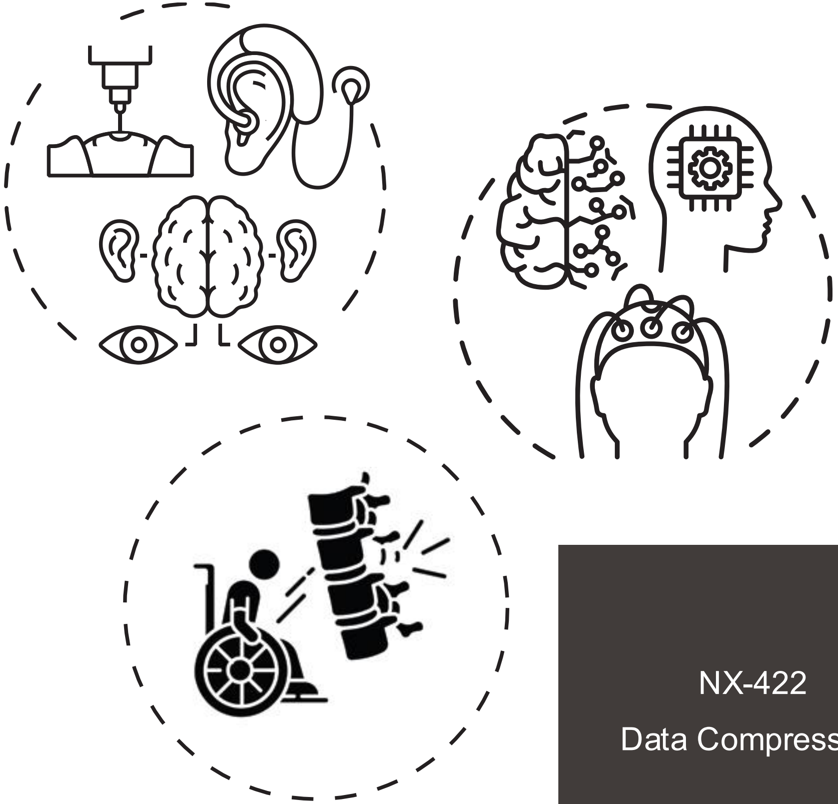


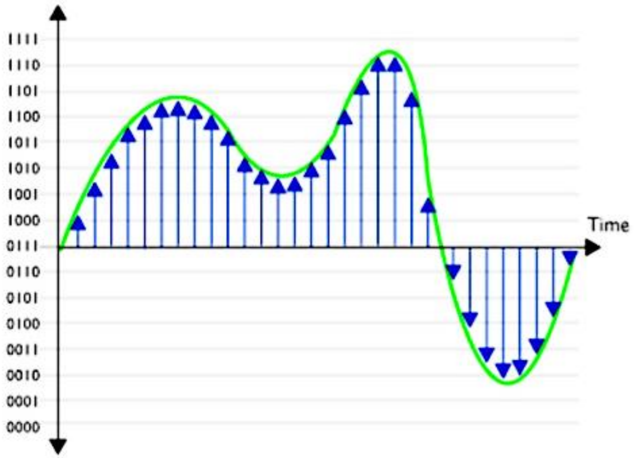
Neural Interfaces

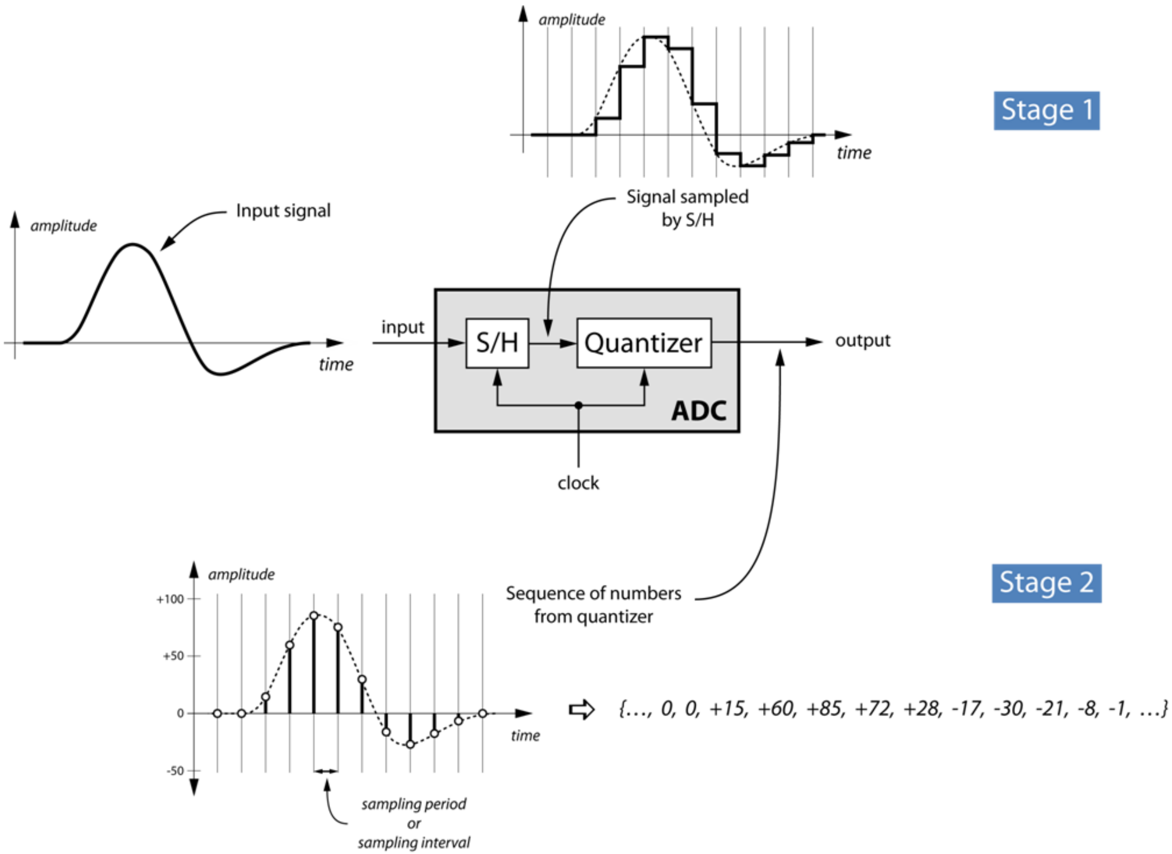
NX-422

Data Compression

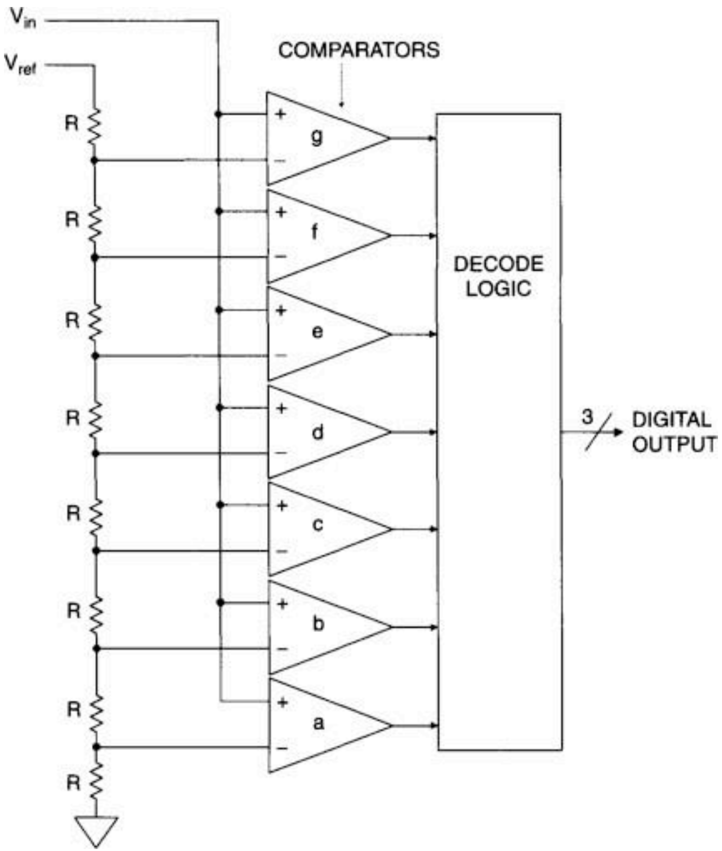
Mahsa Shoaran
IEM and Neuro-X Institutes

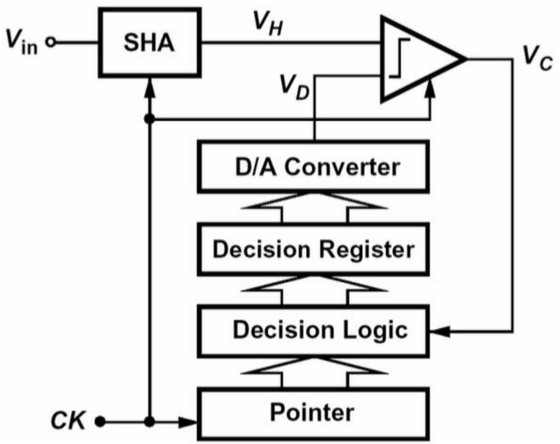
Recap: ADC Basics

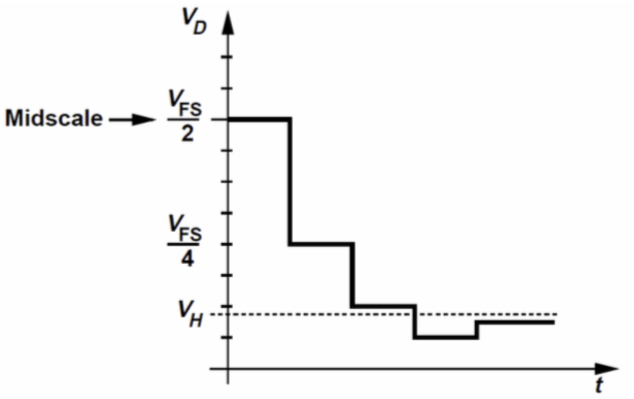




Recap: Flash and SAR ADC

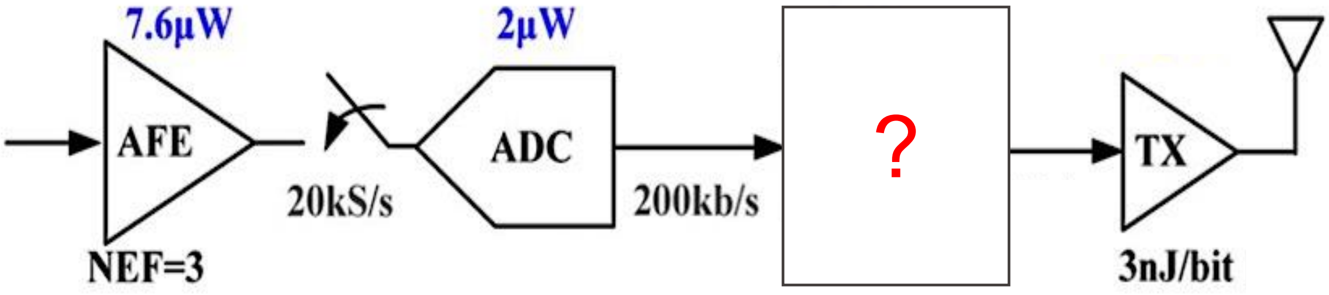






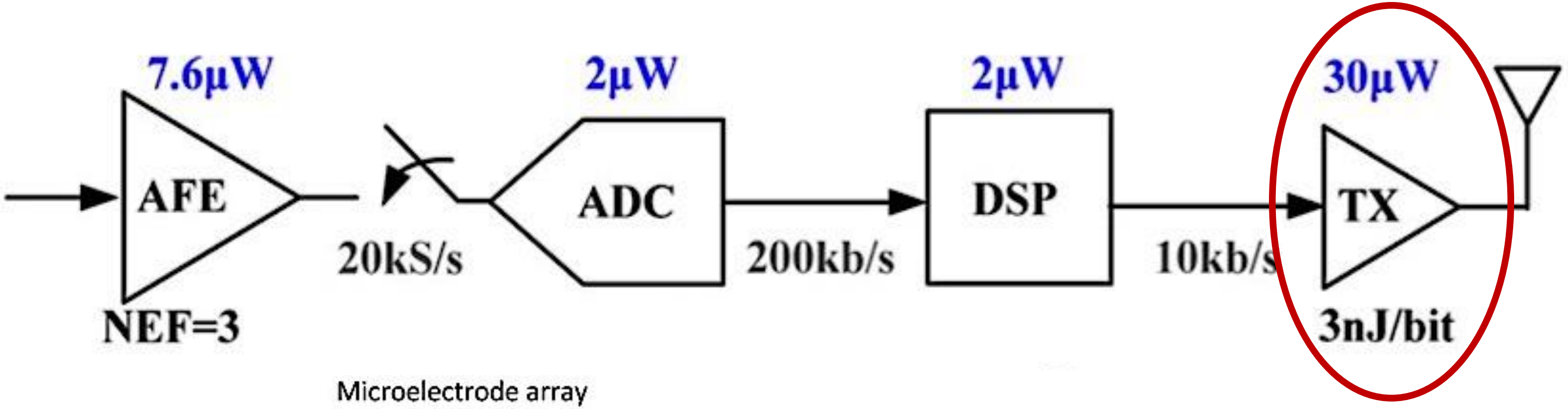
Neural Interface: Compression

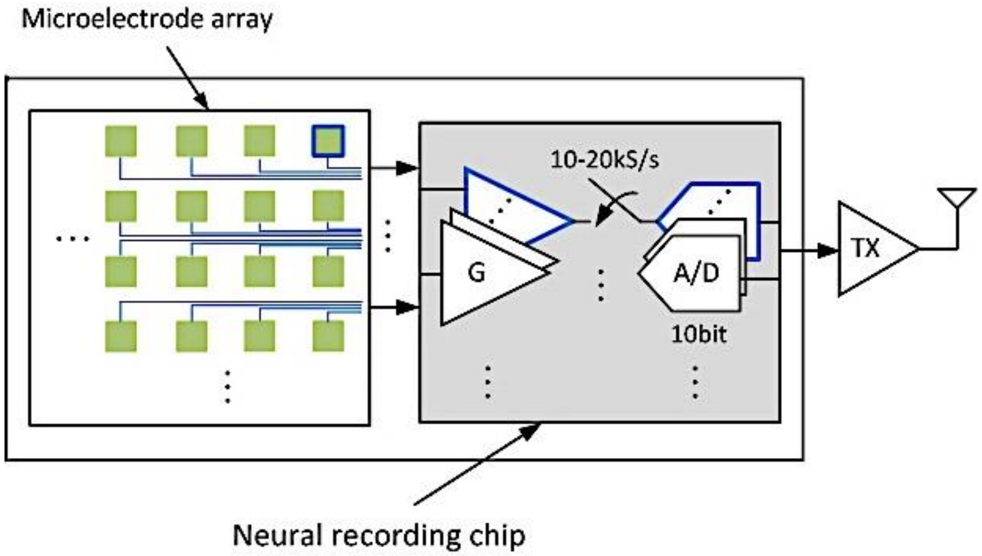
- The typical circuit blocks used in sensors for medical monitoring and their associated energy cost and power consumption



F. Chen et al, *JSSC'12*

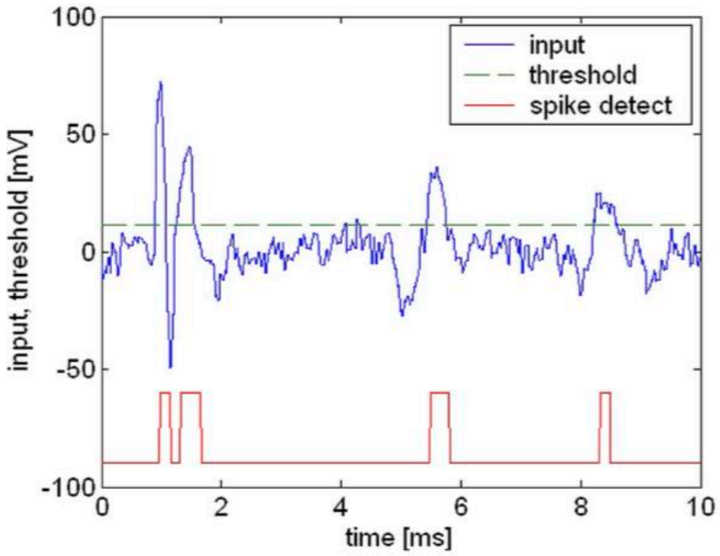
Data Compression

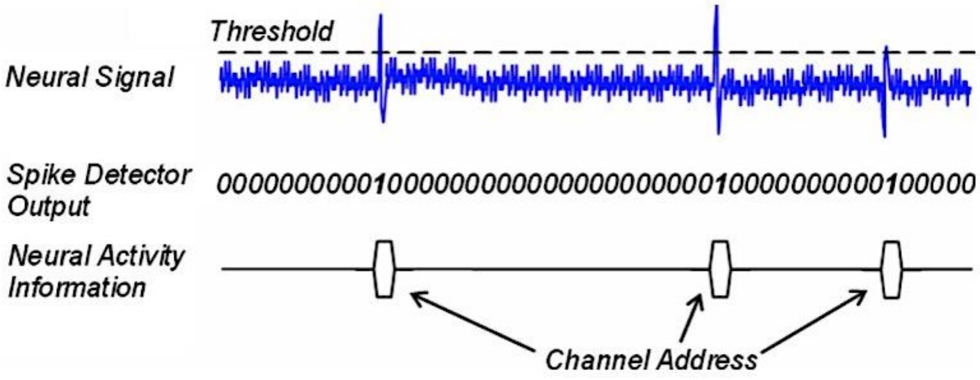




On-Chip Compression of Neural Signal

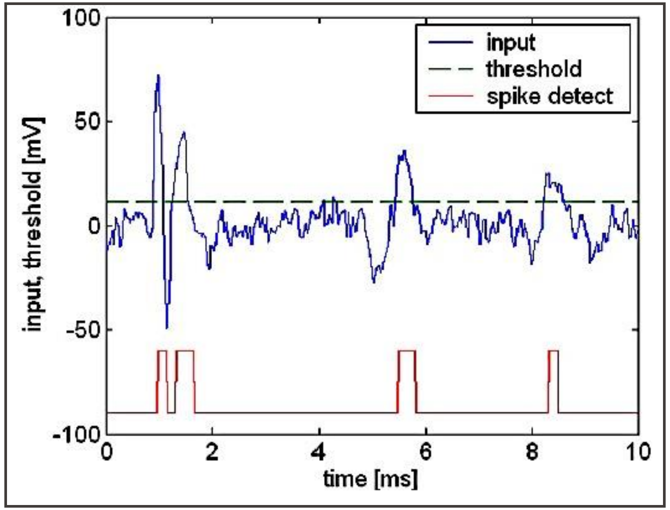
- Spike Detection





Compression of Neural Signal

- Spike Detection
  - High compression ratio (CR)
  - × Losing the raw waveform
  - × Unreliable in long-time



Compression of Neural Signal

- Compressive Sensing (CS):
  - CS relies on the signal of interest being sparse in some basis, Ψ.
  - Many biological signals of interest are sparse e.g. EEG, ECG, etc.

EPFL

Digital Data Acquisition

Foundation: *Shannon/Nyquist sampling theorem*

"if you sample densely enough (at the Nyquist rate), you can perfectly reconstruct the original analog data"

Signal Type	Sampling Rate	Frequency of Events
Extracellular APs	30 kHz	10 – 150 /s

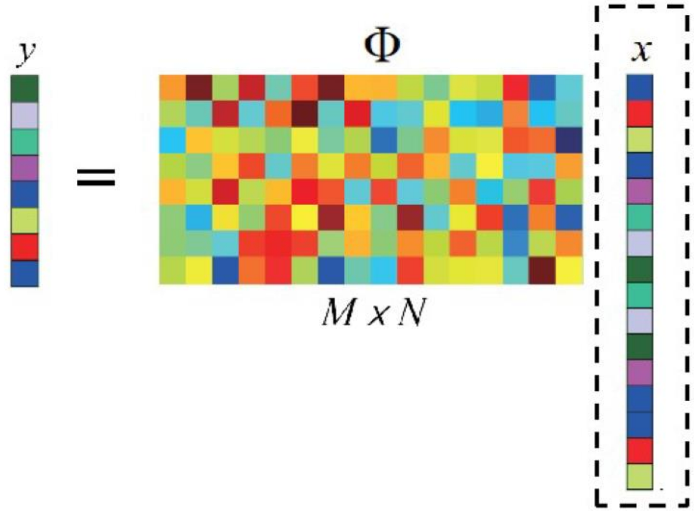
Data Reduction in Wireless Sensors

What we want:

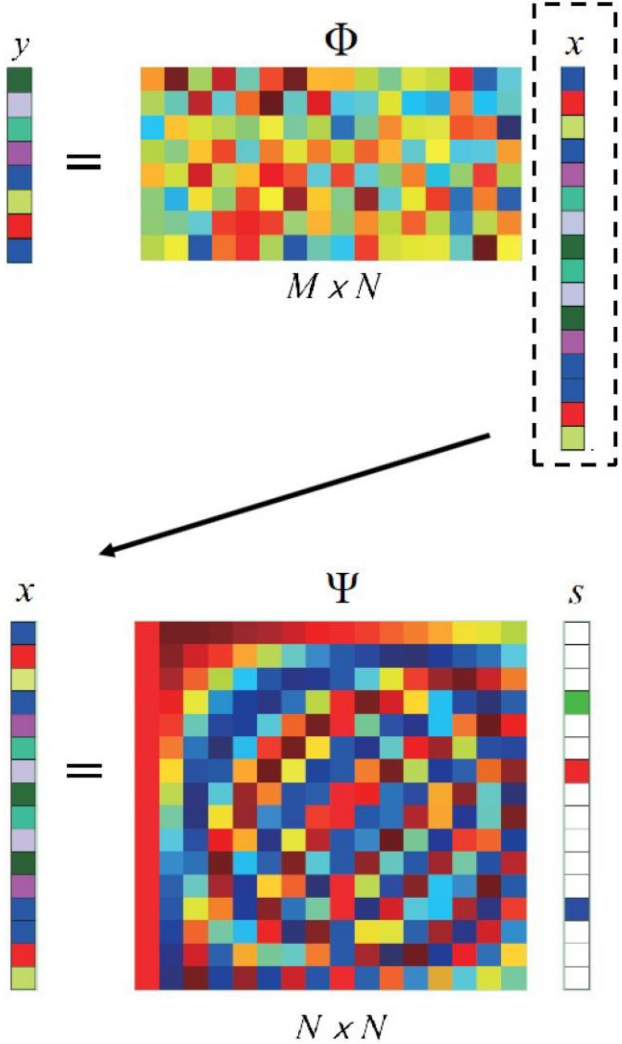
- Compression: minimize data, but retain the information
- Low cost: must be less than transmission savings
- Generality: we don't want to customize every sensor design

Compressive Sensing

- In 2006, **Candès and Donoho** proved that given a signal's sparsity, it may be reconstructed with even fewer samples than the sampling theorem requires
- A compressive sensing system samples a high-dimensional signal with significantly smaller number of measurements than sampled at the Nyquist rate, given that the signal is **sparse in a basis**

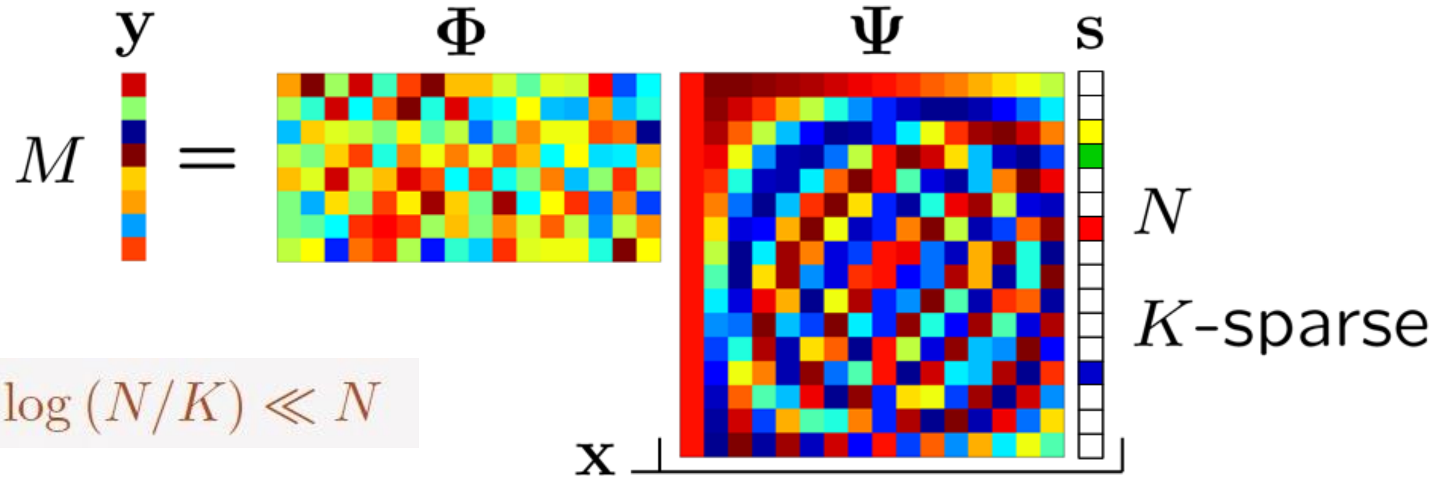


Compressive Sensing



Compressive Sensing

- **Low cost, generality**

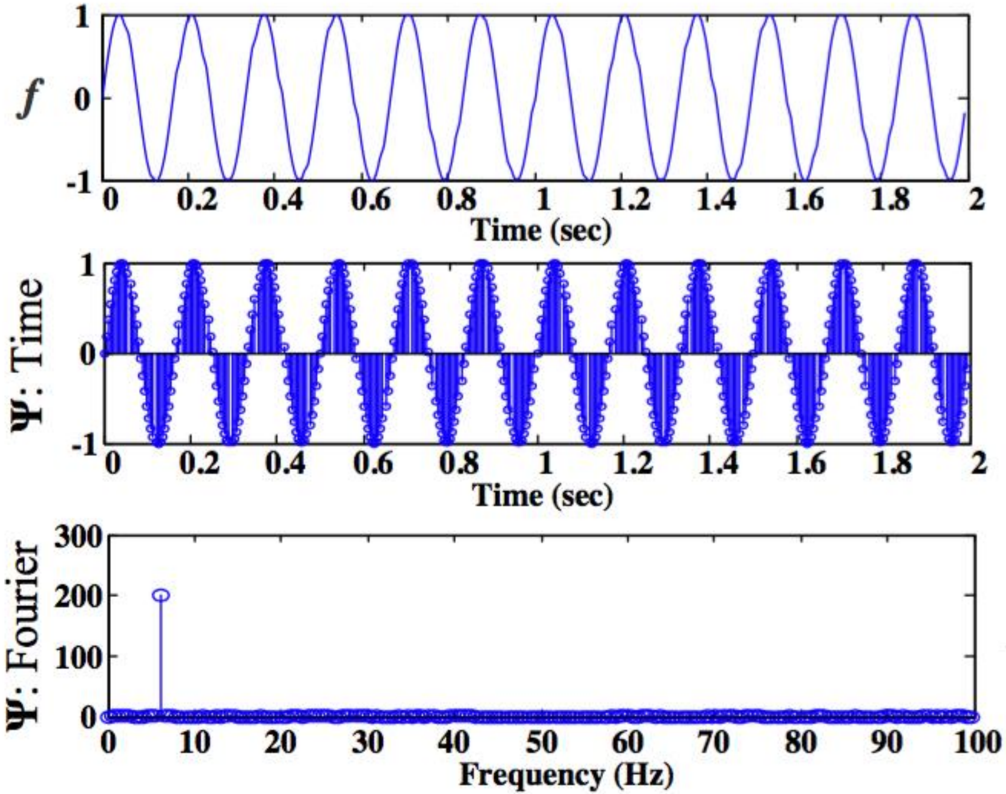


$$M \geq cK \log\left(N/K\right) \ll N$$

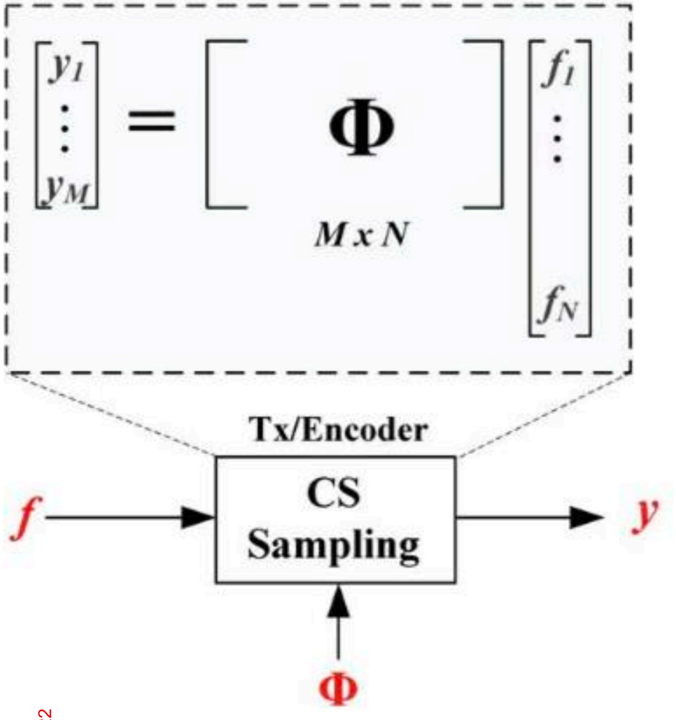
- Random measurement matrix (random 0, 1)
- Recovery: a convex minimization problem

Compressive Sensing

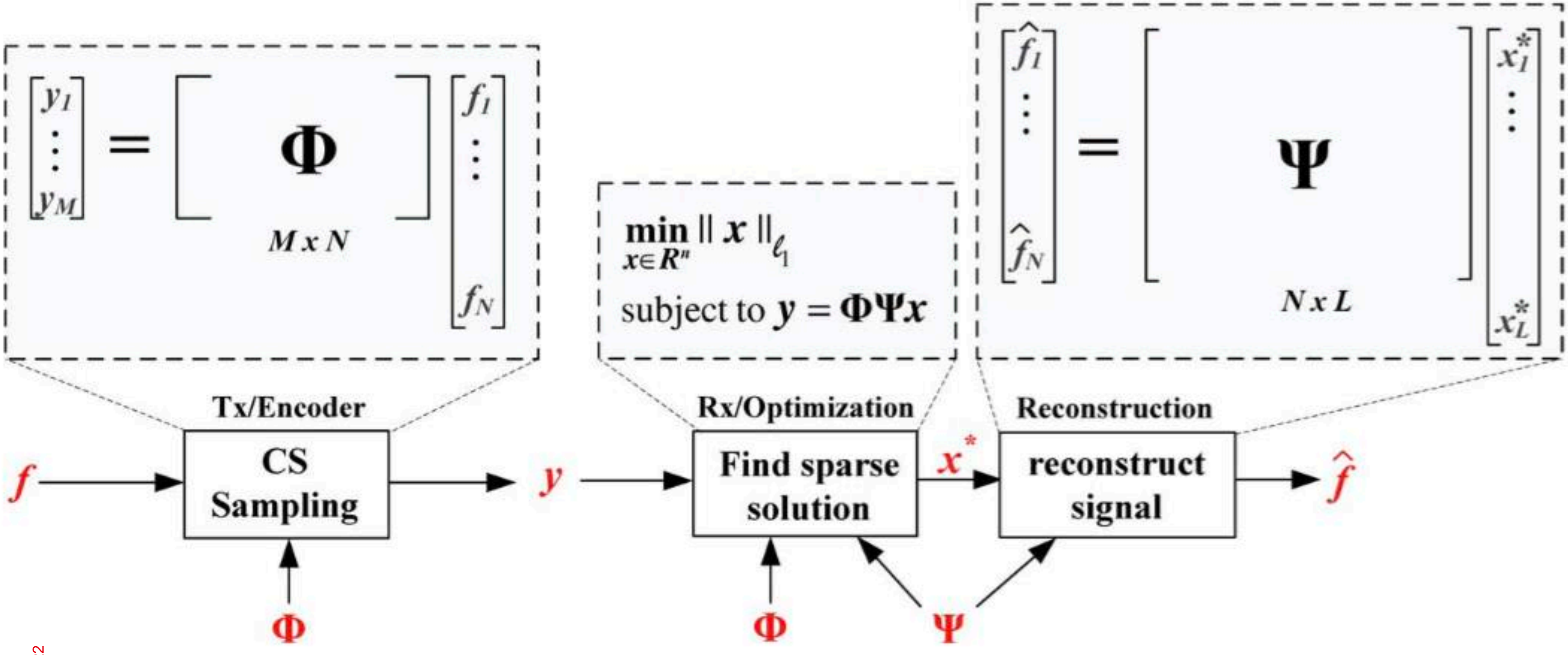
- Sinusoid example:



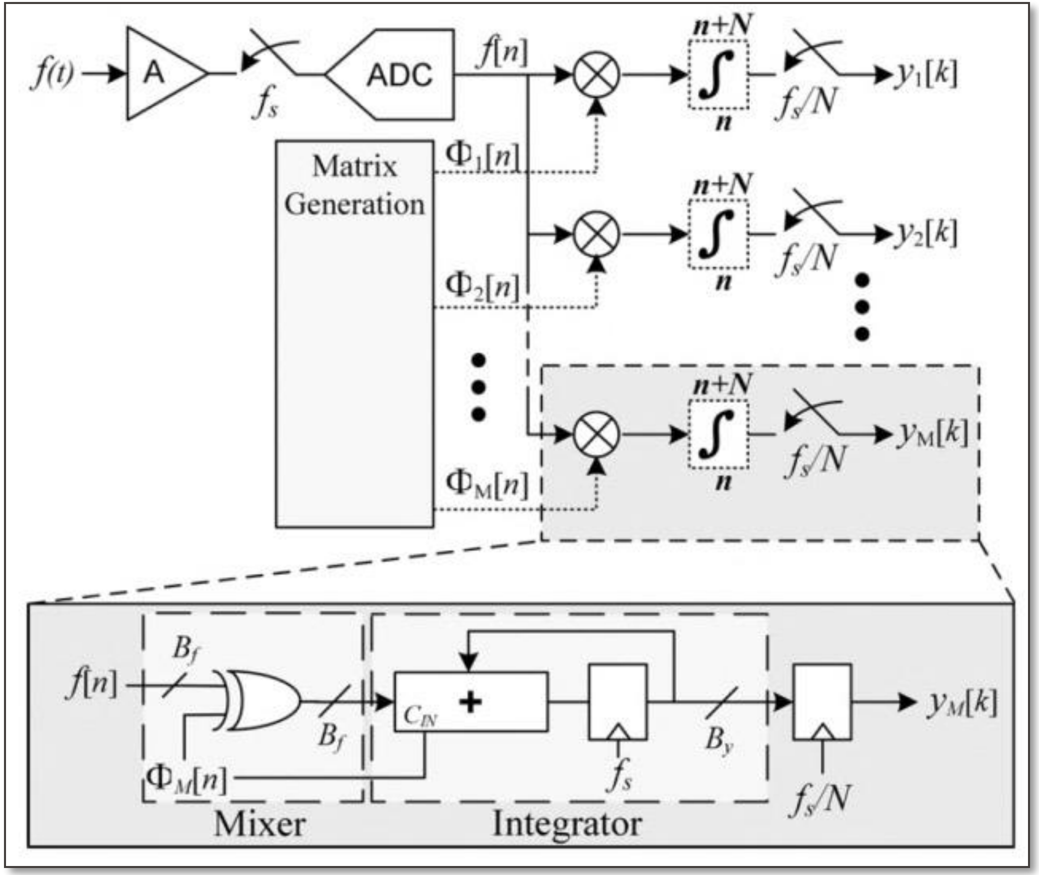
Compressive Sensing



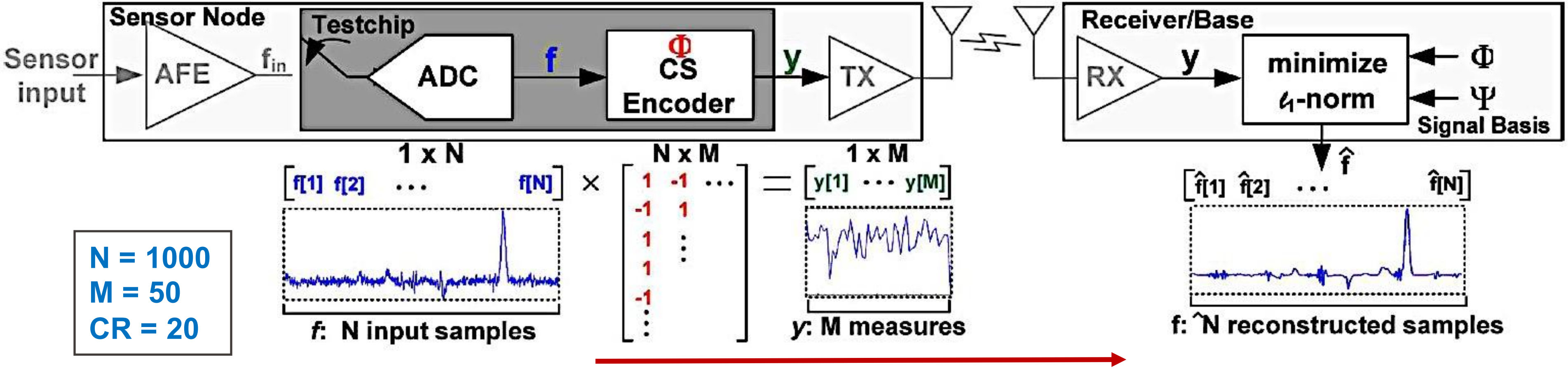
Compressive Sensing



Compressive Sensing Hardware: Digital



Compressive Sensing: Digital



N = 1000
M = 50
CR = 20

F. Chen, JSSC'12

Compressive Sensing: Digital