Combined peak and level-crossing sampling scheme

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Outline

- Motivation
- Signal-dependent sampling
- Combined peak and level-crossing sampling
- Conclusions

Motivation

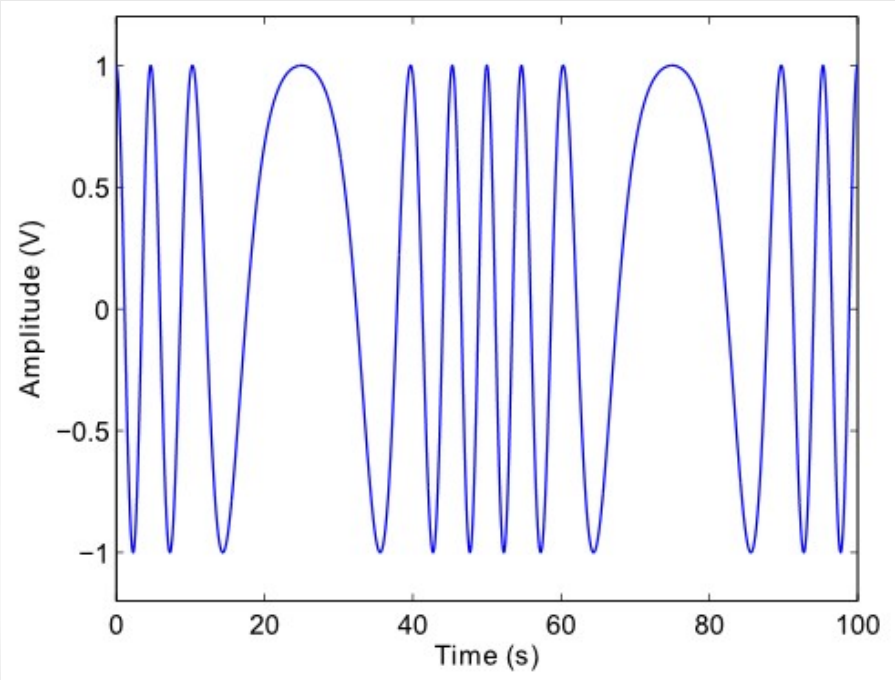
- Uniform sampling is not always the best sampling method for data acquisition
- In wireless sensor networks, it is important to reduce energy consumption of sensor nodes
- As most of the energy is consumed by data transmission, we are interested in data acquisition, which adapts to time-varying frequency properties of the signal
- This can be called signal-dependent sampling, when few samples are taken at low frequency regions and more samples at high frequency regions
- The objective is to find efficient signal-dependent sampling method and simple reconstruction

Signal-dependent sampling

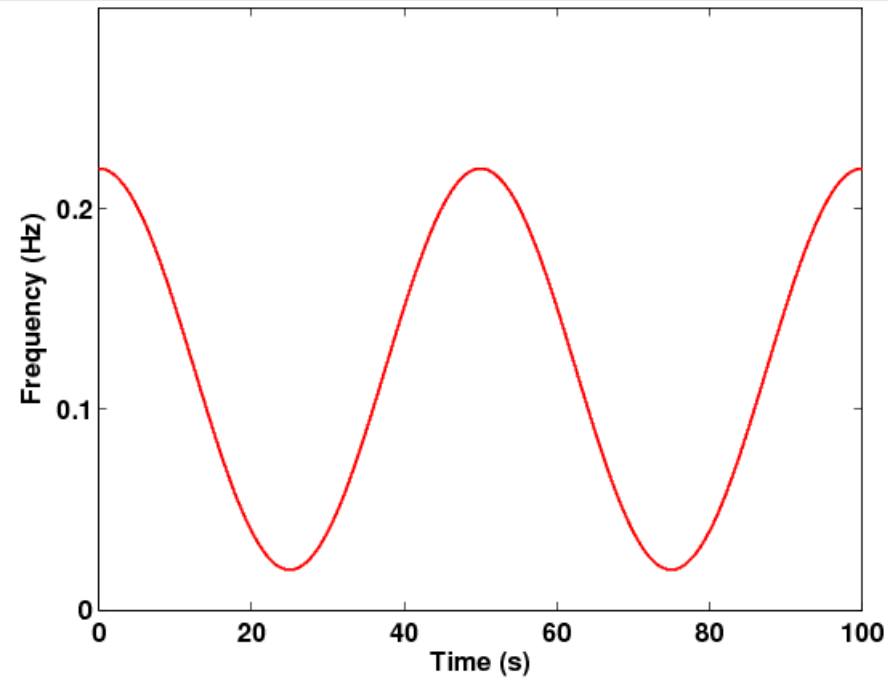
- Samples are taken depending on signal itself (time-varying frequency bandwidth of the signal)

$$y(t)=\cos(\Phi(t)) \qquad \Phi(t)=2\pi\int_{-\infty}^{t} f(t)\,dt$$

Signal



Time-varying frequenci



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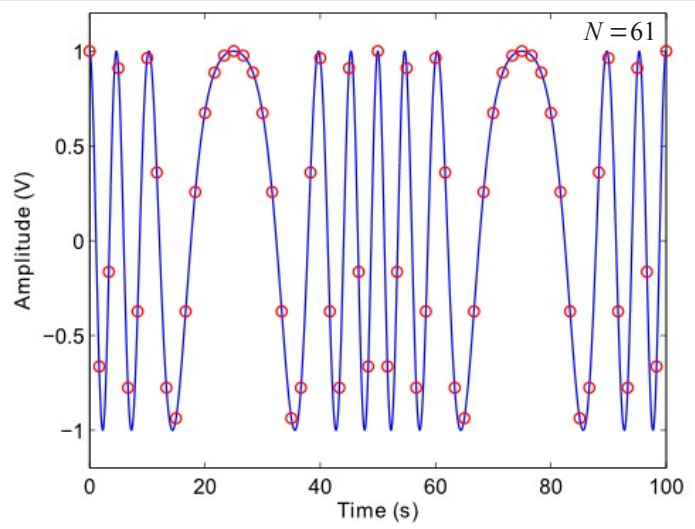

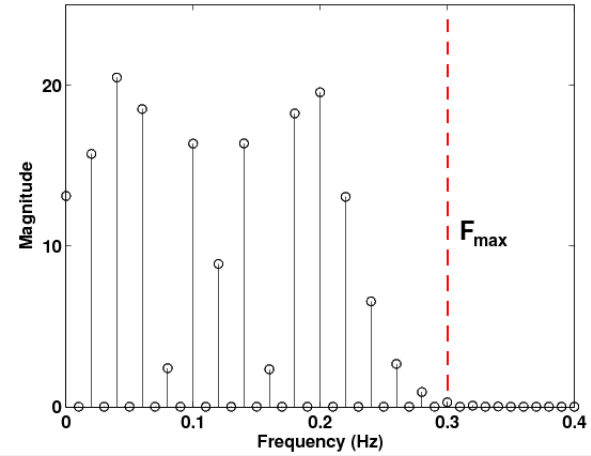

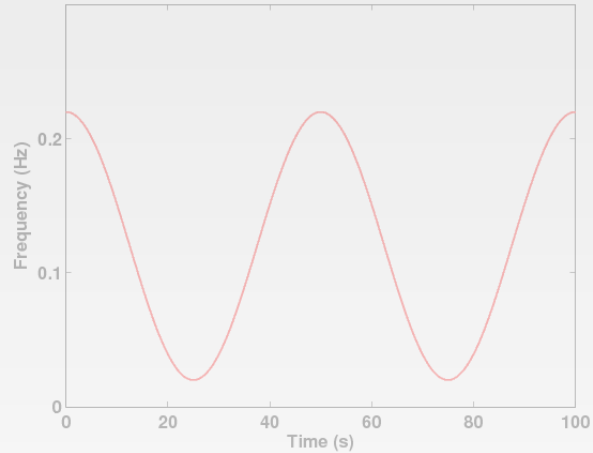

$$y(t)\approx\sum_{n=-\infty}^{\infty} y(t_n)\,\mathrm{sinc}(2\pi F_{max}(t-t_n)), \qquad t_n=\frac{n}{2F_{max}}$$

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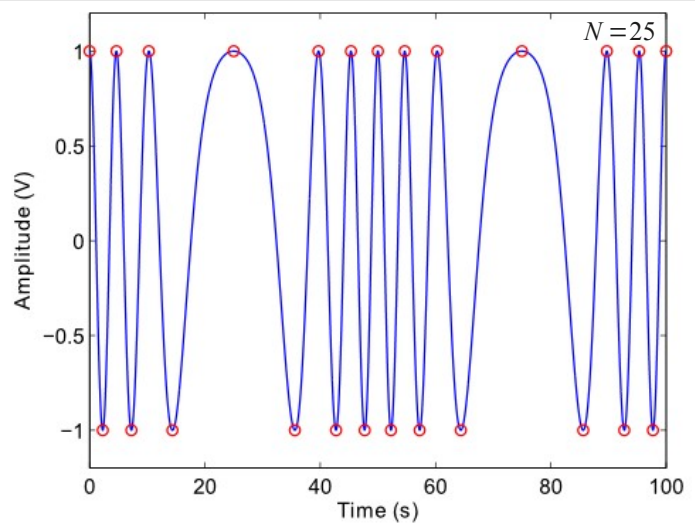
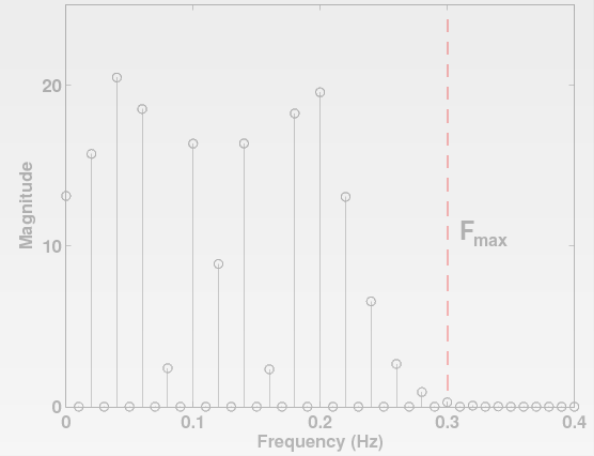
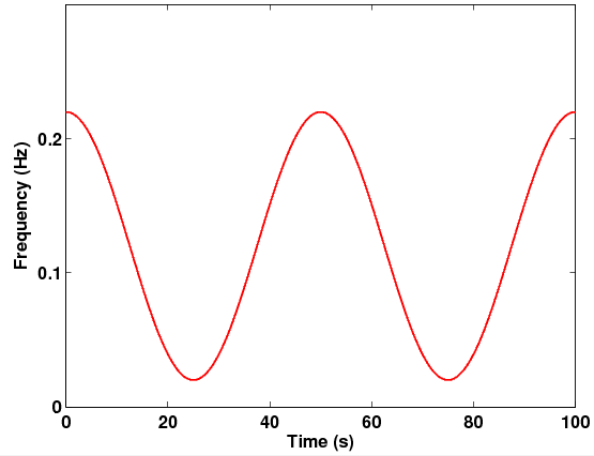






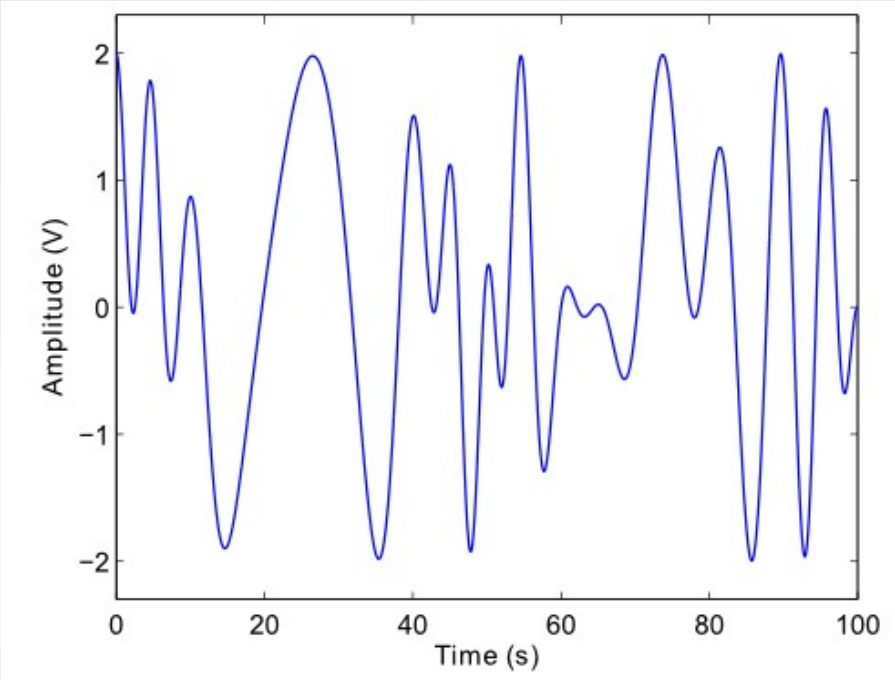
$$y(t)=\sum_{n=-\infty}^{\infty} y(t_n)\,\mathrm{sinc}(\Phi(t)-\Phi(t_n)), \qquad \Phi(t_n)=n\pi$$

Signal-dependent sampling

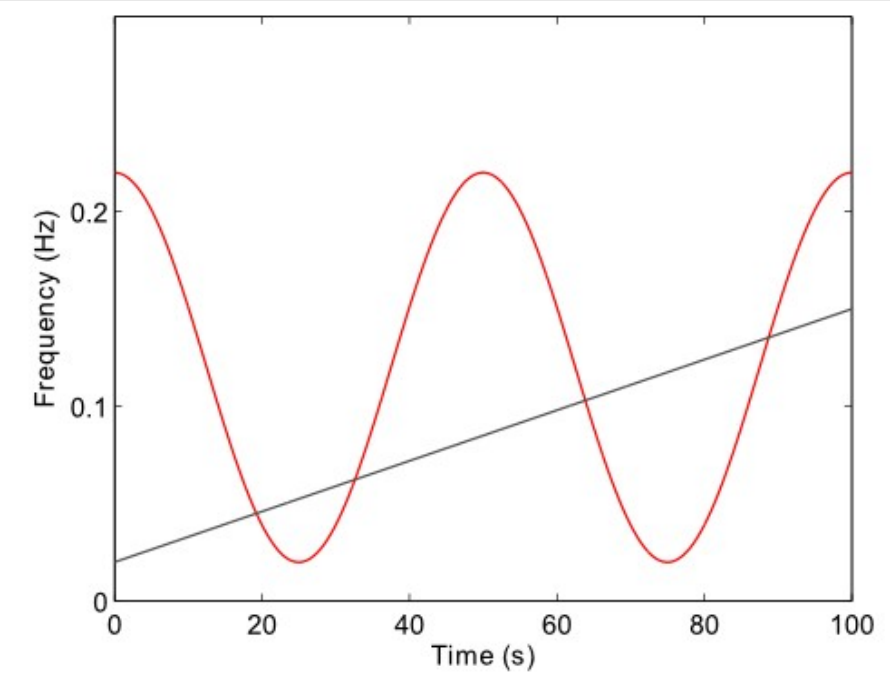
- Samples are taken depending on signal itself (time-varying frequency bandwidth of the signal)

$$s(t)=\sum_{m=1}^{M}\cos(\Phi_m(t)) \qquad \Phi_m(t)=2\pi\int_{-\infty}^{t} f_m(t)\,dt$$

Signal



Frequency traces



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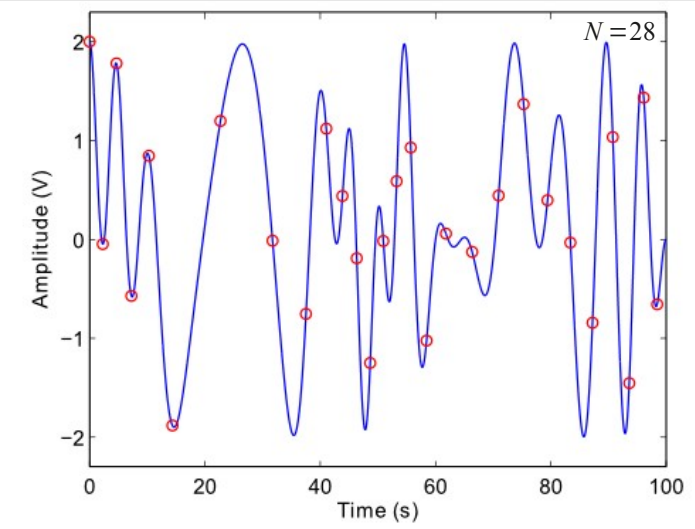
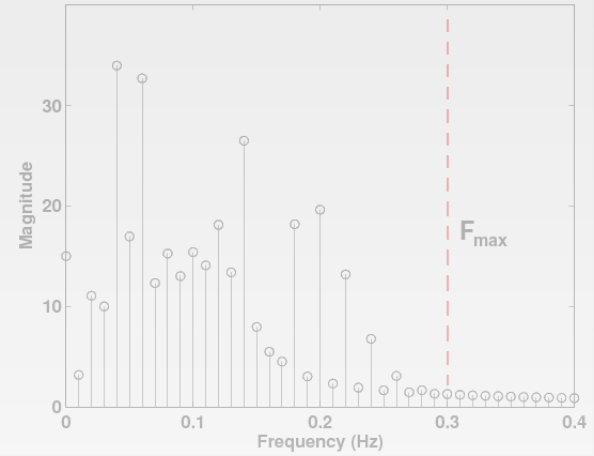
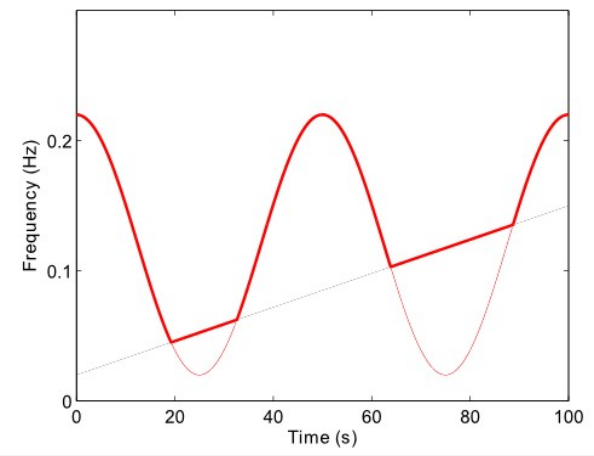


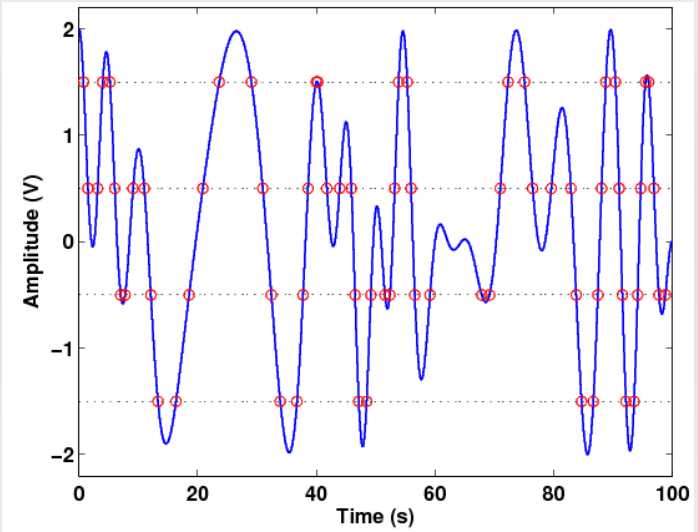




$$s(t)\approx\sum_{n=-\infty}^{\infty} s(t_n)\,\mathrm{sinc}(\Phi(t)-\Phi(t_n)), \quad \Phi(t)=2\pi\int_{-\infty}^{t} f_{max}(t)\,dt, \quad \Phi(t_n)=n\pi$$

Level-crossing sampling

- Samples $s(t_m)$ are taken at level crossings



- Signal reconstruction methods:
  - interpolation
  - iterative interpolation and filtering
  - frequency $\hat{f}_{max}(t)$ estimation and calculation of $\hat{s}(t_n)$ from equation

$$\hat{s}(t)=\sum_{n=1}^{N}\hat{s}(t_n)\,\mathrm{sinc}\left(\hat{\Phi}(t)-\hat{\Phi}(t_n)\right)$$

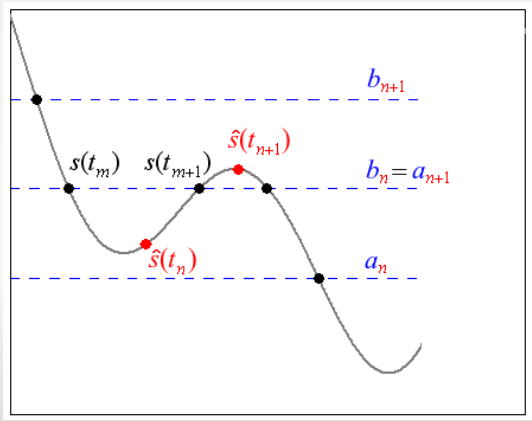
$$\hat{\Phi}(t)=2\pi\int_{-\infty}^{t}\hat{f}_{max}(t)\,dt,\qquad \hat{\Phi}(t_n)=n\pi$$

by minimizing

$$\min_{\hat{\mathbf{s}}}=\hat{\mathbf{s}}^T\left(\mathbf{H}^T\mathbf{H}\right)\hat{\mathbf{s}}-2\left(\mathbf{H}^T\mathbf{s}\right)^T\hat{\mathbf{s}},$$

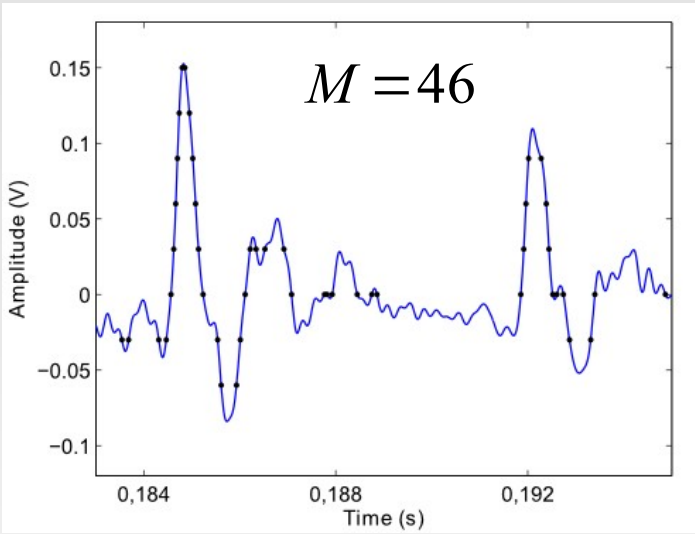
such that

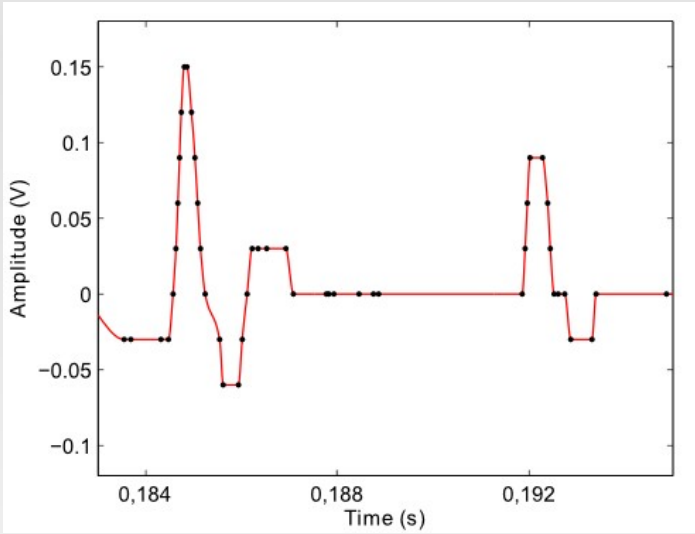
$$a_n\le\hat{s}(t_n)\le b_n$$

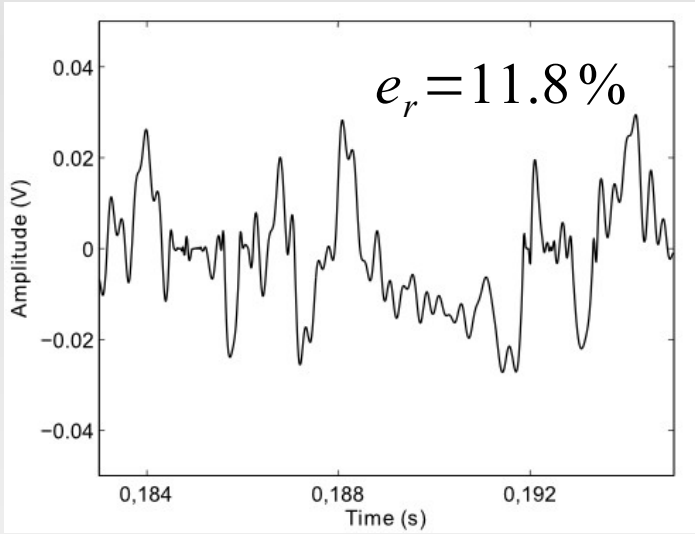


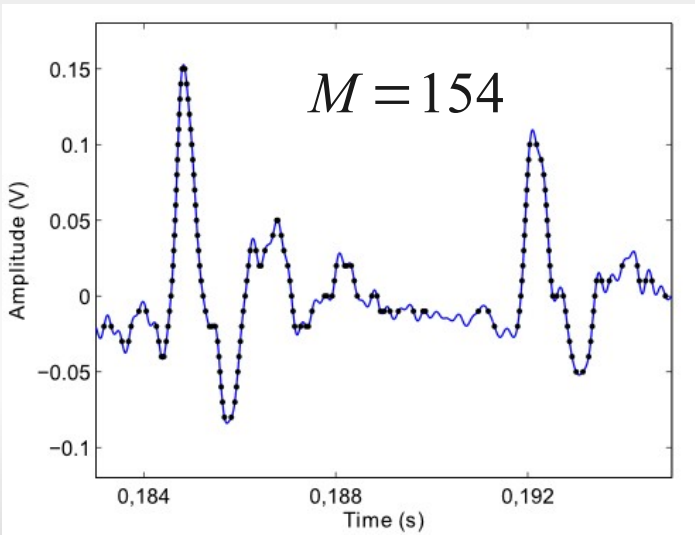
Level-crossing sampling

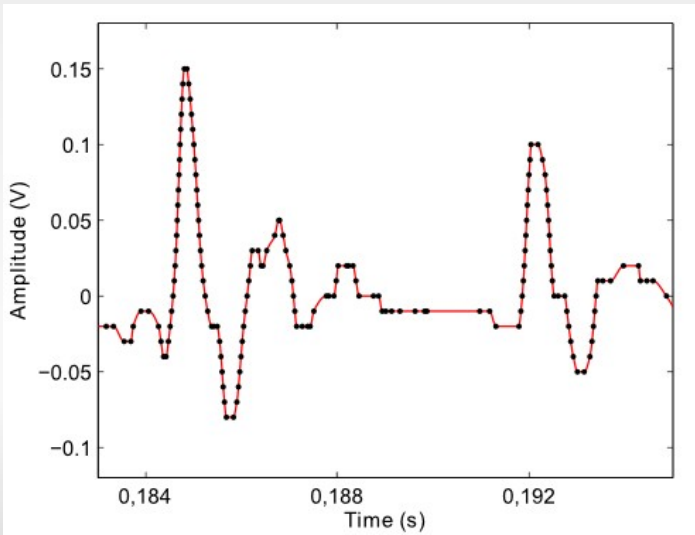
- Number of samples and reconstruction quality

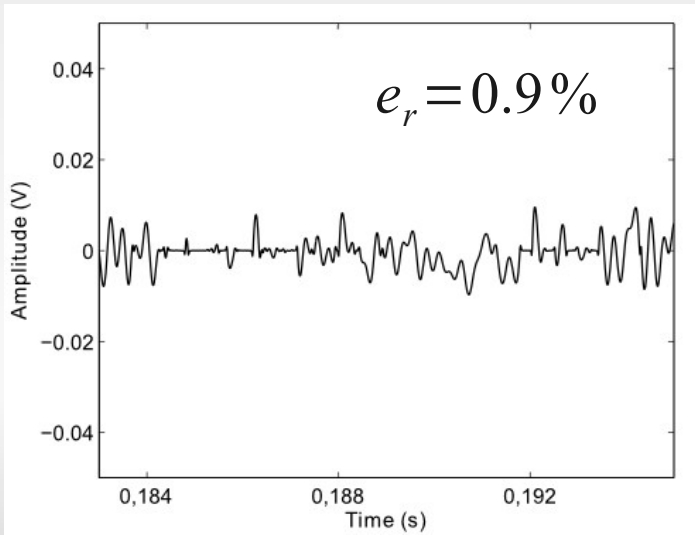












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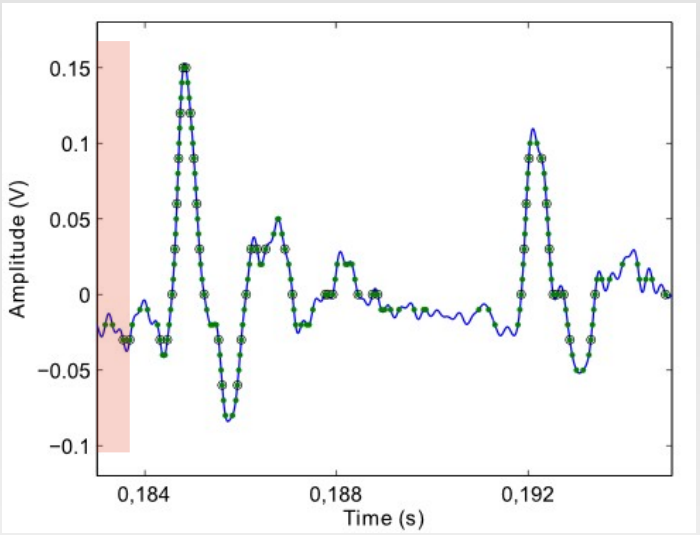

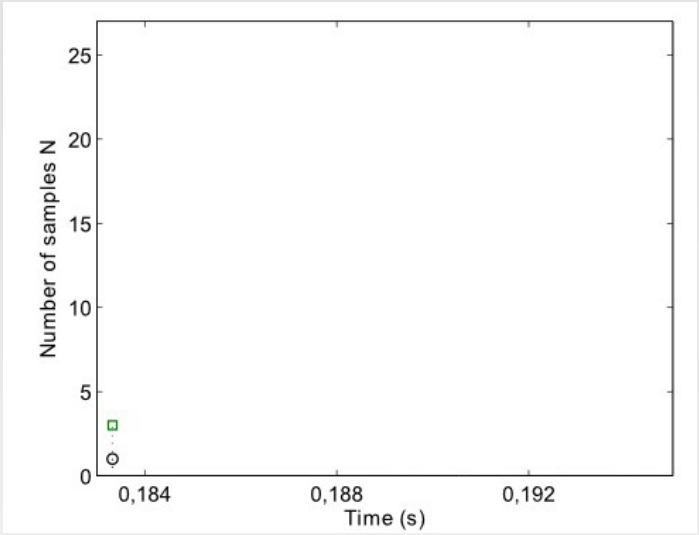

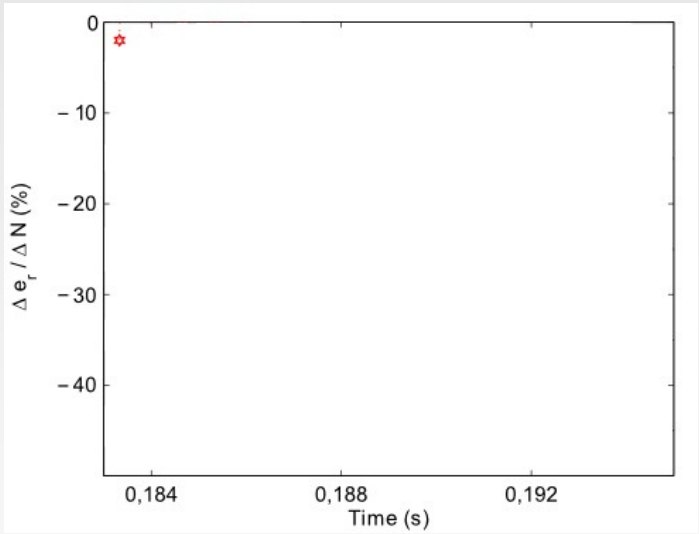

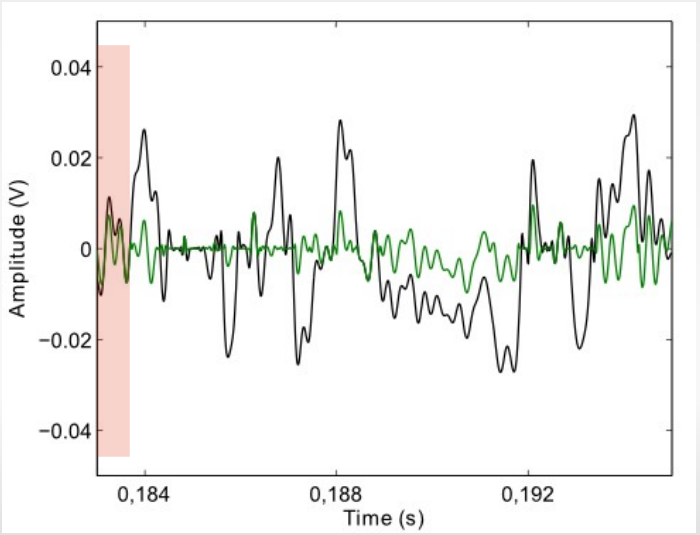

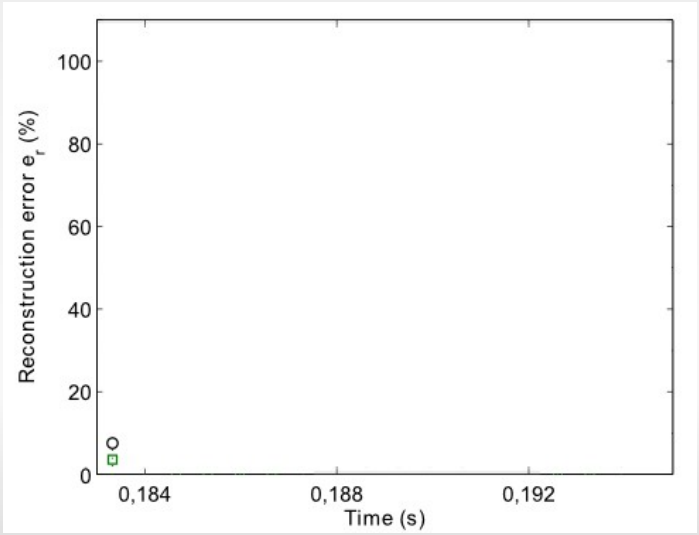

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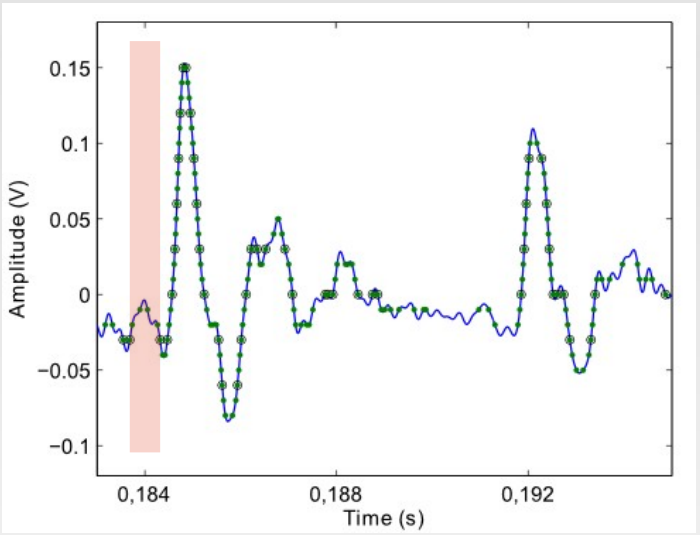
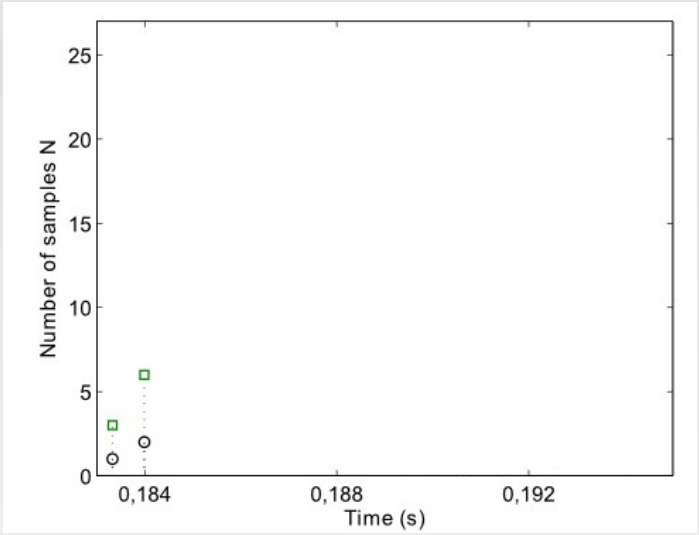
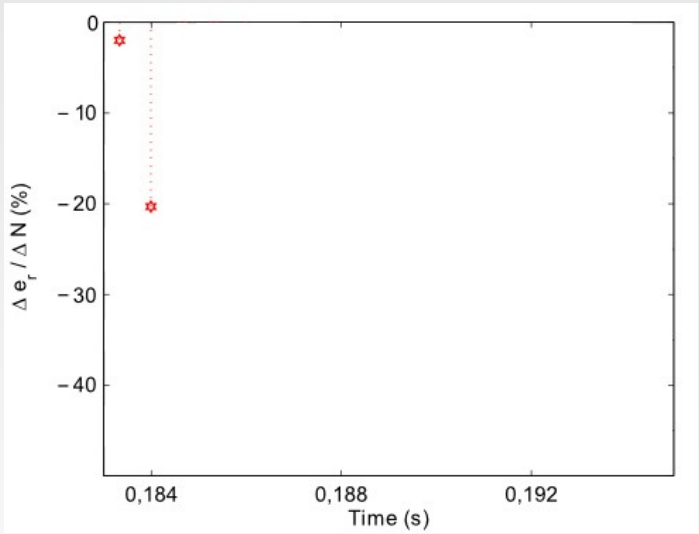
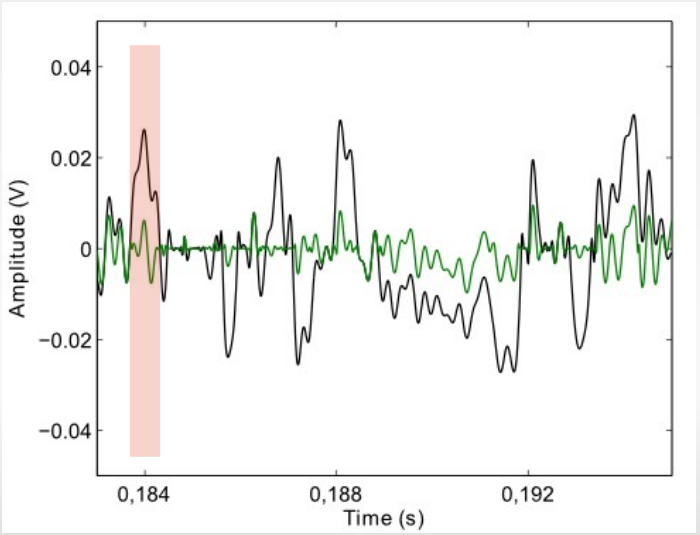
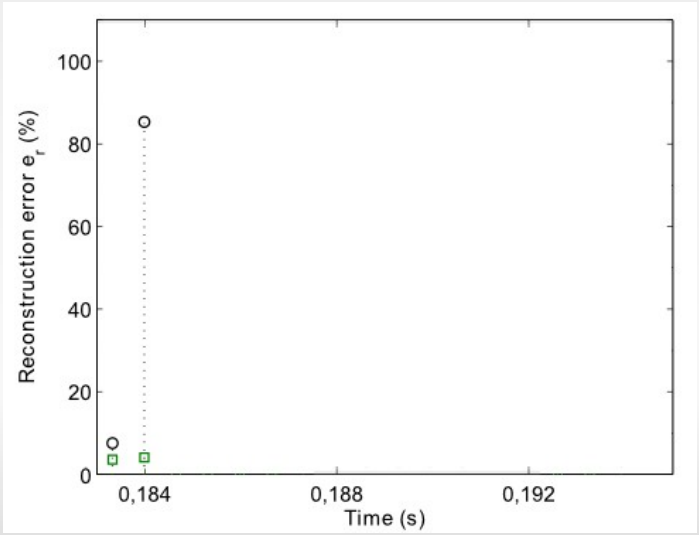




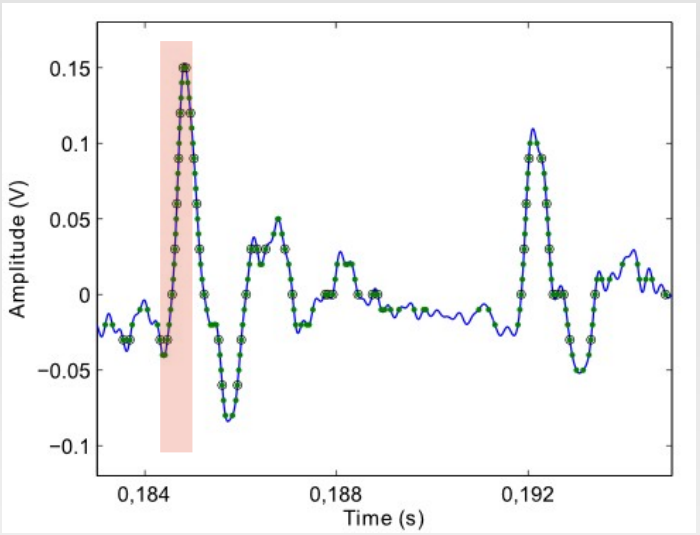


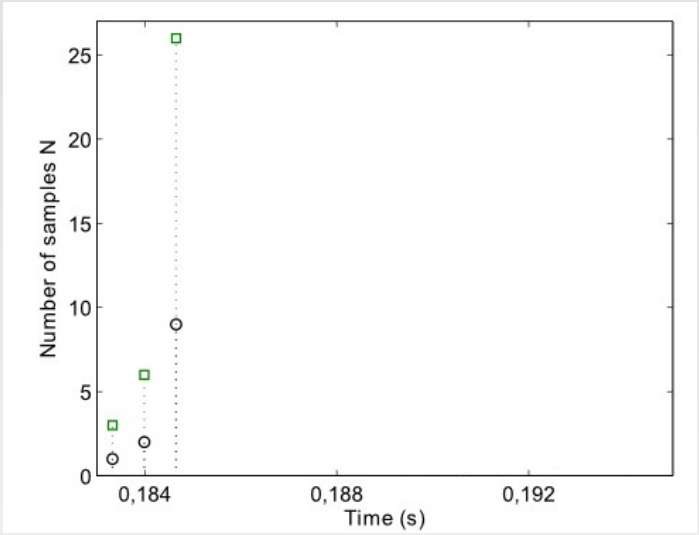


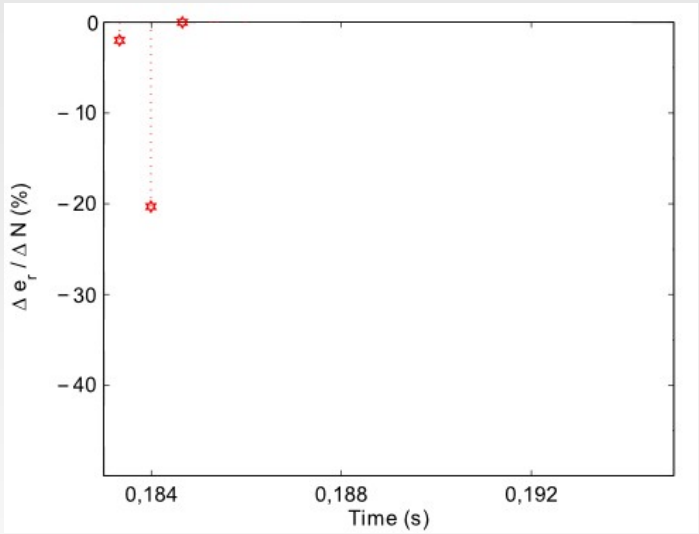


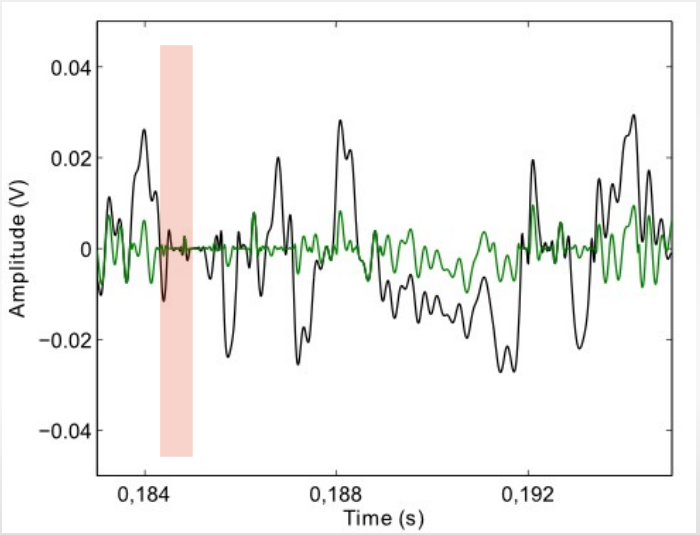
Level-crossing sampling

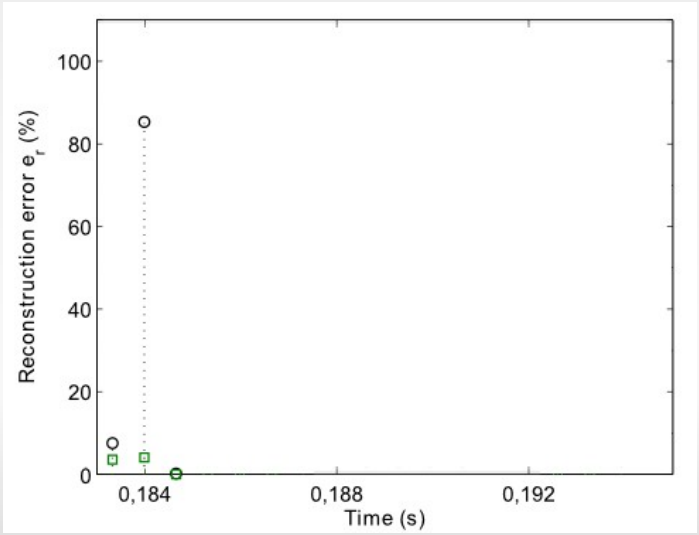
- Number of samples and reconstruction quality











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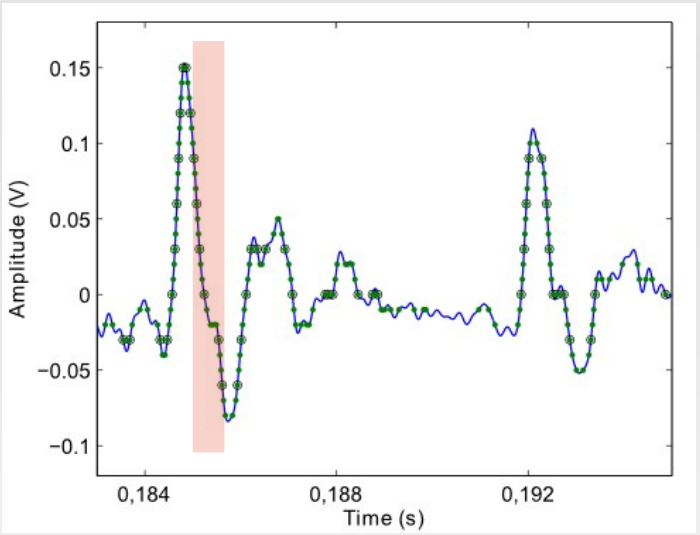

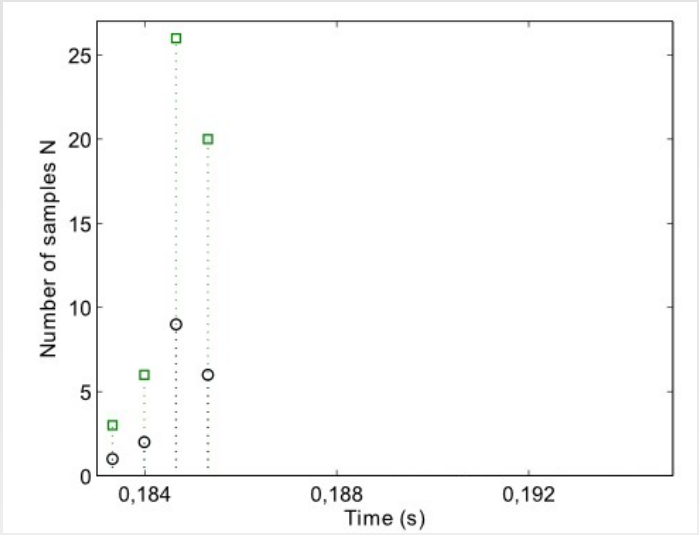

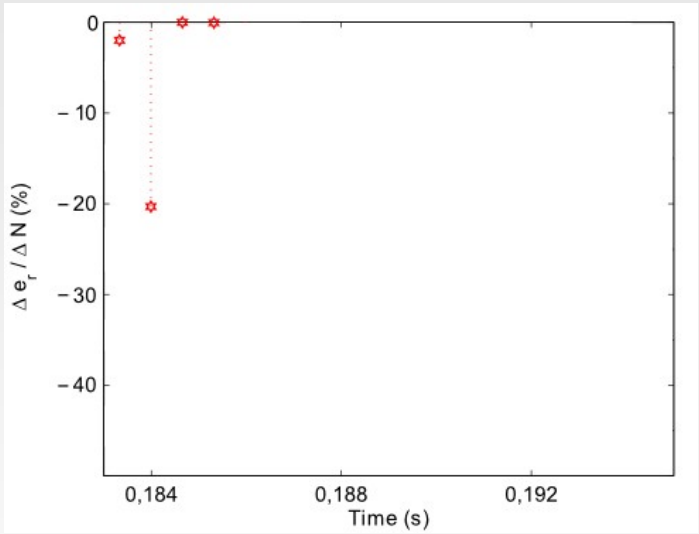

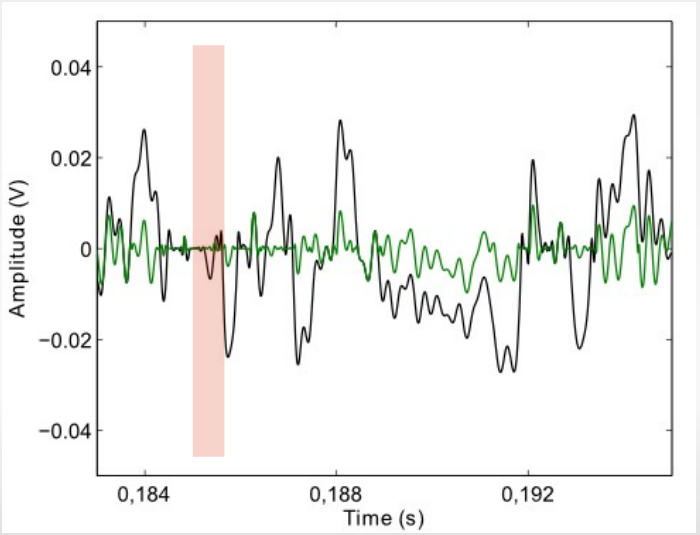

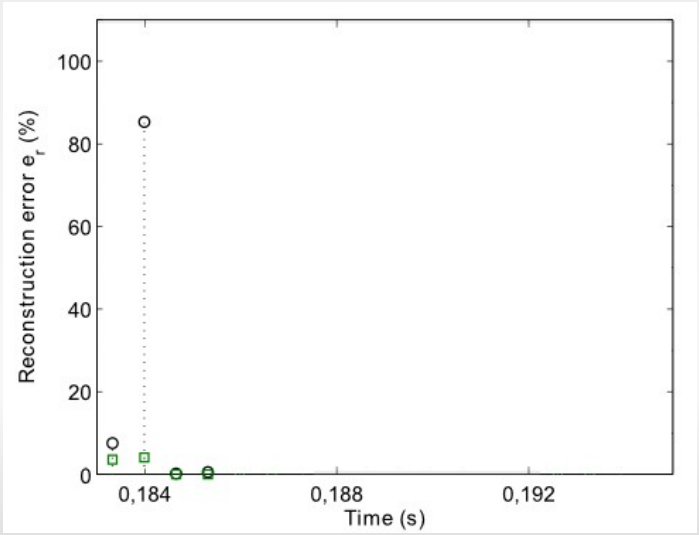

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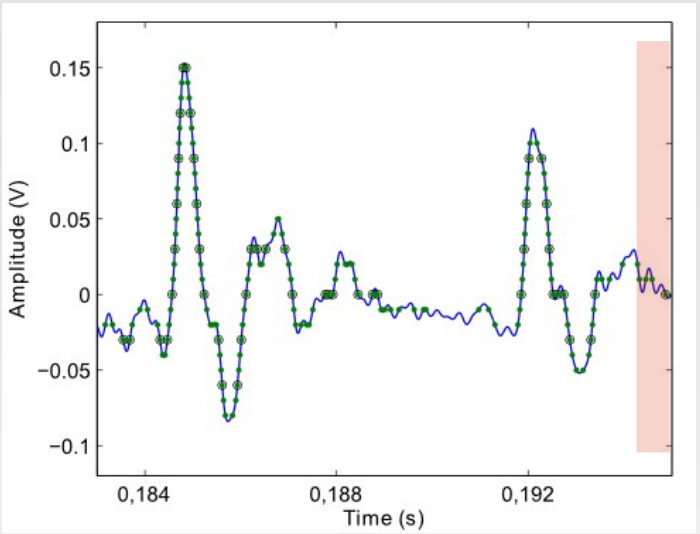
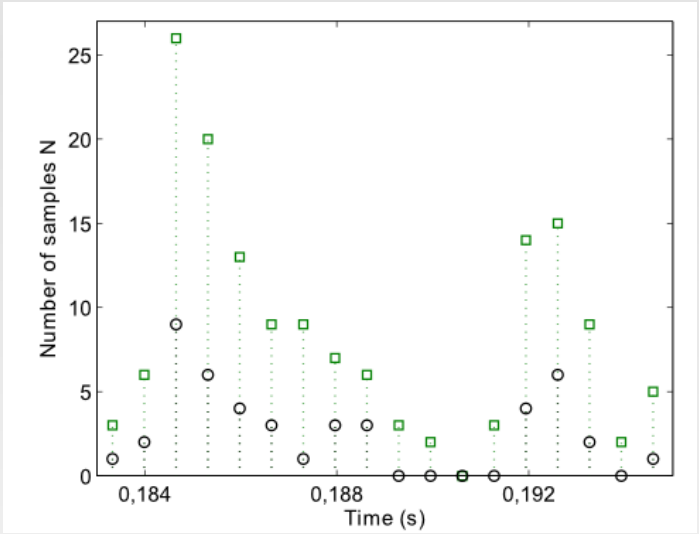
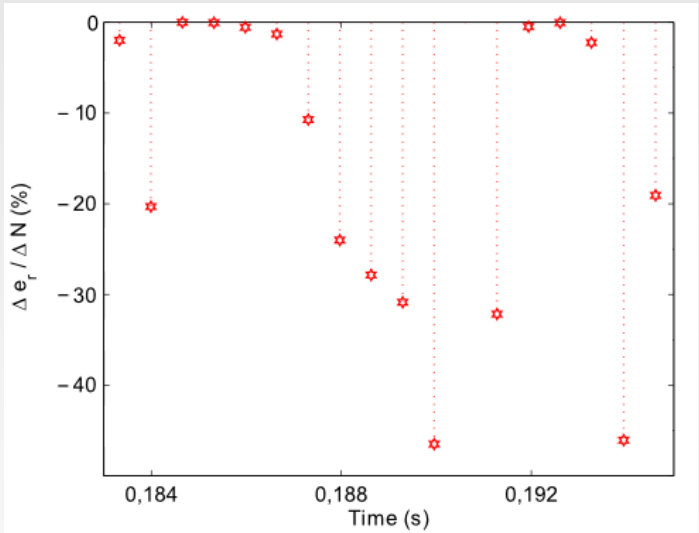
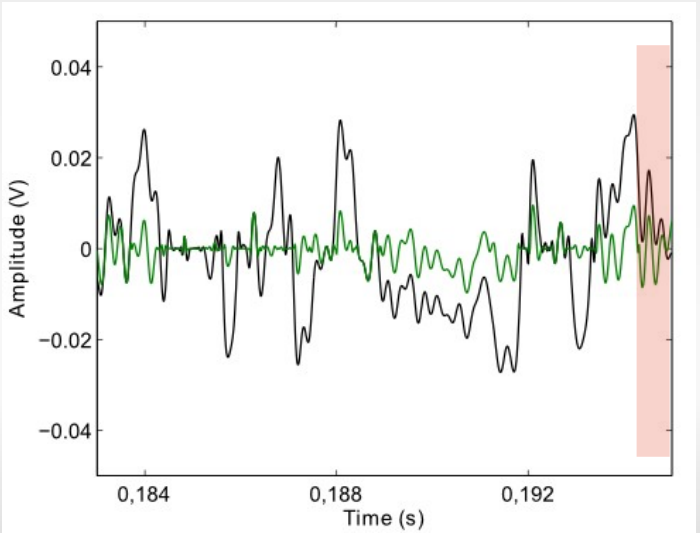
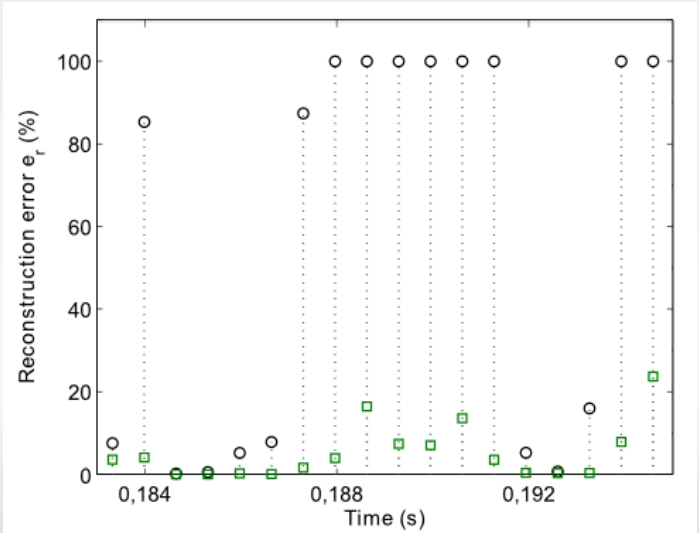
- Number of samples and reconstruction quality





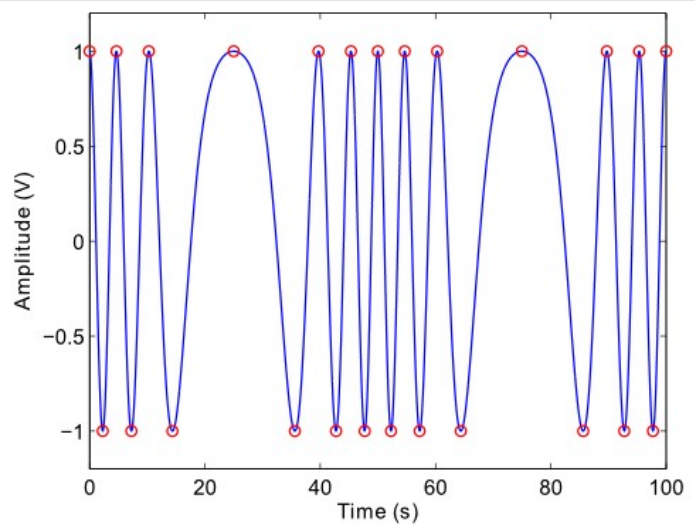


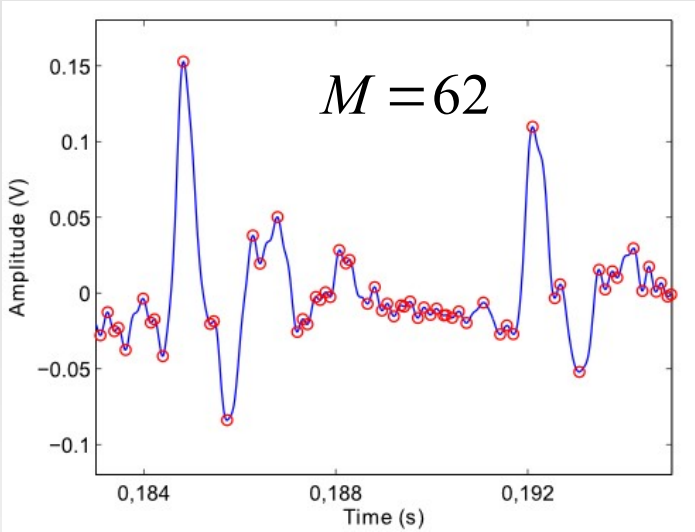




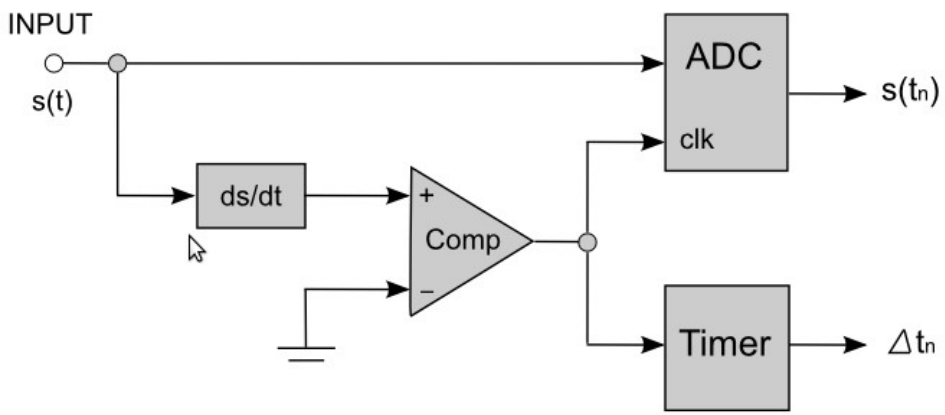
Peak sampling

- Samples are taken at signal peaks



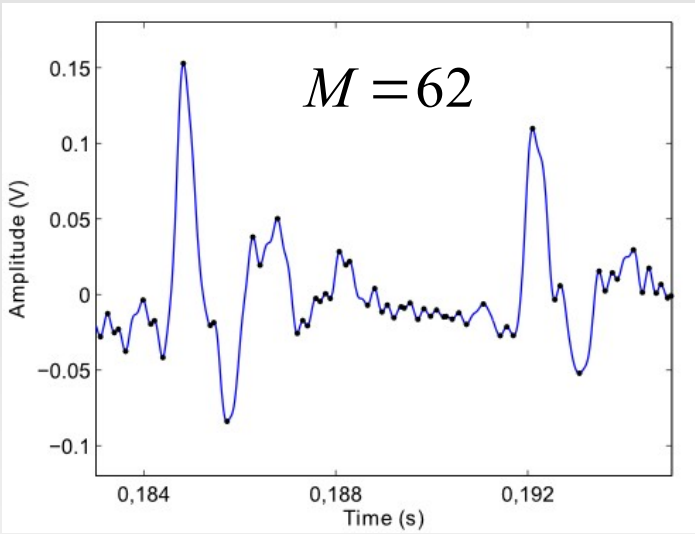


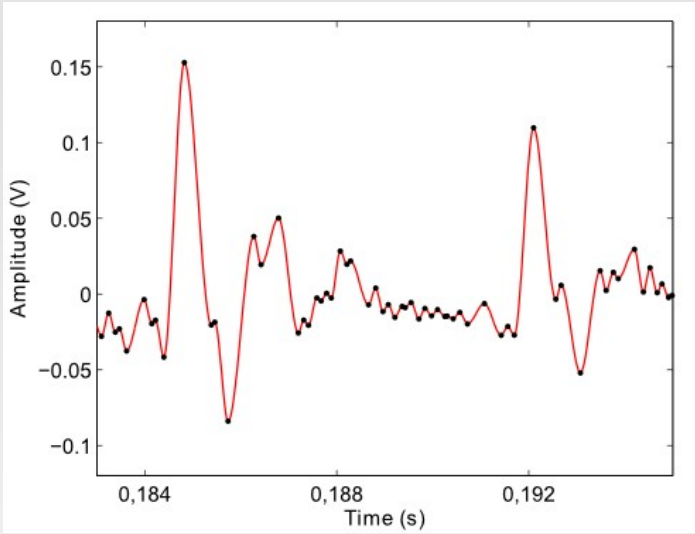
- Block scheme

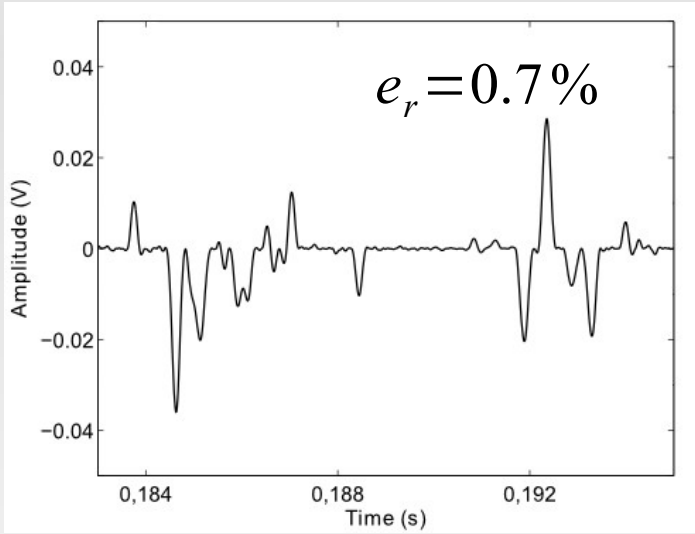


Peak sampling

- Advantage: less samples provide good reconstruction quality







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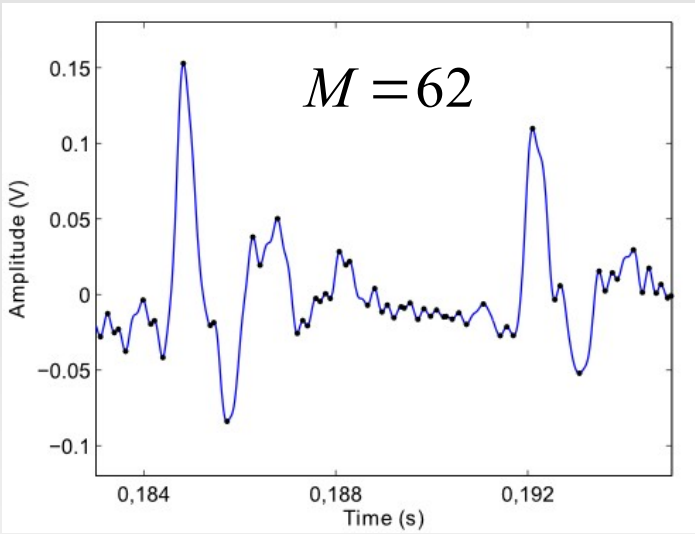
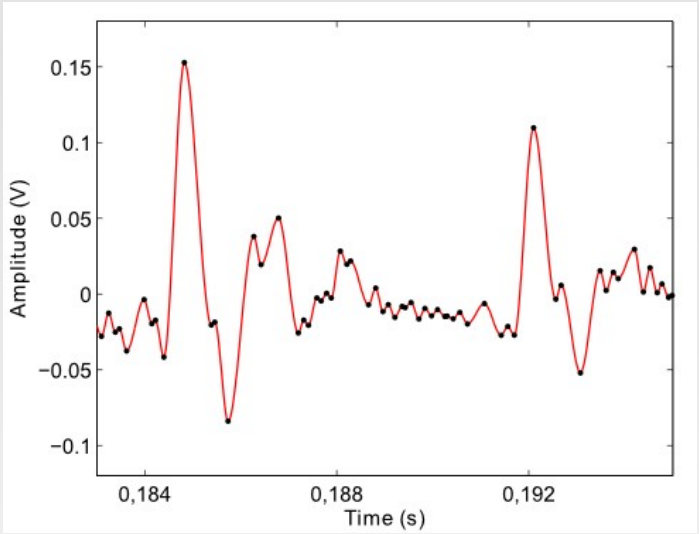
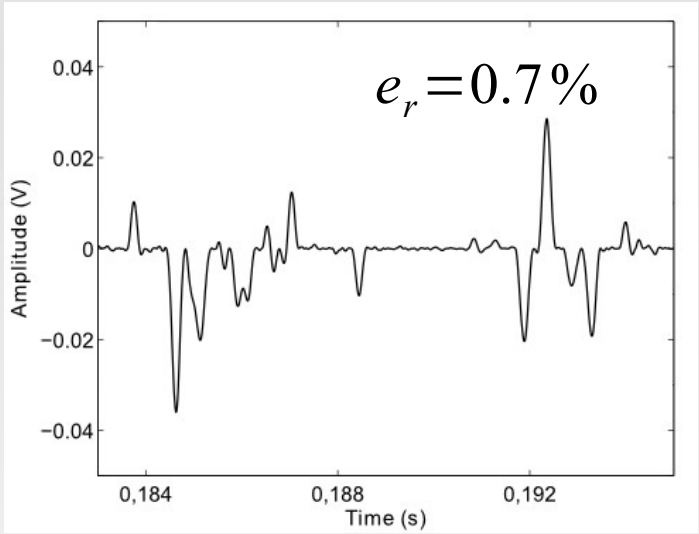
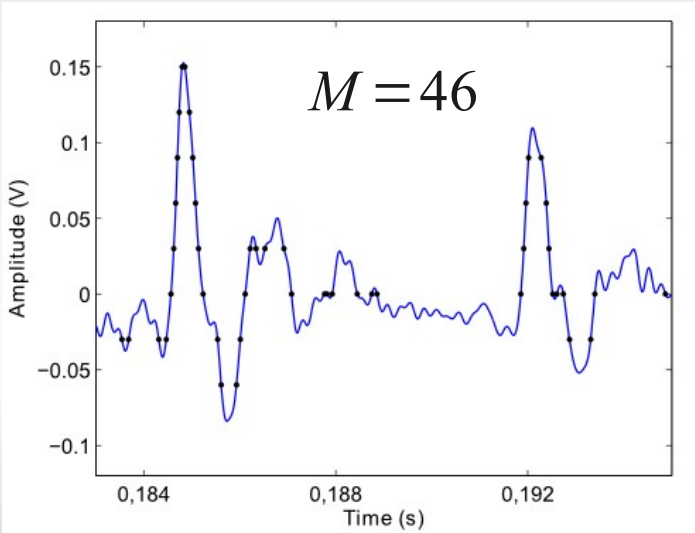
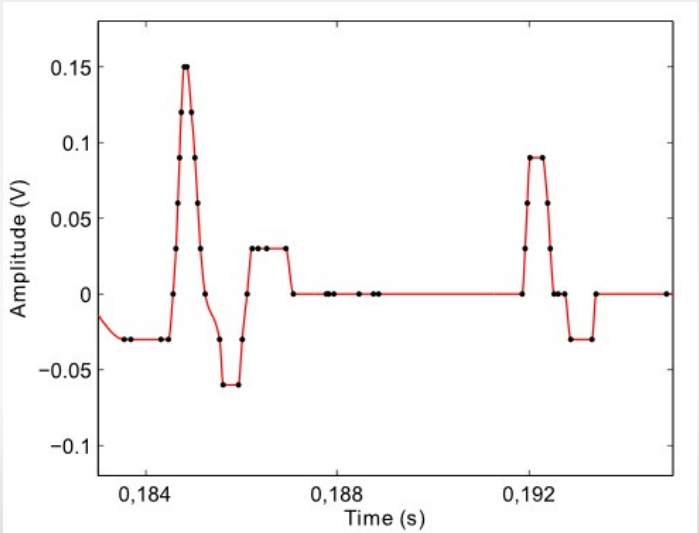
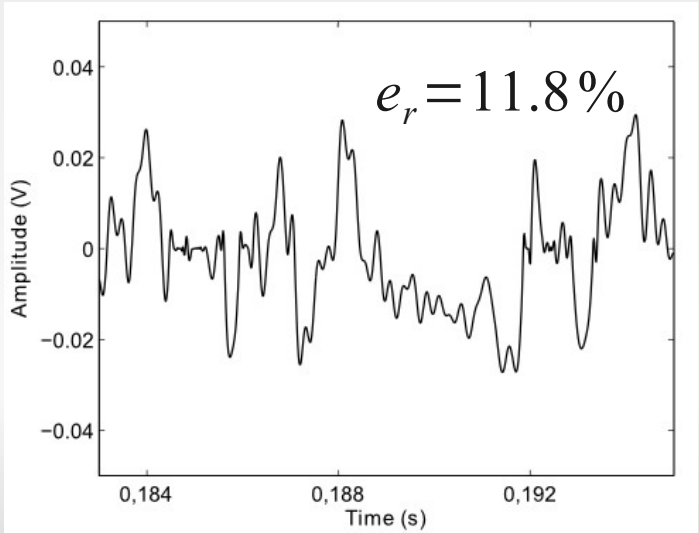






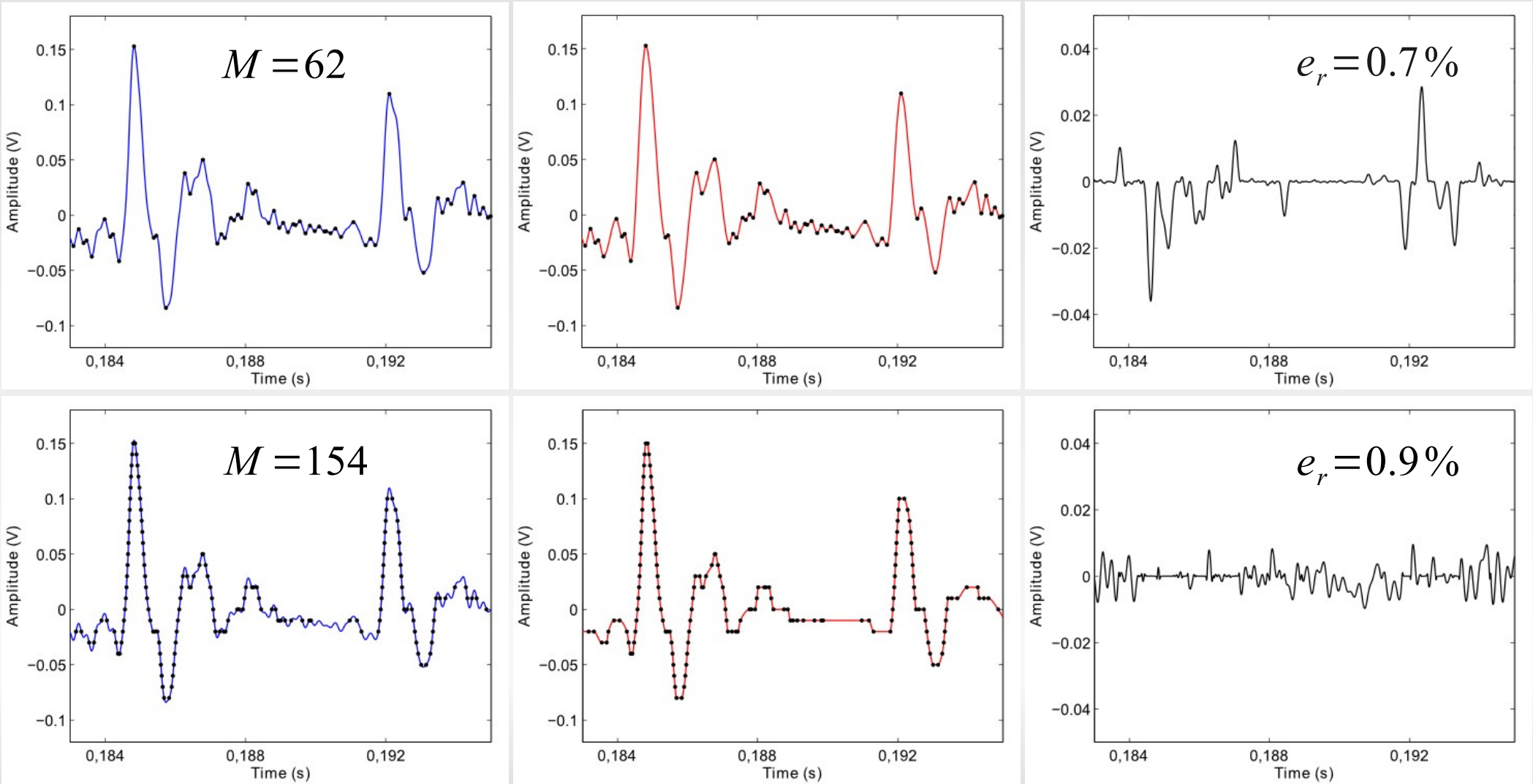






Peak sampling

- Advantage: less samples provide good reconstruction quality



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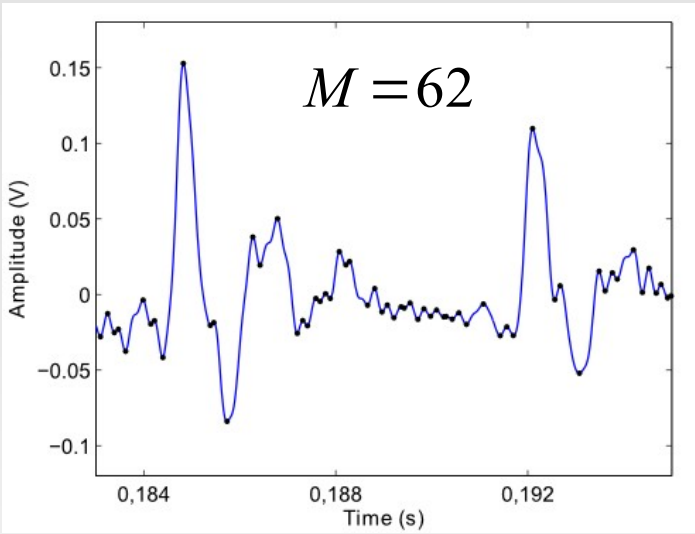
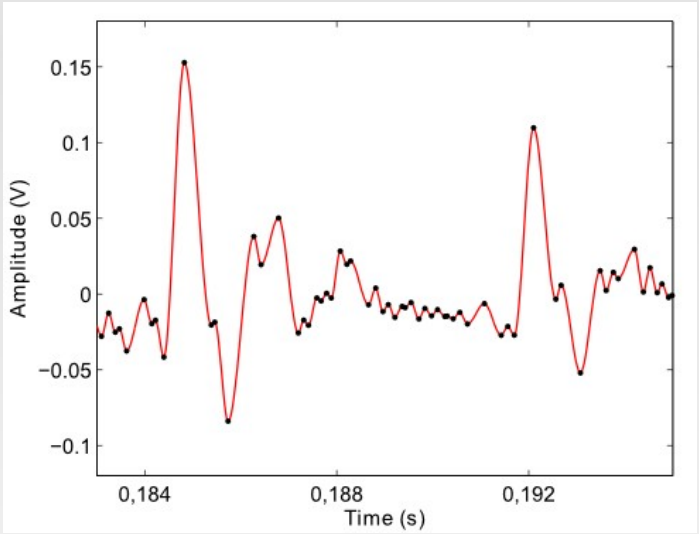
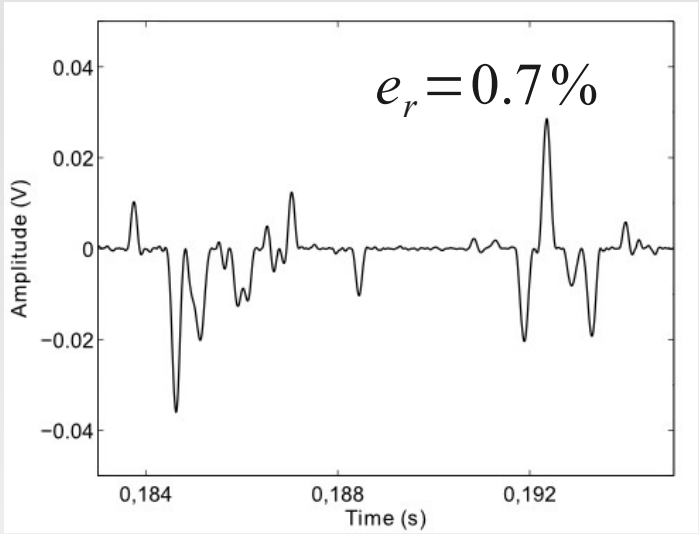


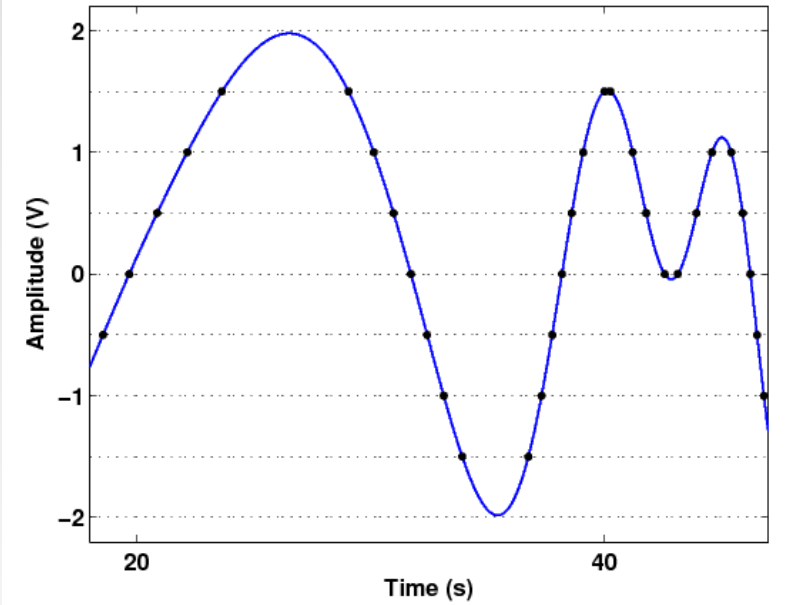




- Drawback: more bits per sample are required for digital representation of the signal – each sample is characterized by its time location t_n and amplitude value $s(t_n)$

Combined sampling

- Samples are taken only at level crossings most closely located to signal peaks



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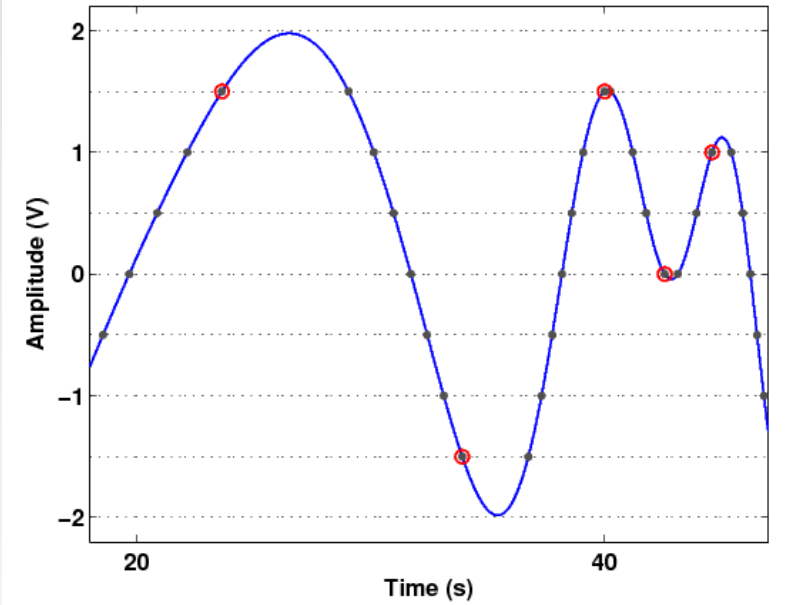

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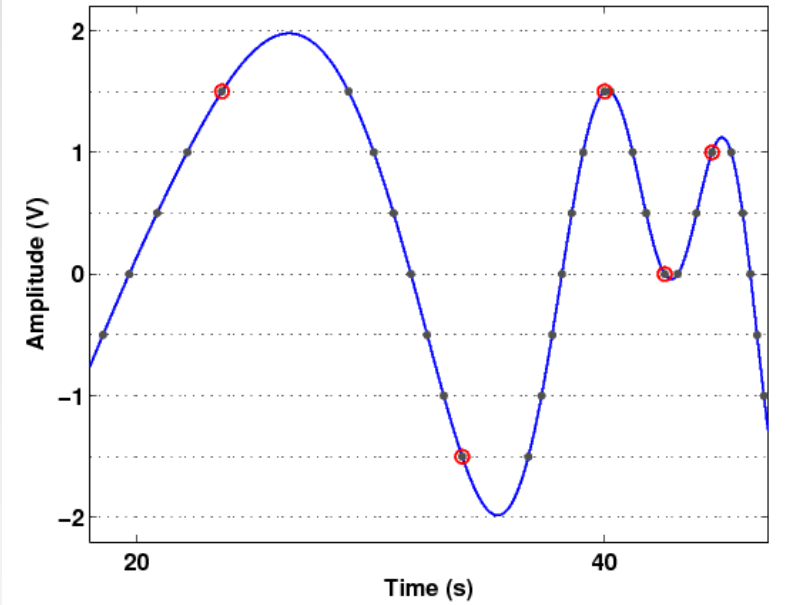

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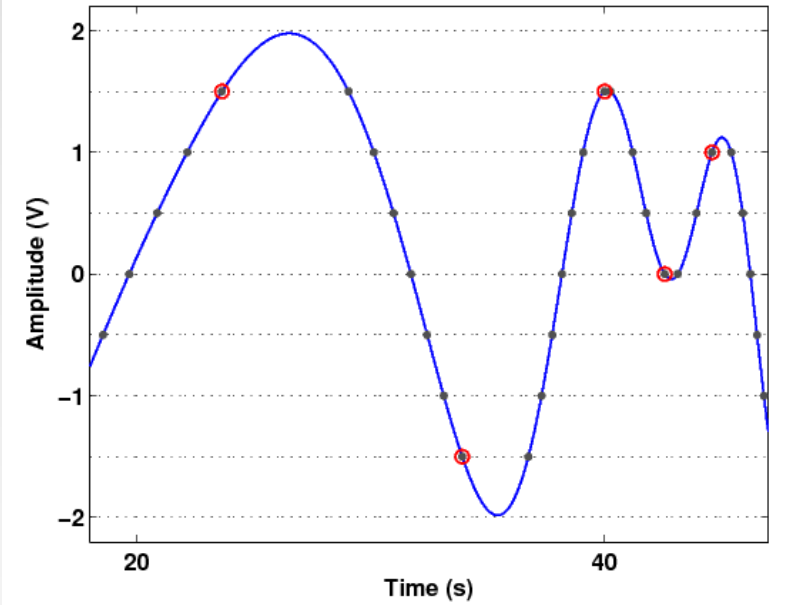

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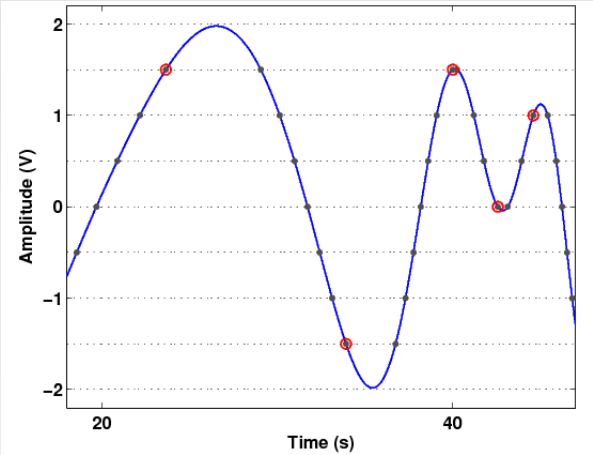
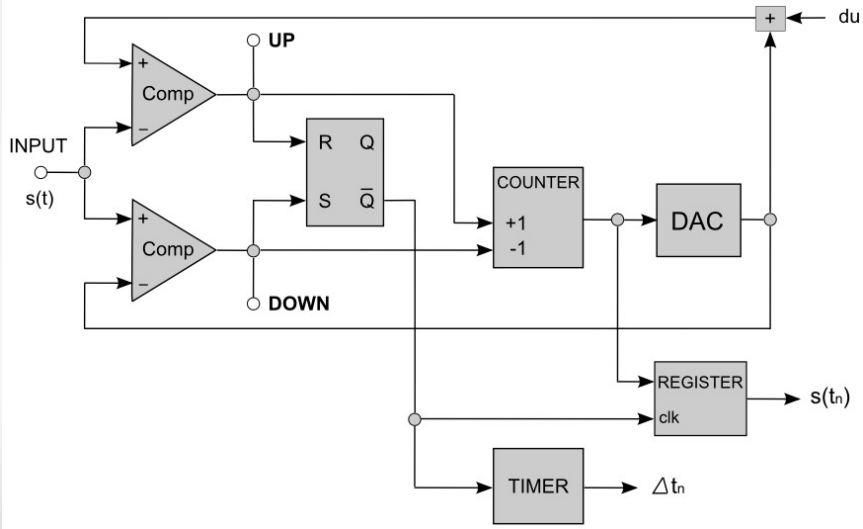
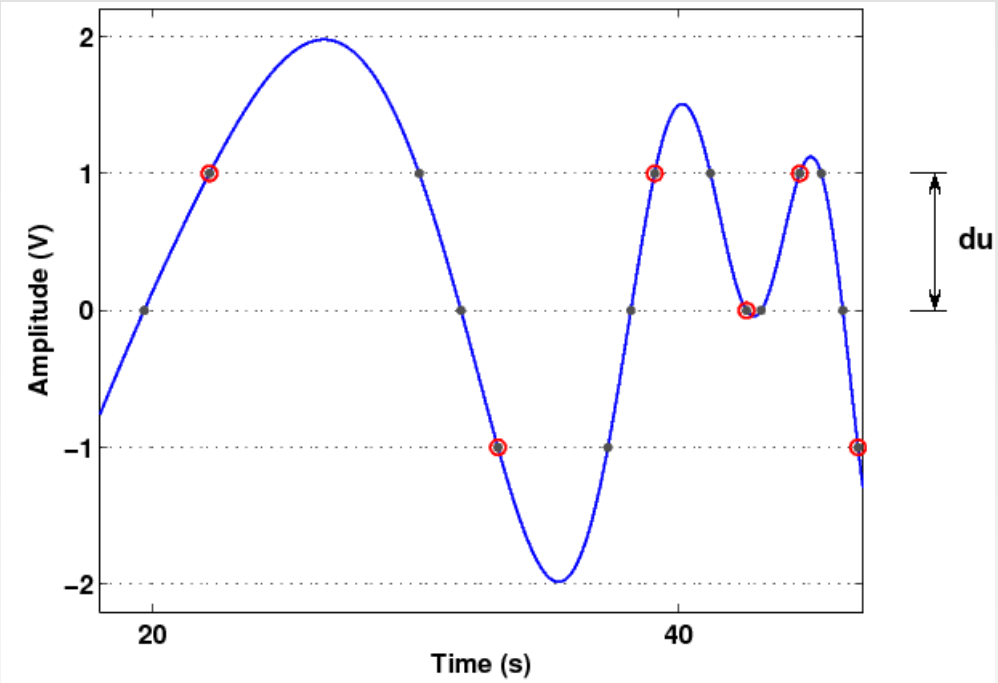


- Block scheme



Combined sampling

- If the distance between adjacent levels is reduced, the obtained samples come closer to signal peaks



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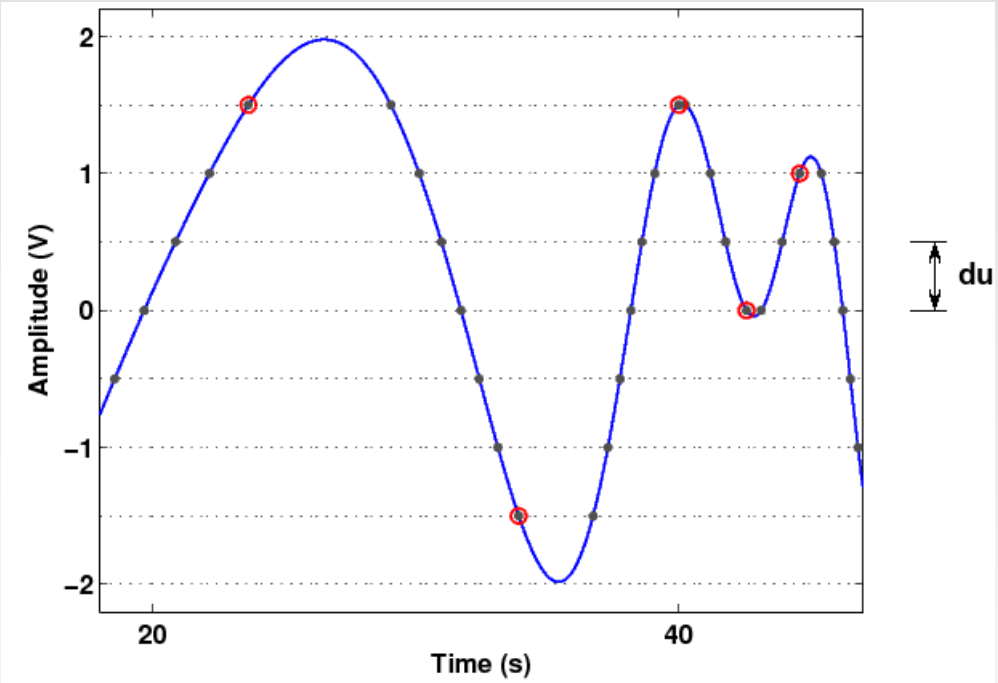

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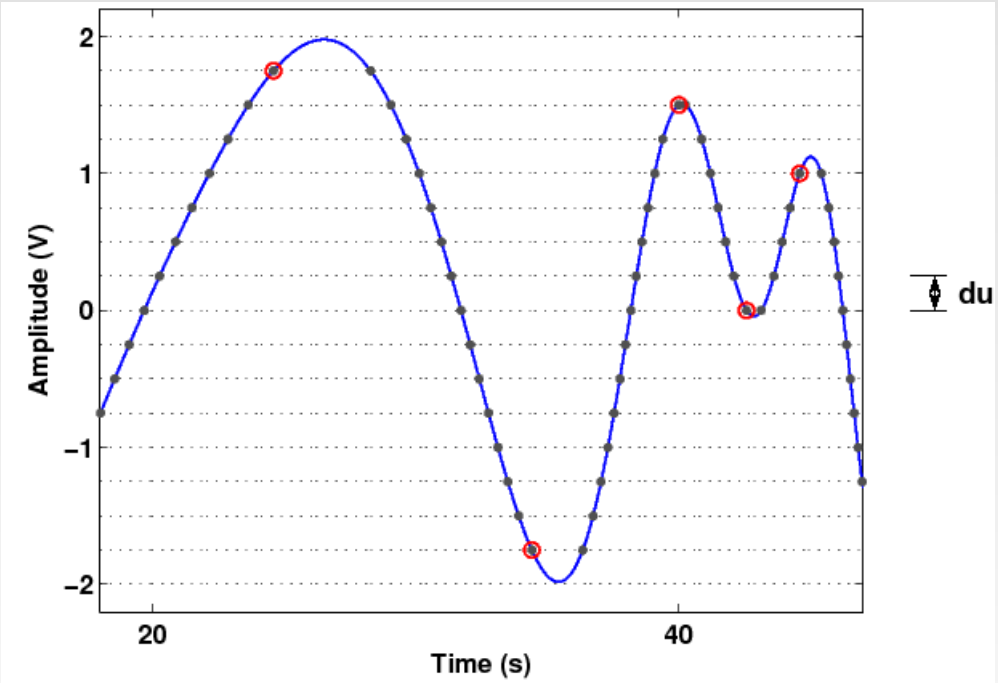
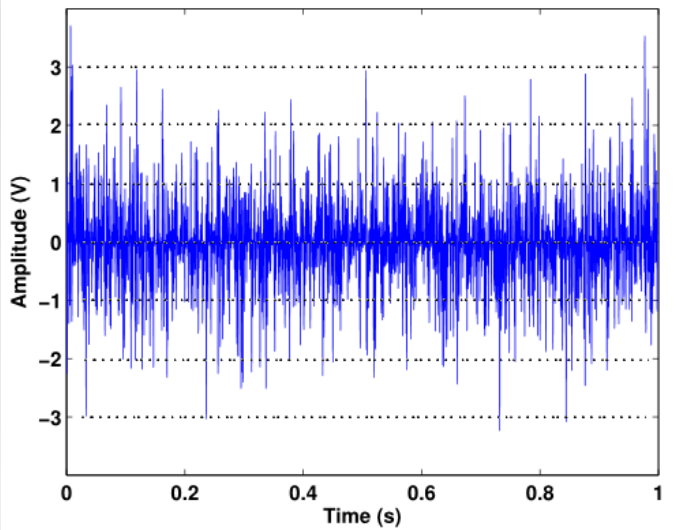


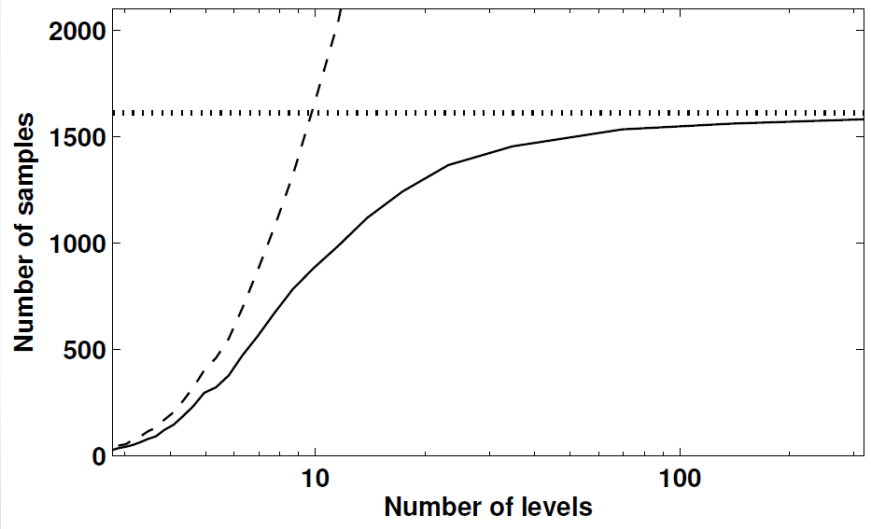
Combined sampling

- Comparison between number of samples and reconstruction quality



zero-mean Gaussian noise

$F_{max} = 1\,\mathrm{kHz}$



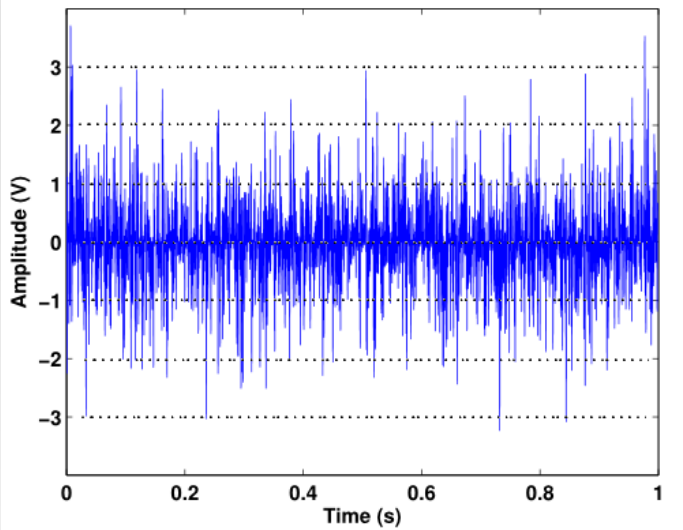
····· Peak sampling

- - - Level-crossing sampling

—— Combined sampling

Combined sampling

- Comparison between number of samples and reconstruction quality



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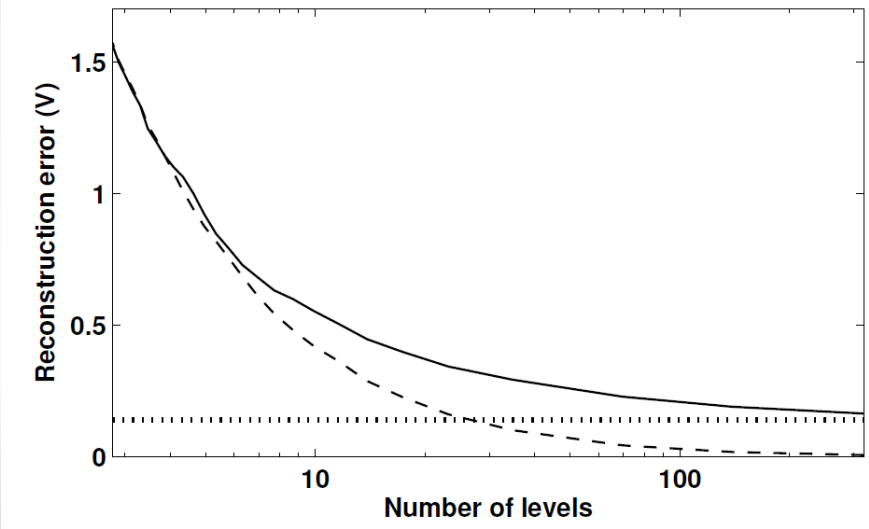

····· Peak sampling

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—— Combined sampling

Combined sampling

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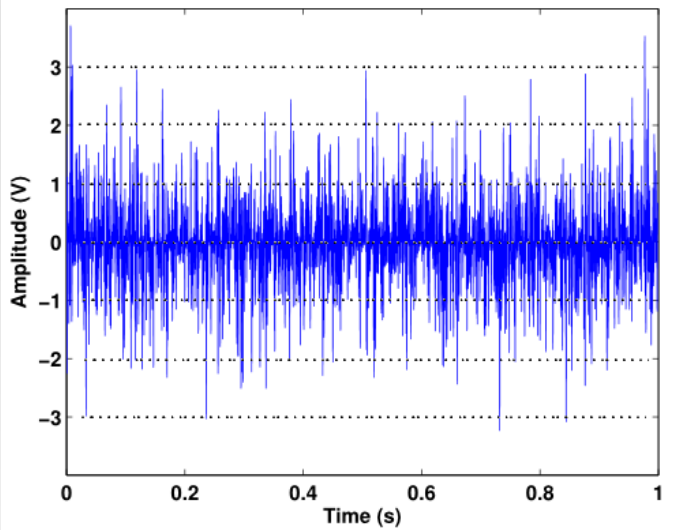

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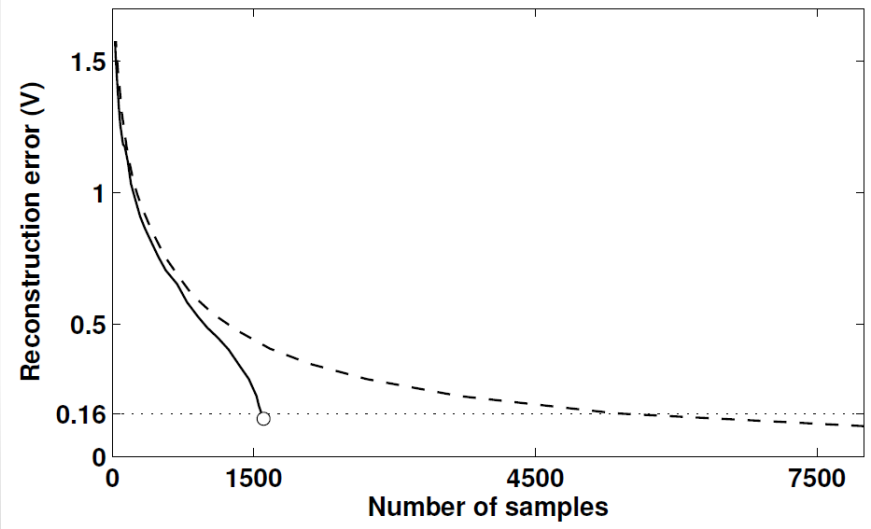

····· Peak sampling

- - - Level-crossing sampling

—— Combined sampling

Conclusions

- The proposed sampling technique can be viewed as the combination of two different sampling schemes: LC sampling and peak sampling
- The idea that comes from LC sampling is that samples are taken only when the input signal crosses any of the predefined levels
- The idea coming from peak sampling is that all LC samples are discarded except those most closely located to signal peaks
- Method allows avoiding high sampling densities in comparison to classical LC sampling, if the levels are placed too densely
- Due to not all peak points and not at exact positions are taken, there might be a necessity for additional samples to improve signal reconstruction

Thank you for your attention!

Questions?

Acknowledgments: this presentation was supported by ERAF funding under the agreement No.2010/0309/2DP/2.1.1.2.0/10/APIA/VIA/012

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