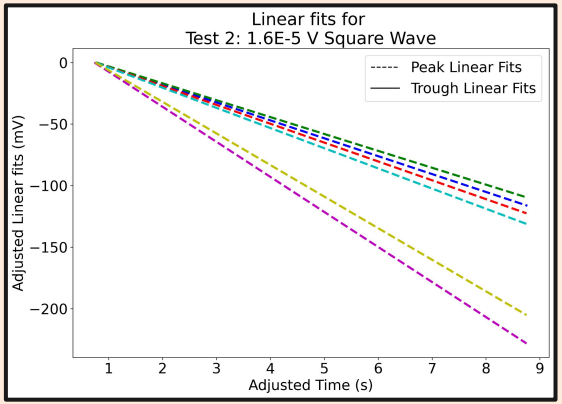
Trials	6	6	6	
Test 2 RC time: 33 us	1.6E-5 V, 0.5 Hz input	1.6E-4 V, 0.5 Hz input	3.1E-4 V, 0.5 Hz input	Advertised
Mean Abs Drift (mV/s)	3.97	16.21	22.45	1.49
Worst Abs Drift (mV/s)	13.58	21.21	35.45	
Mean abs drift peak/trough difference (mV/s)	1.68	5.00	7.03	
Worst F peak/trough dif (mV/s)	3.97	5.82	11.18	
Mean R^2	0.726	0.996	0.994	
Worst R^2	0.0421	0.994	0.99	
Mean Q/L R2 ratio	1.00E+00	1.00E+00	1.00E+00	
Out/In Peak-to-Peak ratio	1.012	0.976	1.032	

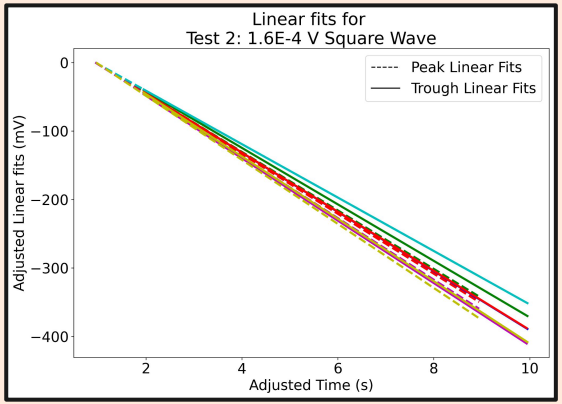
Test 2 Data: Prior to offset adjustment

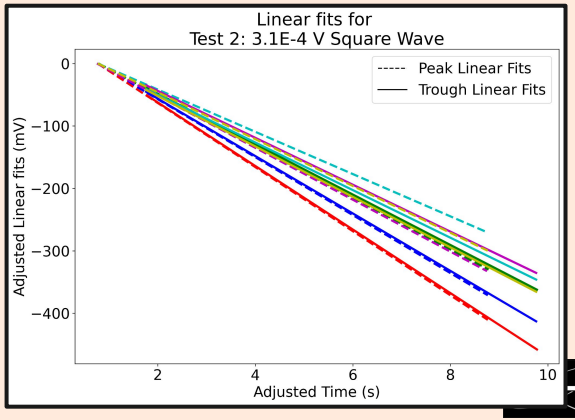












Test 3

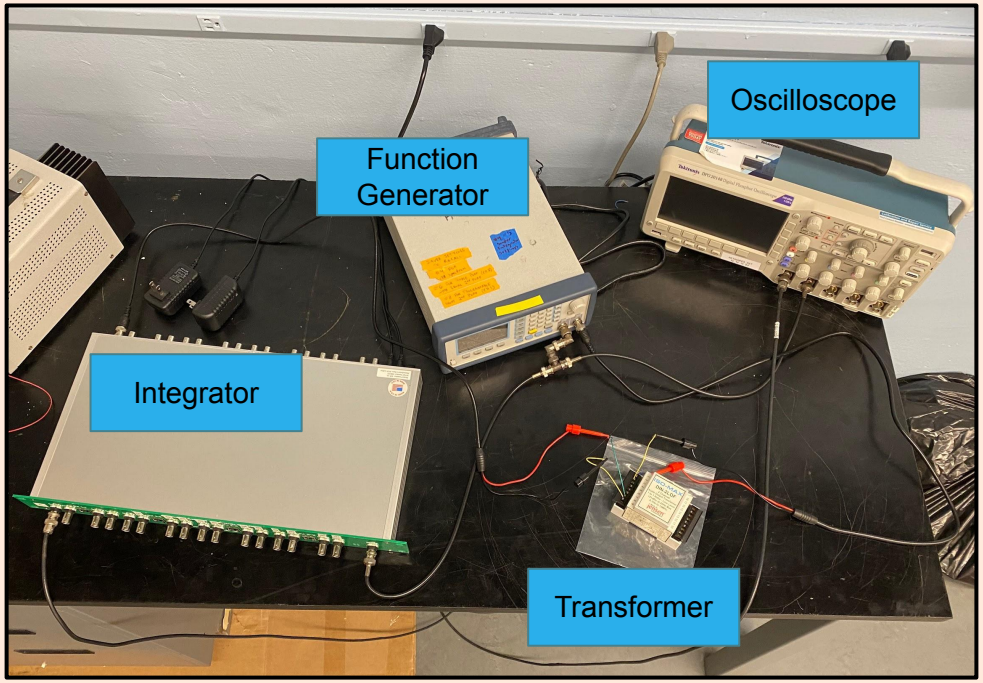
AC current

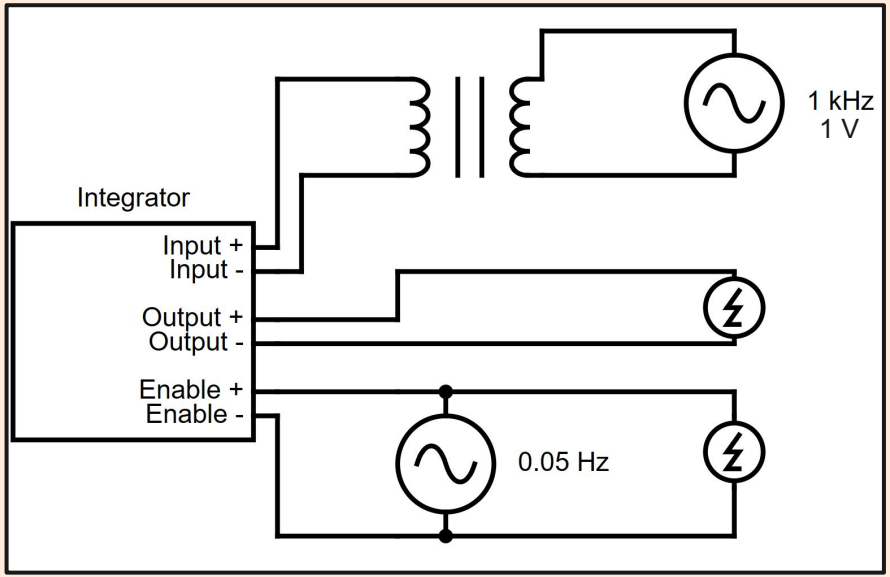
Test 3 Overview

Checked quality of integration of a higher-frequency signal.

- Input signals were ran through a transformer to minimize DC offset.
- The input signals are depicted as starting at t = 0 on the graphs
- A 1 kHz and 5 kHz sine wave signal was used.
- Conducted 10 trials and measured the mean abs drift and R^2 value for each.
- Measurements were done from t = 1 to t = 10 to account for any transient during the first second of integration.

Test 3 Setup

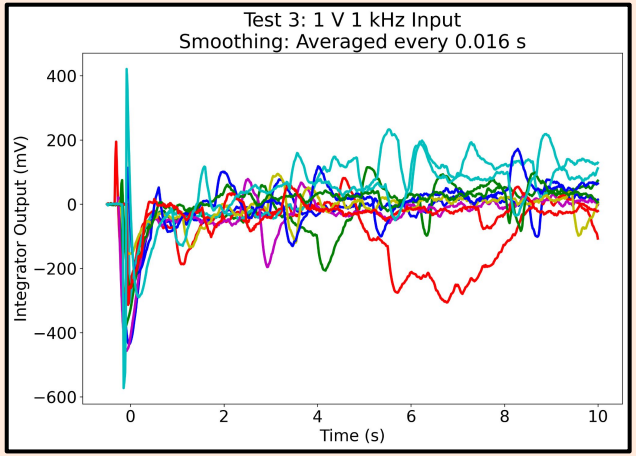

Oscilloscope
Function Generator
Integrator
Transformer

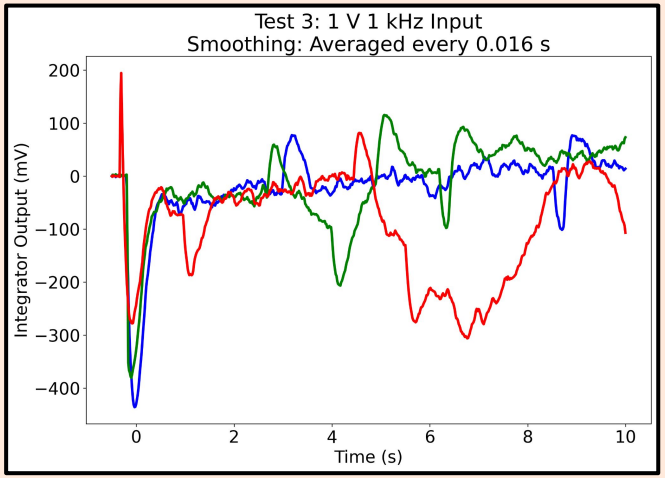

1 kHz
1 V
Integrator
Input +
Input -
Output +
Output -
Enable +
Enable -
0.05 Hz

Test 3 Data

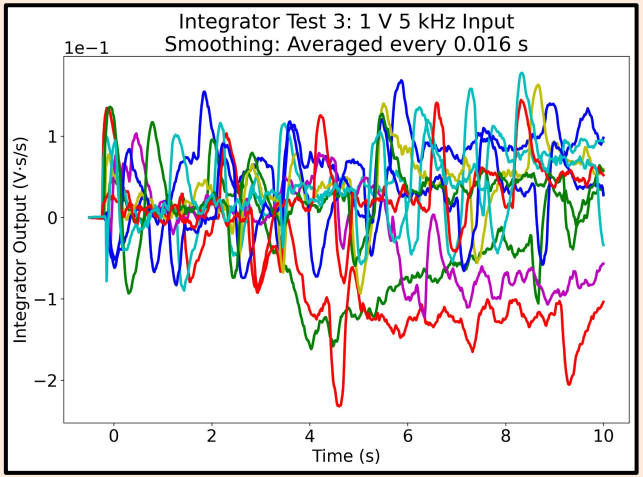
(A few trials picked out)

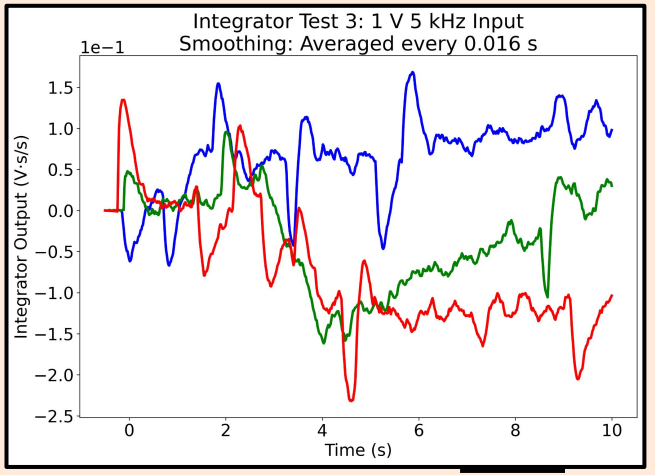
1 kHz Trials





5 kHz Trials





Test 3 Data

Trials	10	10	
Test 3 RC time: 33 us	1 V 1 kHz	1 V 5 kHz	Advertised
Mean Abs Drift (mV/s)	26.33	6.73	1.49
Worst Abs Drift (mV/s)	51.21	16.91	
Mean R^2	0.278	0.266	
Worst R^2	0.0154	0.0362	

Drift Comparisons & Example Waveforms

Drift Comparisons:
EHT advertised = ~1.49 mV/s

Test 1 RC time: 33 us	Wire	Grounded Wire	50 Ohm Resistor	Grounded 50 Ohm Resistor
Mean Abs Drift (mV/s)	1.96	8.24	1.34	4.45
Worst Abs Drift (mV/s)	4.97	23.79	3.97	14.48

Test 2 RC time: 33 us	1.6E-5 V, 0.5 Hz input	1.6E-4 V, 0.5 Hz input	3.1E-4 V, 0.5 Hz input
Mean Abs Drift (mV/s)	3.97	16.21	22.45
Worst Abs Drift (mV/s)	13.58	21.21	35.45

Test 3 RC time: 33 us	1 V 1 kHz	1 V 5 kHz
Mean Abs Drift (mV/s)	26.33	6.73
Worst Abs Drift (mV/s)	51.21	16.91

Test 1 (Switch) RC time: 33 us	Resistor to wire	Wire to resistor
Before switch		
Mean Abs Drift (mV/s)	6.58	1.63
Worst Abs Drift (mV/s)	18.75	5.14
After Switch		
Mean Abs Drift (mV/s)	68.89	60.95
Worst Abs Drift (mV/s)	93.69	84.47

Figure of Merit Comparisons (Drift * RC):

EHT advertised = ~4.50E-8 V

Test 1 RC time: 33 us	Wire	Grounded Wire	50 Ohm Resistor	Grounded 50 Ohm Resistor
Mean F (V-s/s)	6.47E-08	2.72E-07	4.41E-08	1.47E-07
Worst F (V-s/s)	1.64E-07	7.85E-07	1.31E-07	4.78E-07

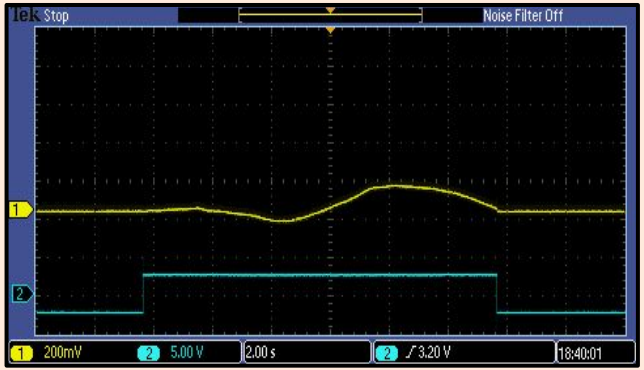
Test 2 RC time: 33 us	1.6E-5 V, 0.5 Hz input	1.6E-4 V, 0.5 Hz input	3.1E-4 V, 0.5 Hz input
Mean F (V-s/s)	1.31E-07	5.35E-07	7.41E-07
Worst F (V-s/s)	4.48E-07	7.00E-07	1.17E-06

Test 3 RC time: 33 us	1 V 1 kHz	1 V 5 kHz
Mean F (V-s/s)	8.69E-07	2.22E-07
Worst F (V-s/s)	1.69E-06	5.58E-07

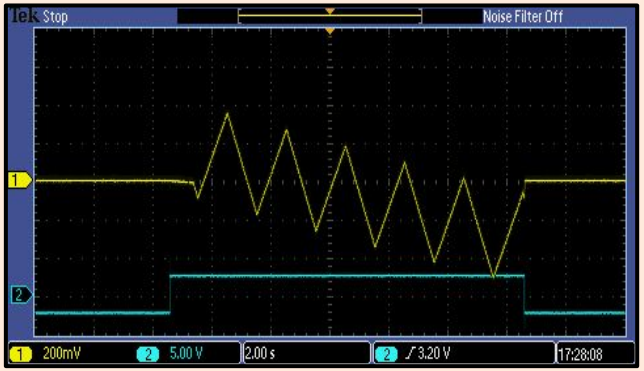
Test 1 (Switch) RC time: 33 us	Resistor to wire	Wire to resistor
Before switch		
Mean F (V-s/s)	2.17E-07	5.39E-08
Worst F (V-s/s)	6.19E-07	1.70E-07
After Switch		
Mean F (V-s/s)	2.27E-06	2.01E-06
Worst F (V-s/s)	3.09E-06	2.79E-06

Example Waveforms

Test 1: Wire



Test 2: 1.6E-5 V square wave



Test 3: 1 V 1 kHz sine wave