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CENTER OF EXCELLENCE FOR ADVANCED AND INTELLIGENT CONTROL

HUSRB/1203/221/020



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Some benefits of noise

Noise as information source

Adding noise to improve performance

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www.noise.physx.u-szeged.hu



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Noise can be found everywhere

- No measurements without noise
- engineering, technical aspects
- Biological processes
- Medical science
- Weather
- Traffic
- Elections, social processes
- Human networks
- Economical processes, stock market
- Games



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Do you know?

- Light is noise („and God said: let there be light”)
- Temperature is noise
- Gas pressure is noise
- Solution, stirring, salting, sugaring, ...
- Stock market, economy
- find out more



Sometimes more good than bad

Noise can be a source of information

- Water boiling
- Engine diagnostics
- Medical diagnostics, heart rate, blood pressure fluctuations
- And many more...

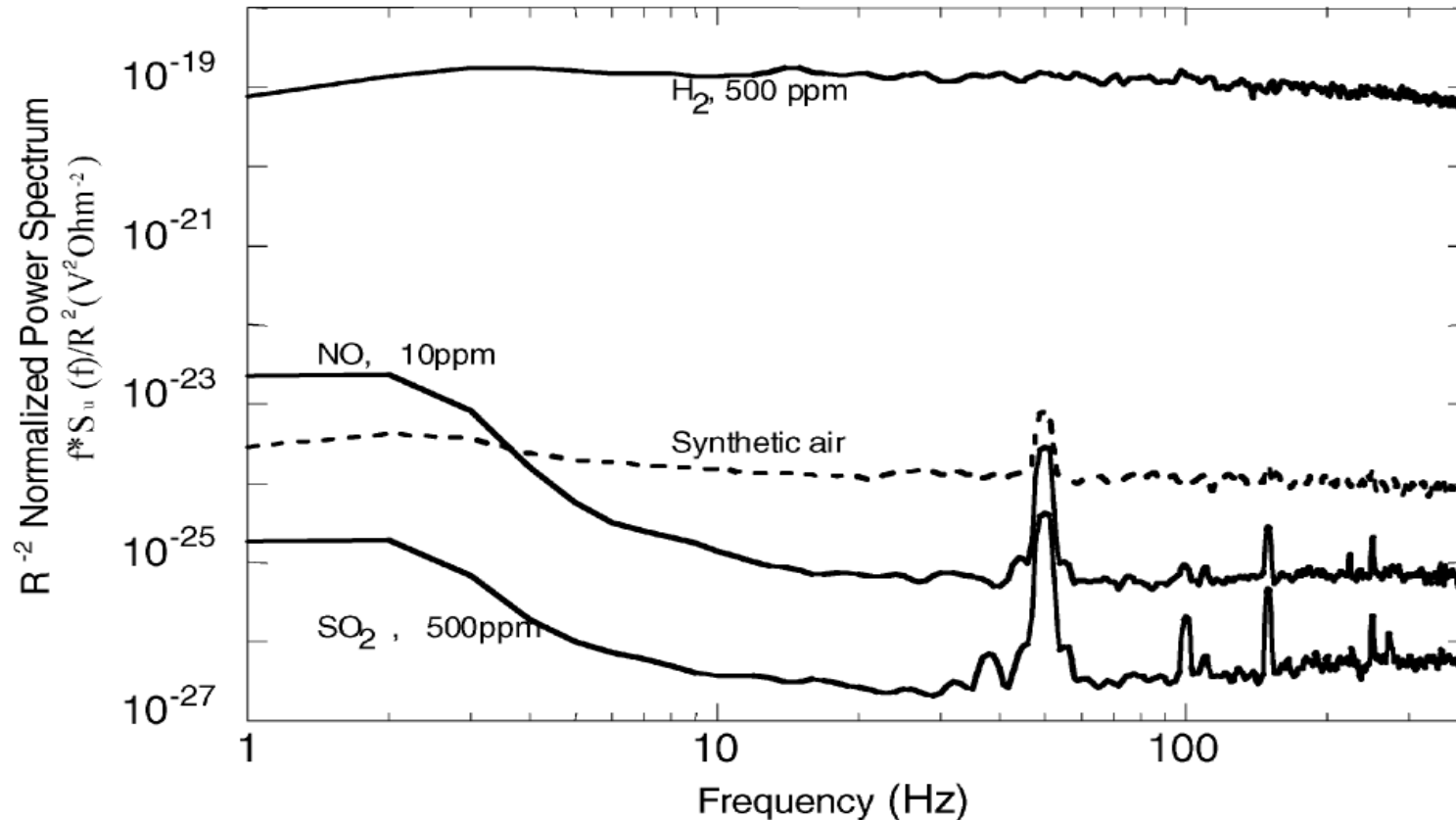
Can higher noise be better than lower noise?



Semiconductor gas sensors resistance – gas concentration



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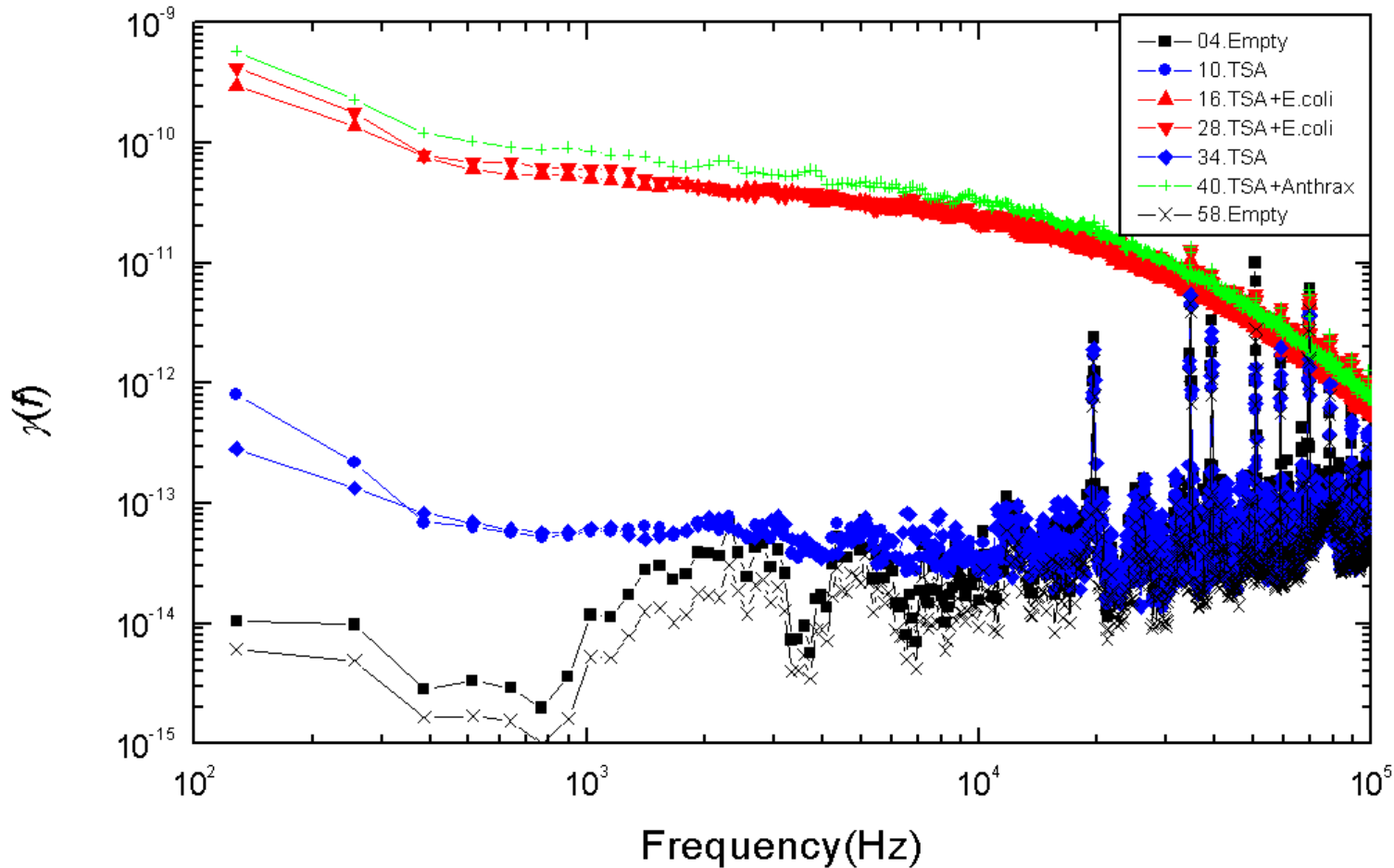


Bacterial odor sensing



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Some fluctuating signals of the human body



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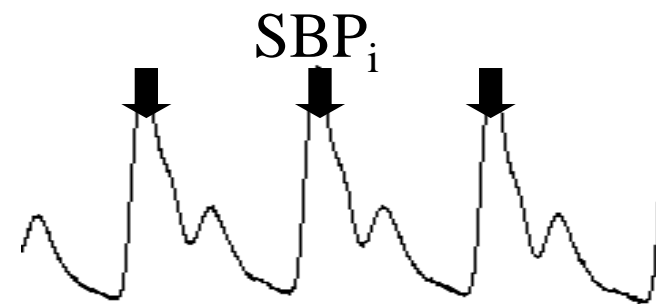
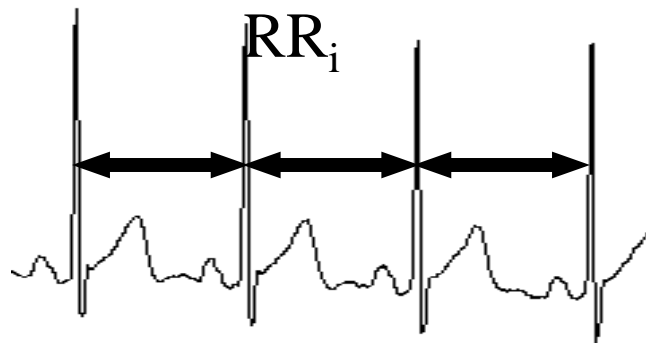
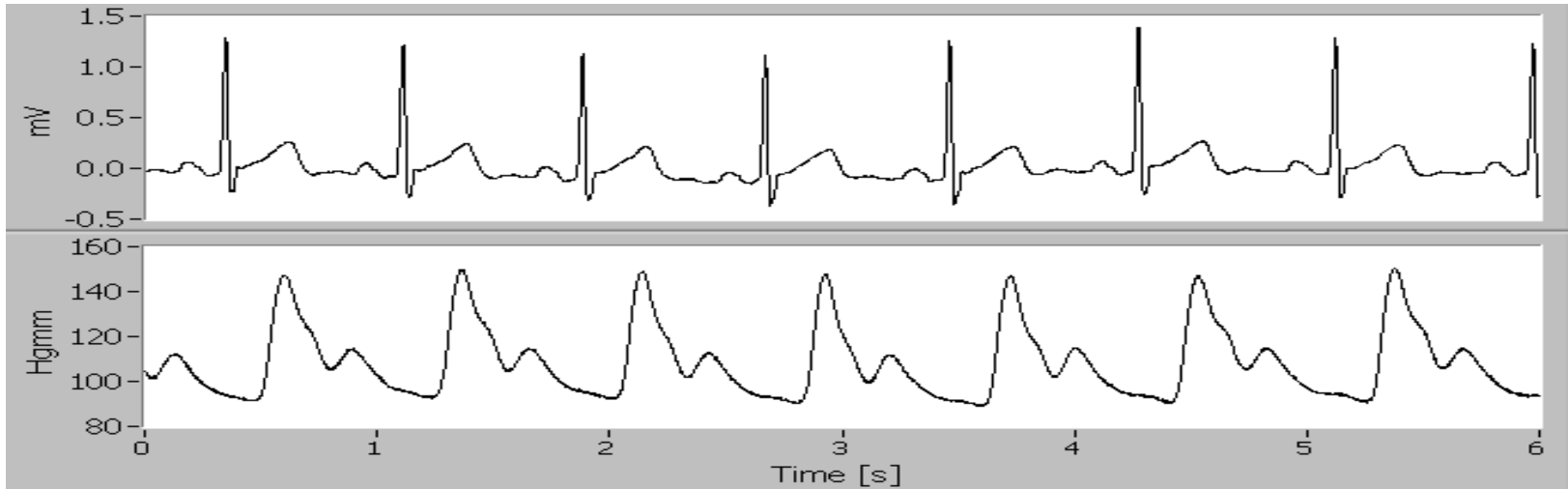
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ECG, blood pressure signals



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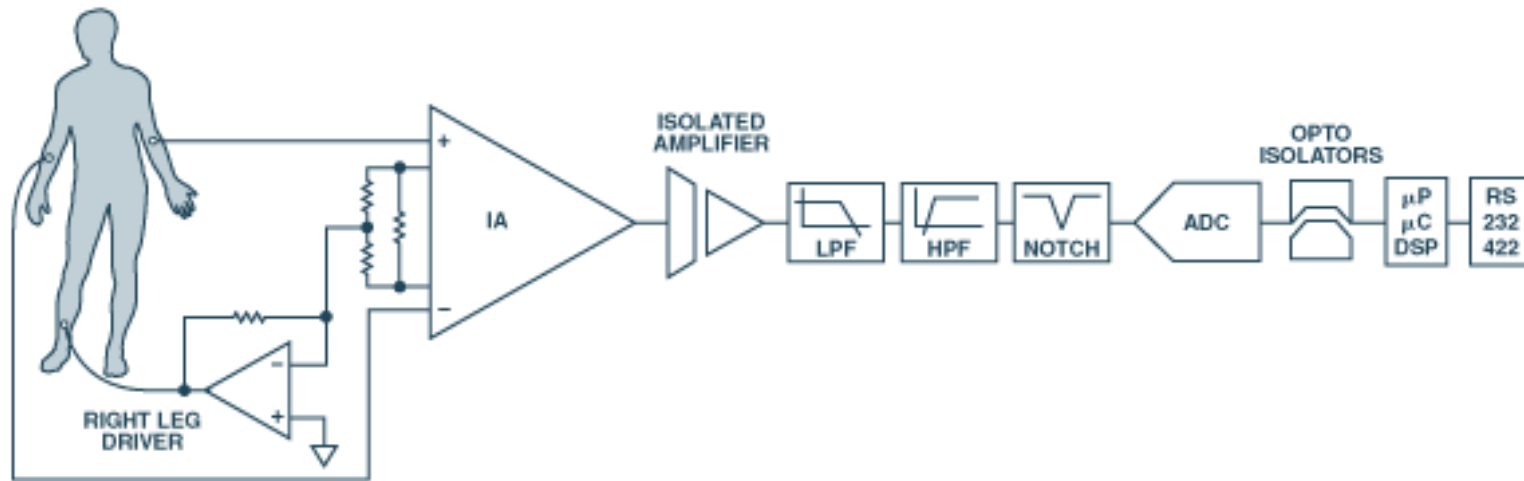


Measurement methods



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- ECG: signal amplification
- Blood pressure: sensor or indirect methods
- Blood flow
- Respiration

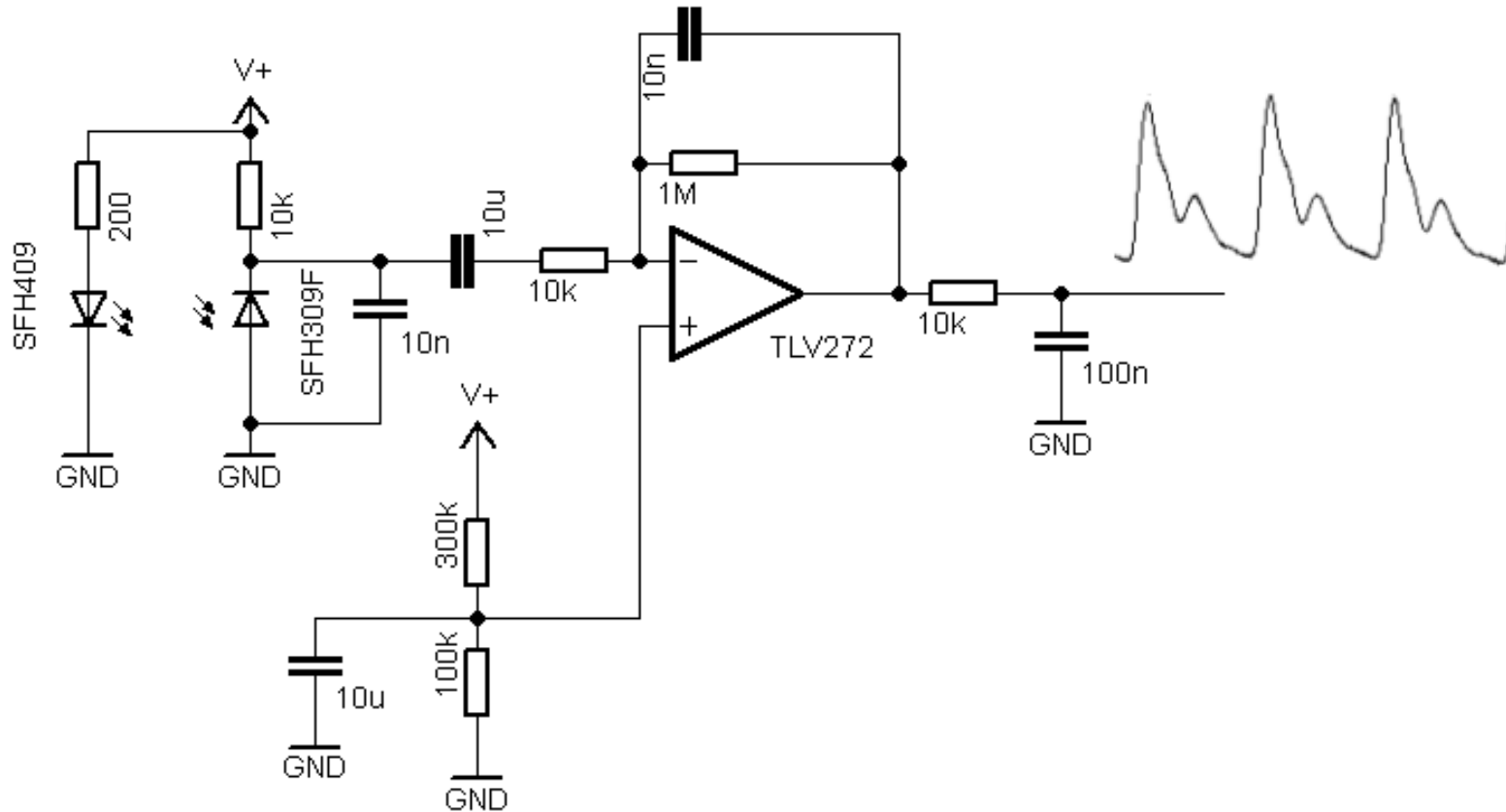


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Finger photoplethysmography



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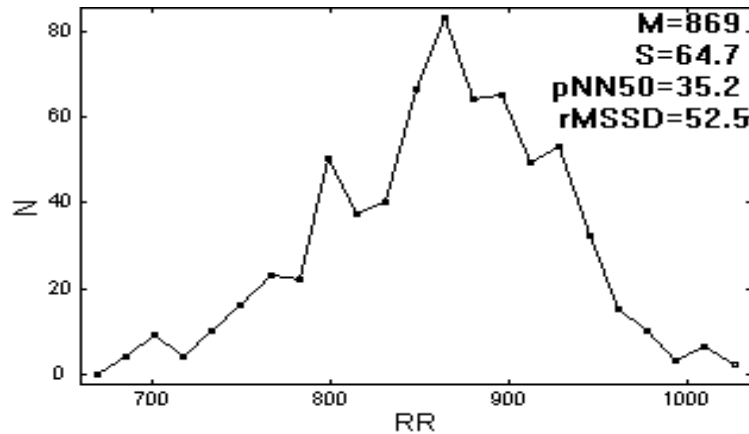
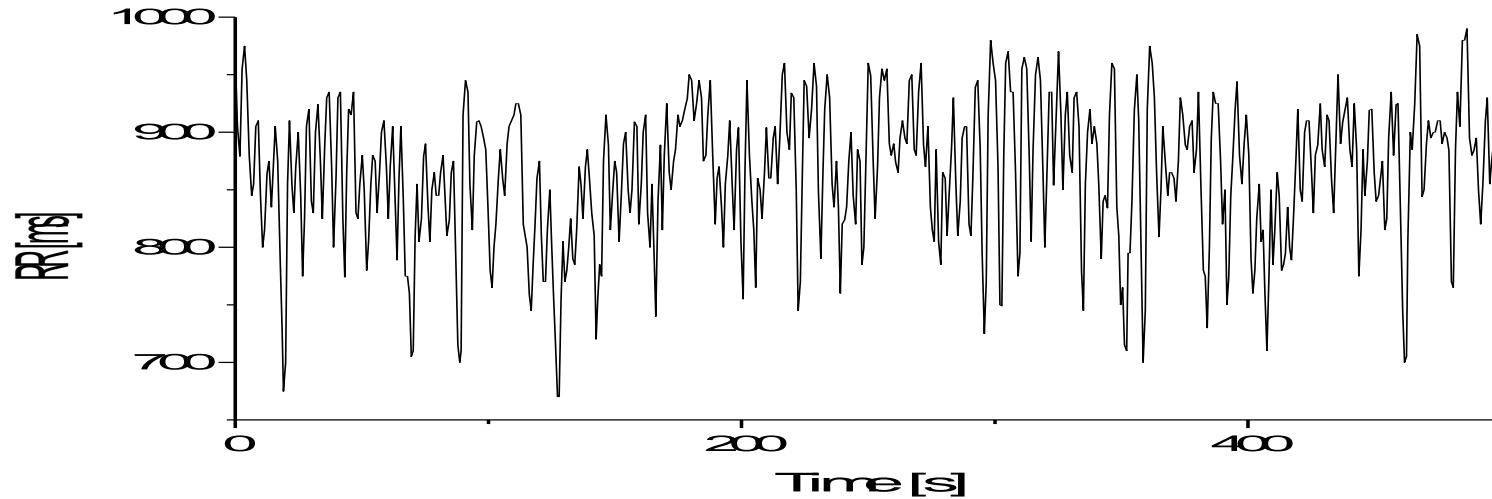


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RR time dependence and spectrum



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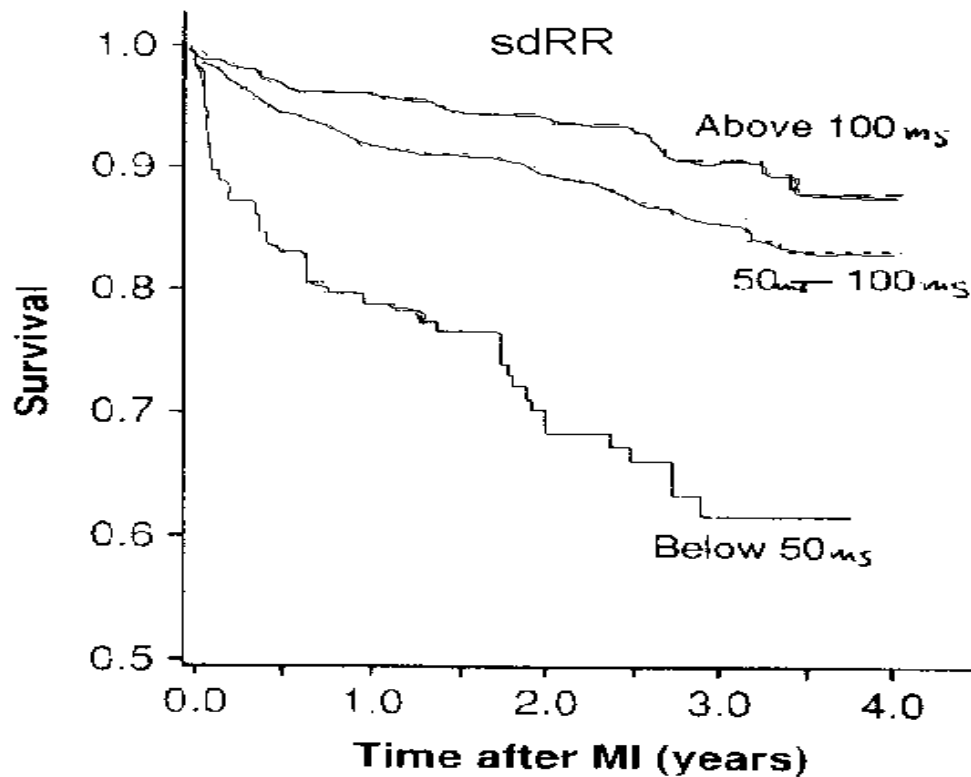
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Smaller fluctuations - higher risk of sudden cardiac death



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Diabetes
Cardiac diseases
Coronary arterial diseases



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The sdRR is a very simple but good predictor and indicator

- Diabetes
- Cardiac diseases
- Coronary arterial diseases

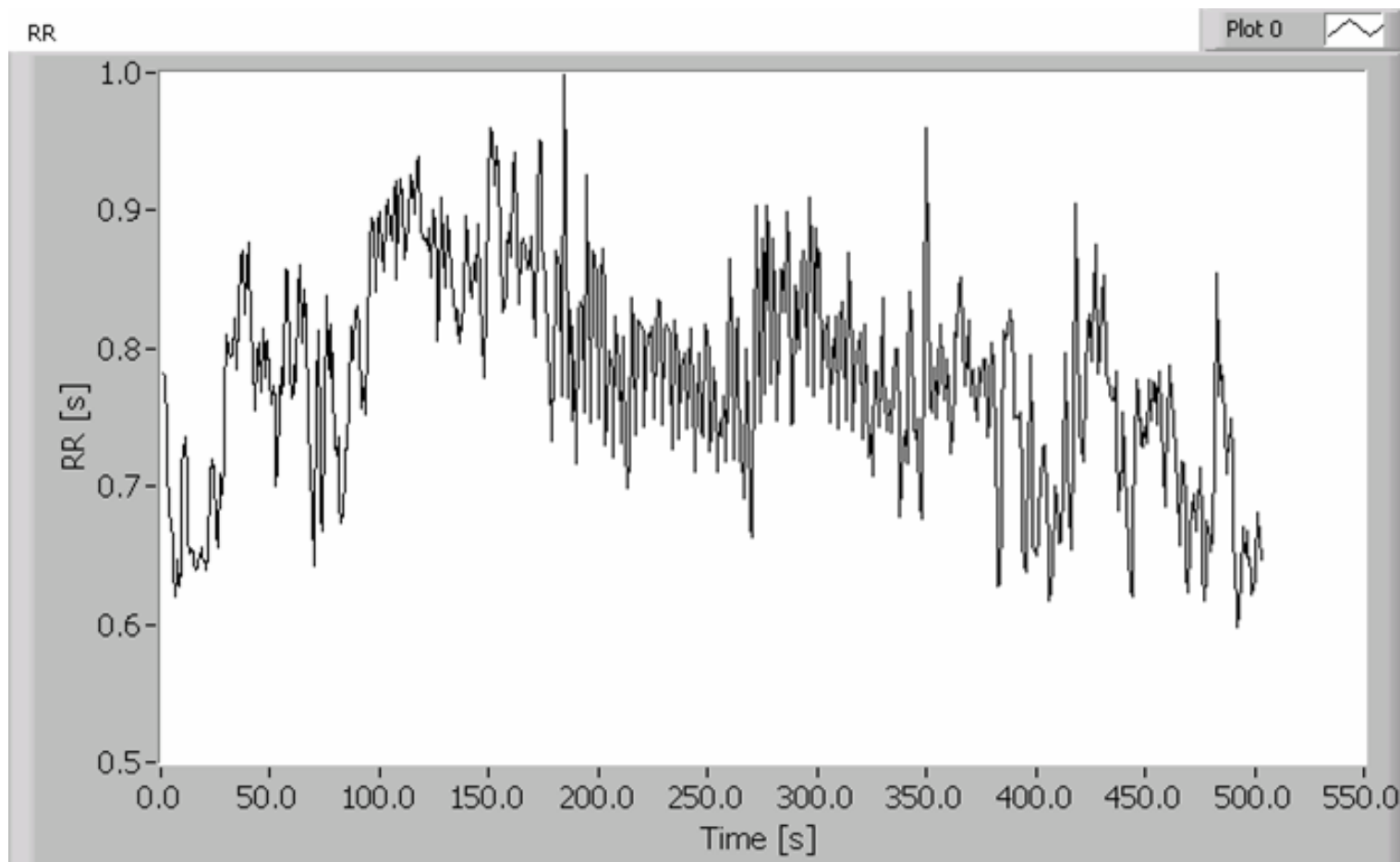


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Long term behaviour



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Adding noise to improve performance?



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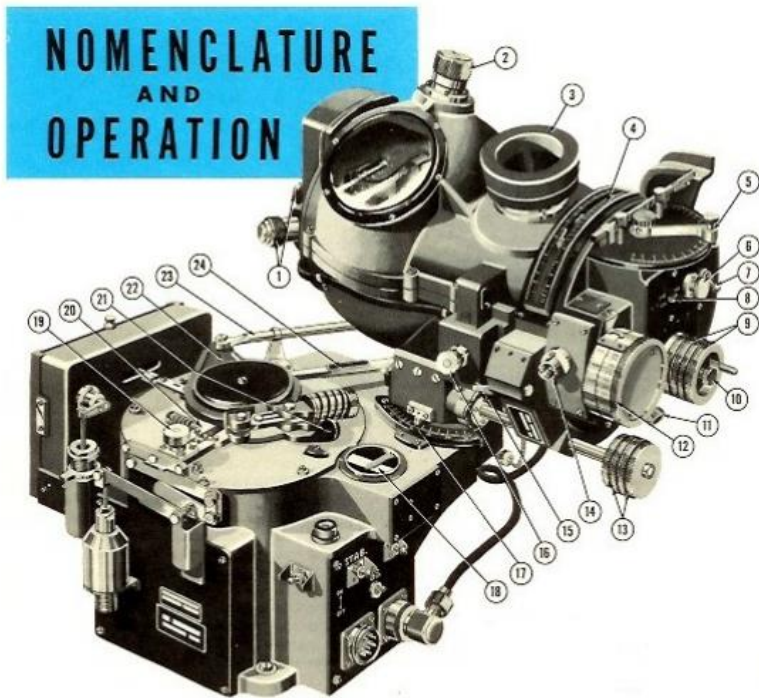
Dithering

Adding noise to improve performance

- Some strange expectations:
 - Improved precision?
 - Better SNR?
 - More efficient information extraction?



Noise improved the performance of mechanical computers (with hundreds of gears and cogs)



- World War II, airplane bombers
- Navigation, bomb trajectory calculations
- Performed more accurately on the aircraft than on the ground

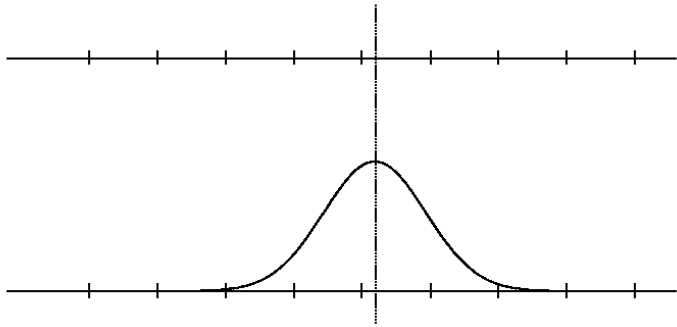
<http://en.wikipedia.org/wiki/Dithering>



Digitizing DC signals

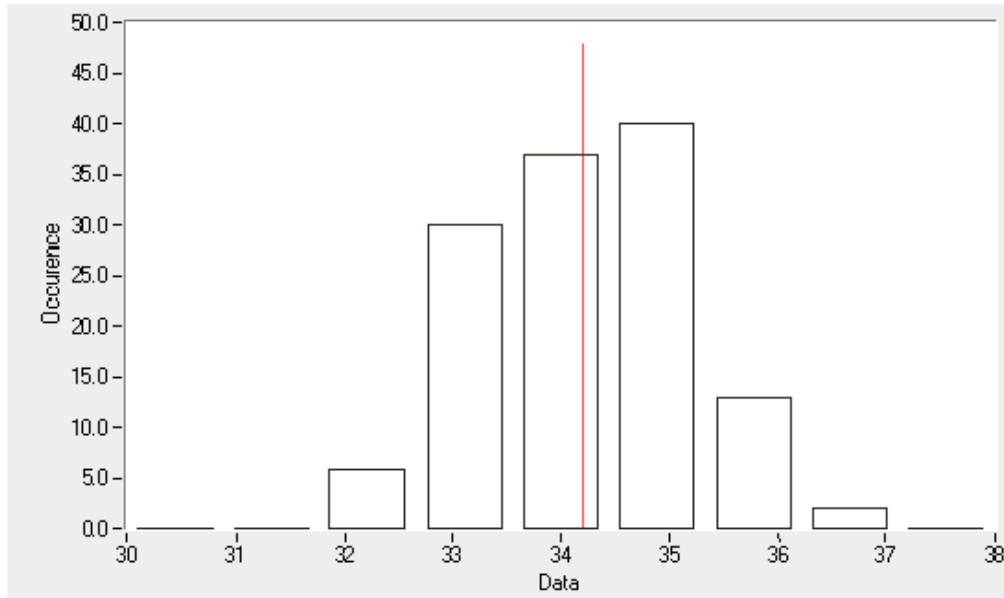


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value: 34.2, dither: 128
points ($\sigma=1$)

Simply digitized data=34,
averaged value=34.23

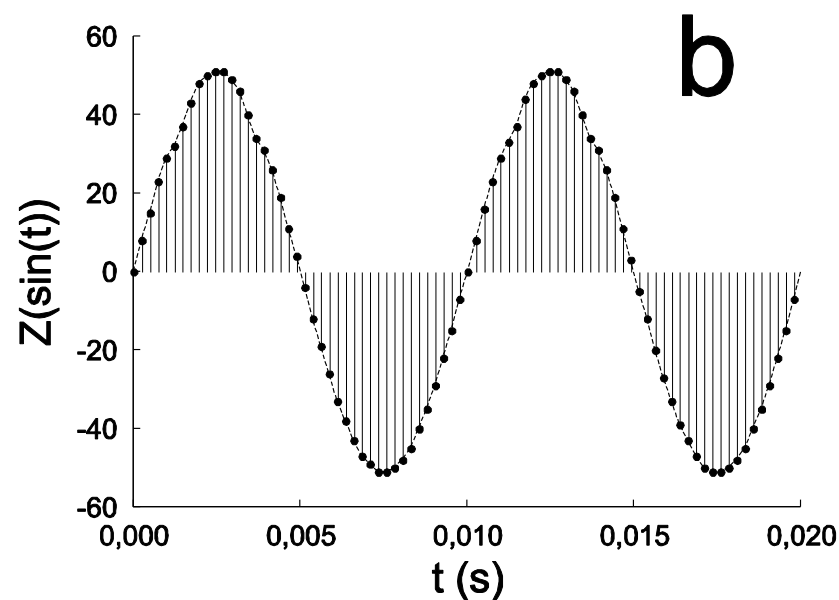
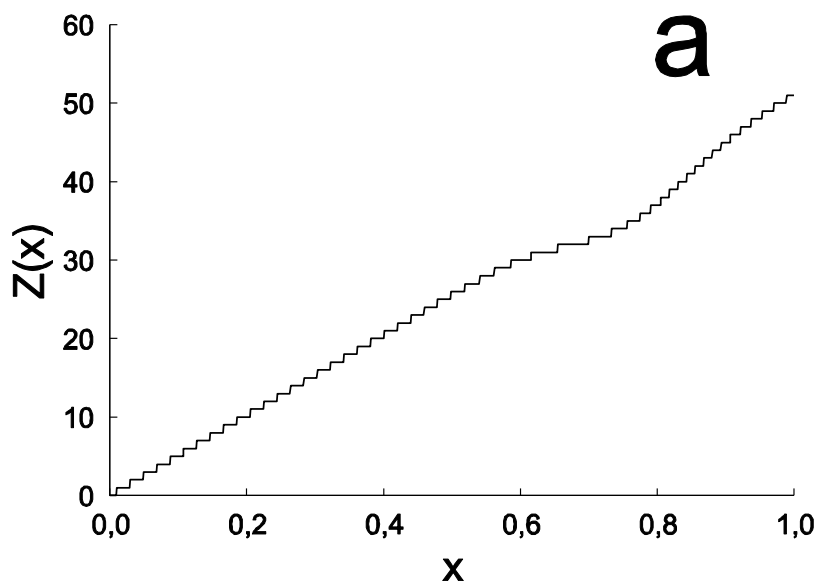


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Improving linearity



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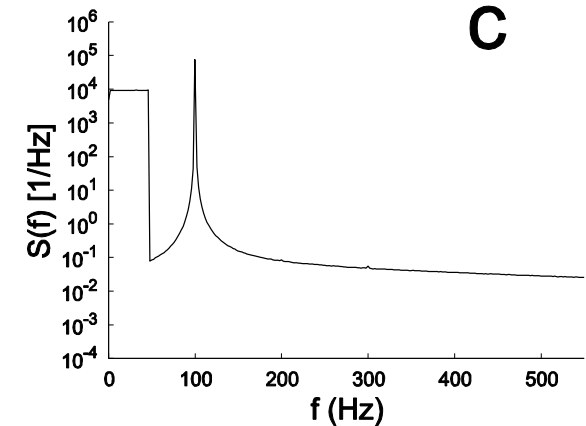
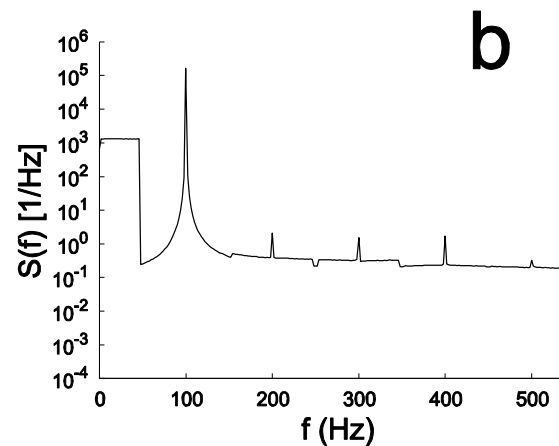
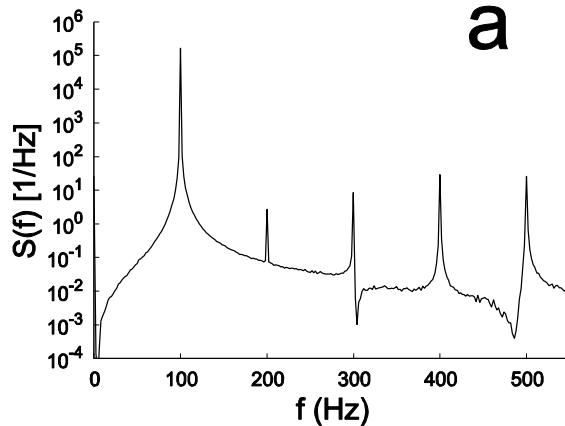


Power spectral densities

a: no additive noise

b: 2 units of additive noise

c: 8 units of additive noise



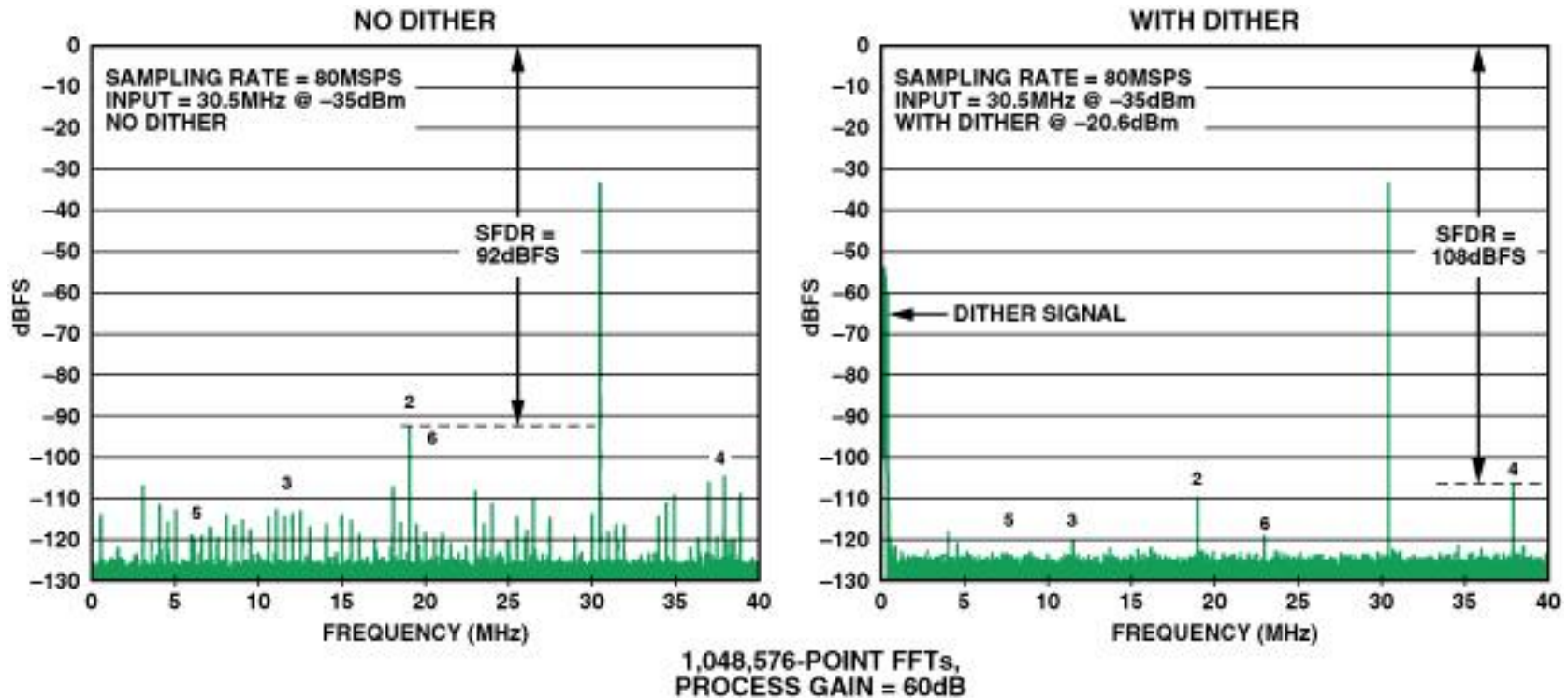
AC linearity improvement

(14-bit A/D converter, AD6645)



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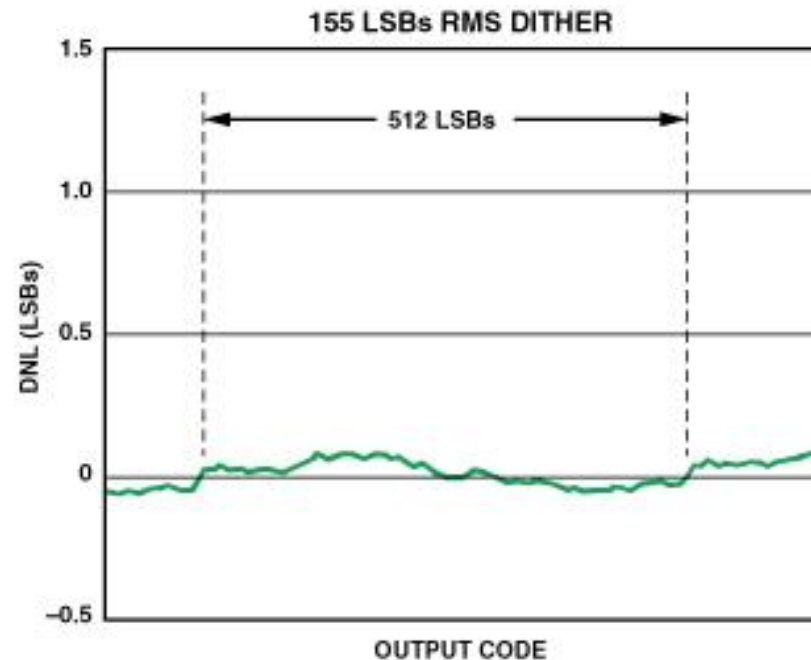
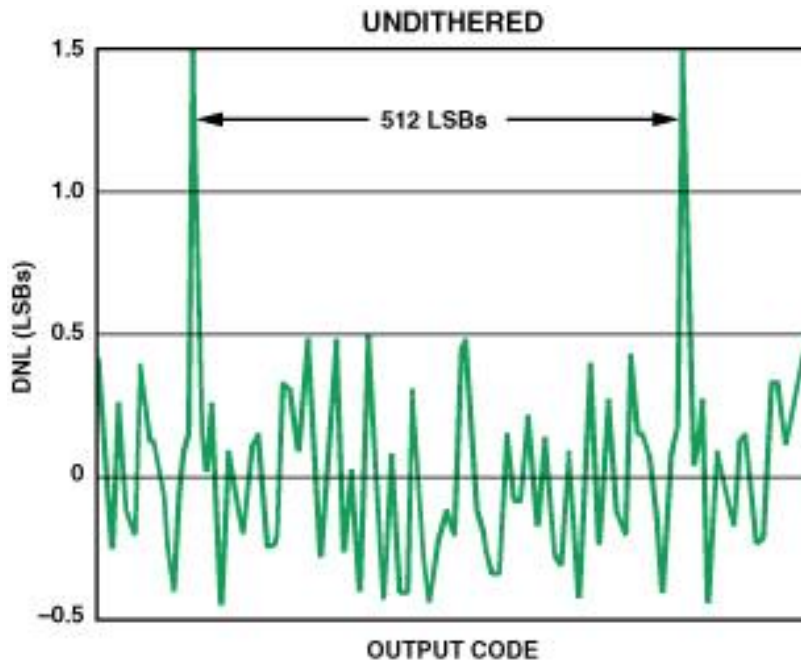
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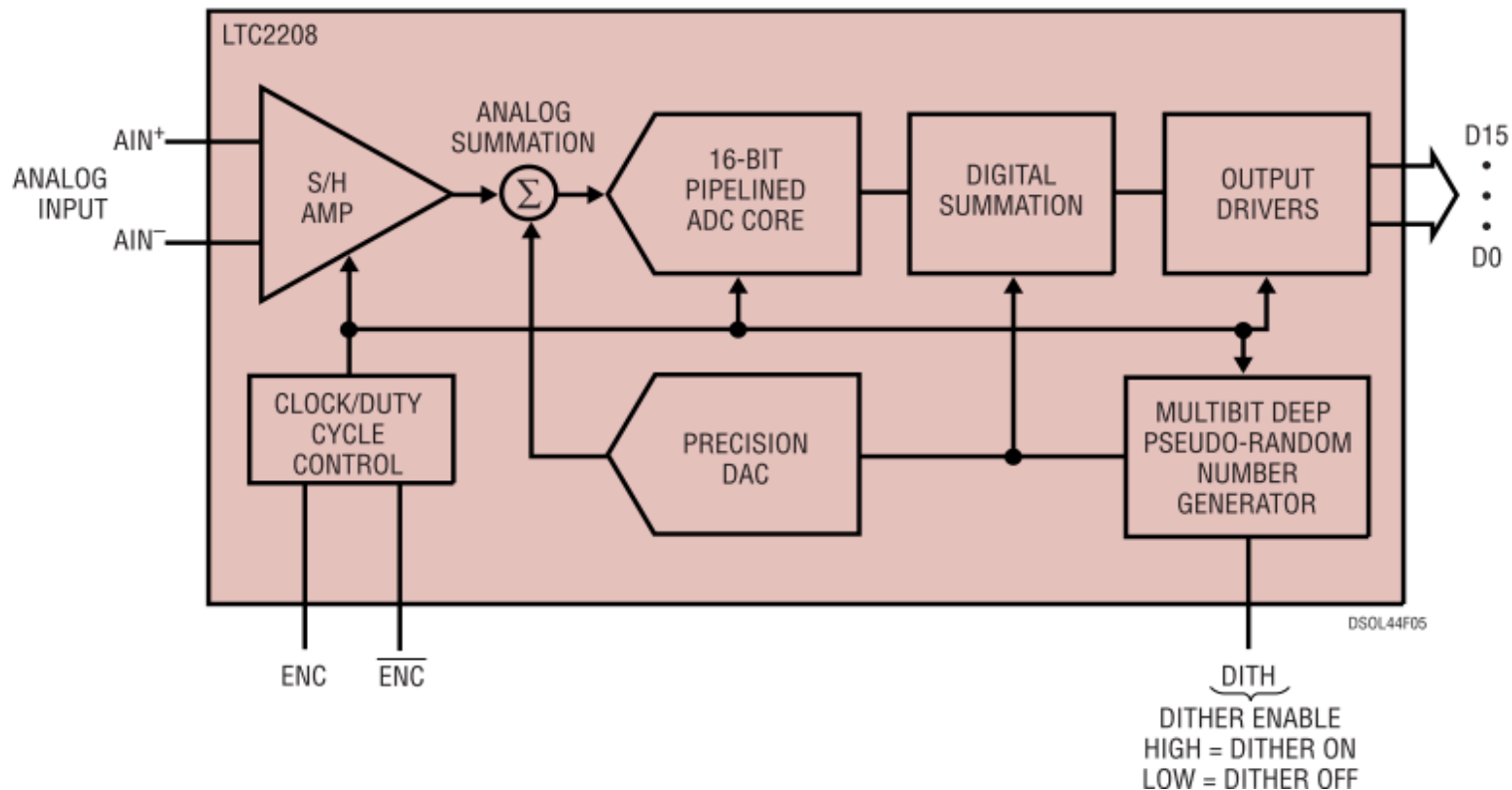
Differential linearity plots



16-bit ADC with on-chip dither

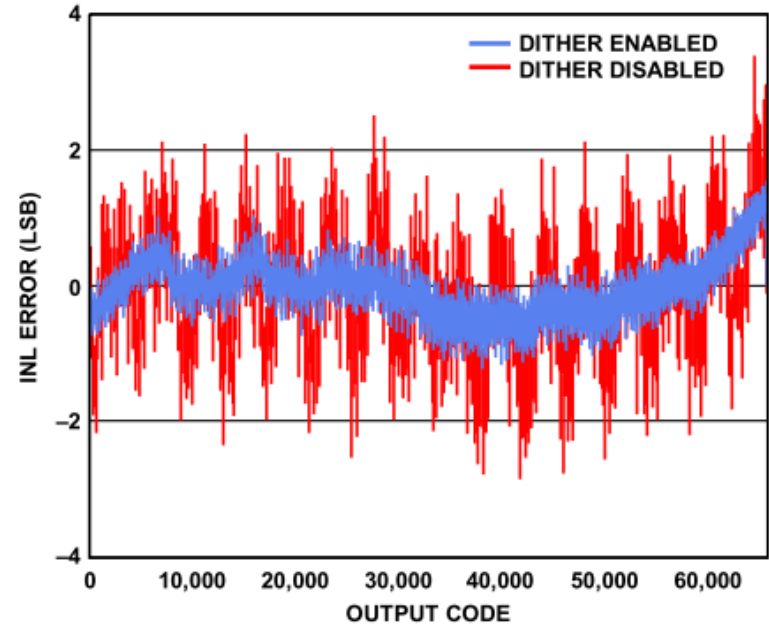
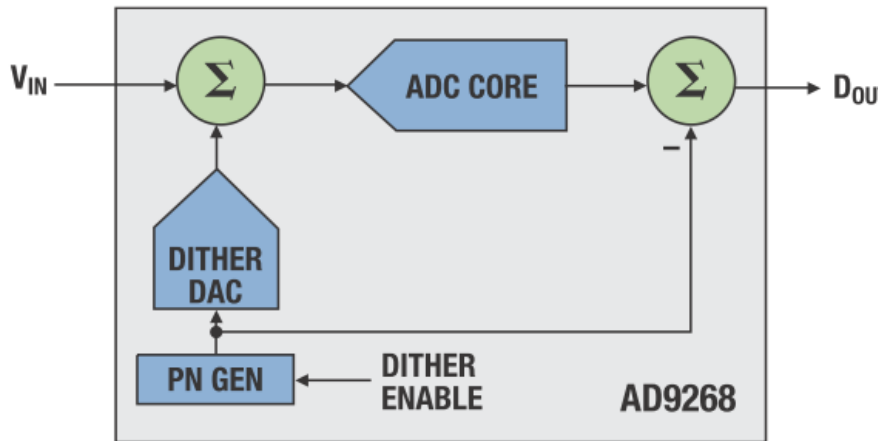


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16-bit ADC with on-chip dither

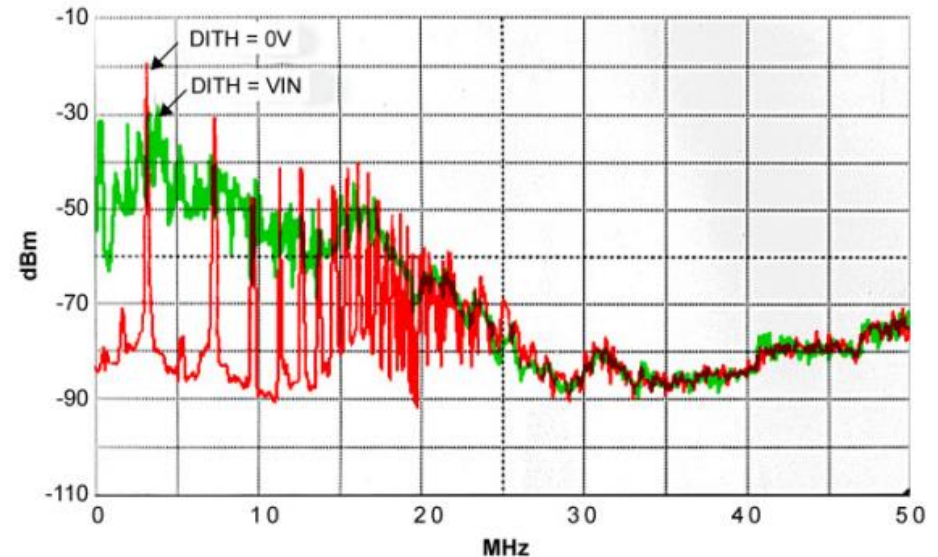


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Reducing EMI by dithering of the switching frequency

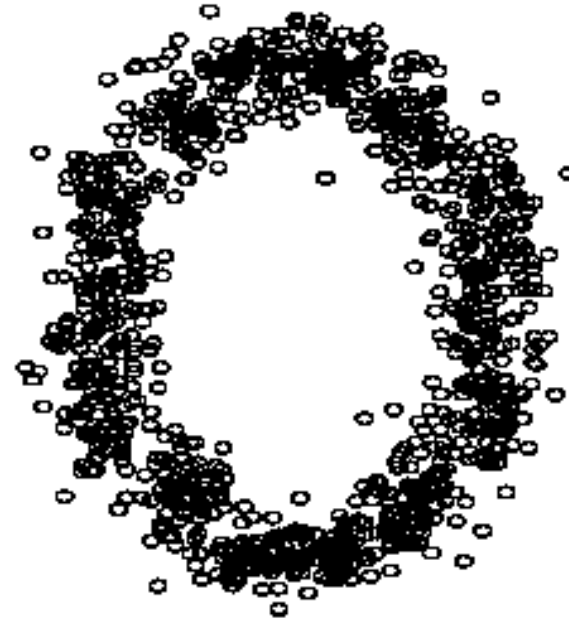
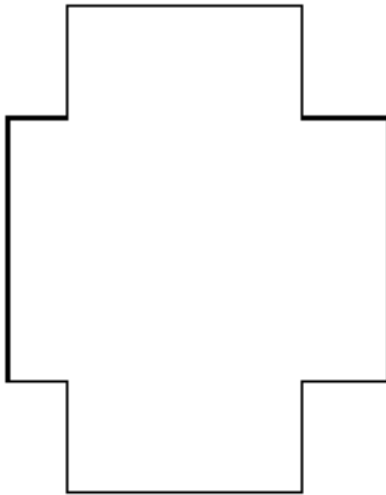
- PWM in AC/DC converters
- Dithering the PWM frequency spreads out spectrum of the power supply
- E.g.: MIC2250 boost regulator



Digitized pictures, drawings



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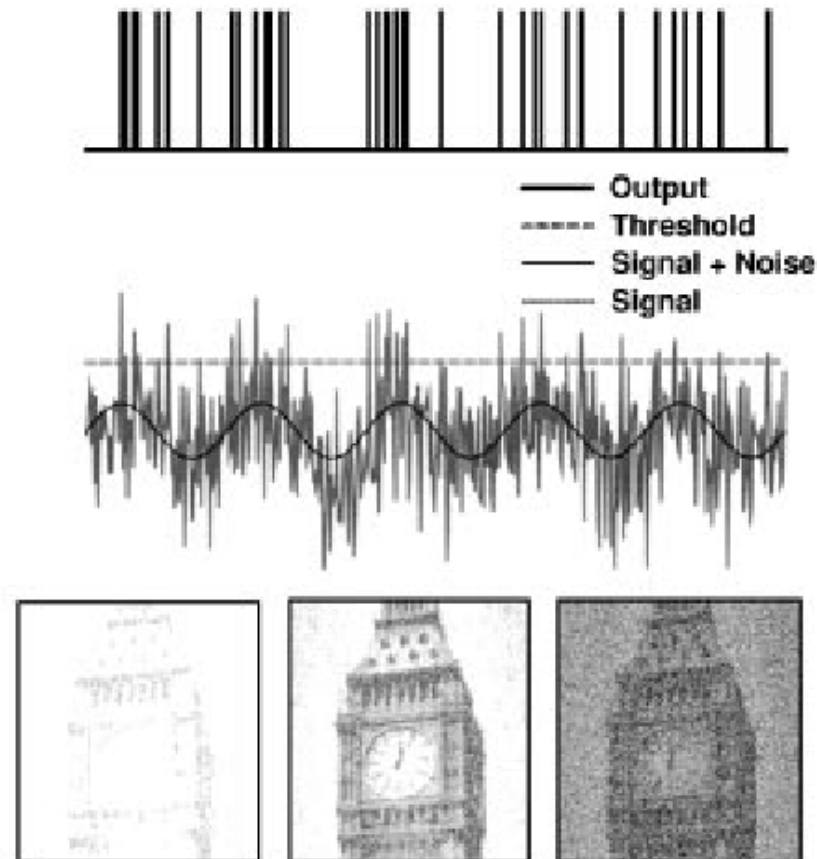
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*(Simonotto et al., Phys Rev Lett
78 (1997) 6)*



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Dithering to improve quality of color images



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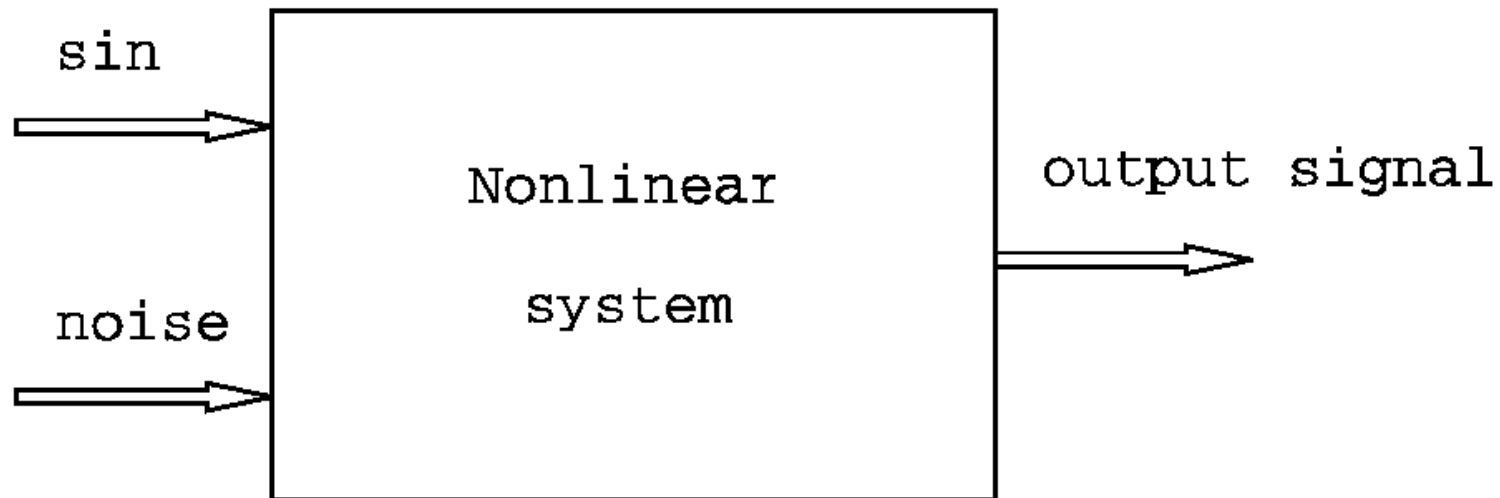
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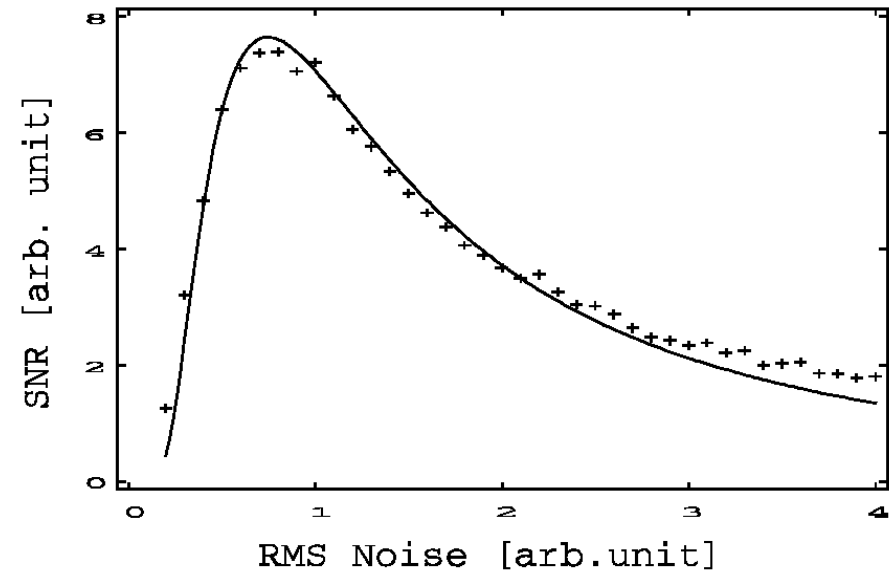
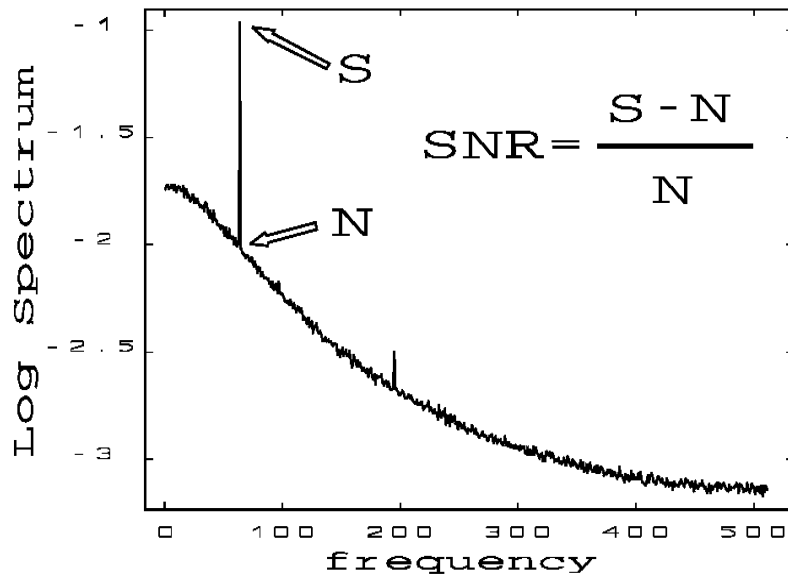


Stochastic resonance

- SNR improvement by adding noise
- May occur in some special nonlinear systems



SNR has a maximum as a function of the input noise strength



In other words: noise can improve signal transmission

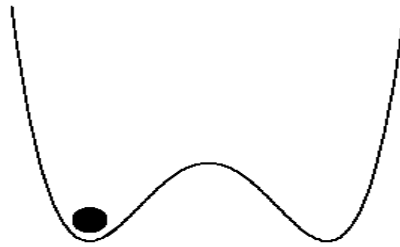




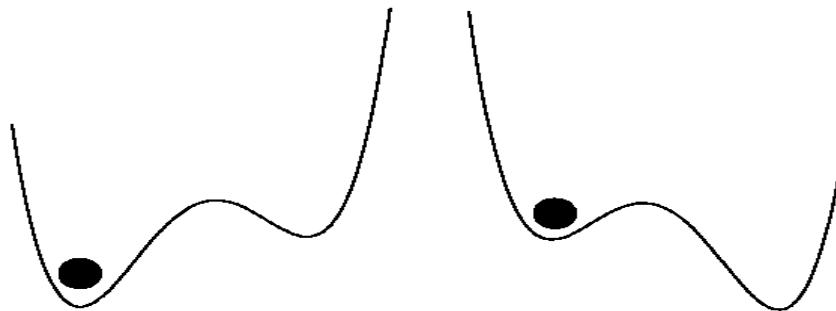
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Simple example: double well potential



$$U(x,t) = -ax^2 + bx^4 + \epsilon x \sin(\omega t)$$



T1

T2



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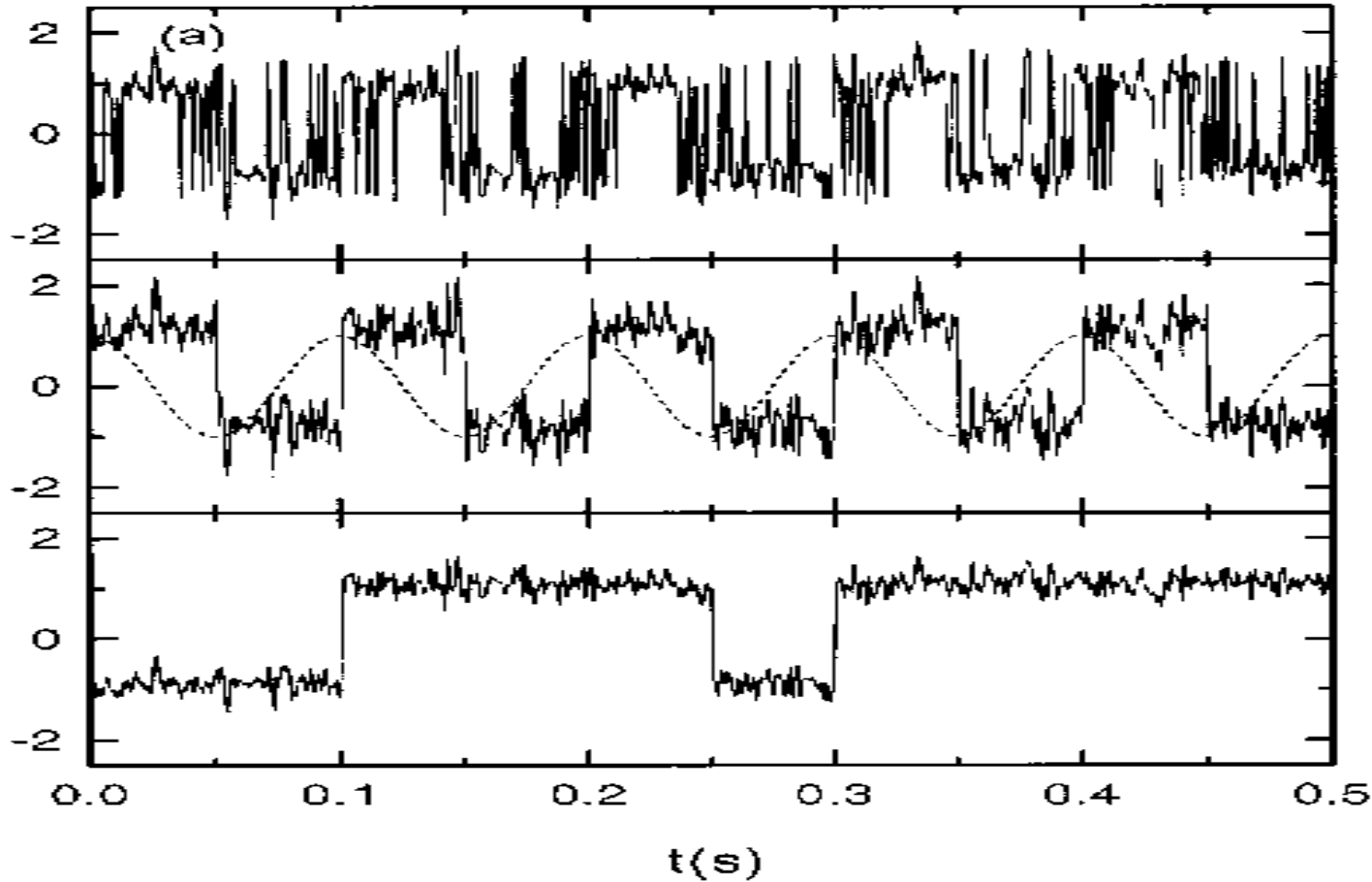
34

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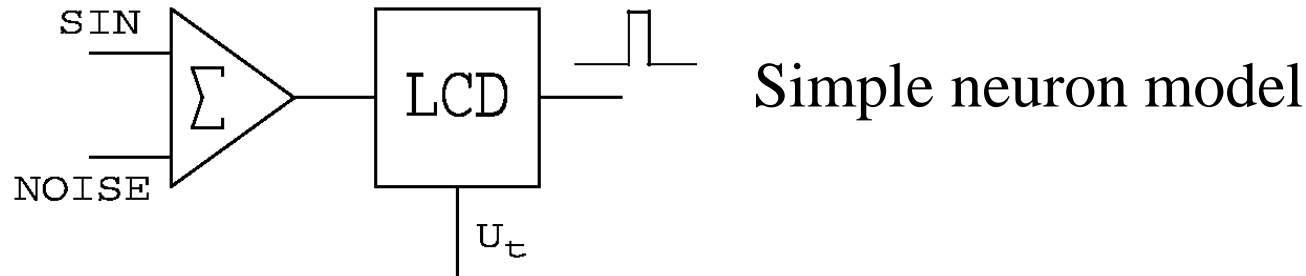




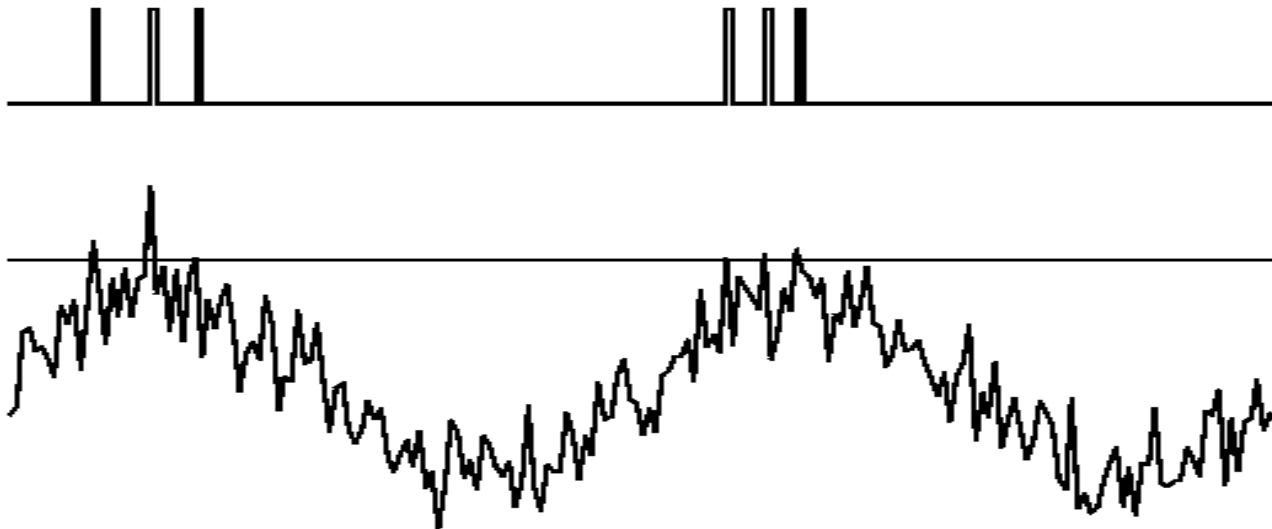
Typical signals



Even more simple example: non dynamical SR

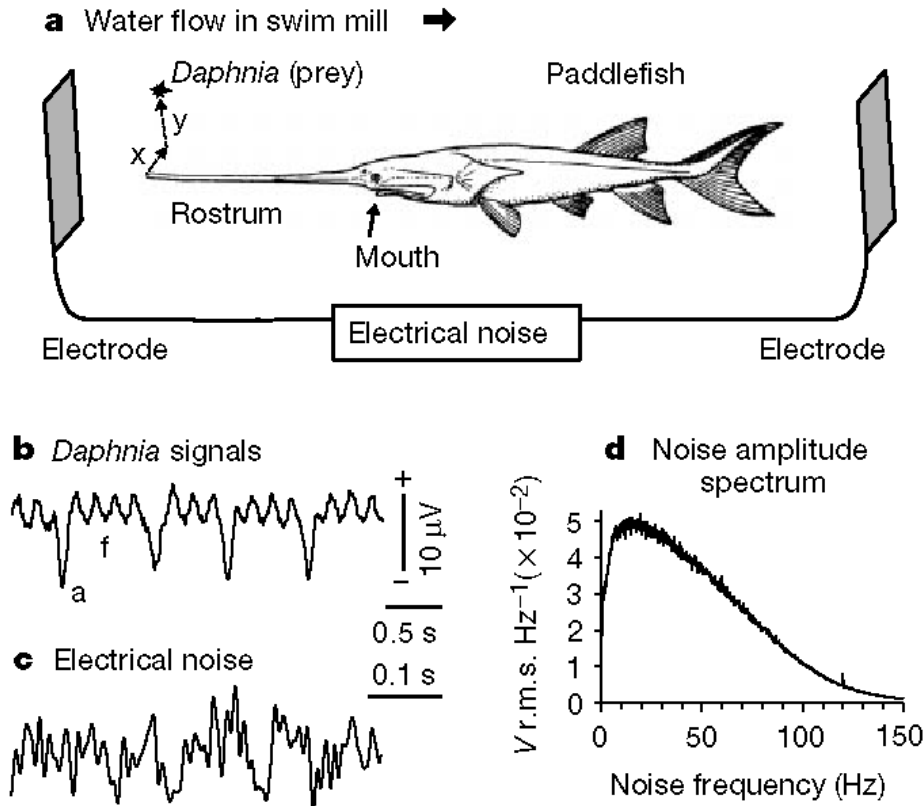


Simple neuron model



How does paddlefish hunt?

(D.F. Russell et al., Nature 402 (1999)18)

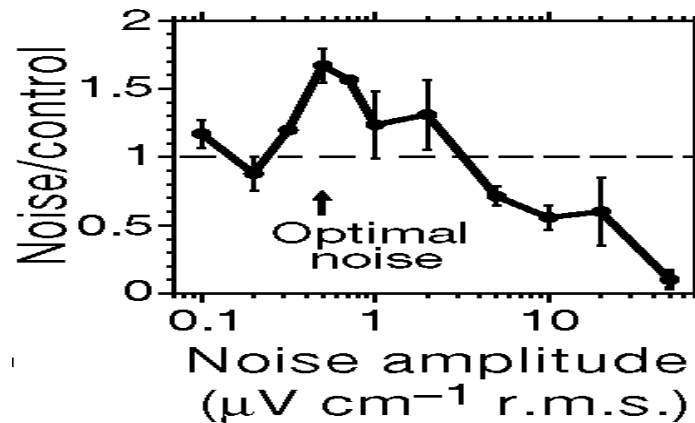
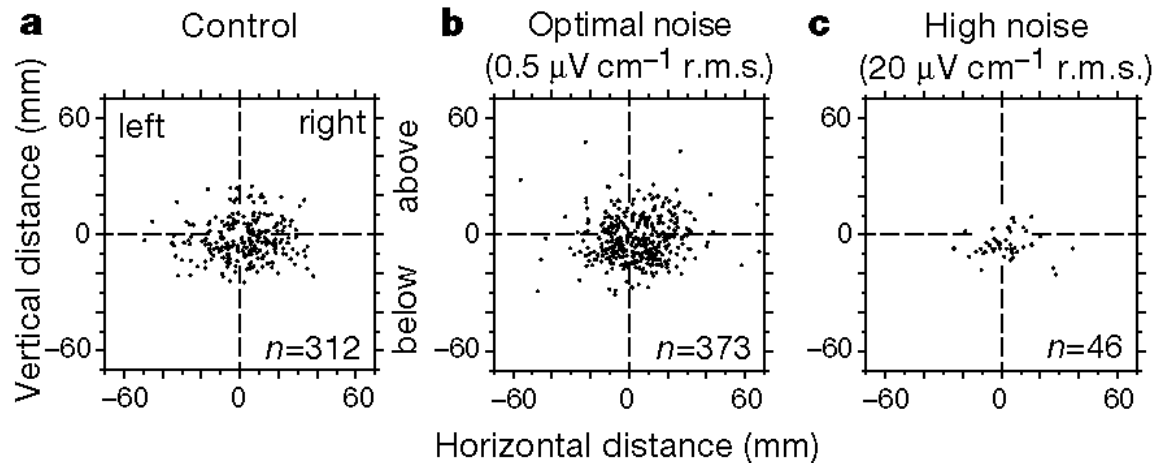


noise can optimize „efficiency”:



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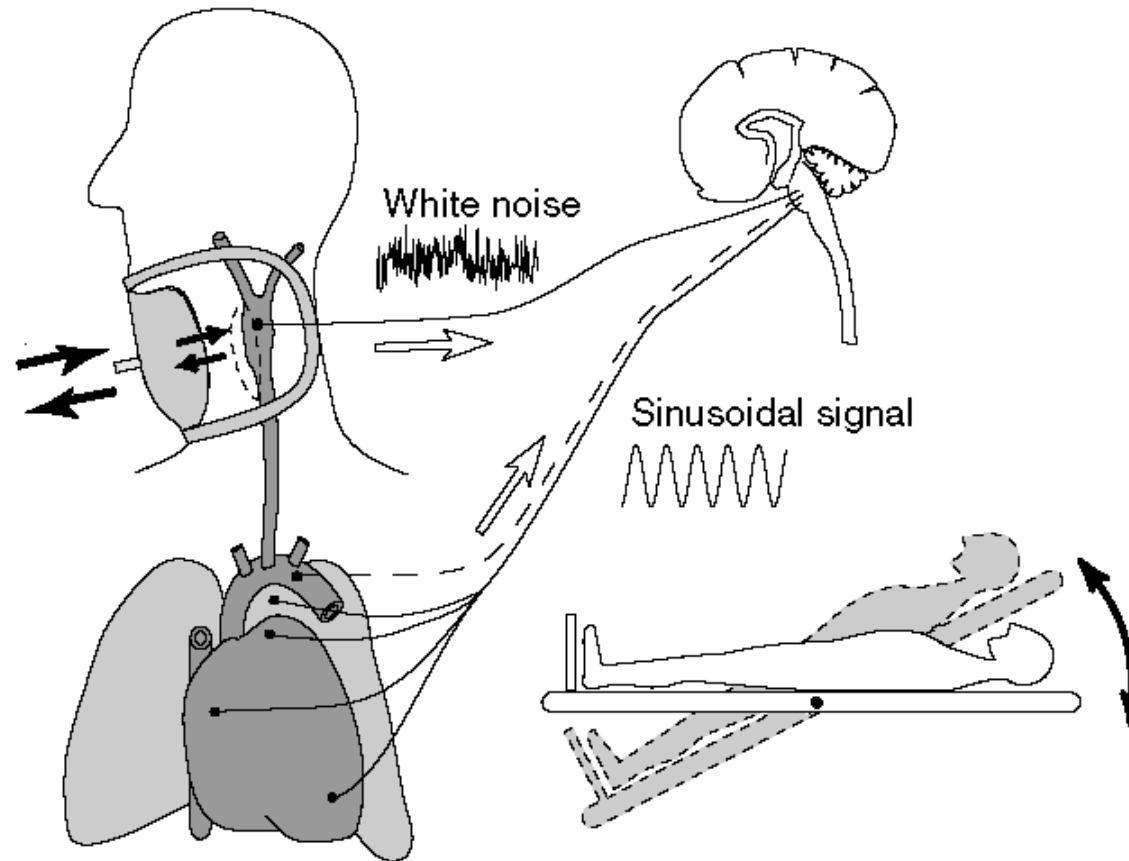


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Baroreflex mechanism in humans

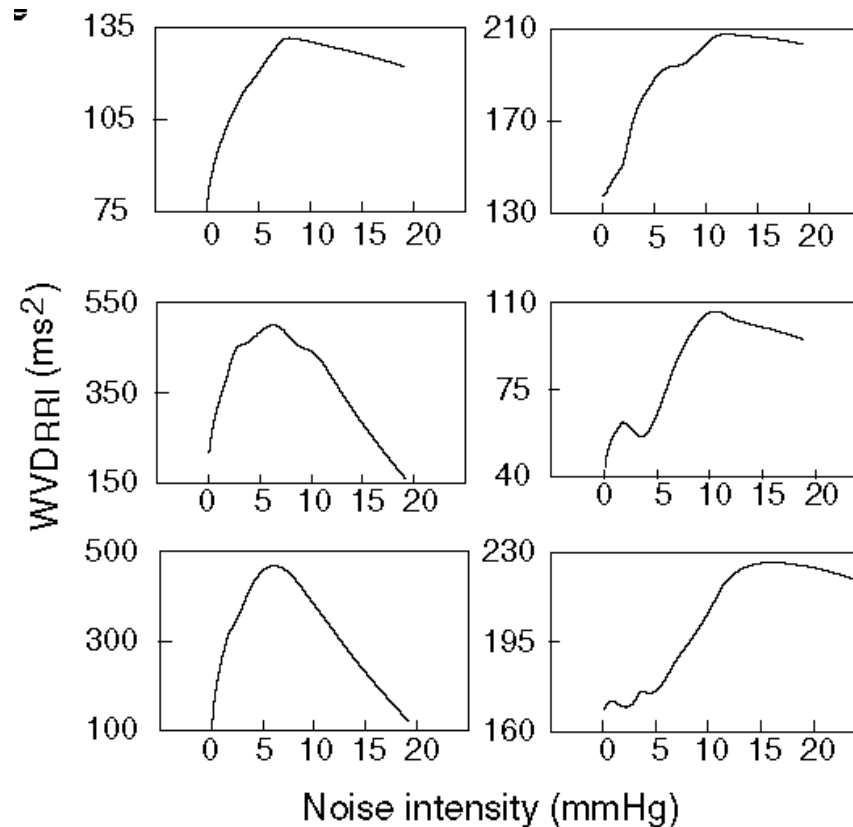
(Hidaka et al., Phys Rev Lett, 85 (2000) 17)



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Baroreflex sensitivity as a function of noise intensity





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Cochlear implants



Cochlea-beültetés: a külső mikrofon jelét a jelföldolgozó egység elektromos impulzusokká alakítja, amelyeket a csigában (*cochlea*) elhelyezett elektródák továbbítanak



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How added noise can help?

- Hair cells detect sound, emit impulses can be detected by neurons
- Defective or missing hair cells can be simulated by implants
- Hearing of speech can be still poor
- Adding noise makes the simulated signals more natural

http://www.scholarpedia.org/article/Suprathreshold_stochastic_resonance





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Summary

- Noise can serve as information source
- Noise analysis tools for many signals
- Adding noise can help to
 - improve quality of measurements
 - information transfer
 - Reduce EMI
 - and more



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