DSP Project

Where you should be with the project:

- ➢ Design is basically done.
- ➢ Breadboarding portions of the project is done.
- ➢ Debugging of breadboarded portions should be done.
- ➢ **You should be doing significant amounts of construction**

  → soldering, box making, drilling, etc …
- ➢ Partial debugging of soldered circuitry.

Recommendation:

➢ Construct your circuit in independent modules that can be tested and debugged separately.

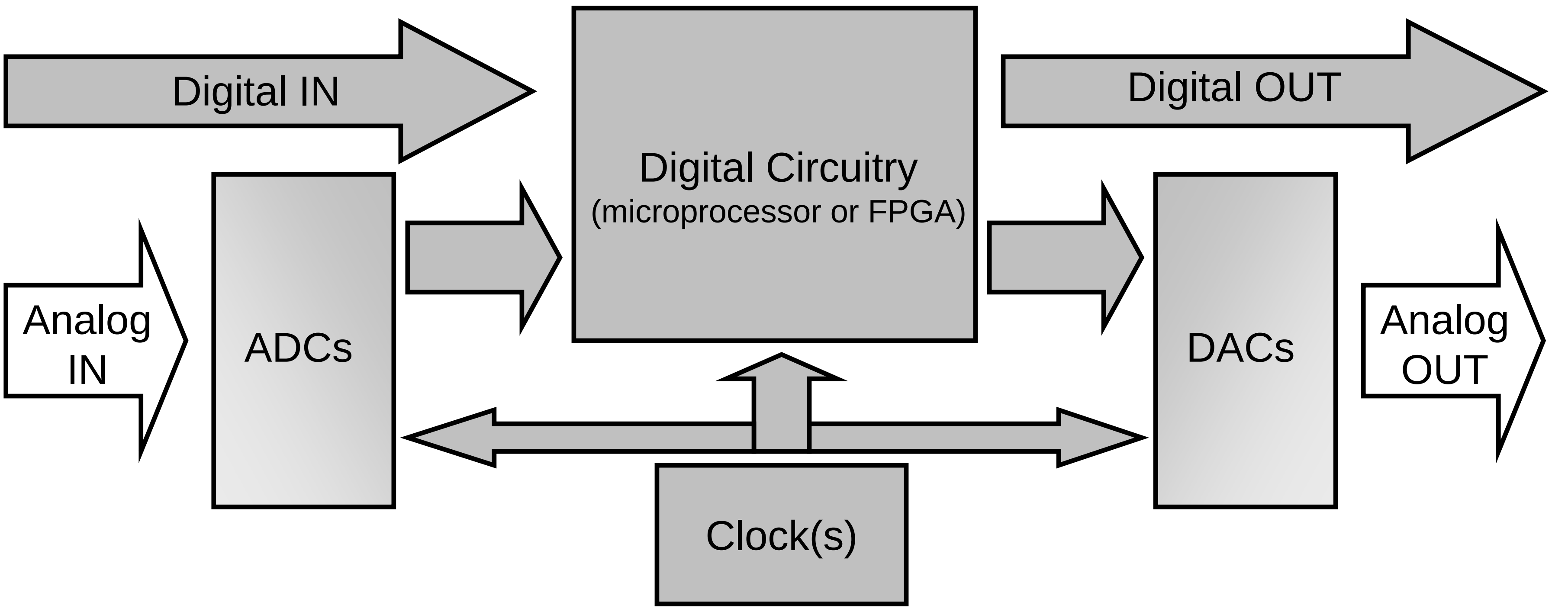
➢ Soldering the entire project together and then debugging is very hard and frustrating.

Introduction to DSP
or
What is Digital Signal Processing?

Outline

1. Basic DSP Architecture
2. Applications
3. Basic Algorithms
    a. FFT.
    b. Perfect mixer … divider.
    c. Digital filters (FIR and IIR filters).

Basic DSP Architecture



DSP applications

DSP Advantages:

- DSP is frequently **cheaper (in money and time)** than an equivalent analog circuit (especially circuit development).
- Analog electronics is hard … but programming is **easier**.
- **Frequently DSP is the only option:** DSP circuits can do certain operations that are not possible with analog circuitry.

A few DSP applications:

- ***Long distance communication:*** digital communication has lower noise and can be compressed.
- ***Voice and image recognition:*** Use complex recognition algorithms.
- ***"Software" Radio:*** DSP can efficiently demodulate a signal from its RF carrier.

DSP in Physics

DSP is relatively young and has not yet made broad in-roads into physics instrumentation. There are a few outstanding examples:

- **Complex coincidence triggering** in particle physics and quantum optics.

- **Custom feedback loops:** When PID feedback just isn’t good enough, a DSP-tailored feedback loop gain gives you some extra feedback bandwidth.

- **DSP lock-in amplifiers:** Very stable and accurate, high dynamic range, and stable long-term integration.

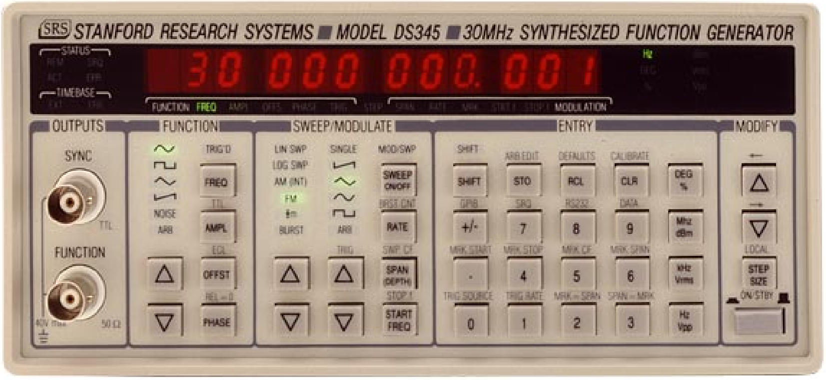
- **Synthesized signal generator:** these devices generate their output signals using DSP.

  → arbitrary waveforms possible.

  → Very quick frequency changes.

  → Phase continuous frequency changes!

  → Extremely stable.



When should you use DSP ?

You should use DSP when …

… you know that you could solve your circuit design by processing your signals with a computer, i.e. Maple, MatLab, Mathematica, C/C++, etc ...

→ DSP just replaces the computer with a dedicated microprocessor or an FPGA.

→ DSP is faster, cheaper, and more stable than a desktop computer.

Basic DSP algorithms

- ***Fast Fourier Transform***
- ***Multiplication … division***
- ***Digital filters***

FFT: Fast Fourier Transform

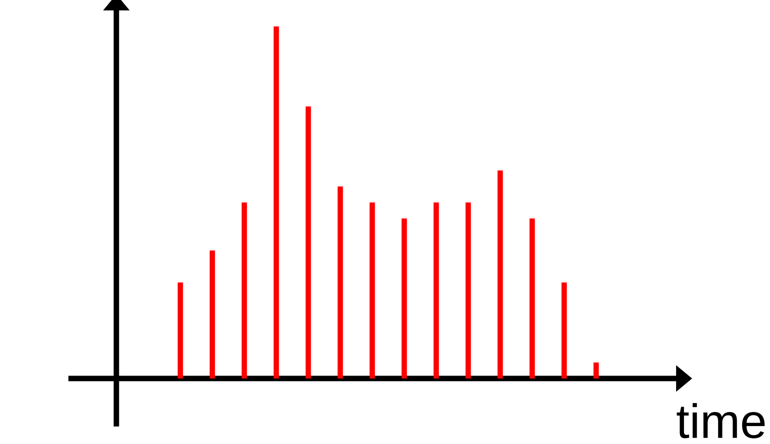
- Originally discovered by Gauss (~1805).
- Re-discovered by Cooley and Tukey (1965).
- Operates on a discrete set of N sampled values.
- Most FFT libraries require $N = 2^n$.
- Discrete fourier transform computation time ~ N^2.
- FFT computation time ~ $N \log_2(N)$.

  → FFT is cheaper and faster.

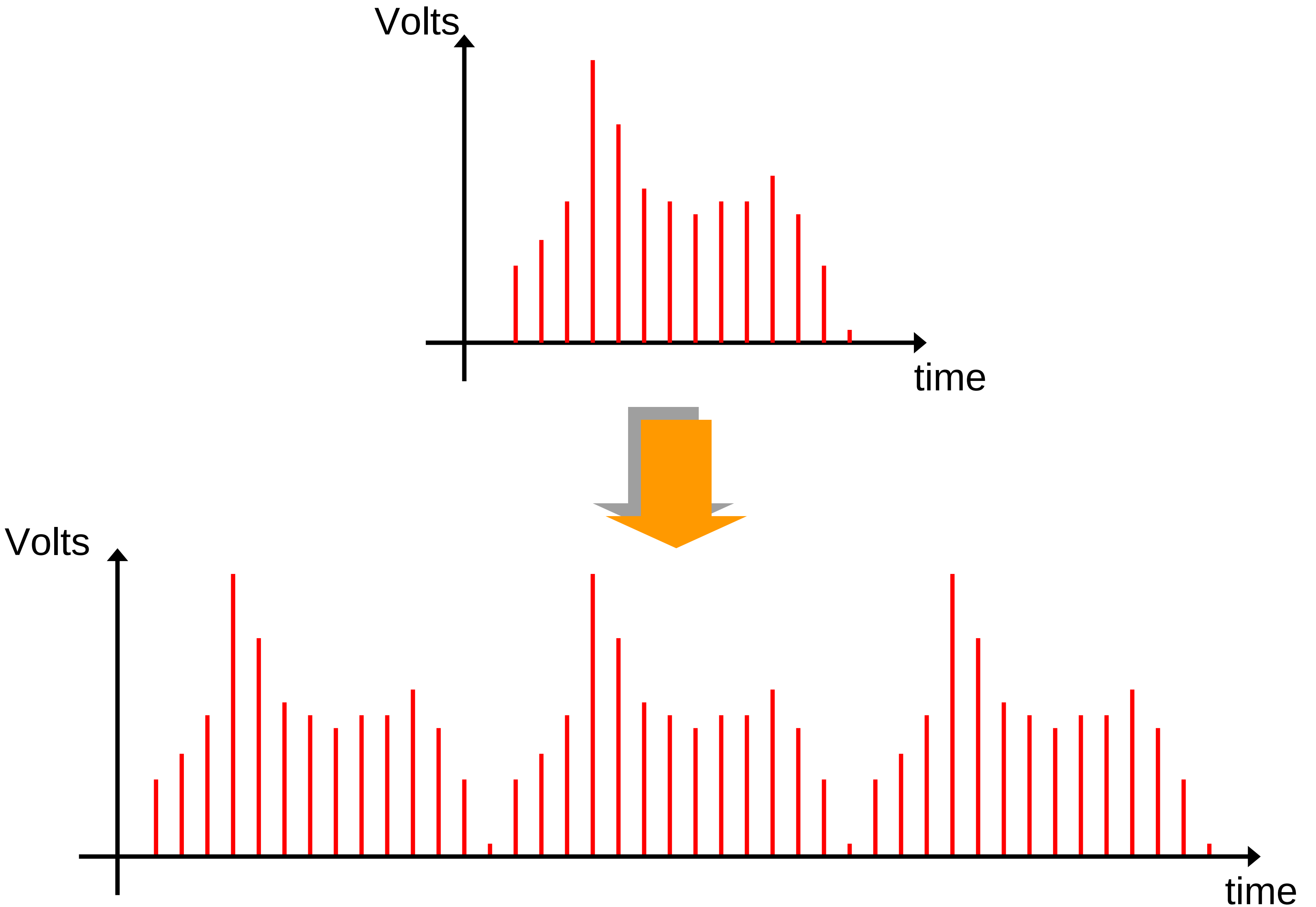
→ An FFT allows you to do DSP in frequency space.

→ The FFT is a standard programming library item for microprocessors and FPGAs.

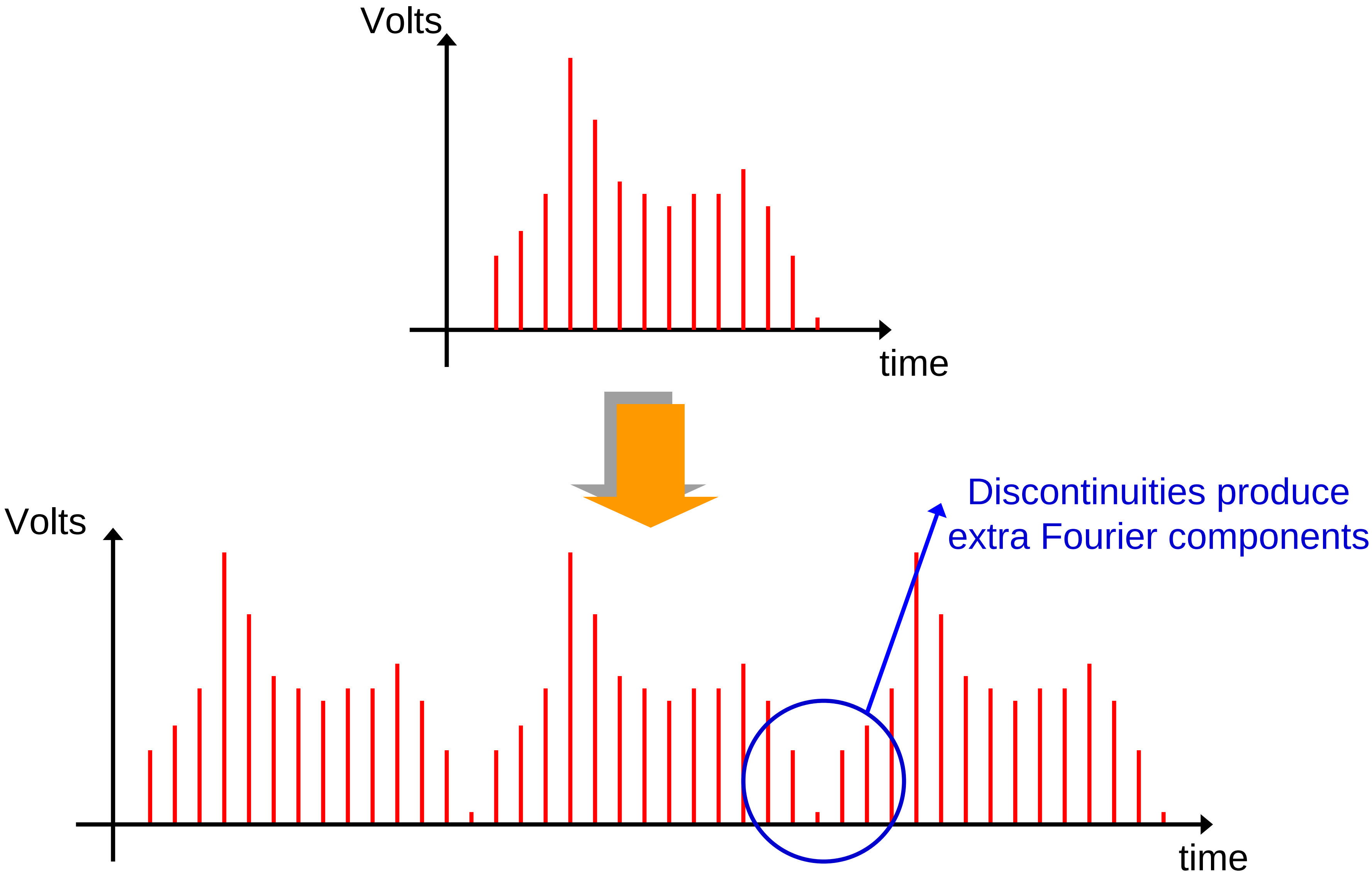
Data Windowing (I)



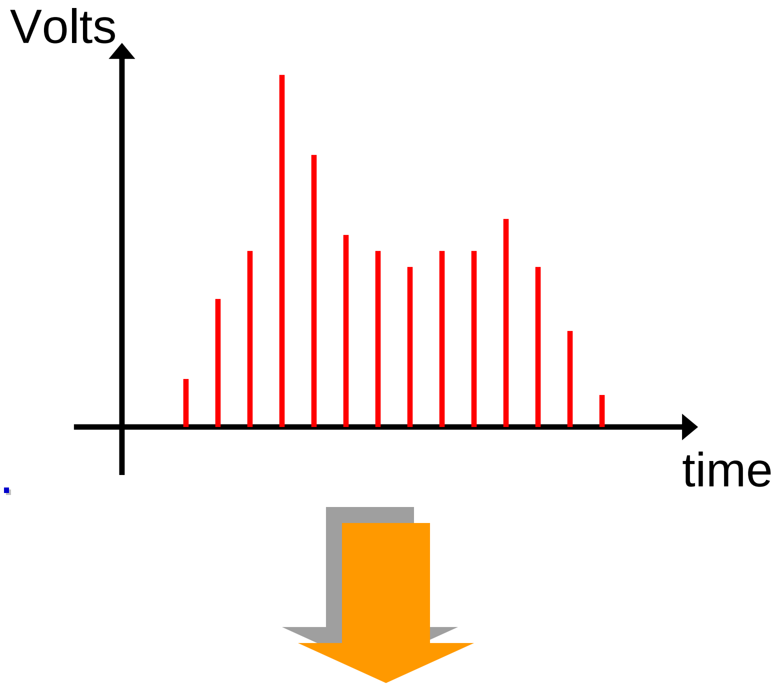
Data Windowing (I)



Data Windowing (I)

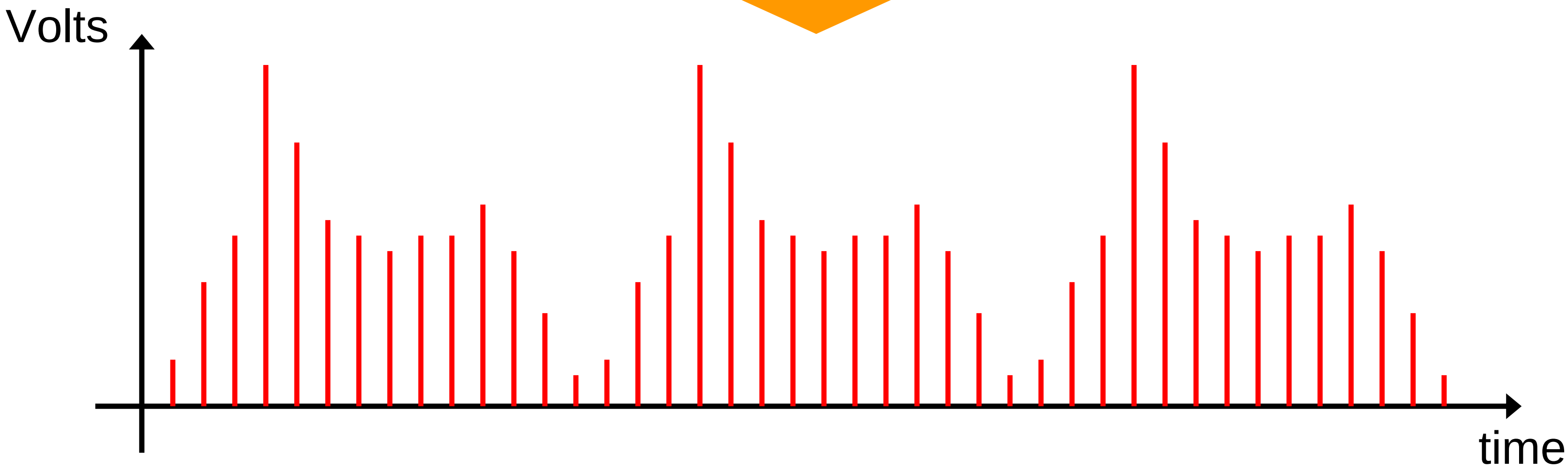


Data Windowing (II)

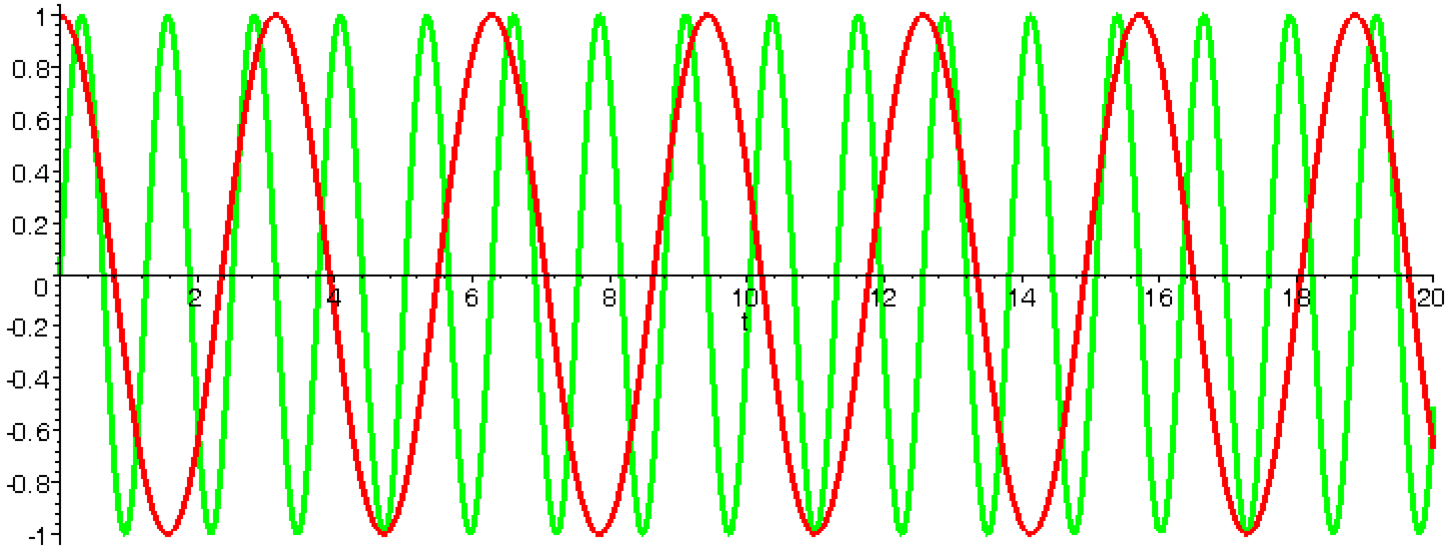


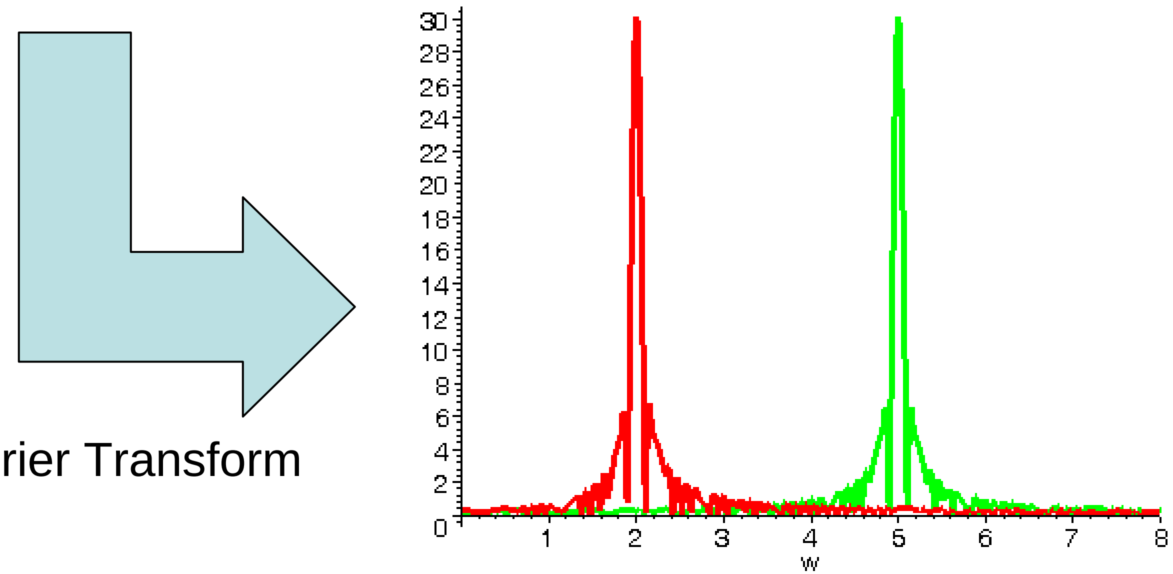
Smooth the data to ZERO at the edges.

→ Reduces spurious Frequency structures.



Digital Mixing (I)

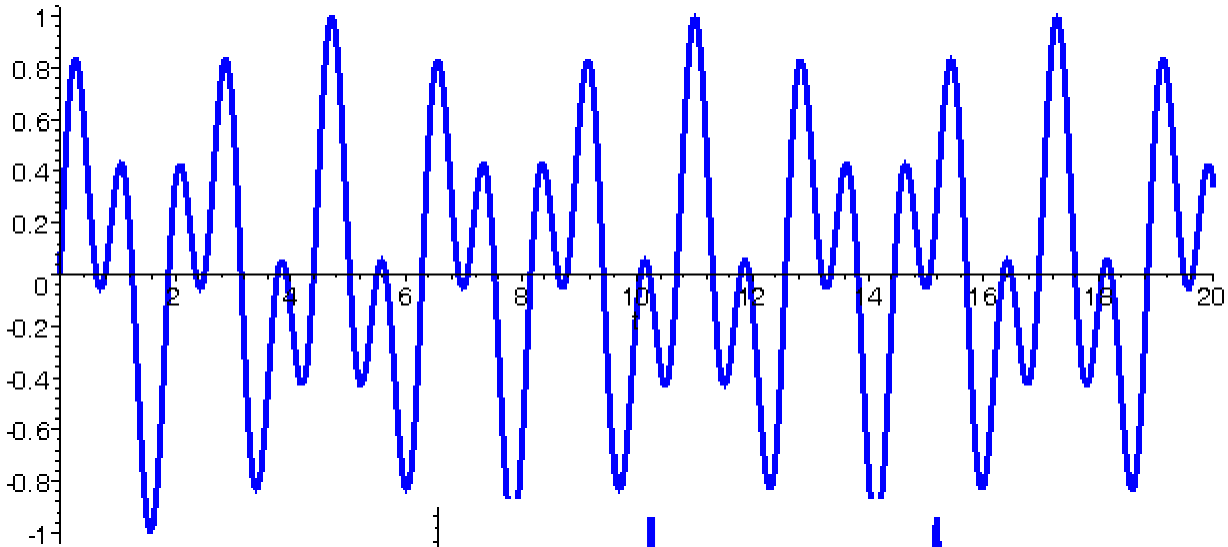




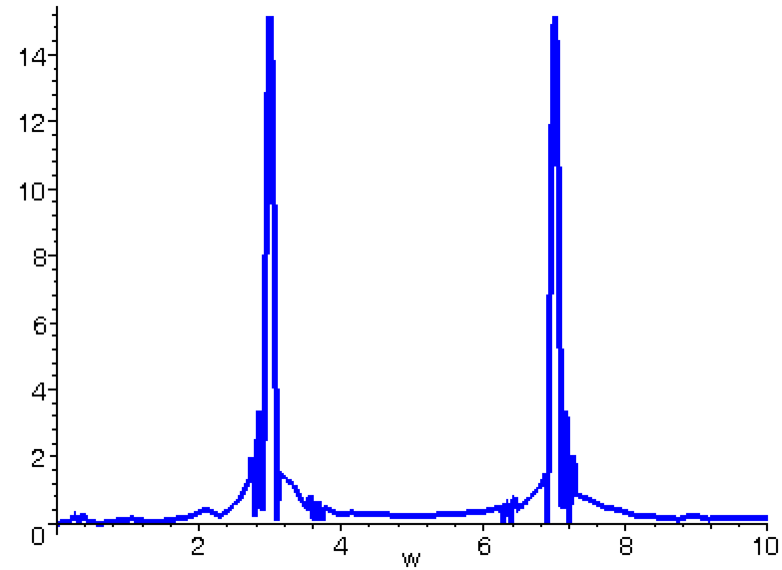
Fourier Transform

Digital Mixing (II)

RED x GREEN = BLUE



Fourier Transform



Digital mixing does not produce any extra harmonics, unlike analog mixers