Introduction to Digital Signal Processing

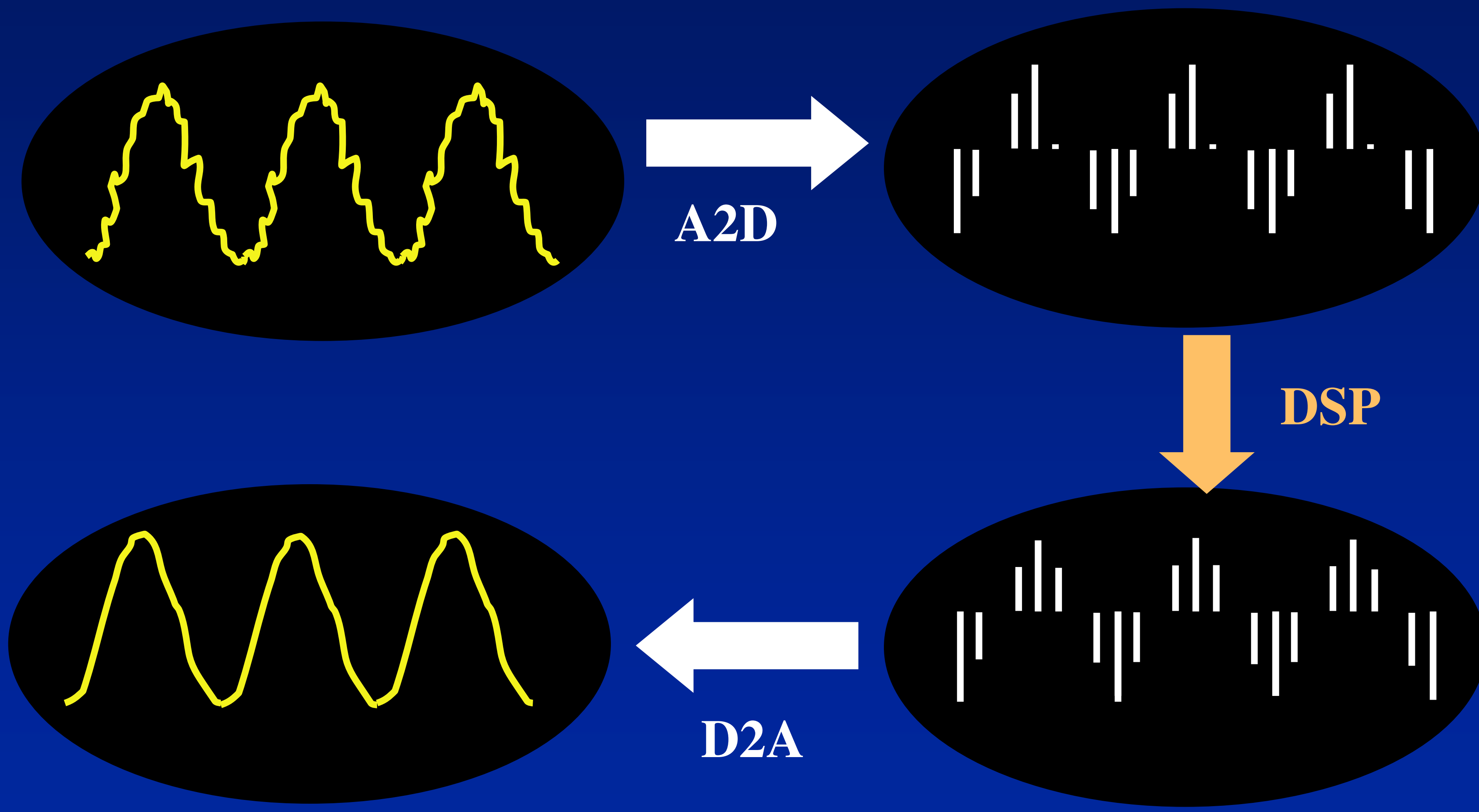
Digital Signal Processing

- Perform useful transformations on signals represented in discrete form
- Challenges
  - Process information ***fast***
    - Often deal with real world signals
  - Process ***enough*** information
    - Ensure no useful information is lost

Why is DSP so popular

- Repeatability
  - component tolerances very high
- Versatility
  - can be reprogrammed
- Simplicity
  - many transformations done easily in digital domain

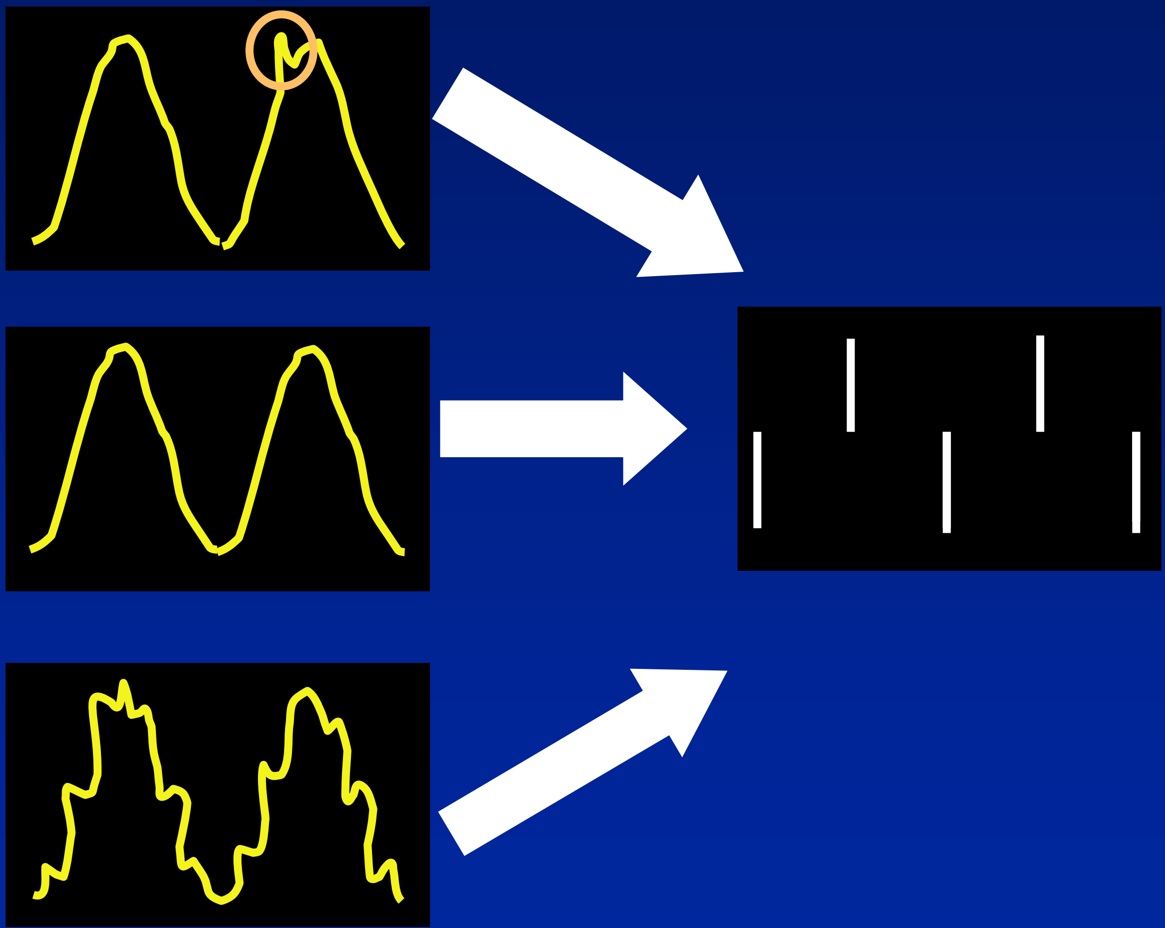
Typical DSP flow



Digitization Issues

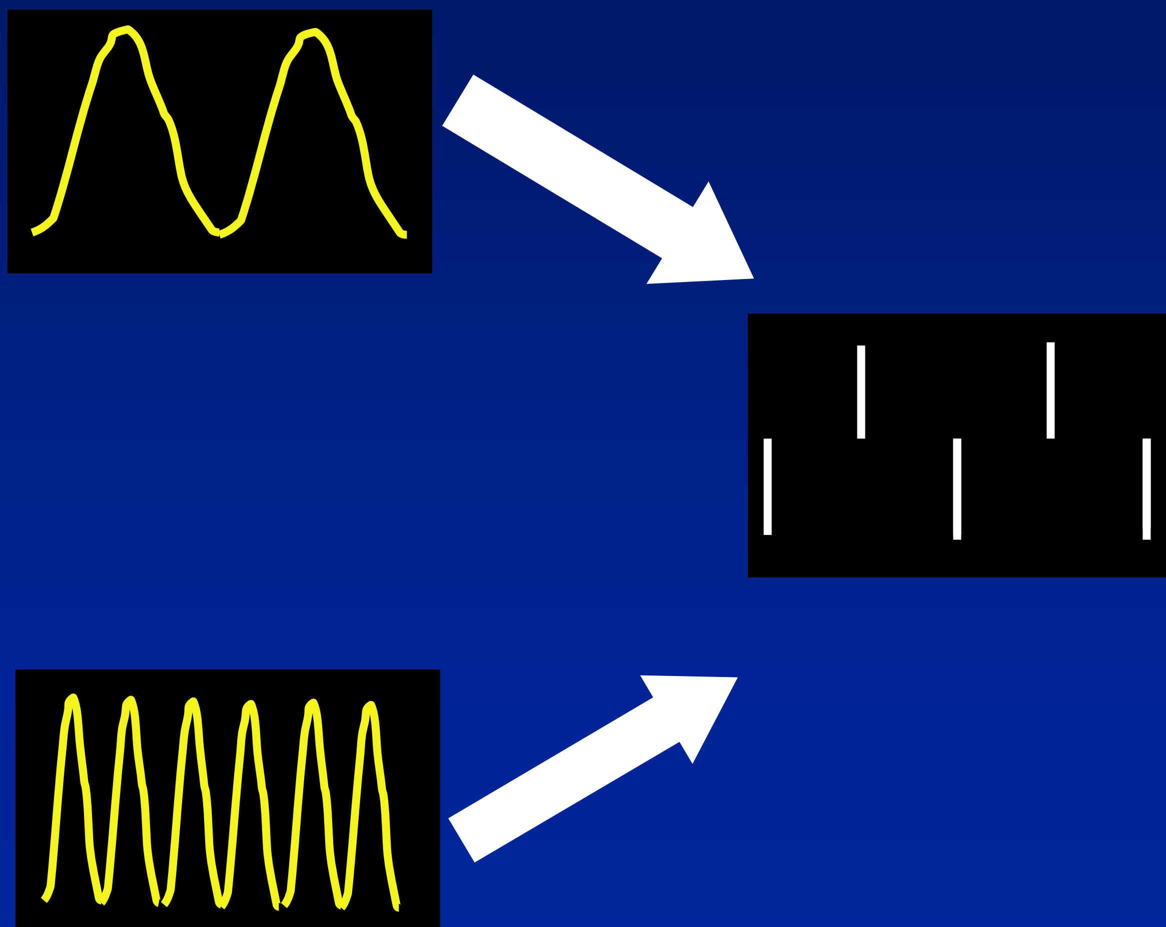
- Sampling clock errors
  — bad for timing
- Sample measurement accuracy
  — bad for small changes
- Finite length of sampling
  — bad for slow changes
- Finite sample intervals
  — bad for fast changes

Effect of low sampling-rate



- Miss glitches
- Miss high frequency components

Aliasing



- Interpret a high frequency as a lower one wrongly

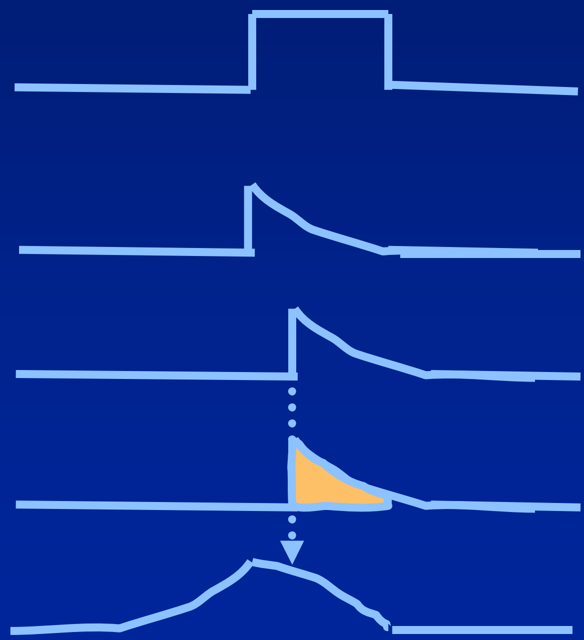
Aliasing

- Nyquist: : sampling-rate >= 2*largest_sig_freq
- Avoiding aliasing
  - use antialiasing filter before sampling
  - inhibits freq components > 0.5*sampling_rate

Time domain processing

- Correlation

$$r(n) = \sum_{k=0}^{N-1} x(k) \times y(n+k)$$



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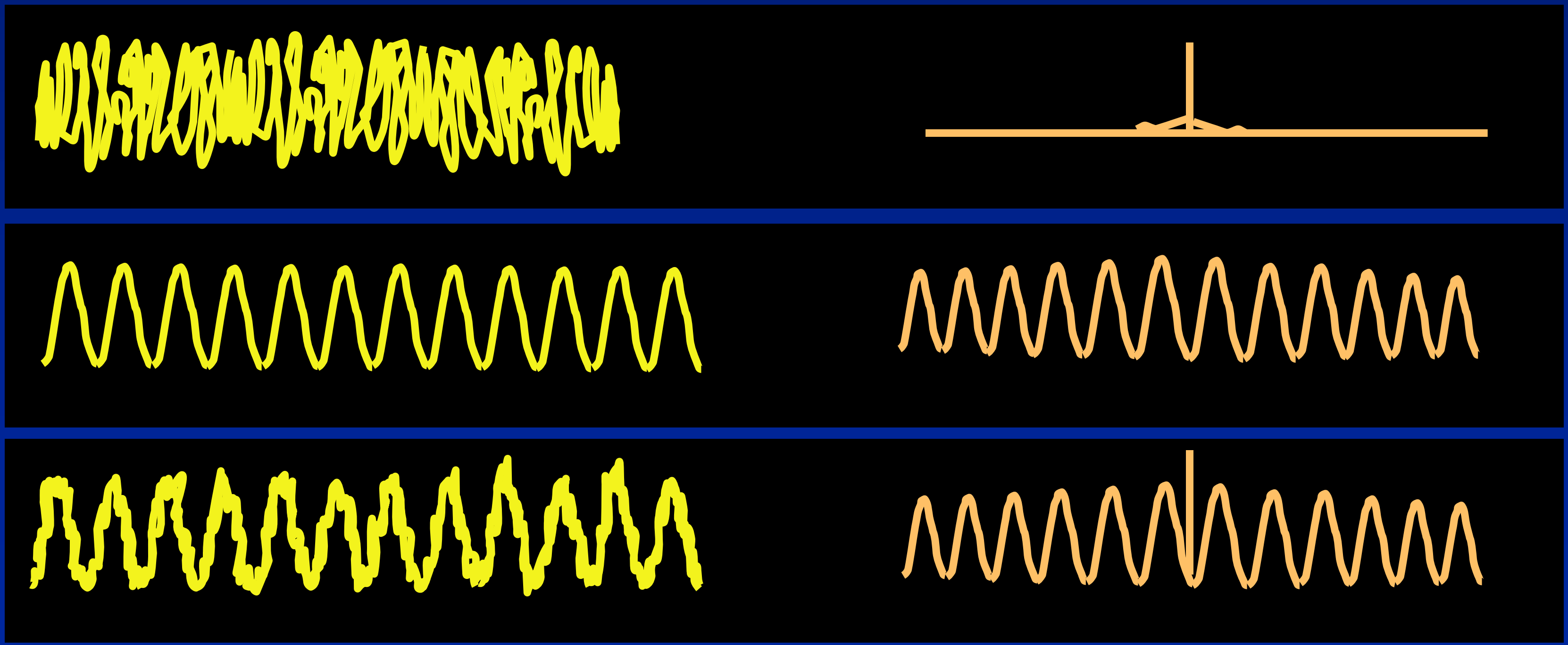
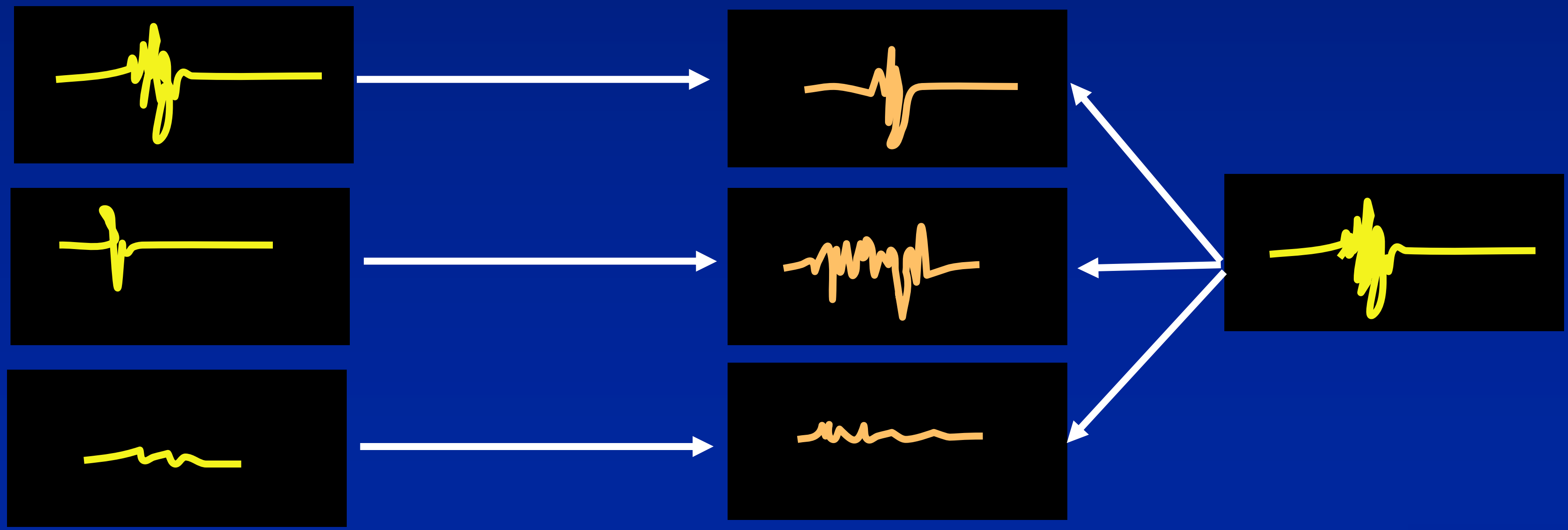
Correlation

- Autocorrelation
  - — extract signal from noisy environment



Correlation

- Cross correlation
  - correlate input signal with library of signals



Convolution

$$X(\omega)=\sum_{k=0}^{N-1} x(k)\times e^{-\frac{j2\pi\omega k}{N}} \quad Y(\omega)=\sum_{p=0}^{N-1} y(p)\times e^{-\frac{j2\pi\omega p}{N}}$$

$$R(\omega)=X(\omega)\times Y(\omega)=\sum_{k=0}^{N-1} x(k)\times e^{-\frac{j2\pi\omega k}{N}}\times\sum_{p=0}^{N-1} y(p)\times e^{-\frac{j2\pi\omega p}{N}}$$

$$=\sum_{n=0}^{N-1}\sum_{k=0}^{N-1} x(k)y(n-k)\times e^{-\frac{j2\pi\omega n}{N}}$$

$$R(\omega)=\sum_{n=0}^{N-1} r(n)\times e^{-\frac{j2\pi\omega n}{N}}$$

Convolution

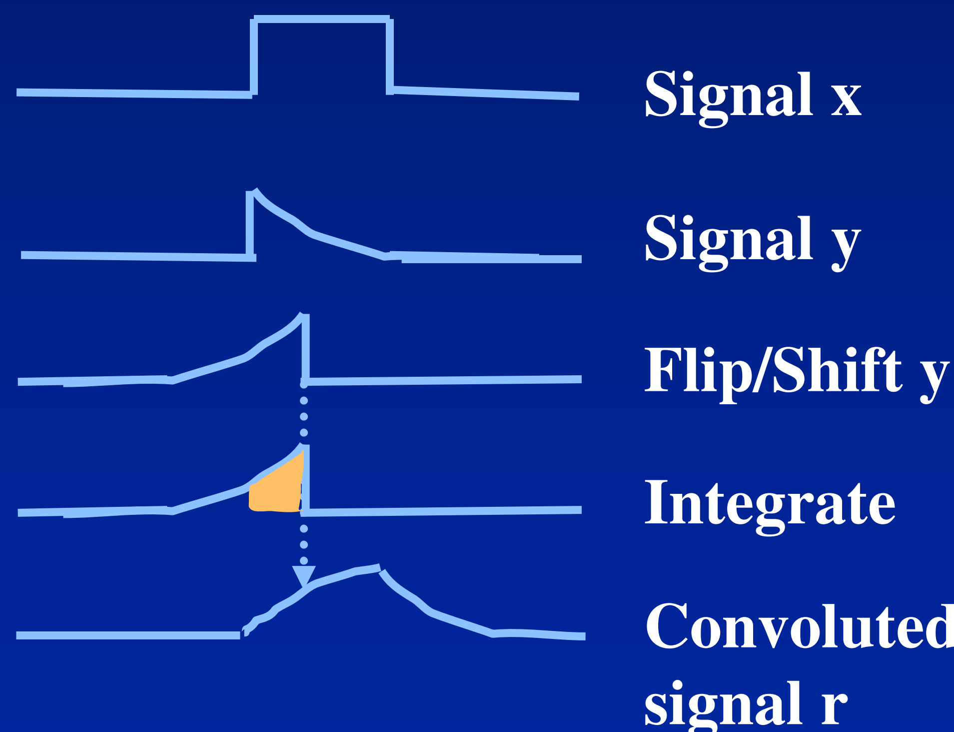
$$R(\omega) = X(\omega) \times Y(\omega) \Rightarrow$$

$$r(n) = \sum_{k=0}^{N-1} x(k)\,y(n-k)$$

- Multiplication in frequency domain => convolution in time-domain

Convolution

$$r(n) = \sum_{k=0}^{N-1} x(k) \times y(n-k)$$



Time domain processing

- Correlation

$$r(n) = \sum_{k=0}^{N-1} x(k) \times y(n+k)$$

- Convolution

$$r(n) = \sum_{k=0}^{N-1} x(k) \times y(n-k)$$

- Multiply/accumulate are the most widely used core functions for DSP

Conclusions

- Why DSP is popular
- Effect of sampling
- Aliasing
- Correlation
- Convolution

VLSI Signal Processing in FPGAs

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Sections

- Introduction to DSP
- VIRTEX Architecture
- Filters in FPGAs
- FFTs in FPGAs
- MPEG decoding in FPGAs
- Cordic Algorithms in FPGAs
- Low-power solutions
- Specific DSP architectures as FPGAs