

Decomposition of Baseline Noise Sources in Hard Disk Position Error Signals Using the PES Pareto Method

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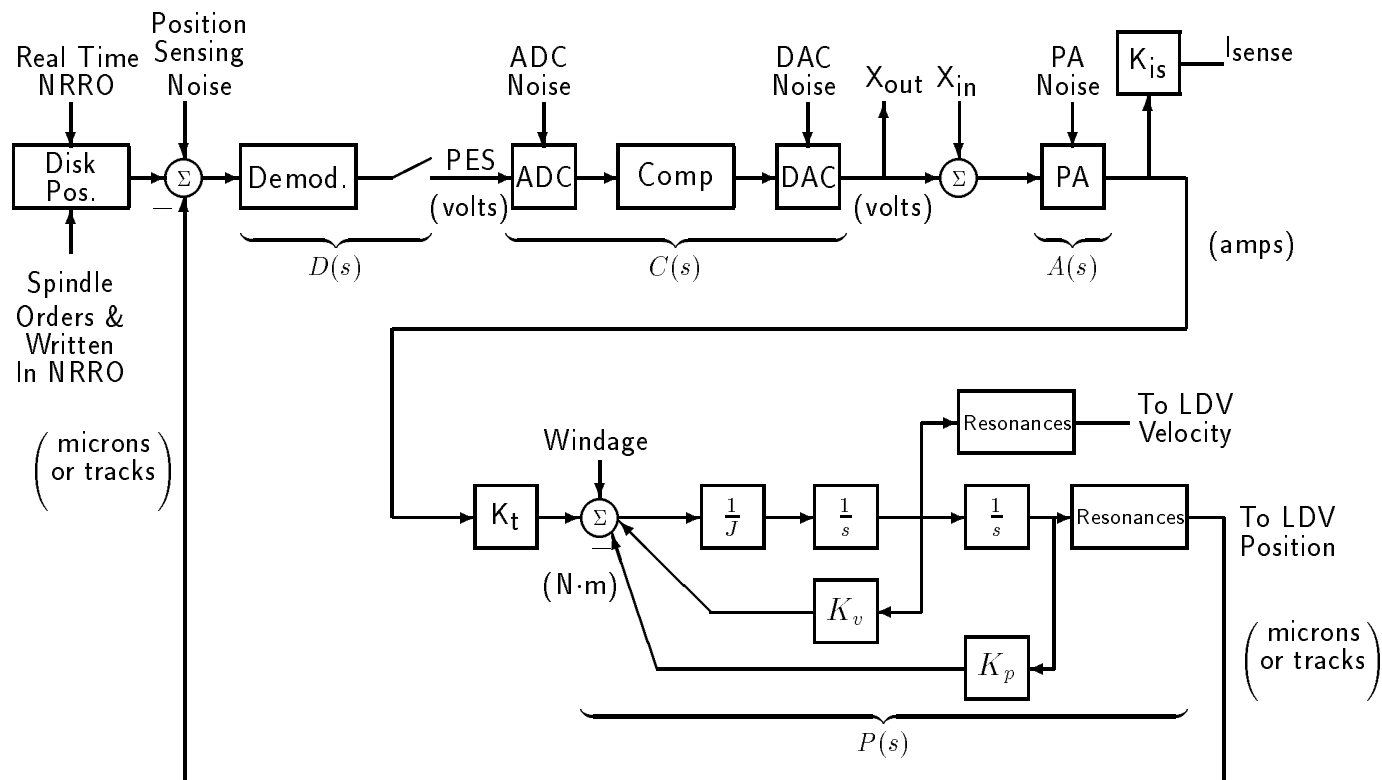
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Palo Alto, CA 94304*

June 6, 1997

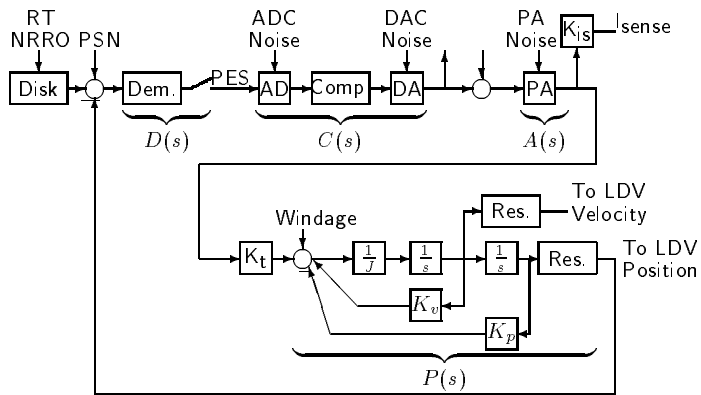
When you have eliminated the impossible, whatever remains, *however improbable* must be the truth. —
Sherlock Holmes

PES Pareto: Filtering Noise Sources Through the Loop to PES



- Isolate measurement of noise source ("common mode reject")
- Filter backwards for source PSD
- Filter forwards for effect on PES PSD
- Compare and add to cumulative

Power Amp Noise

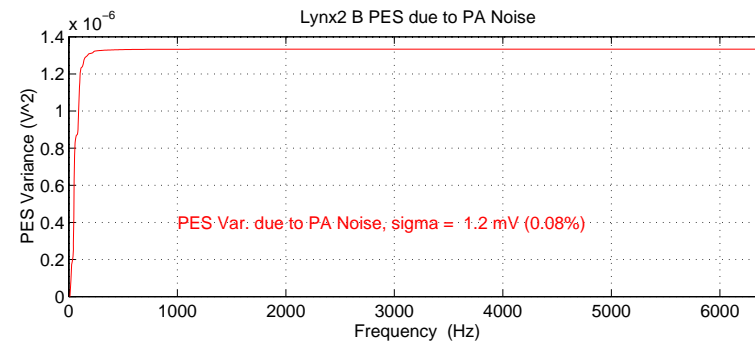
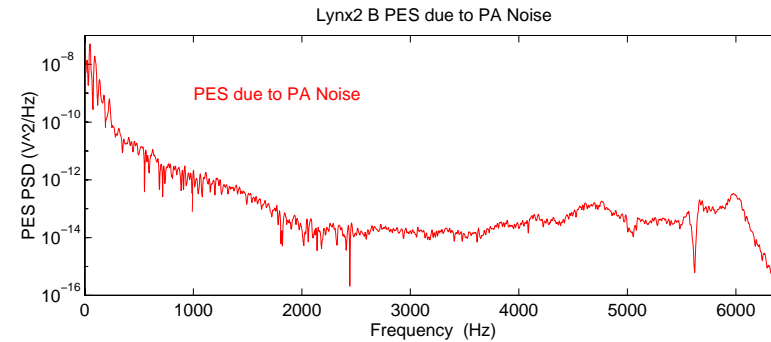
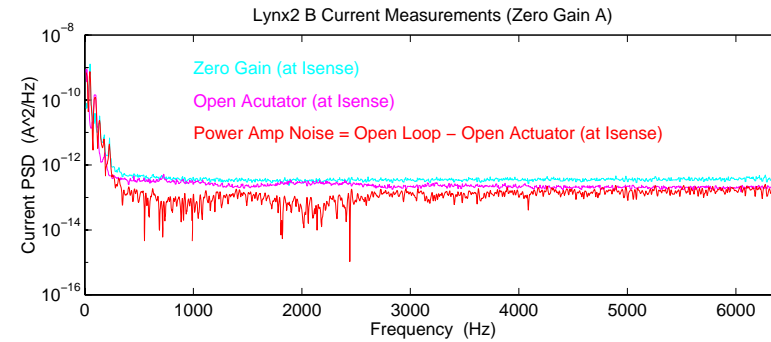


- Measured at I_{sense} .
- Back filter to source:

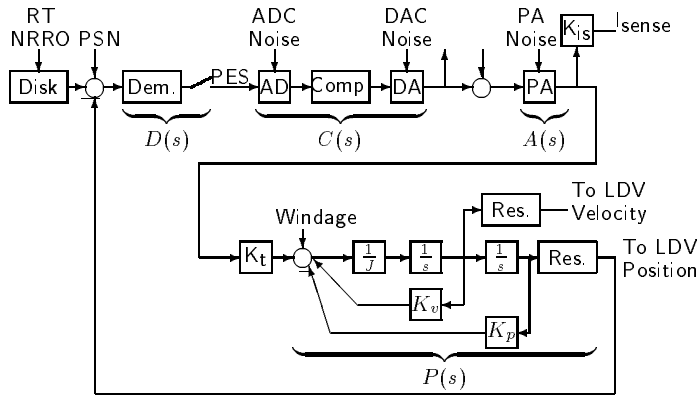
$$1$$

- Forward filter to PES:

$$\left\| \frac{K_t P(s) D(s)}{1 + K_t P(s) D(s) C(s) A(s)} \right\|^2$$



Windage

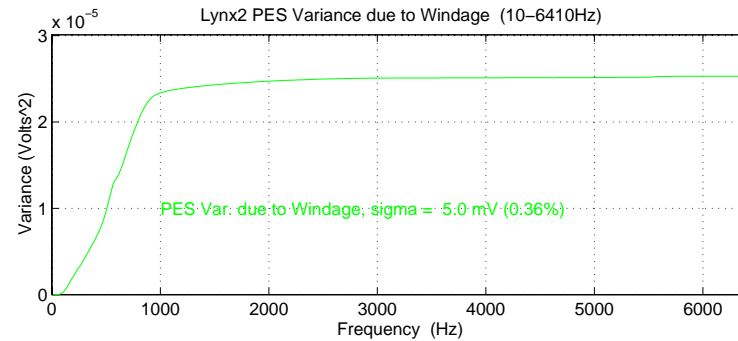
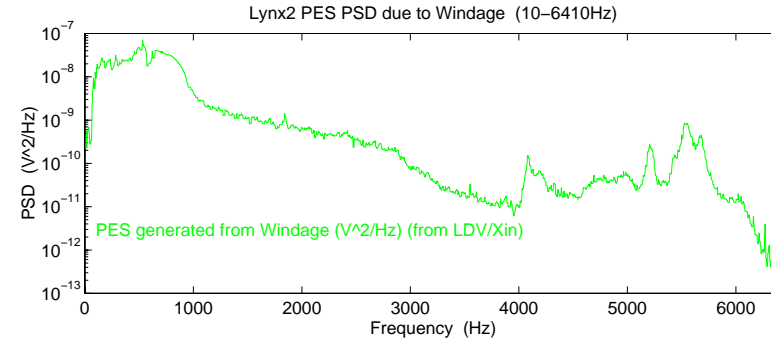
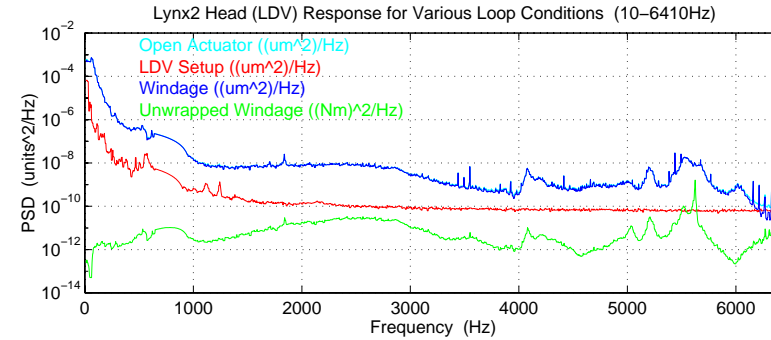


- Measured at LDV.
- Back filter to source:

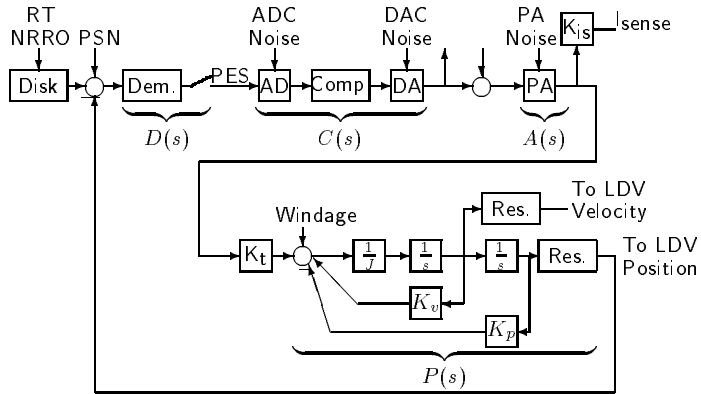
$$\left\| \frac{1}{P(s)} \right\|^2$$

- Forward filter to PES:

$$\left\| \frac{P(s)D(s)}{1 + K_t P(s)D(s)C(s)A(s)} \right\|^2$$



DAC Noise



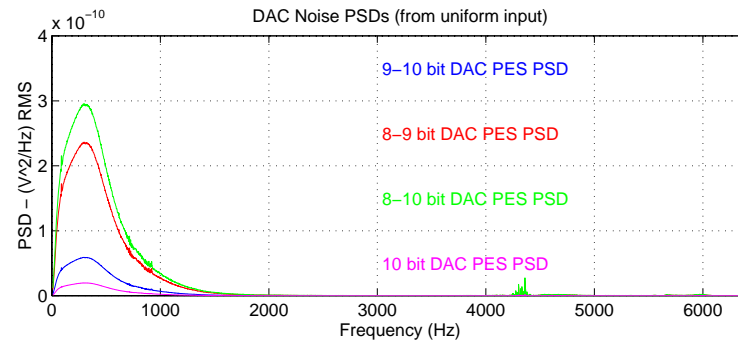
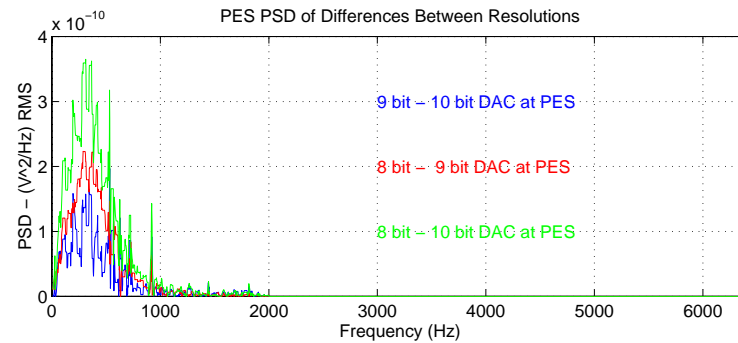
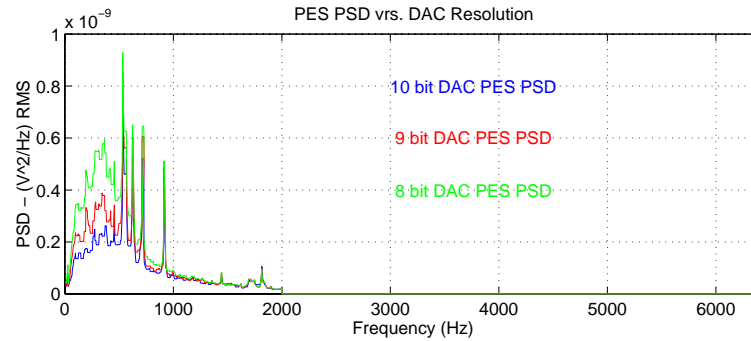
- Back calculated from PES measurements by assuming a uniform input noise distribution.

- Derived, effective quantization level:

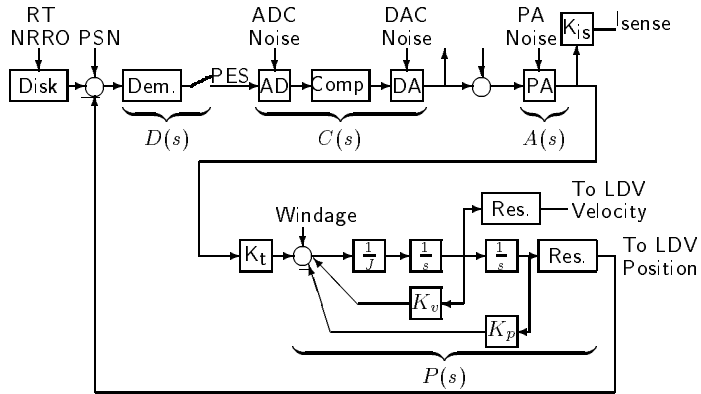
$$q = \frac{0.3125 V}{512 counts} * \frac{1}{9}$$

- Forward filter to PES:

$$\left\| \frac{K_t P(s) D(s) A(s)}{1 + K_t P(s) D(s) C(s) A(s)} \right\|^2 = \left\| \frac{C(s)}{T_{cl}} \right\|^2$$



ADC Noise



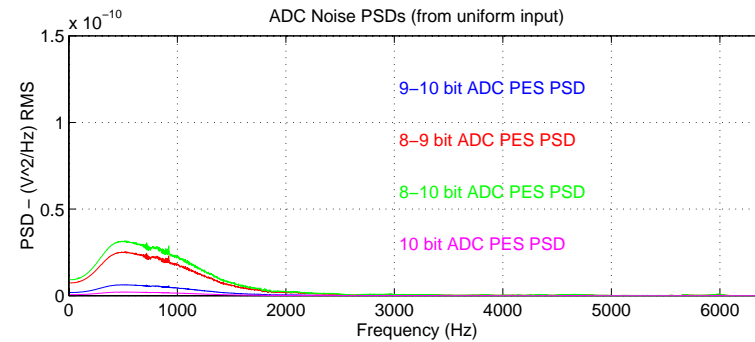
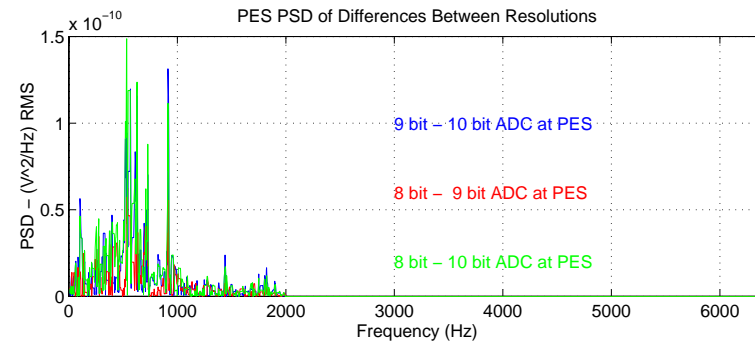
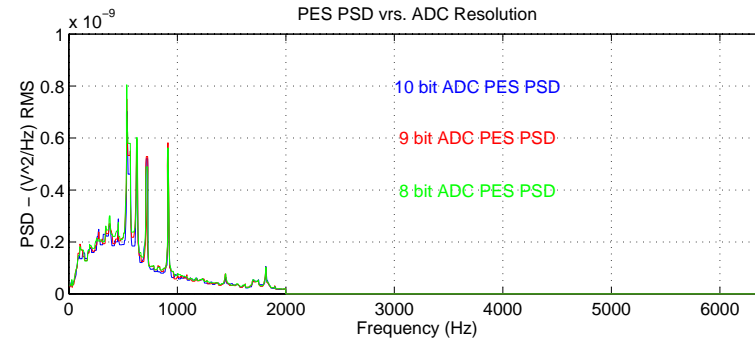
- Back calculated from PES measurements by assuming a uniform input noise distribution.

- Derived, effective quantization level:

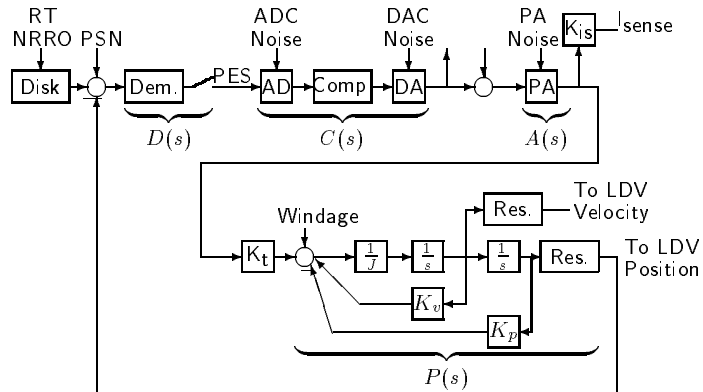
$$q = \frac{1.25 V}{512 \text{ counts}} * \frac{1}{20}$$

- Forward filter to PES:

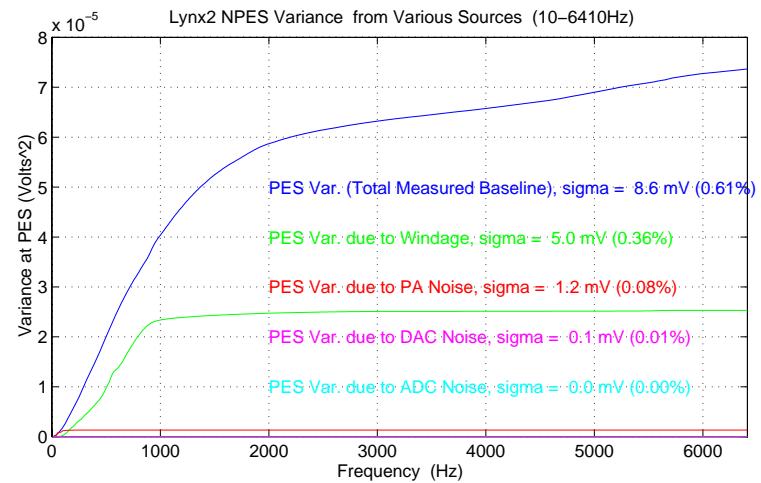
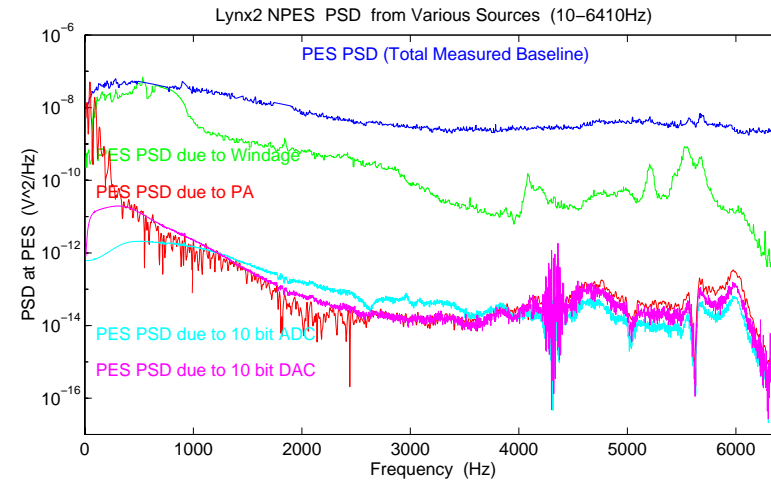
$$\left\| \frac{K_t P(s) D(s) C(s) A(s)}{1 + K_t P(s) D(s) C(s) A(s)} \right\|^2 = \left\| \frac{1}{T_{cl}} \right\|^2$$



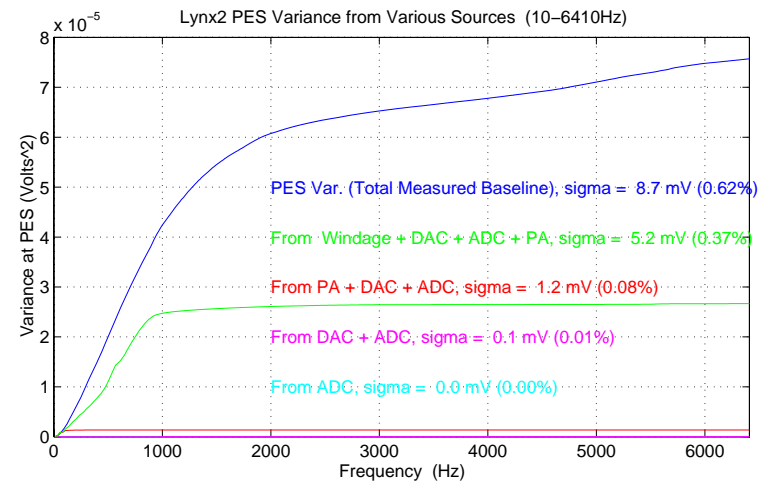
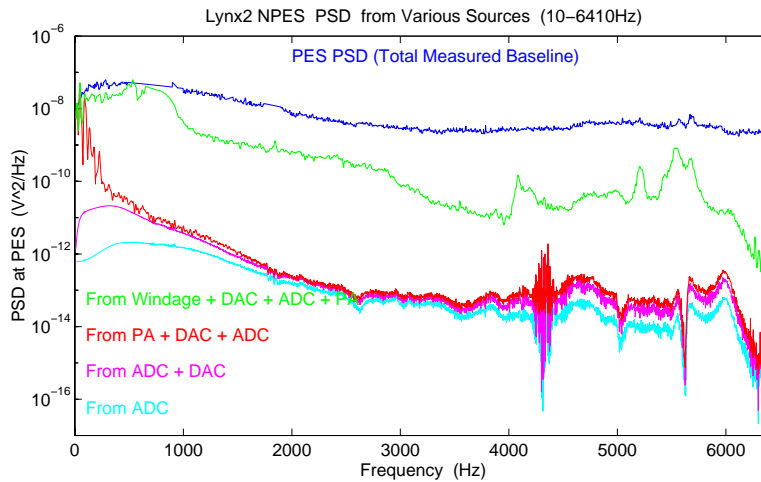
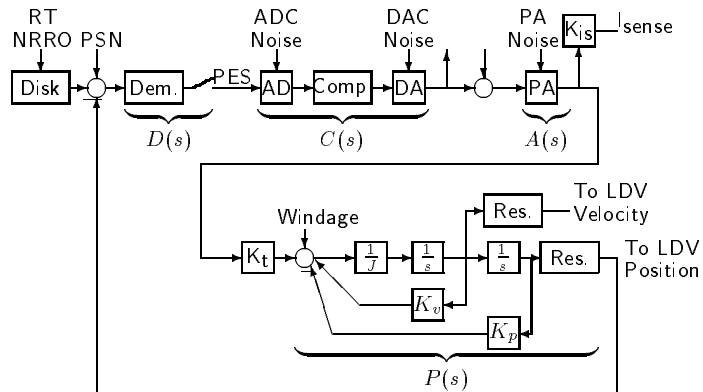
Putting it together at PES



- Feed all the noise sources to PES with appropriate unit conversions.
- Show them independently.

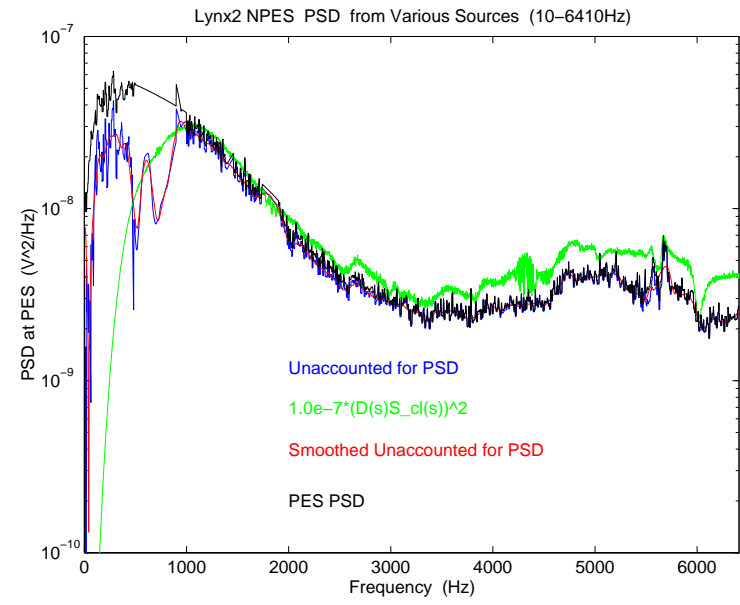
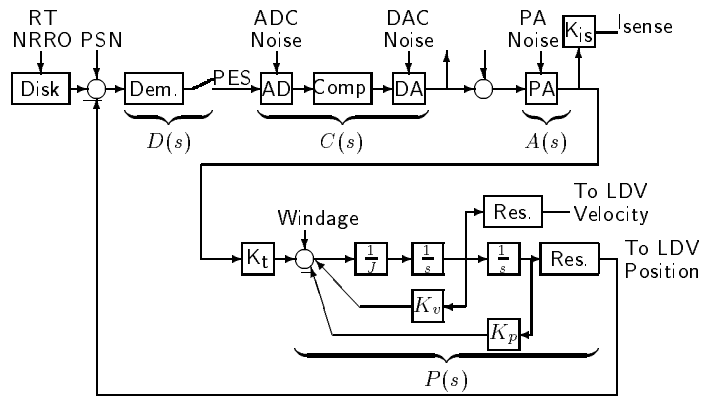


Cumulative Noise Sources at PES



- Feed all the noise sources to PES with appropriate unit conversions.
- Stack them up.

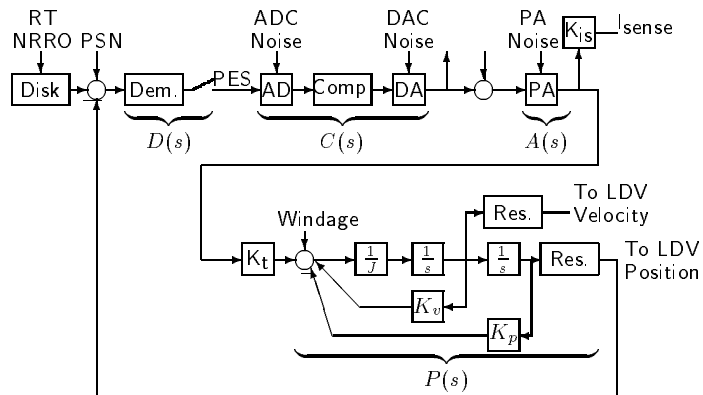
Unaccounted for Noise at PES



- PES PSD - Cumulative PSD
- What's left over looks very much like

$$k * \|D(s)S_{cl}(s)\|^2$$

Unaccounted PES Noise as an Input

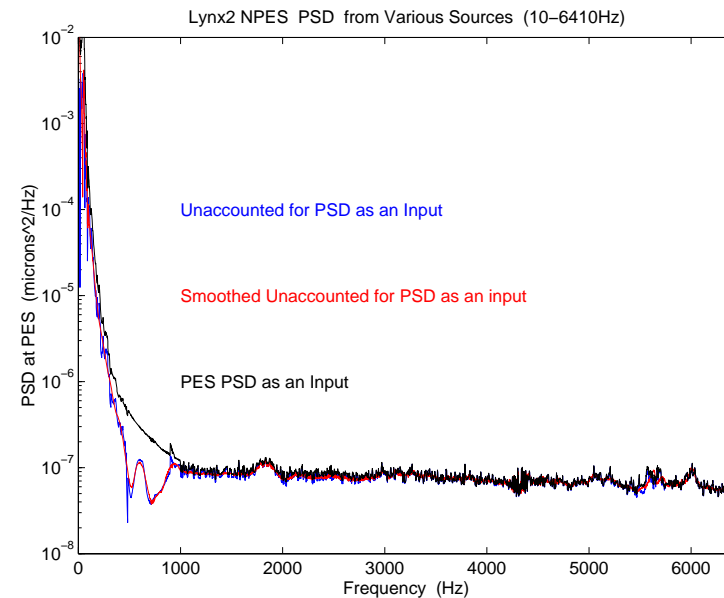


- Position Sensing Noise (PSN) enters right in front of PES.
- Filter PES PSD and unaccounted for PSD by

$$\left\| \frac{1}{D(s)S_{cl}(s)} \right\|^2$$

to get possible input PSN PSD.

- *Qualitatively* and *quantitatively* matches what ANOVA says we should get.



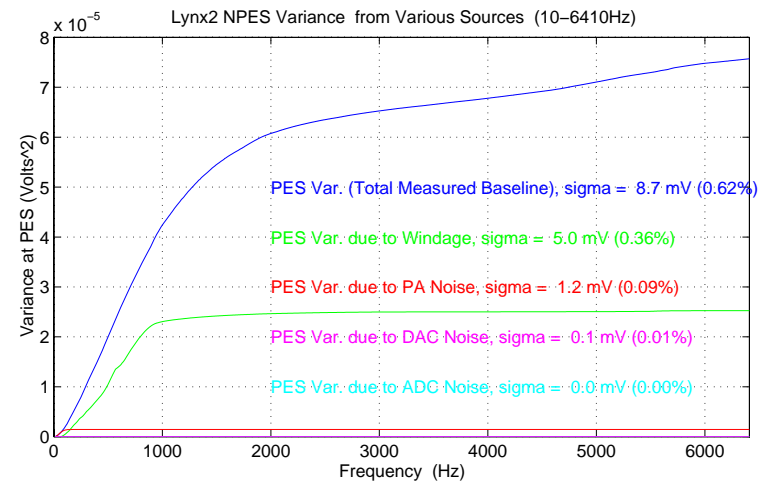
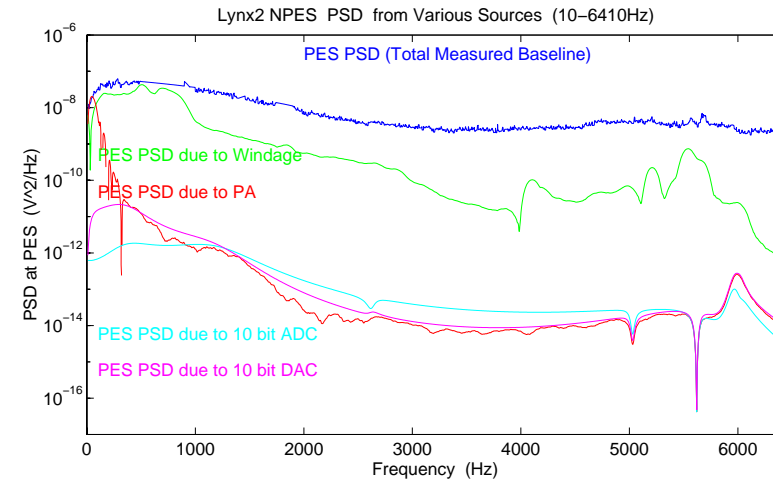
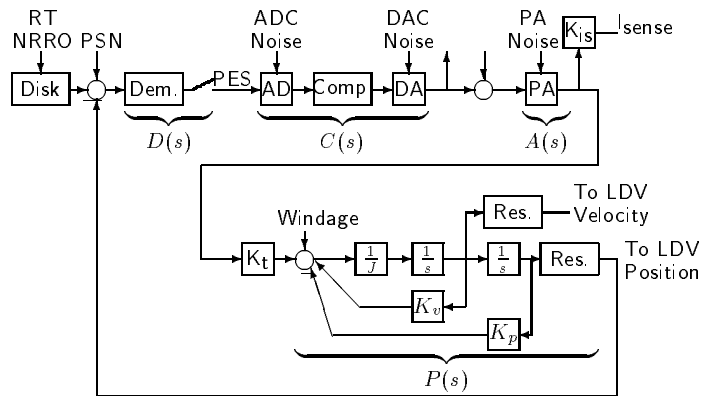
A Few Extrapolations

I shall take the simple-minded view that a theory is just a model of the universe, or a restricted part of it, and a set of rules that relate quantities in the model to observations we make. It exists only in our minds and does not have any other reality (whatever that might mean). A theory is a good theory if it satisfies two requirements: It must accurately describe a large class of observations on the basis of a model that contains only a few arbitrary elements, and it must make definite predictions about the results of future observations.

— *Stephen Hawking in “A Brief History of Time”*

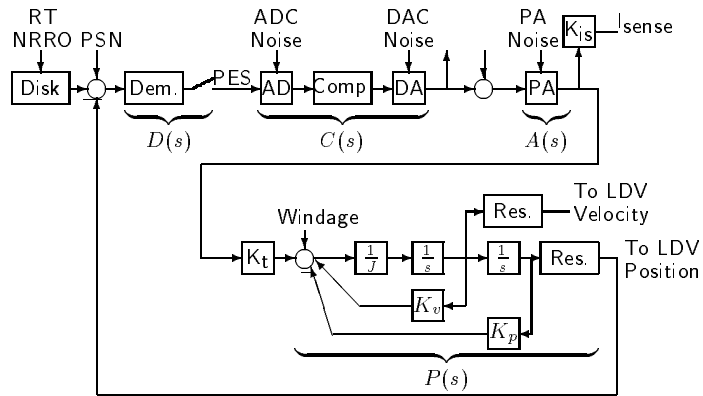
Science, therefore, for all the reasons above, is not what it appears to be. It is not objective and impartial, since every observation it makes of nature is impregnated with theory. Nature is so complex and so random that it can only be approached with a systematic tool that presupposes certain facts about it. Without such a pattern it would be impossible to find an answer to questions even as simple as ‘What am I looking for?’ *James Burke in “The Day the Universe Changed”*

Putting it together at PES Using Model

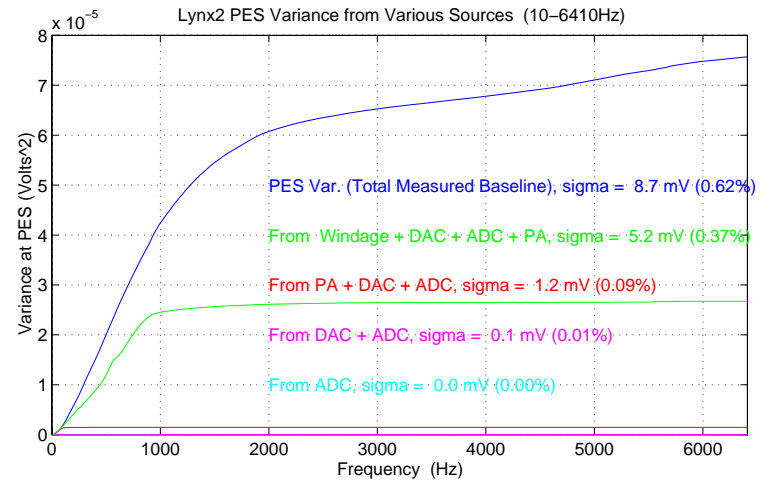
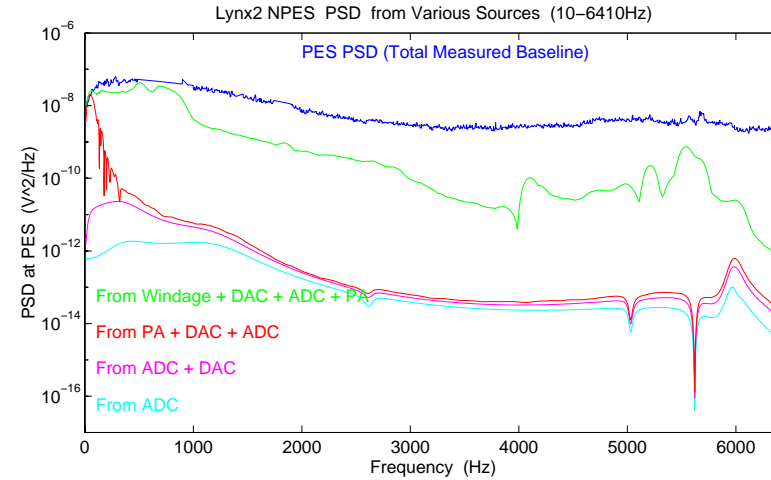


- Use best fit model to filter data.
- Feed all the noise sources to PES with appropriate unit conversions.
- Show them independently.

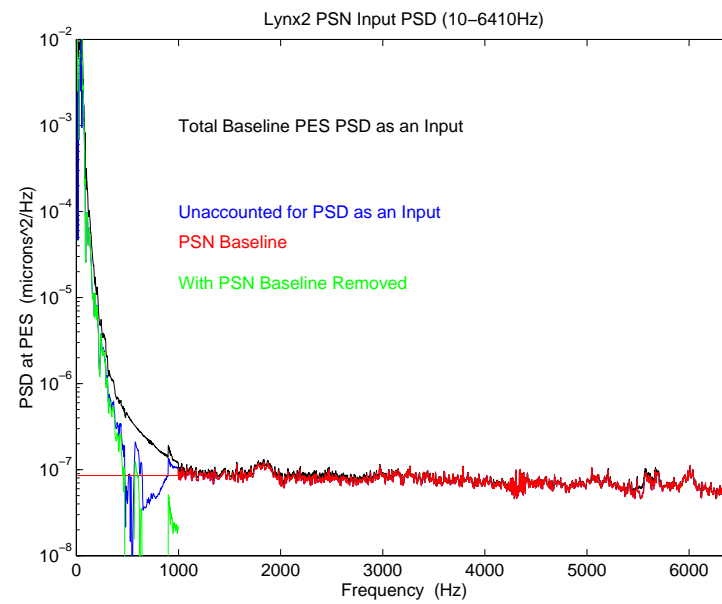
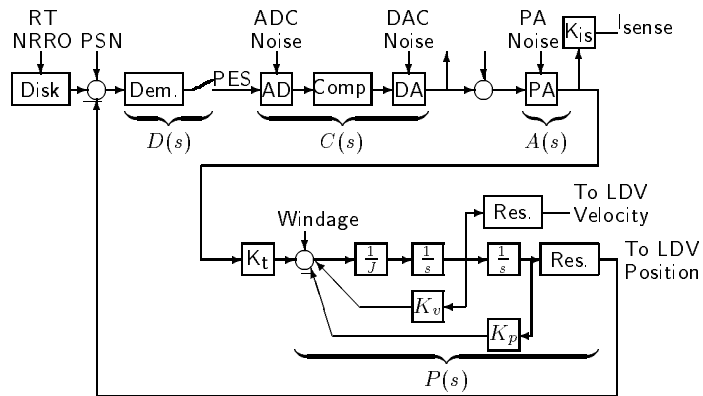
Cumulative Noise Sources at PES Using Model



- Use best fit model to filter data.
- Feed all the noise sources to PES with appropriate unit conversions.
- Stack them up.

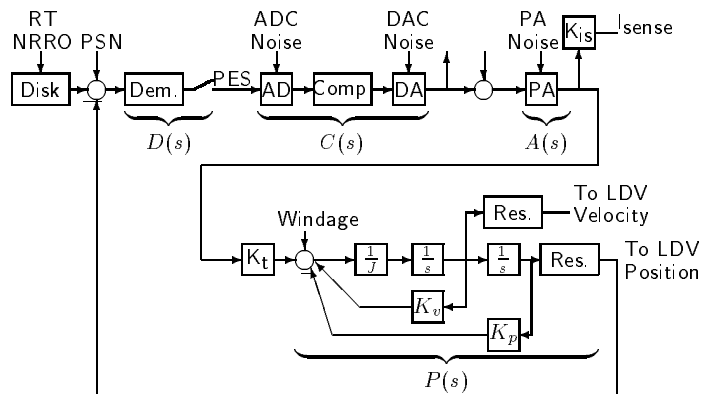


Extrapolation: Baseline PSN

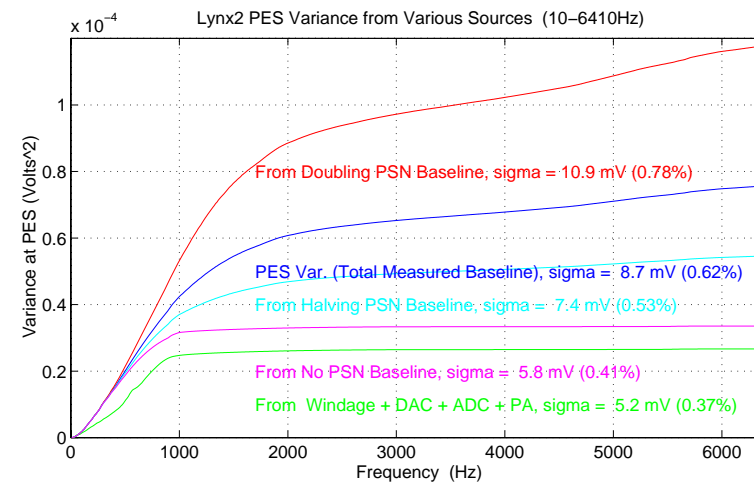
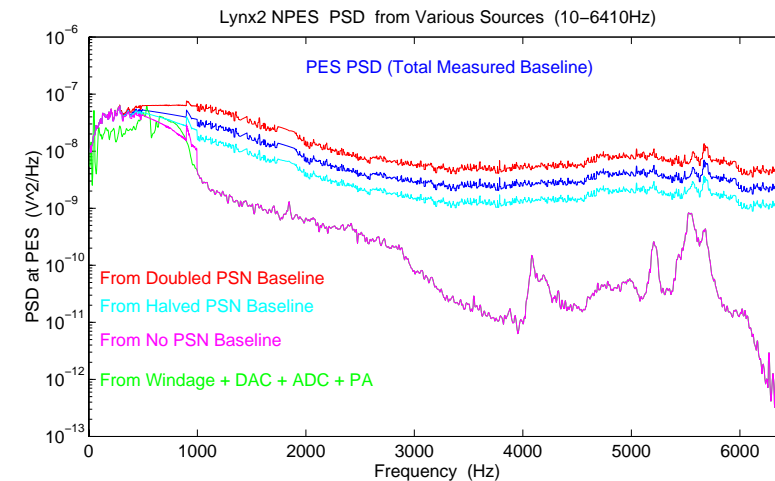


- Isolate “white” baseline input.
- Subtract from unaccounted for PES PSD.

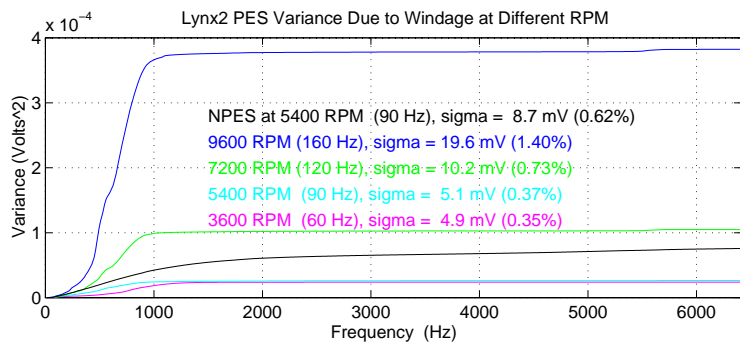
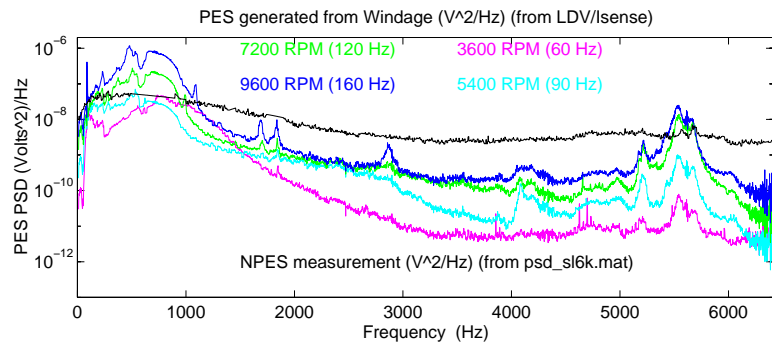
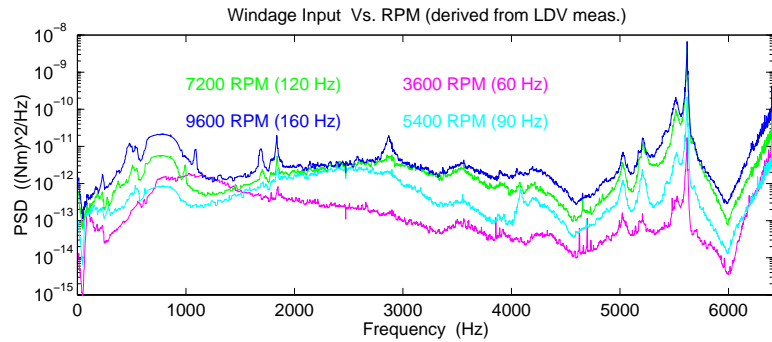
Extrapolation: Changing Baseline PSN



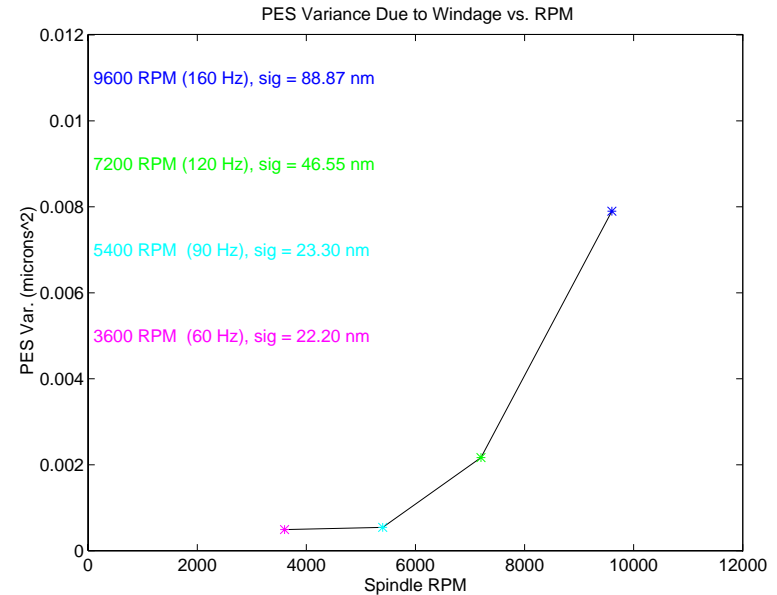
- Standard Lynx 2 servo loop.
 - Standard sample rate (8640 Hz)
 - Standard bandwidth (≈ 500 Hz OL crossover)
- Change value of baseline PSN.
- Add to other PES PSD sources, for new PES PSD.



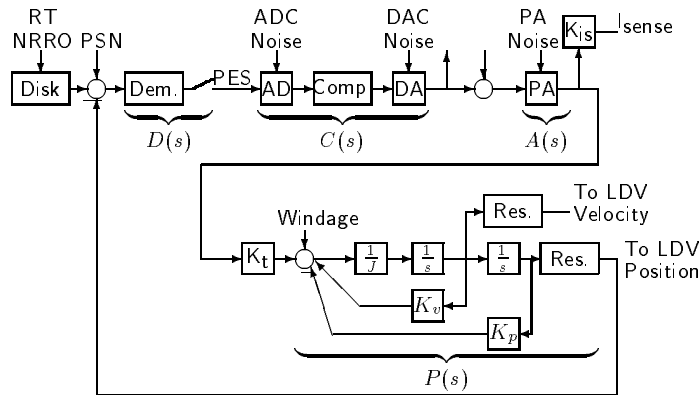
Extrapolation: Windage Versus RPM



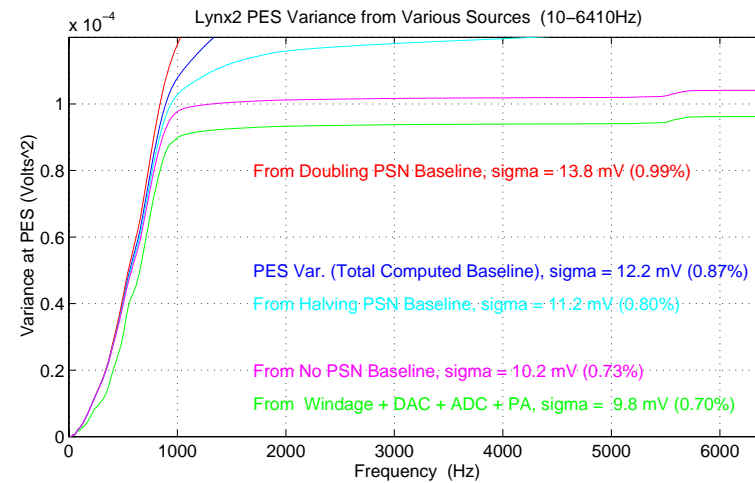
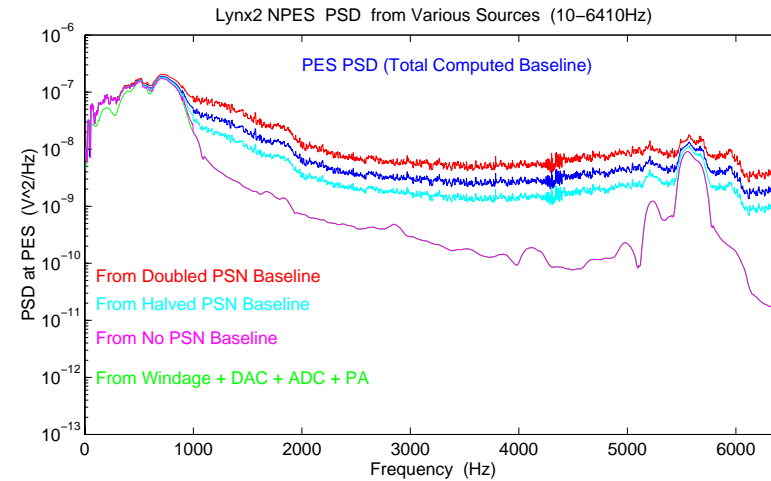
- Change spindle RPM: 3600, 5400, 7200, 9600.
- Change in PES PSD is not linear.



Extrapolation: Baseline with Windage Due to 7200 RPM



- Use 7200 RPM windage data.
- Standard Lynx 2 servo loop.
 - Standard sample rate (8640 Hz)
 - Standard bandwidth (≈ 500 Hz OL crossover)



Conclusions

- There are two major baseline noise sources:
 - Windage
 - Position Sensing Noise (PSN)
- Step on one and you amplify the other (Bode's Integral Theorem)
- Windage gets significantly worse at higher RPM.
- To drive down PES baseline noise:
 - ⇒ We need to reduce windage input noise.
 - ⇒ We need a better position sensing method to dramatically reduce PSN.