WELCOME TO PHYC 493L
Contemporary Physics Lab

Spring Semester 2016

Instructor: Dr Michael Hasselbeck

Teaching Assistant: Chih Feng Wang (CHTM)

WHAT IS THIS COURSE ABOUT?

Laboratory experience for advanced physics undergraduate students

Challenging experiments lasting multiple weeks

Report preparation, technical writing

Students encouraged to take independent initiative

HOW THE COURSE WILL WORK

Organized around modules lasting ~ 3 weeks

Teams of 2. Some rotation will occur

Student teams select from available modules

Machine shop module mandatory

Complete 4 modules, including machine shop

No exams; No textbook

MODULE GRADING:

50% on quality of work, lab notes

50% on the quality of report

Modules

1) Mechanical Practices in Experimental Science (Required)

2) Nuclear Physics

3) Wavemeter

4) Diffraction of Single Photons

5) Doppler Velocimetry

6) Lock-in Amplifier **New this semester**

7) Cryostat **New this semester**

8) Independent Project

Module 1: Mechanical Practices in Experimental Science (Required)

Instructor: Anthony Gravagne, PandA prototype machinist

Elementary machine shop skills; interpret drawings

Each student must build a device

Milling (3 weeks), Lathe (1—2 weeks)

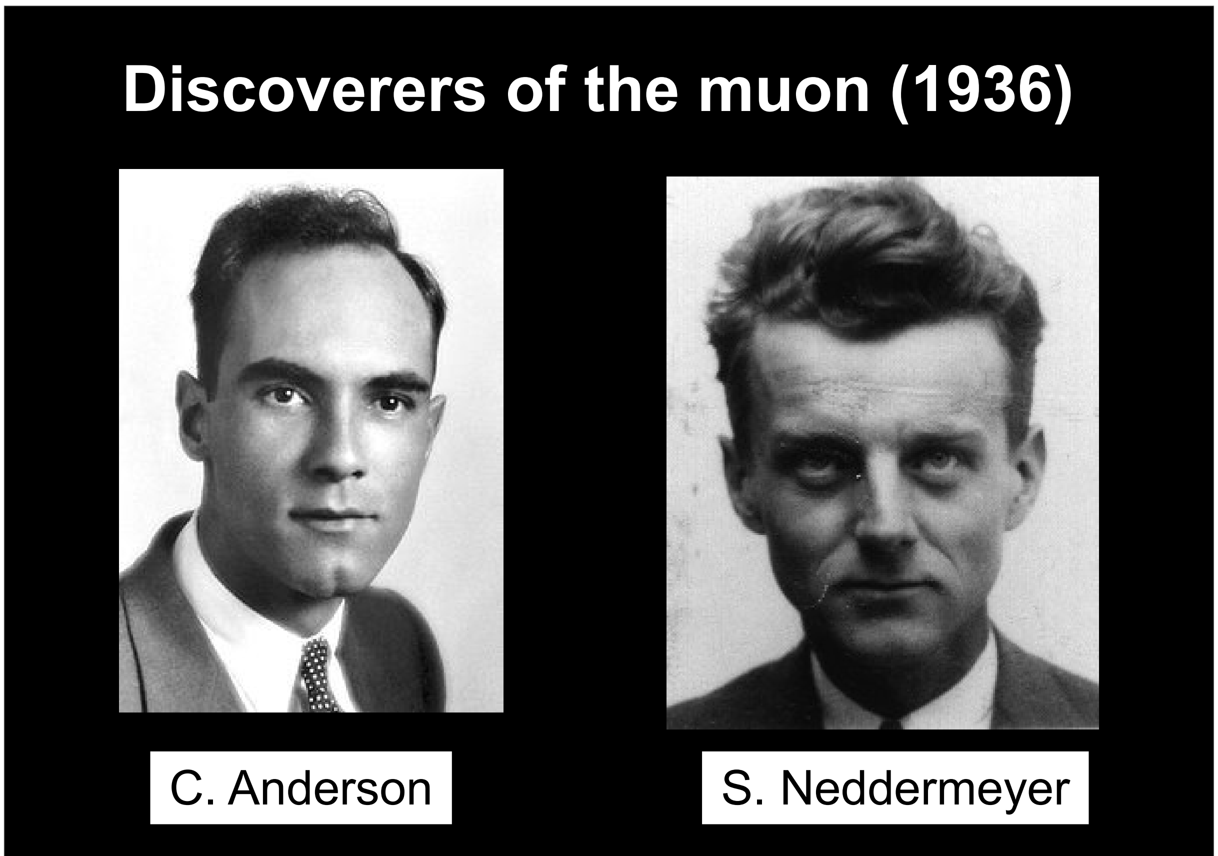
Multiple choice quiz at conclusion

No writeup required

Module 2: Nuclear Physics

i) Gamma ray spectroscopy

ii) Muon lifetime measurement (NIM electronics and/or DAQ device)



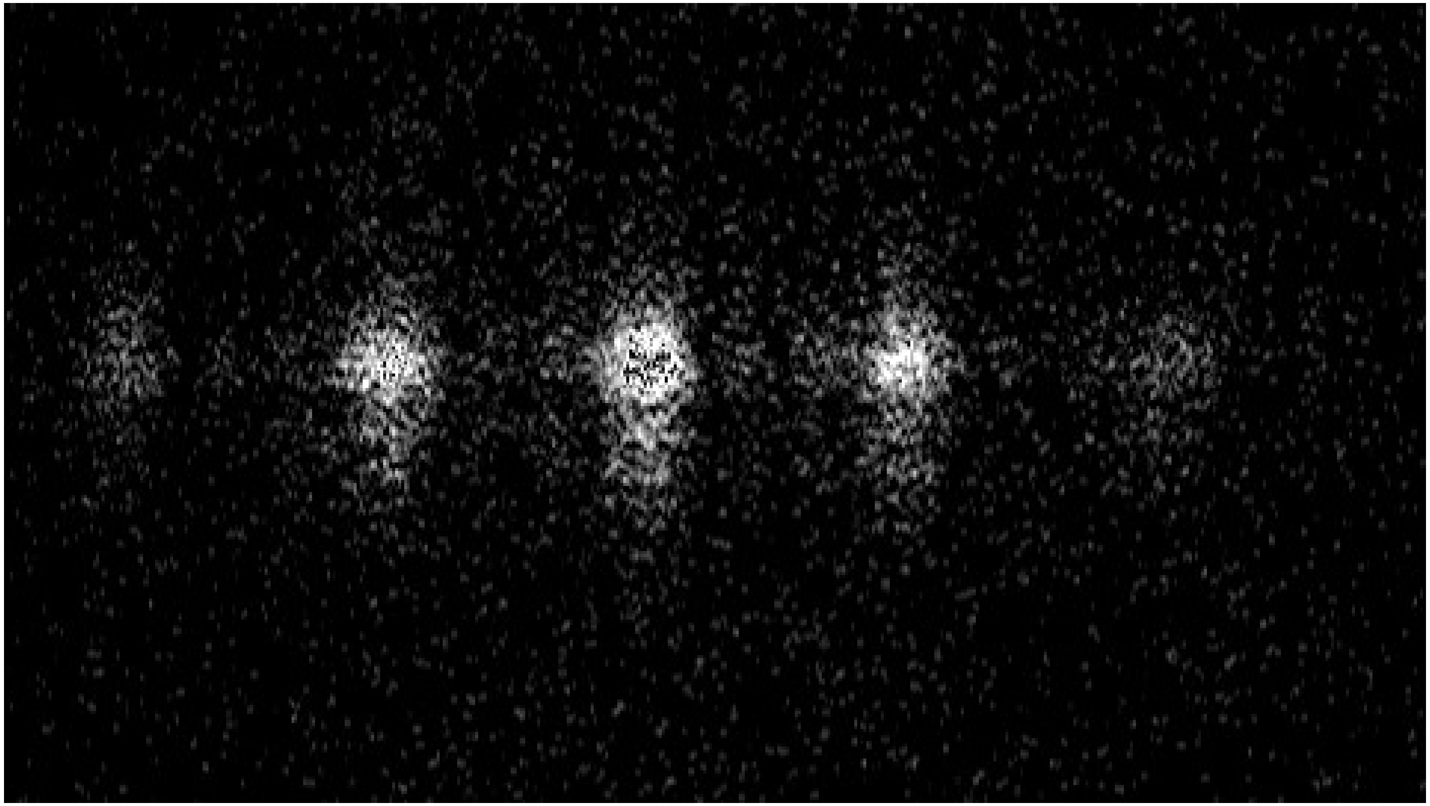
Module 3: Wavemeter (shared with Optics Lab)

Measure the wavelength/frequency of one laser using 2nd laser as reference

Concepts: laser beam alignment, interferometry, polarization, detectors

Module 4: Single Photon Interference

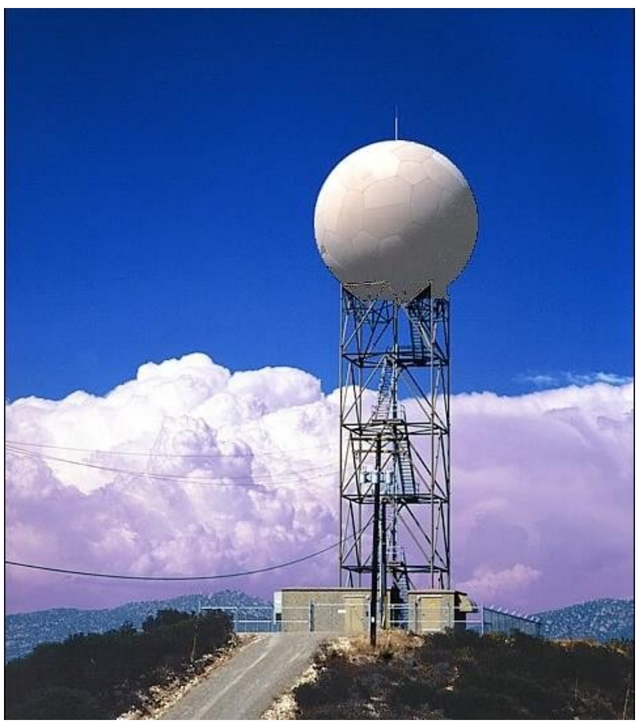
Concepts: Interferometry, polarization, diffraction, wave-particle duality, Uncertainty Principle



Module 5: Doppler Velocimetry (shared with Optics Lab)

Coherent interference to measure velocity

Concepts: laser beam alignment, interferometry, polarization, detectors



Weather radar

Police radar

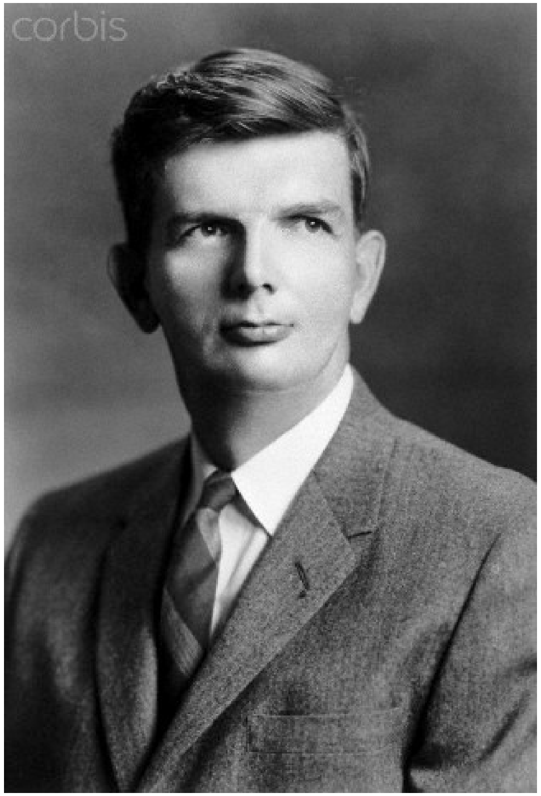
Module 6: Lock-in Amplifier (New for Spring 2016)

Detection of ultra-weak signals; << background noise level

Develop analog lock-in experiment

Compare to software implementation with DAQ device

LabVIEW programming required



Robert Dicke

Module 7: Cryostat (New for Spring 2016)

Write LabVIEW program to read temperature

Modify VI to control temperature using P-I algorithm

Temperature-dependent measurement?

Concepts: vacuum techniques, cryogenics (LN2),
temperature control

Module 8: Independent Project

Student teams propose and develop an experiment of their own choosing

Limited budget to acquire additional hardware and resources

Lab Notebook

All students are required to maintain a lab notebook (provided)

Record with a pen

Date each page

Each experiment starts on a new page; include a title and objectives

Have instructor or TA initial each page at the end of each session

Lab notebook guidelines are here

Writeups: Technical journal format

Abstract: Brief statement of methodology and results. If a quantitative result was found, report its value and uncertainty (eg. $\lambda = 633 \pm 8$ nm).

Introduction: Background material, motivation for the experiment, general description of your experimental approach. Relevant equations and most references are found here.

Experiment: Describe your experimental setup here. You will need at least one diagram. Provide enough information that a physics professional could reproduce the experiment.

Results/Analysis: Here is where the data gets presented, usually involving tables and/or graphs (best). This is a good place to describe the experimental errors and how they affect the uncertainty of the measurements. Do the results support theory? What are the limitations of the experiment? How could it be improved?

Summary/Conclusion: Concisely summarize the experiment here: what you did, what you found, what went right, what went wrong. This section is similar to the Abstract, but includes more information

References

Writeups: Technical journal format (continued)

Label all figures/diagrams and include a caption. Figures must be referenced in the text. Copying figures/pictures from other sources is discouraged, but if you do this include a reference to that source.

Be consistent with your referencing methodology. The APS citation scheme looks as follows:

S.H. Neddermeyer and C.D. Anderson, Phys. Rev., 884 (1937).

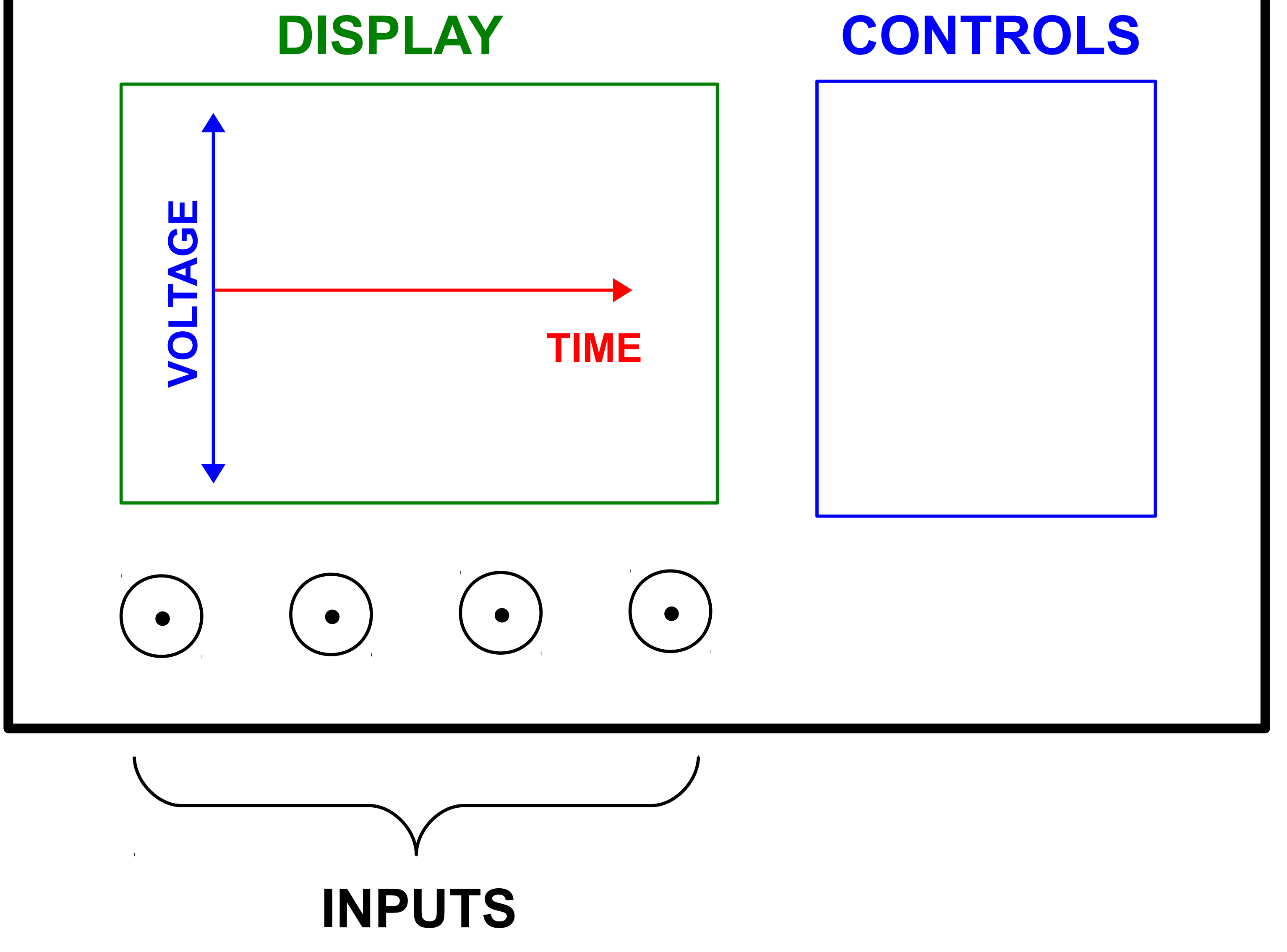
Use a template from a research journal (eg. APS, OSA). Look online or in hallways for examples.

No page limit, but write clearly and concisely.

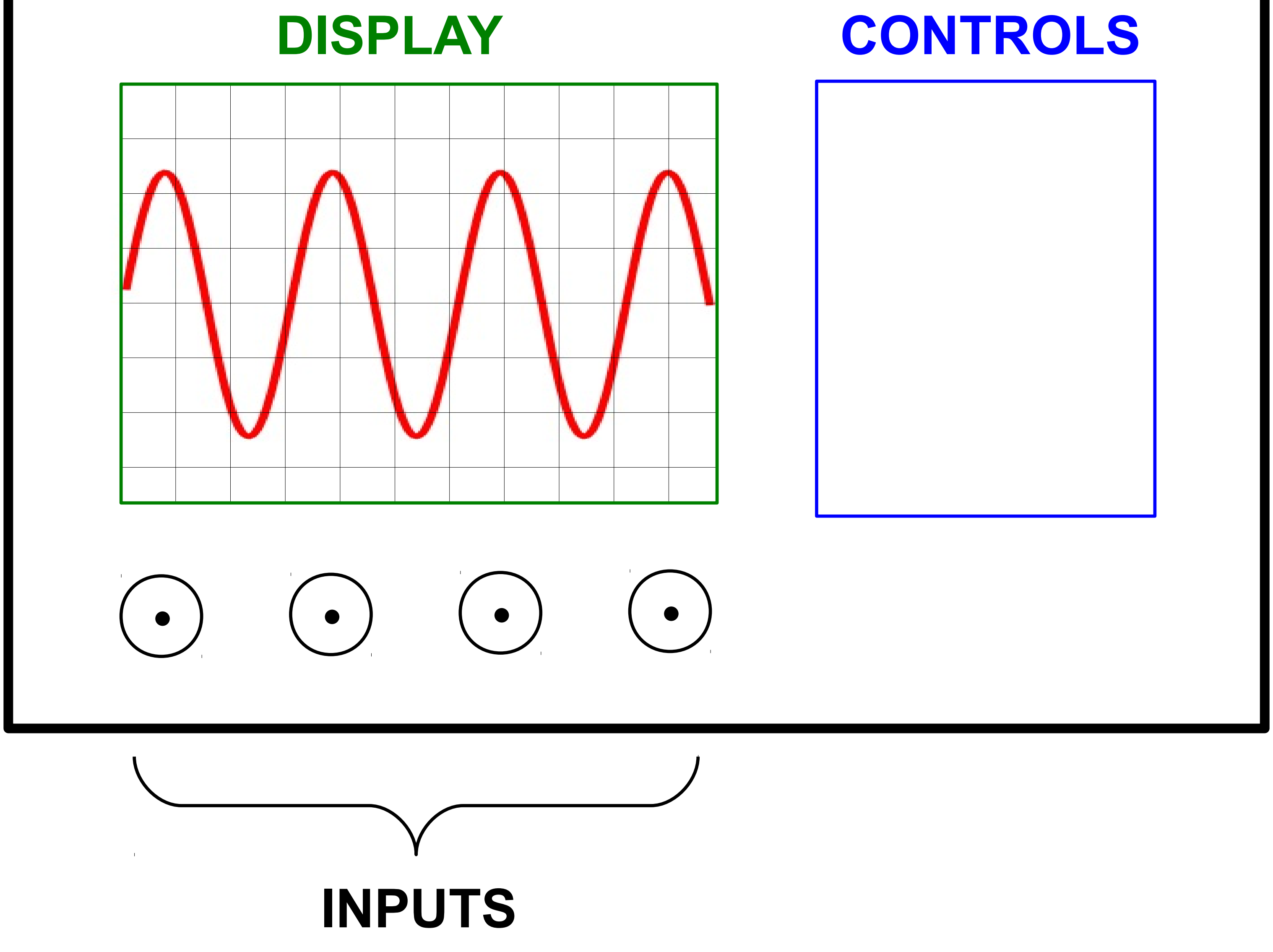
Reports are due no later than 2 weeks after conclusion of a module. Files in .pdf format are strongly preferred.

OSCILLOSCOPE REVIEW

OSCILLOSCOPE



OSCILLOSCOPE

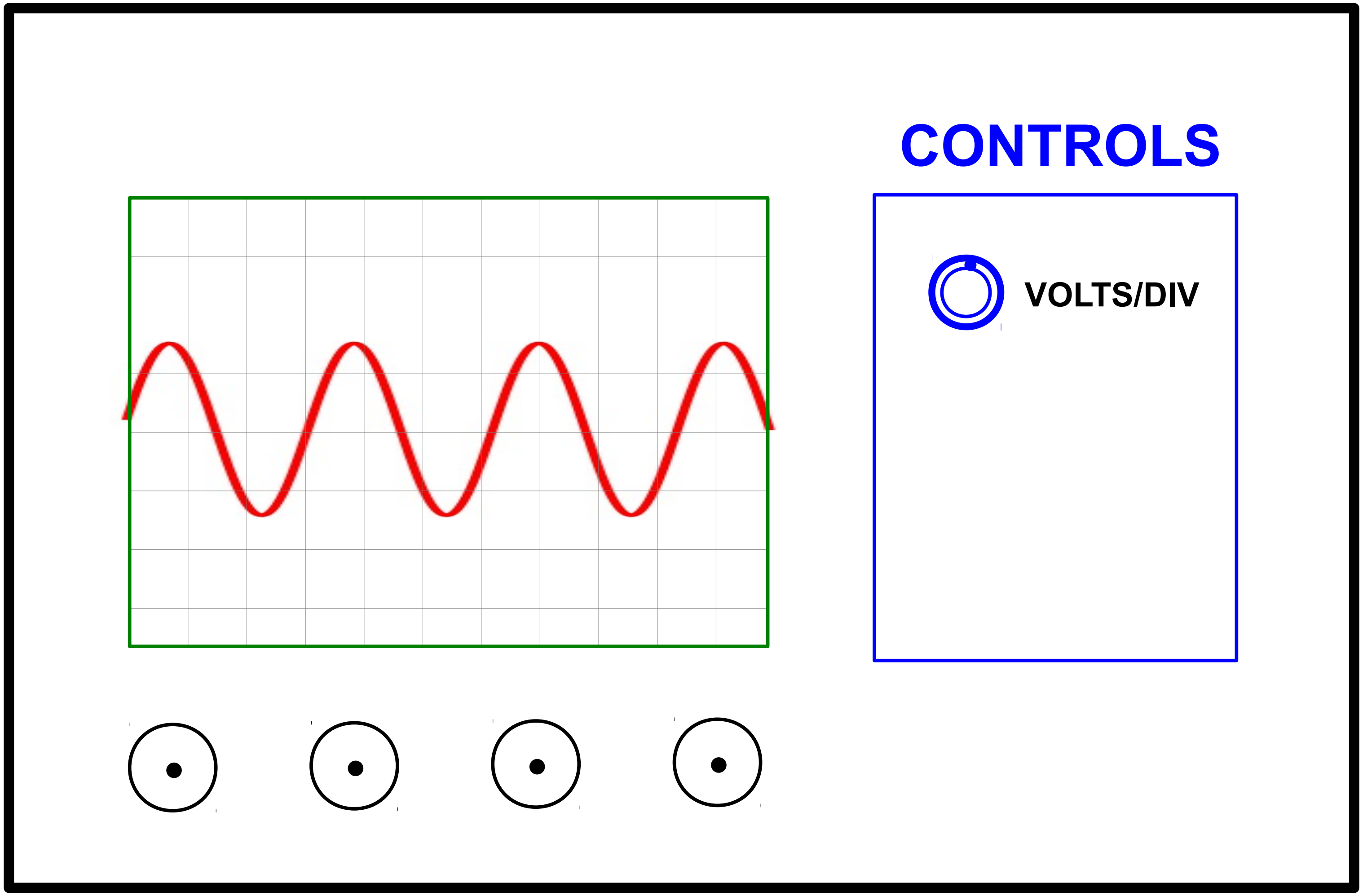


ANALOG: Cathode ray tube, swept electron beam

DIGITAL: A/D converter, LCD display

Although physical operation is completely different, controls are nearly identical

DISPLAY ADJUSTMENT



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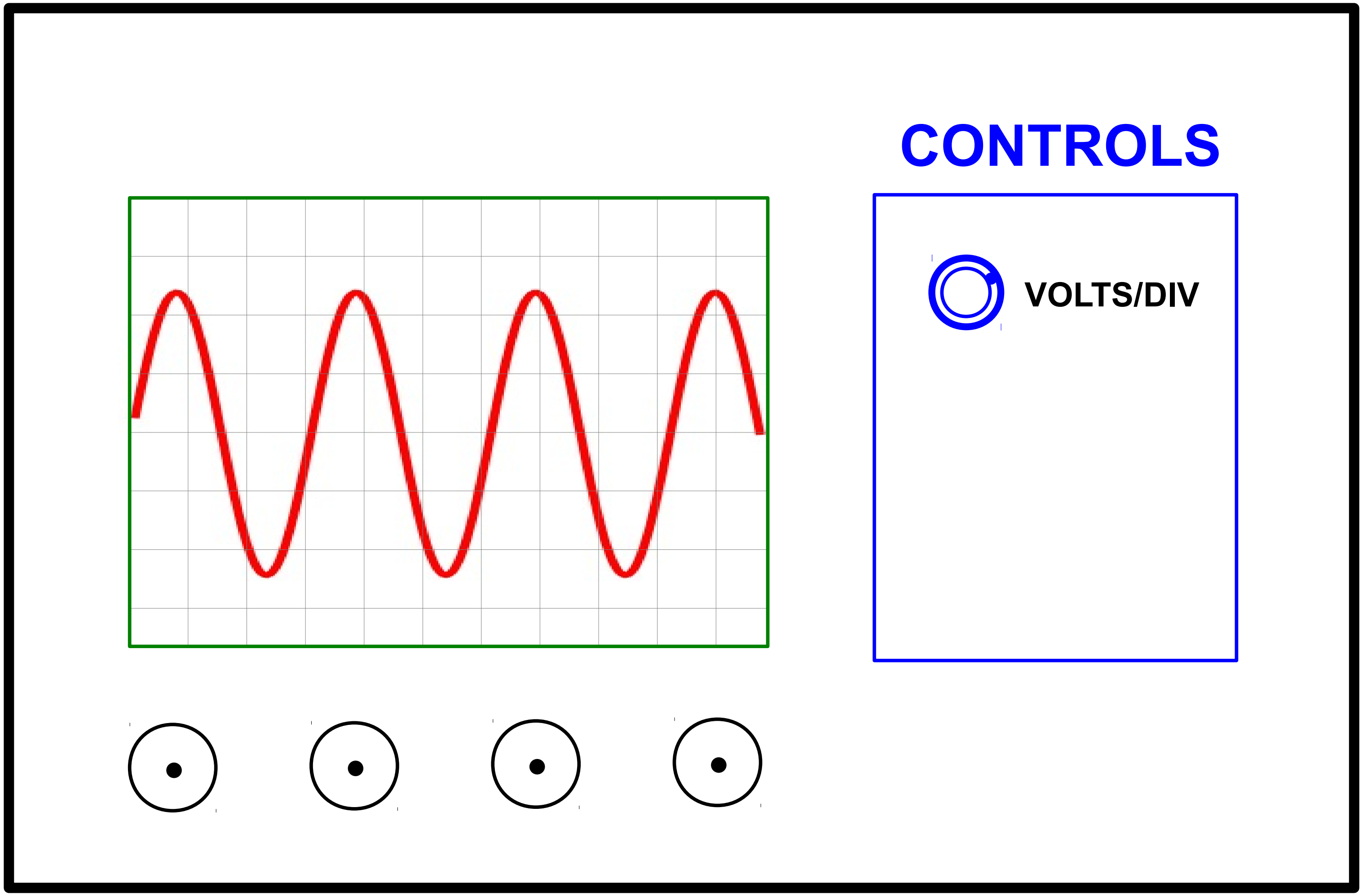

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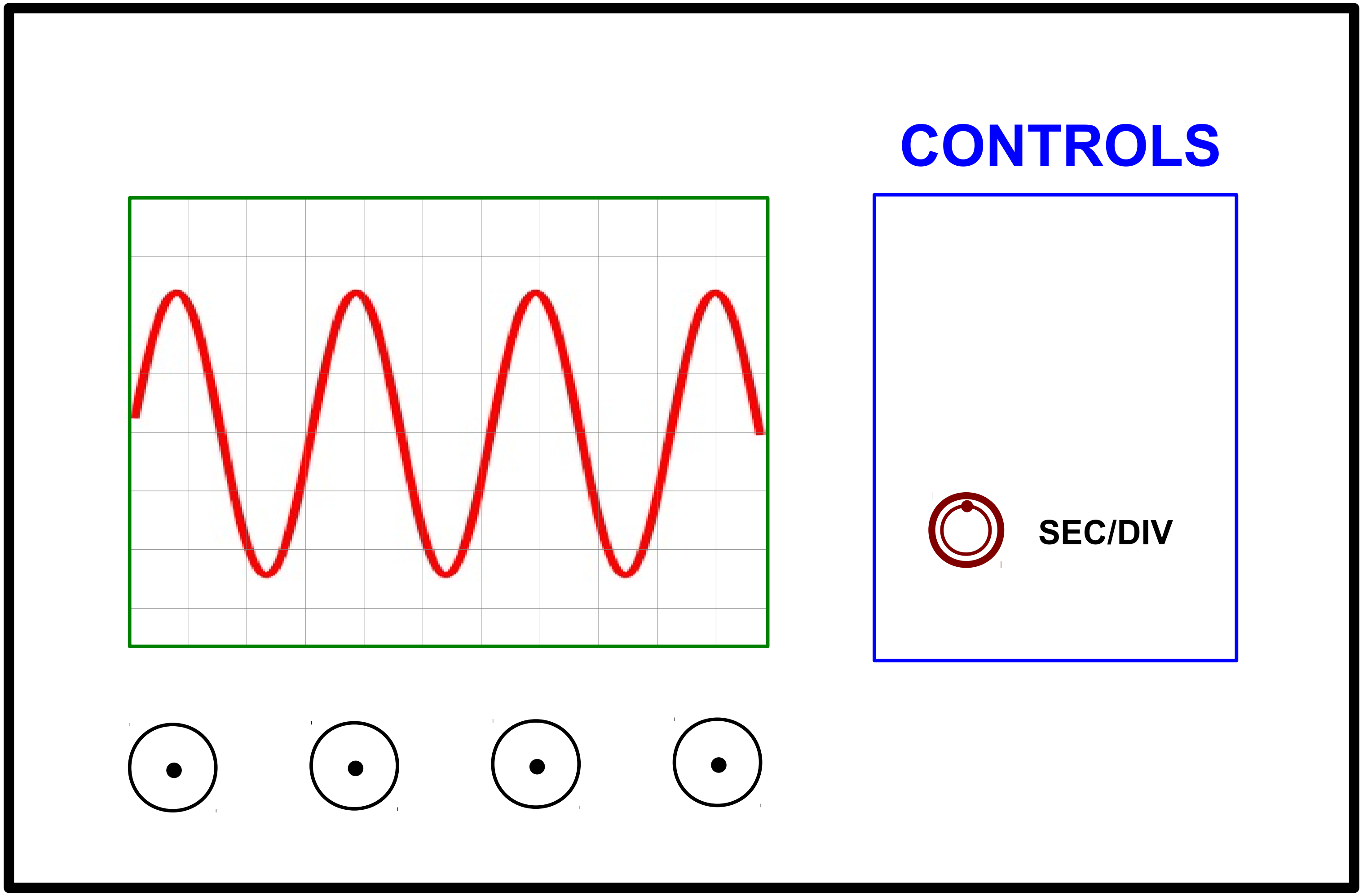

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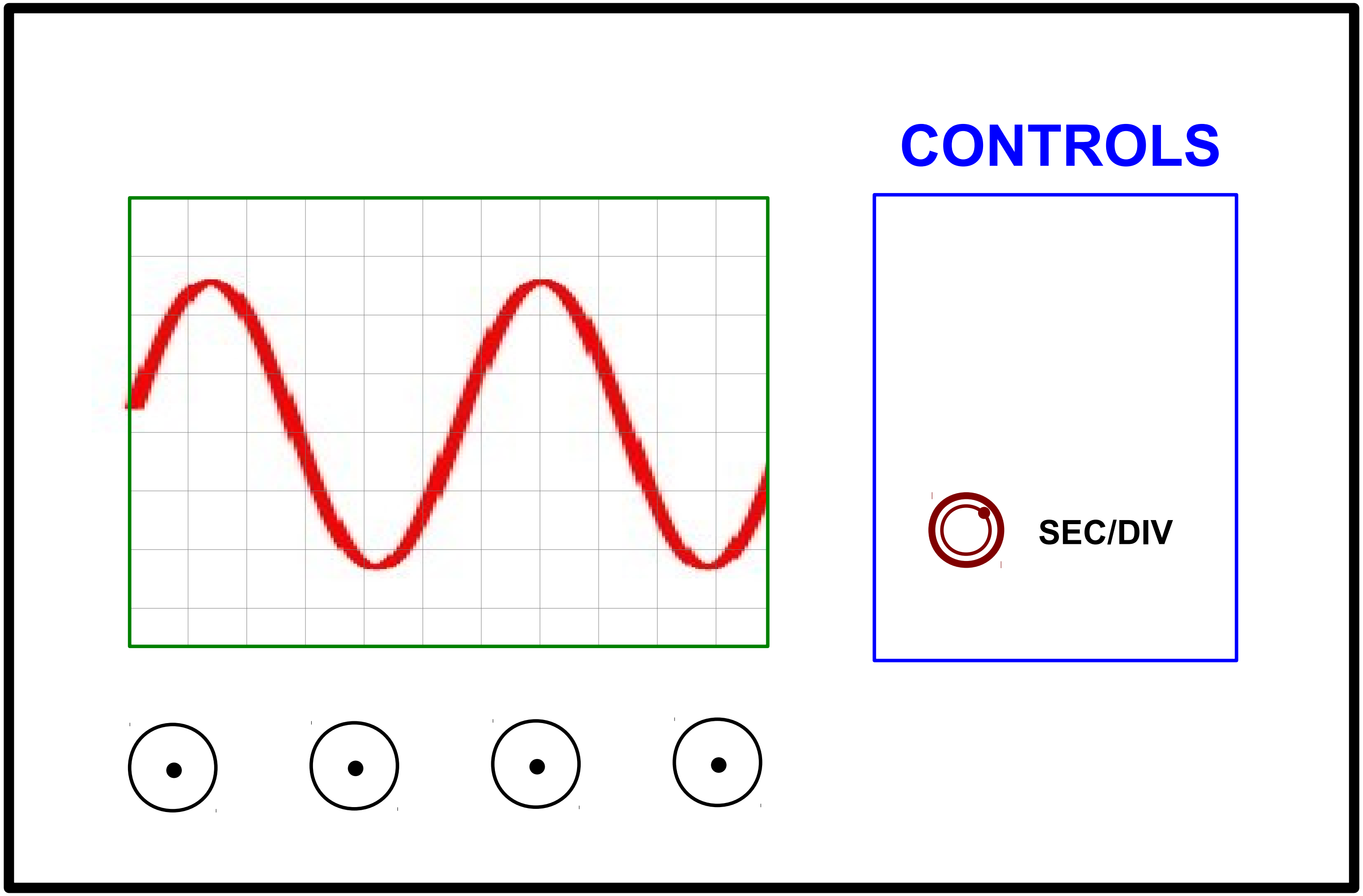
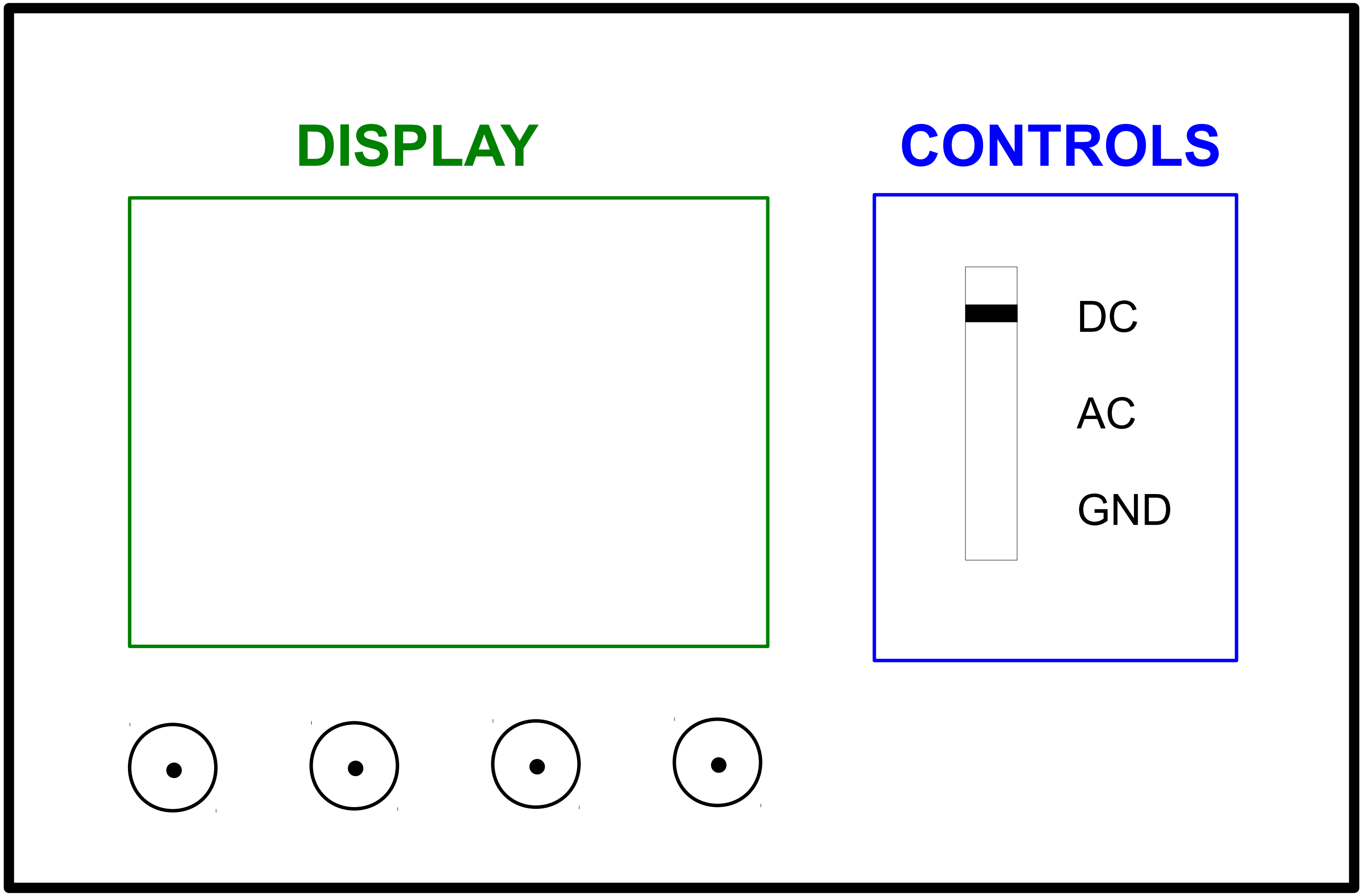
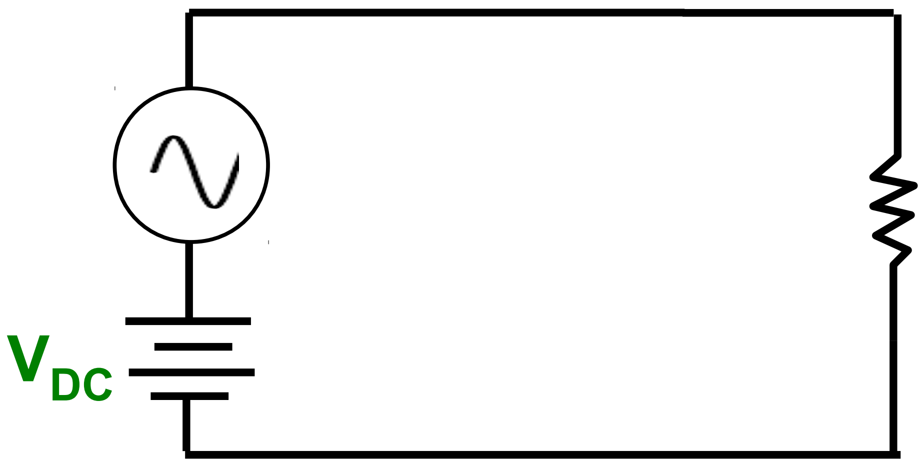
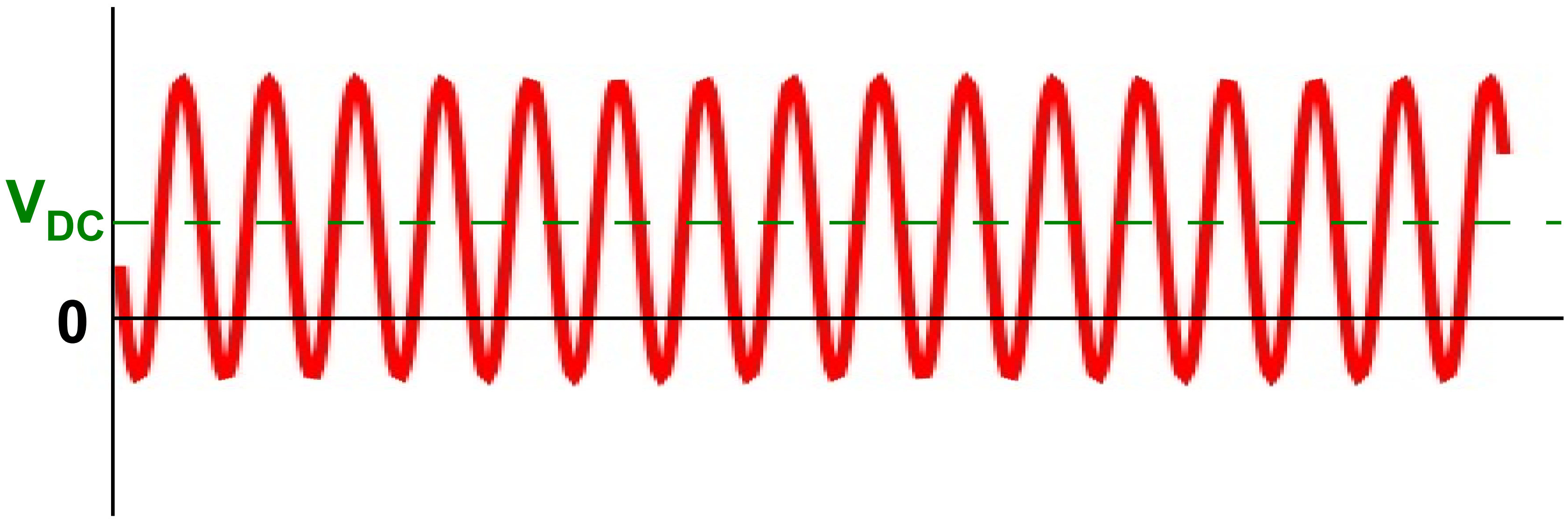


DC coupling, AC coupling, and Ground

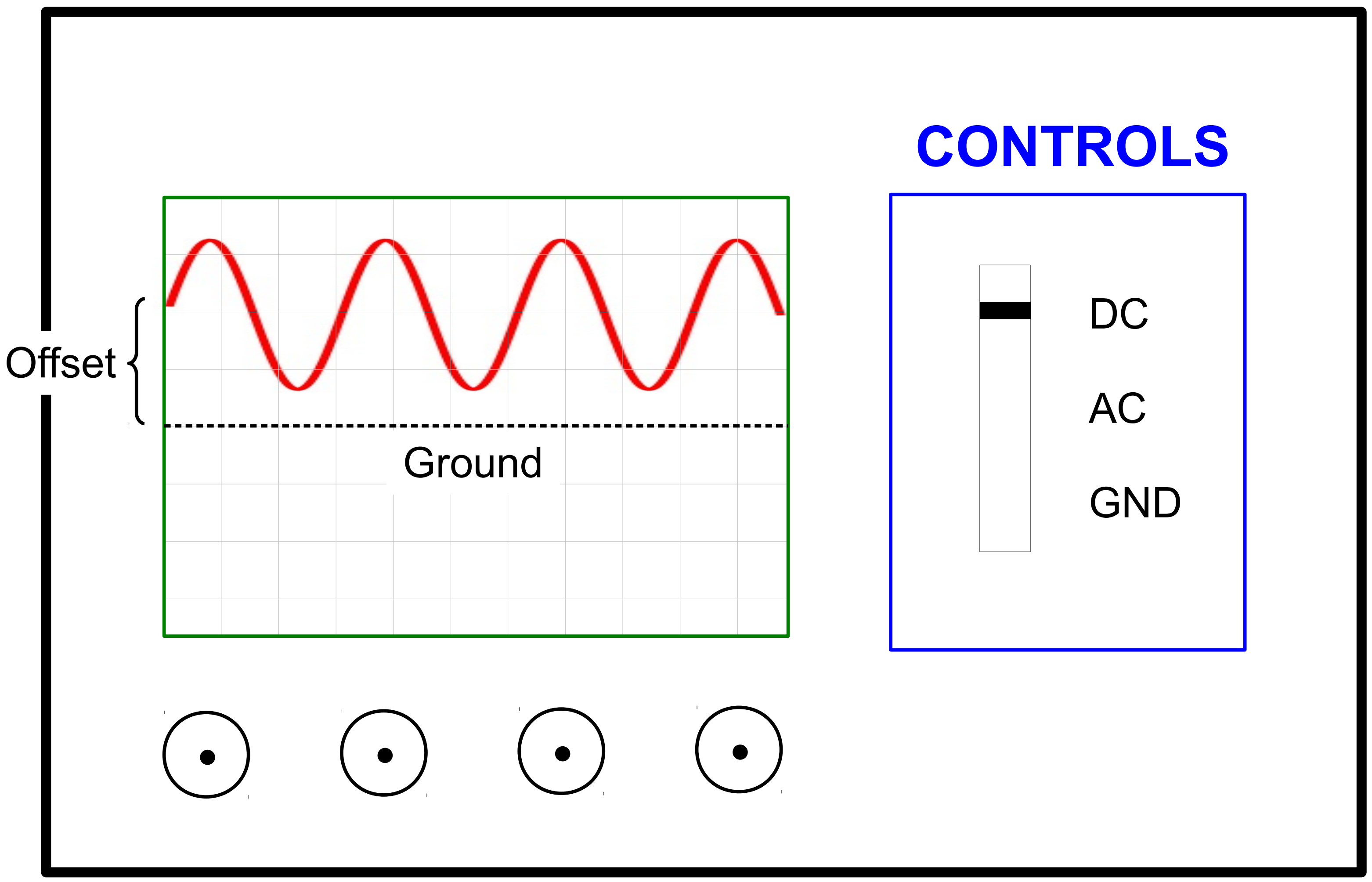


EXAMPLE: Sinusoidal wave source + DC offset

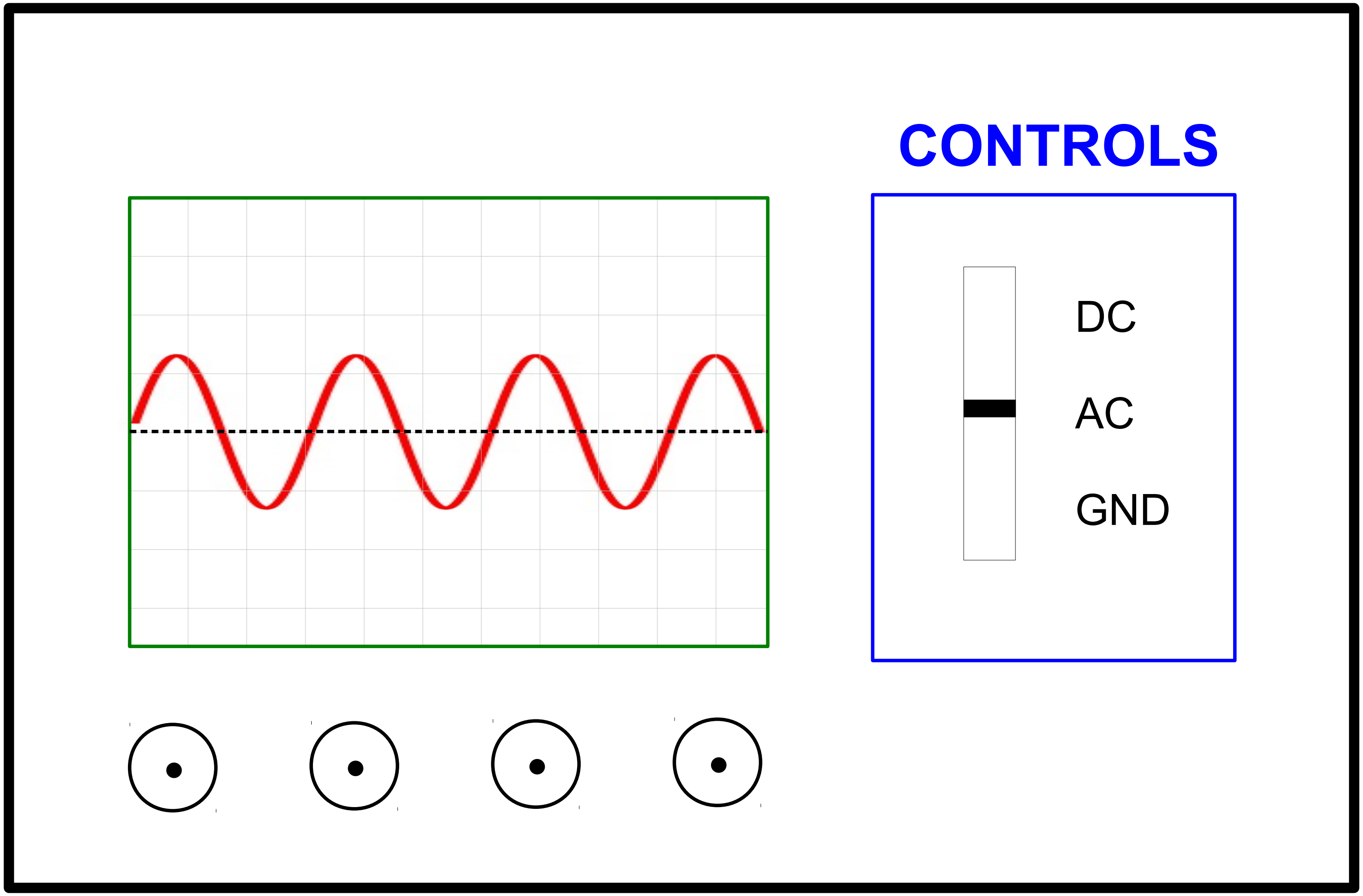




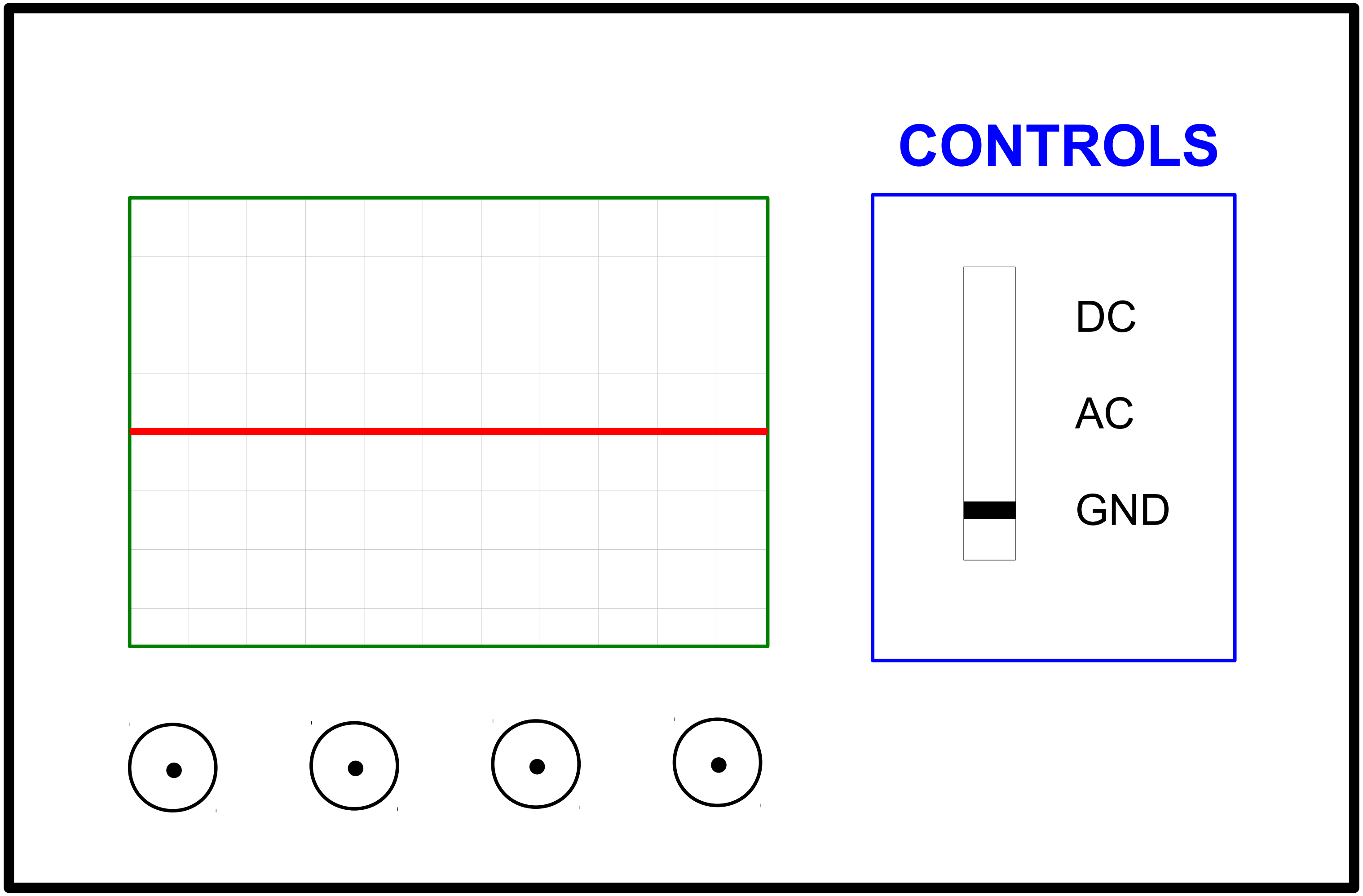
DC COUPLING



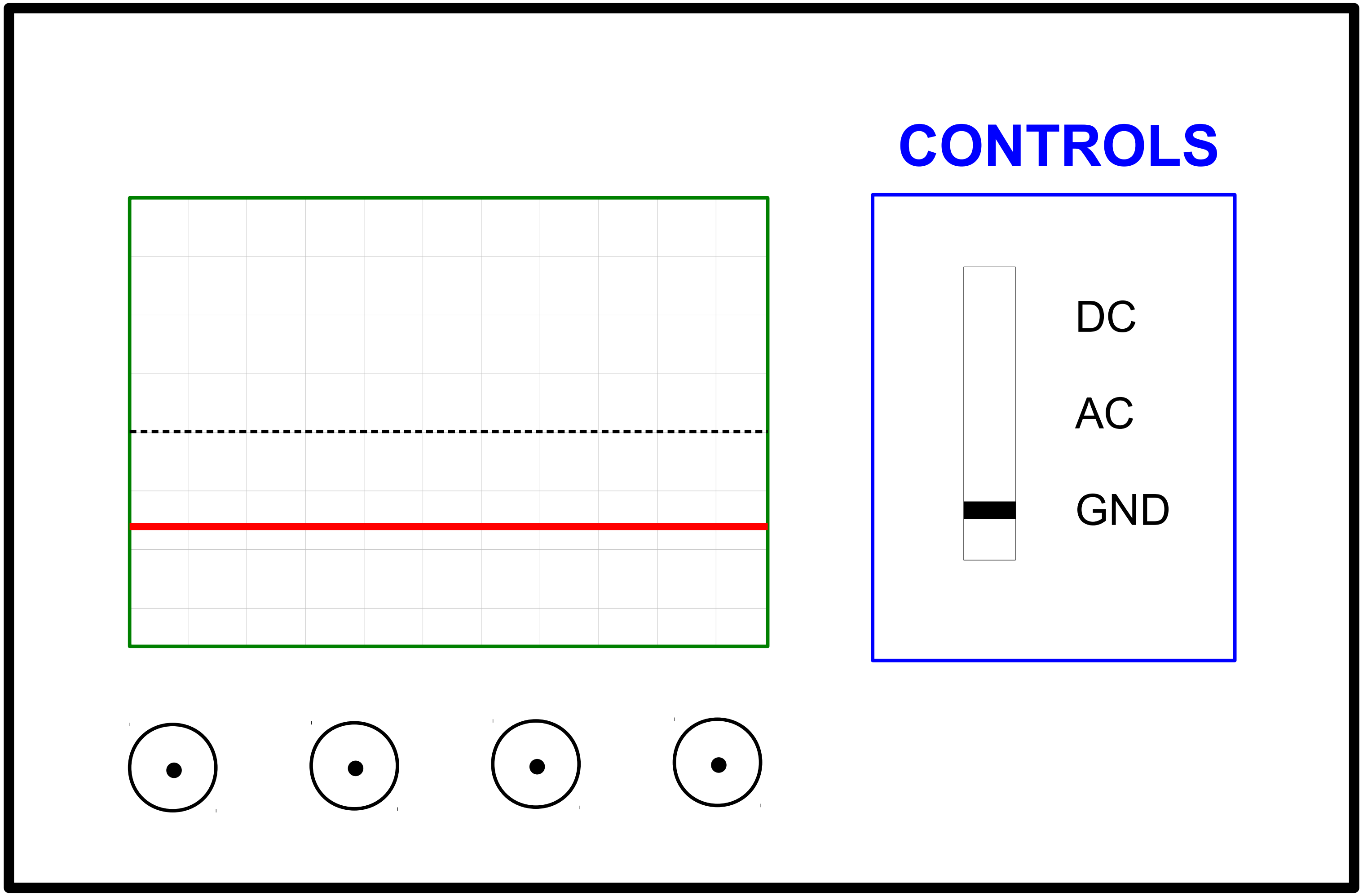
AC COUPLING



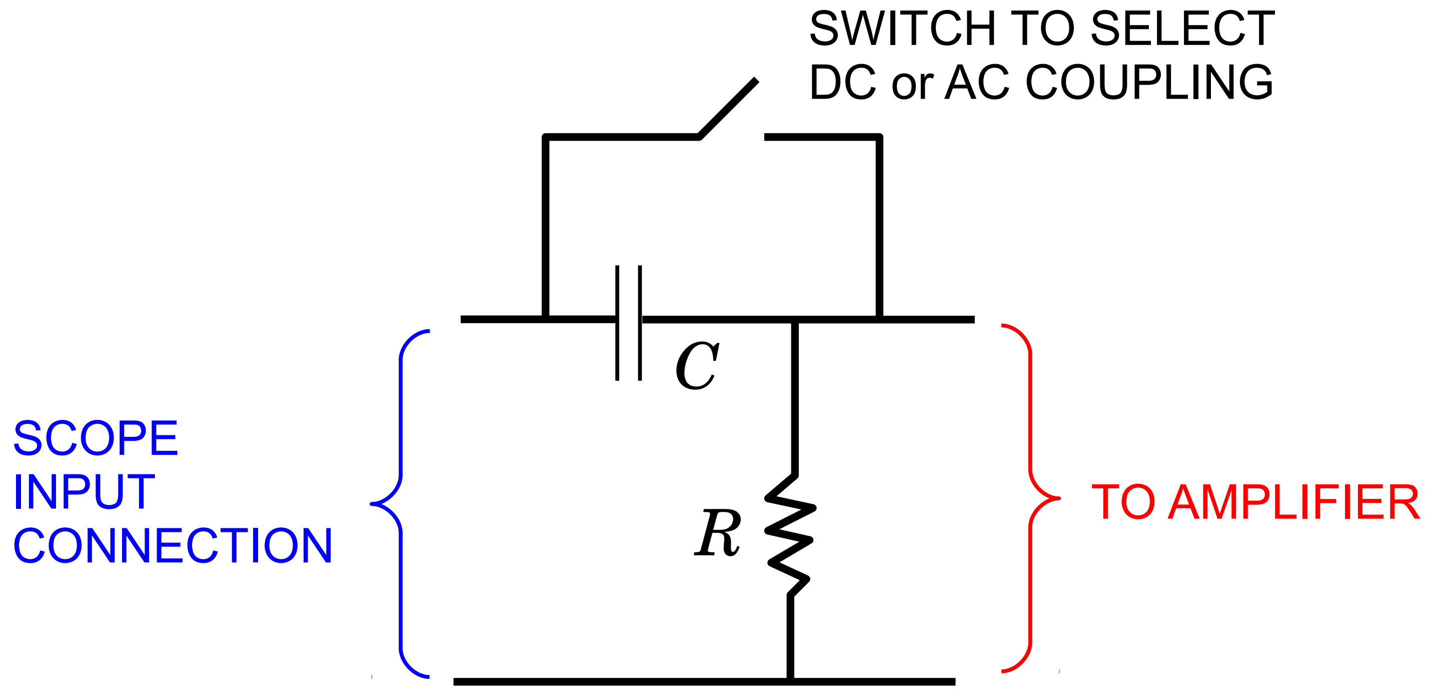
GROUND: Defines location of 0 Volts



GROUND can be positioned at any convenient level



AC coupling implemented with an RC high-pass filter



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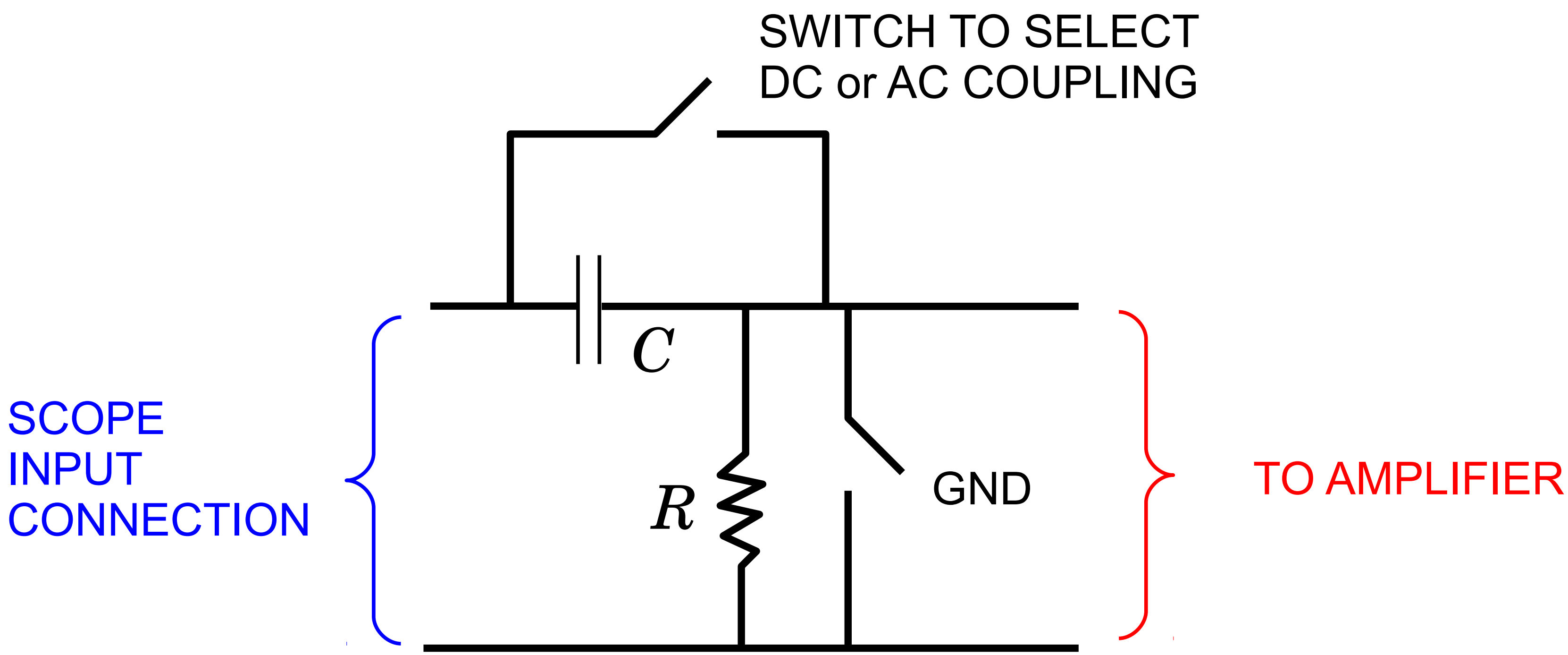
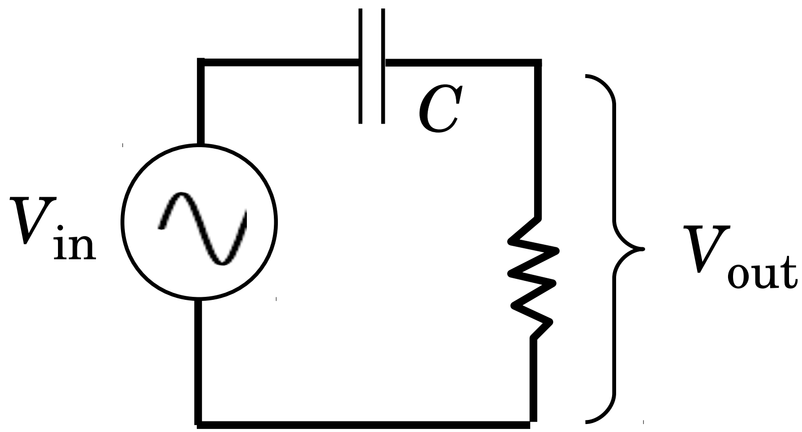
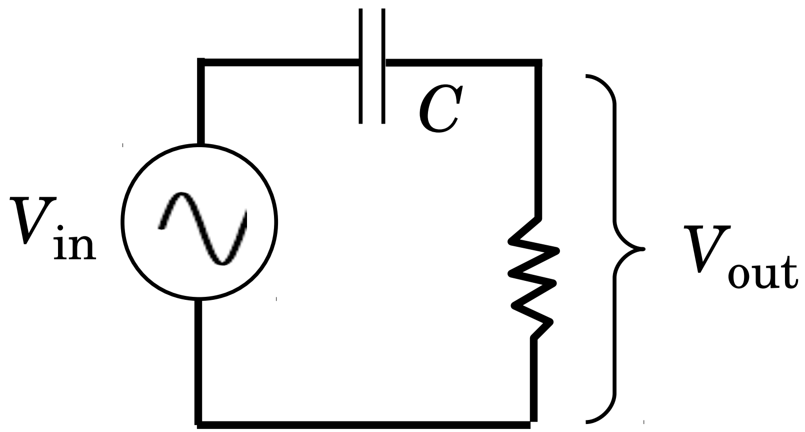


Harmonic analysis of RC high-pass filter



$$\frac{V_{OUT}(\omega)}{V_{IN}(\omega)} = \frac{R}{R + 1/j\omega C}$$

Harmonic analysis of RC high-pass filter



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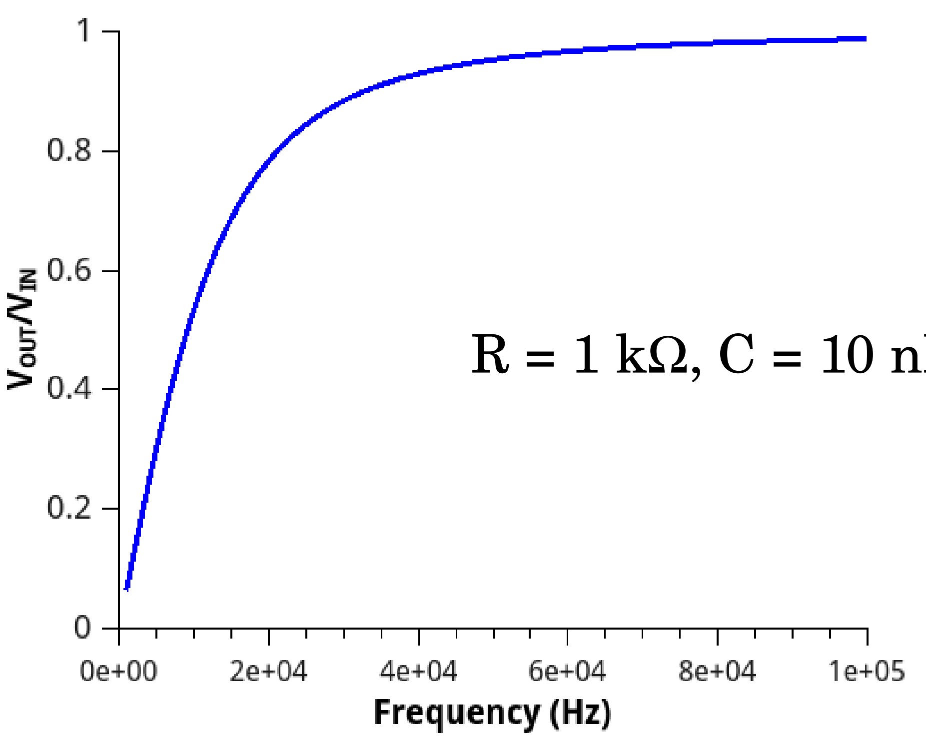
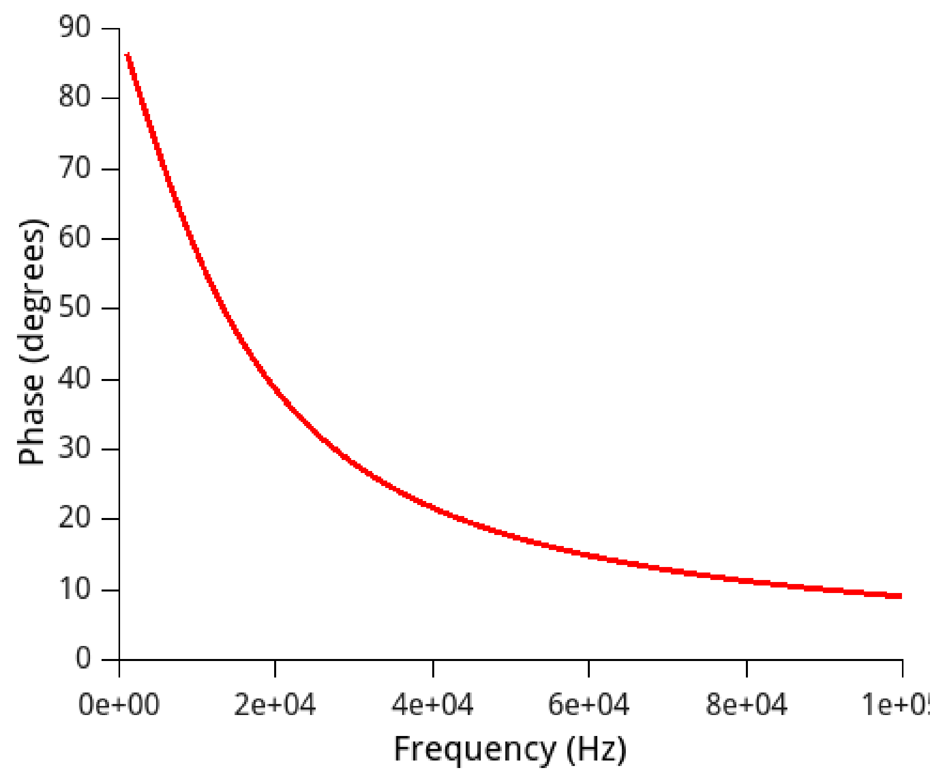


R = 1 kΩ, C = 10 nF



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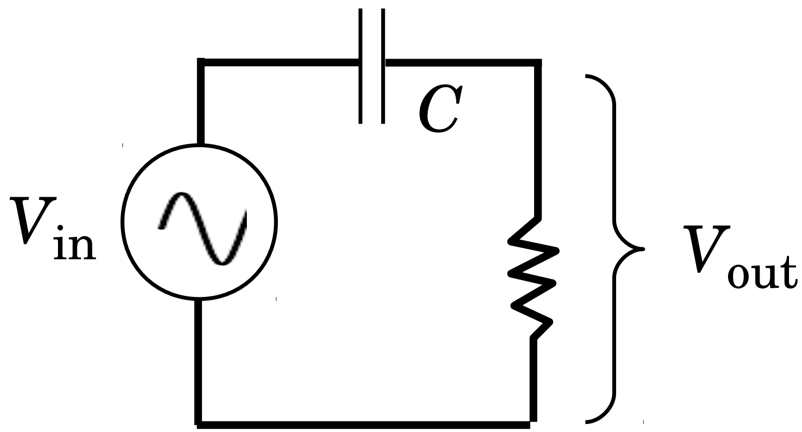
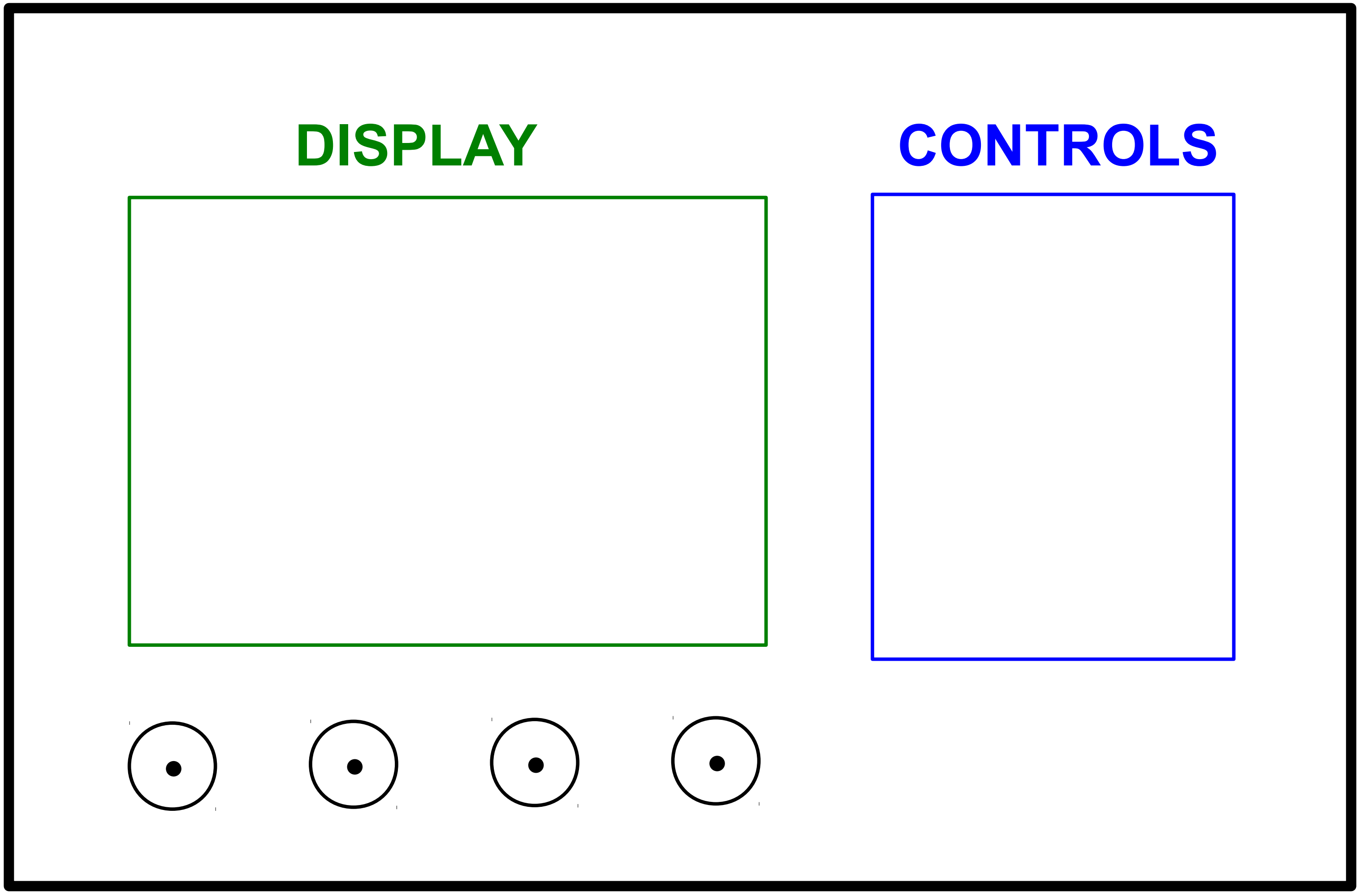


$$\frac{V_{OUT}(\omega)}{V_{IN}(\omega)} = \frac{R}{R + 1/j\omega C}$$

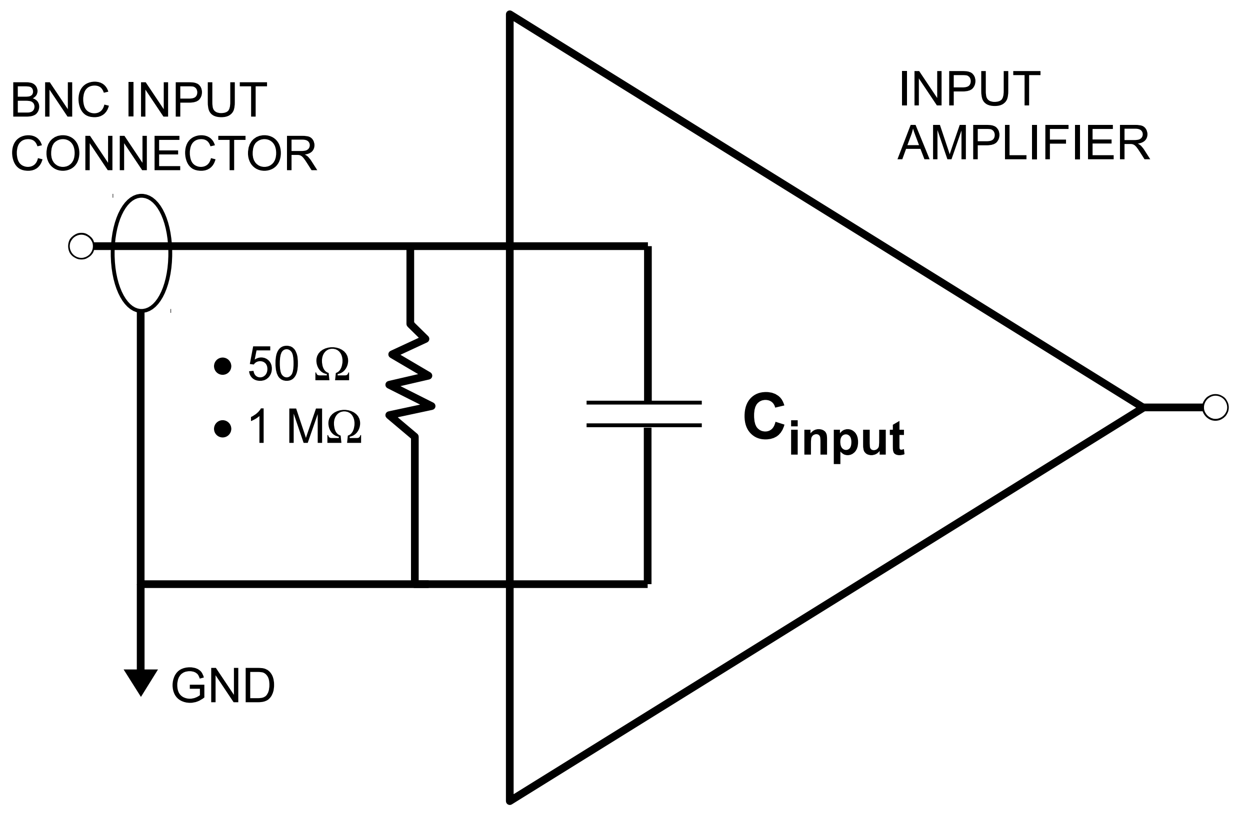
A typical oscilloscope has an *RC* high-pass cutoff in the range 1—10 Hz when AC coupling is used

Be careful when measuring slow signals:
AC coupling blocks more than just DC

INPUT RESISTANCE: 50 Ω or 1 MΩ?



All oscilloscopes have stray (unavoidable) capacitance at the input terminals: C_{input} = 15—20 pF



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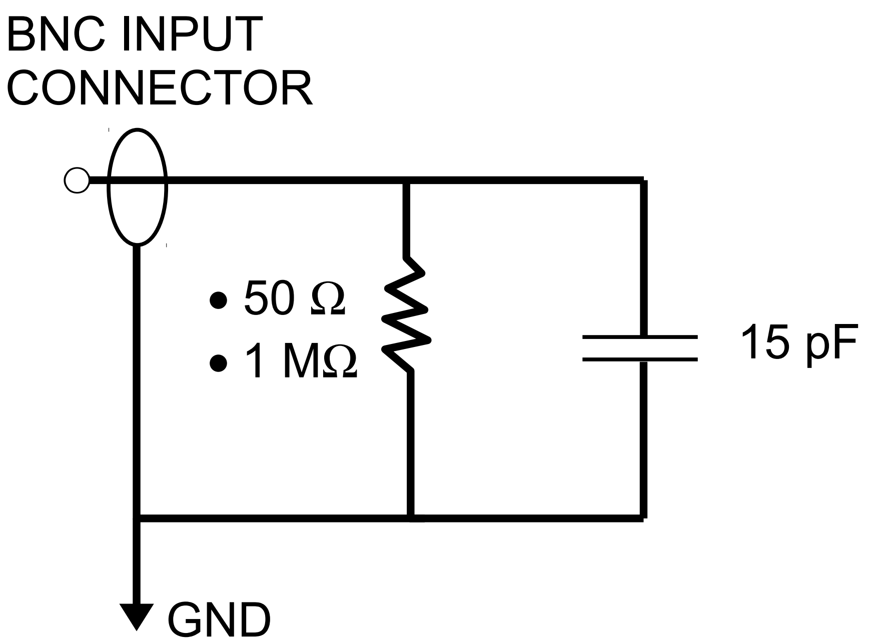
$$Z_{in} = \frac{R_{in}}{1 + j\omega R_{in} C_{in}}$$



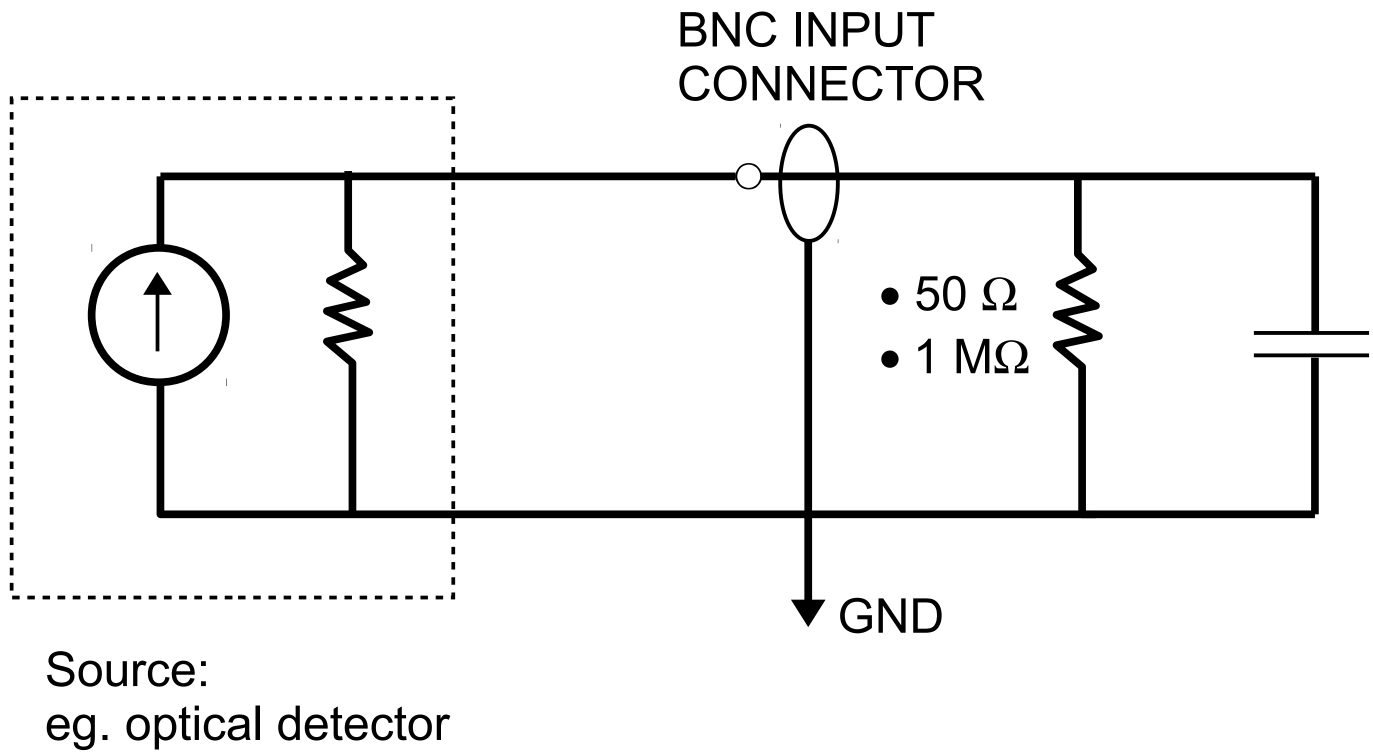
- 1 MΩ rolloff ~ 8 kHz

- 50 Ω rolloff ~ 160 MHz

Compensation possible with scope probe

Why do we use 1 MΩ if frequency response is so low?

ANSWER: Signal level (voltage) will drop enormously at 50 Ω unless source can provide enough current



TRIGGERING

Auto: Scope gives continually updated display

Normal: User controls when the slope triggers; Level, Slope
Trigger source: Channel 1, Channel 2, etc

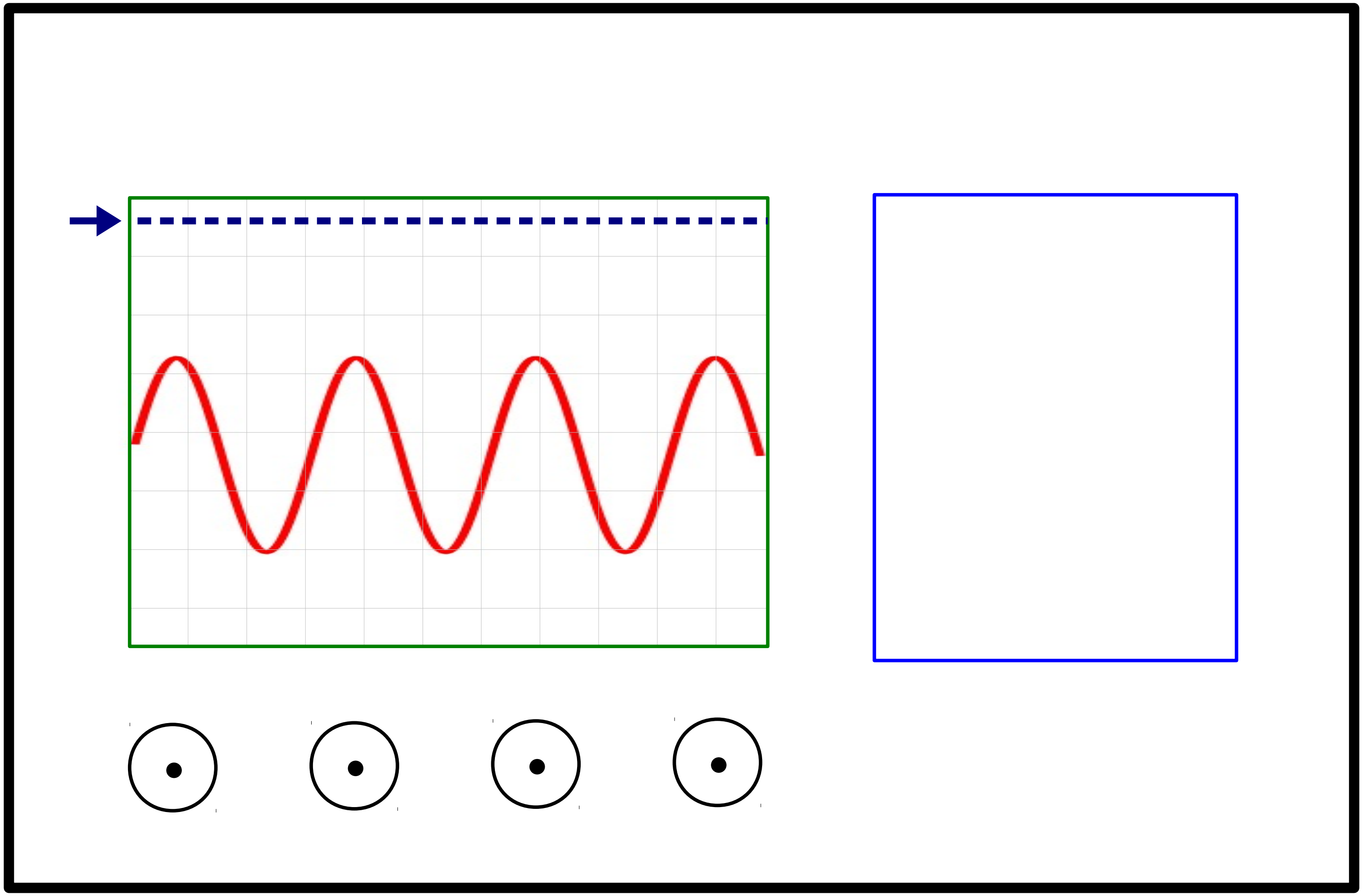
Line: Triggers on 60 Hz AC

Single event

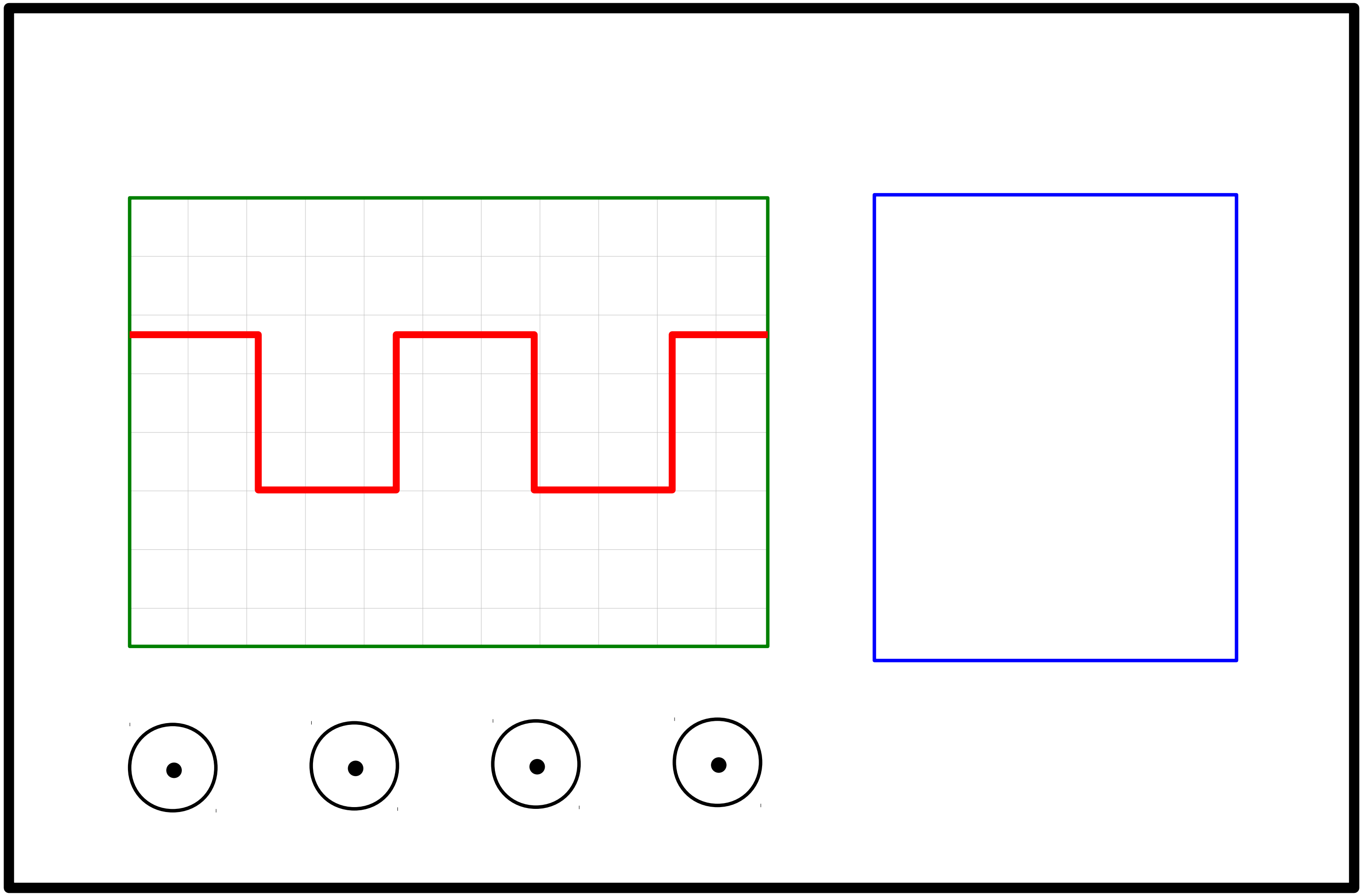
External

Use **Auto-Set** only when all else fails!

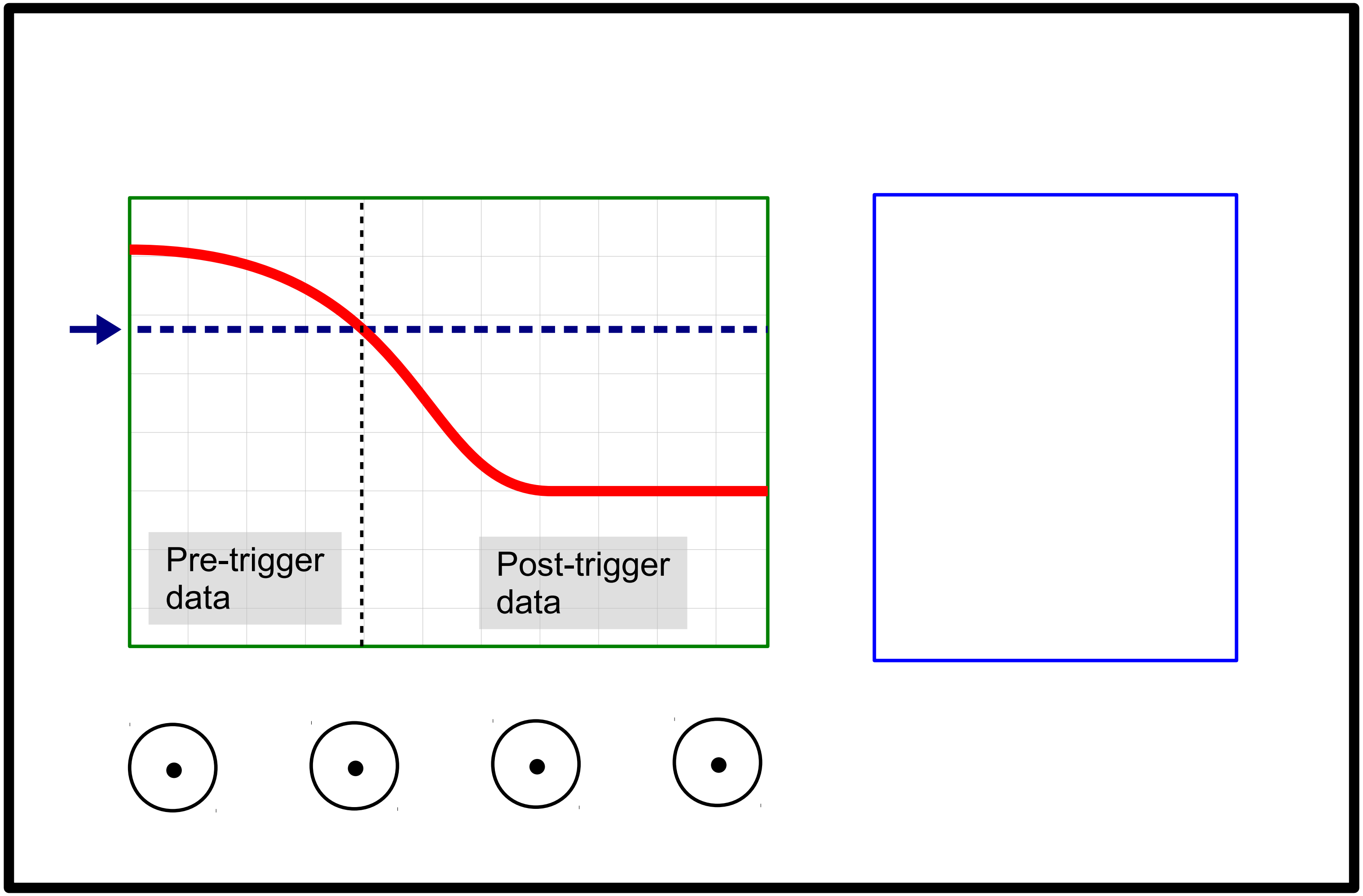
Setting normal trigger level



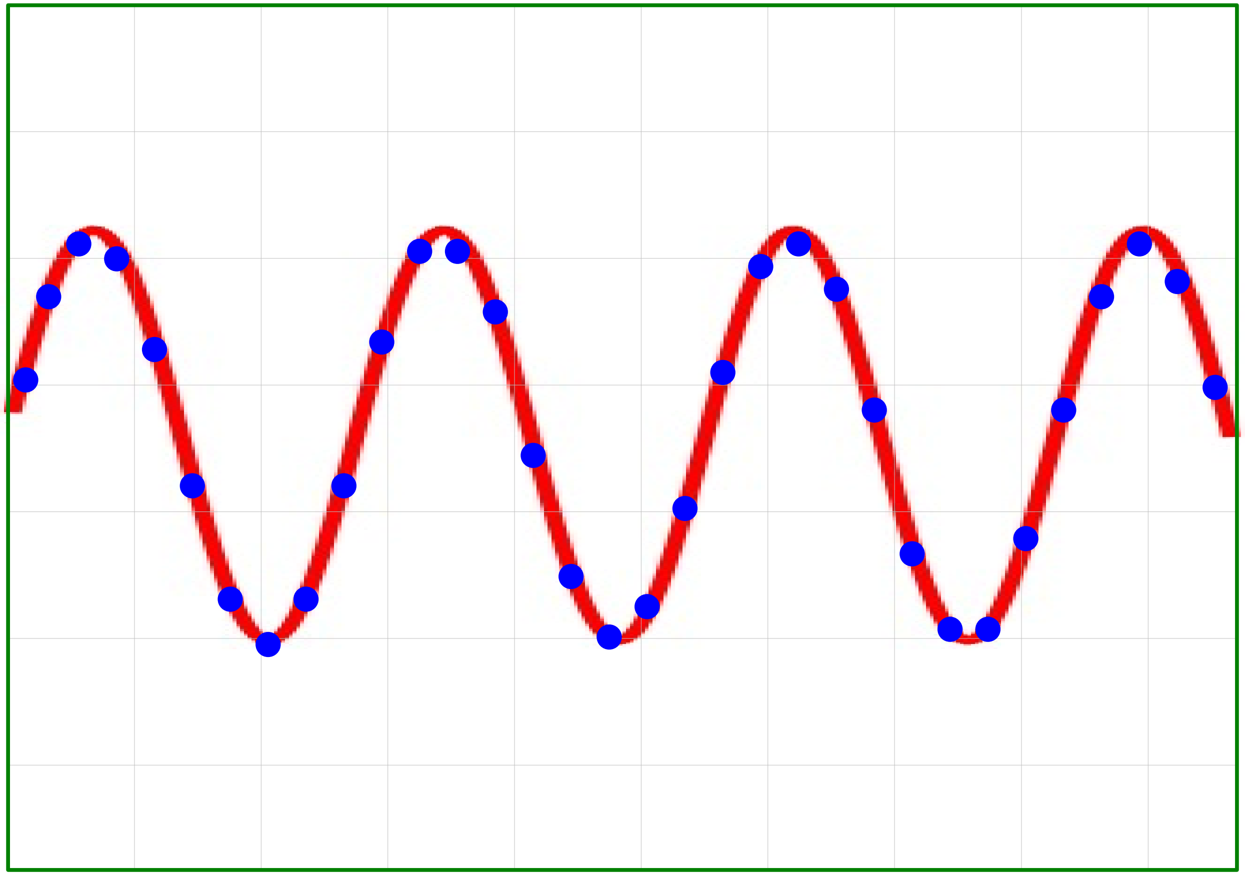
Example: Measure fall time of square wave



SOLUTION: Trigger on negative slope



DIGITAL SCOPE:
SAMPLING BANDWIDTH



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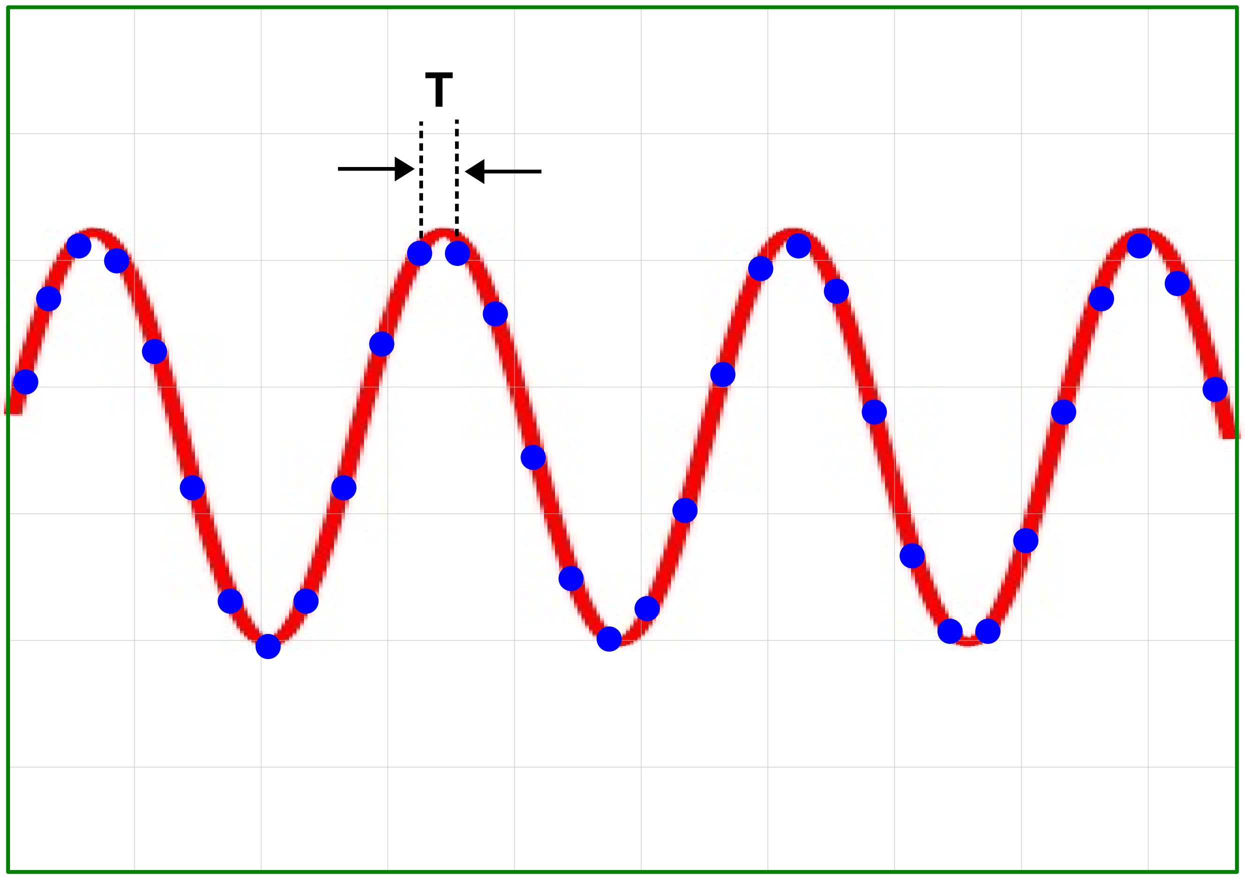

Sample spacing: **T** (sec)

Sampling bandwidth = 1 / **T** (samples/sec)

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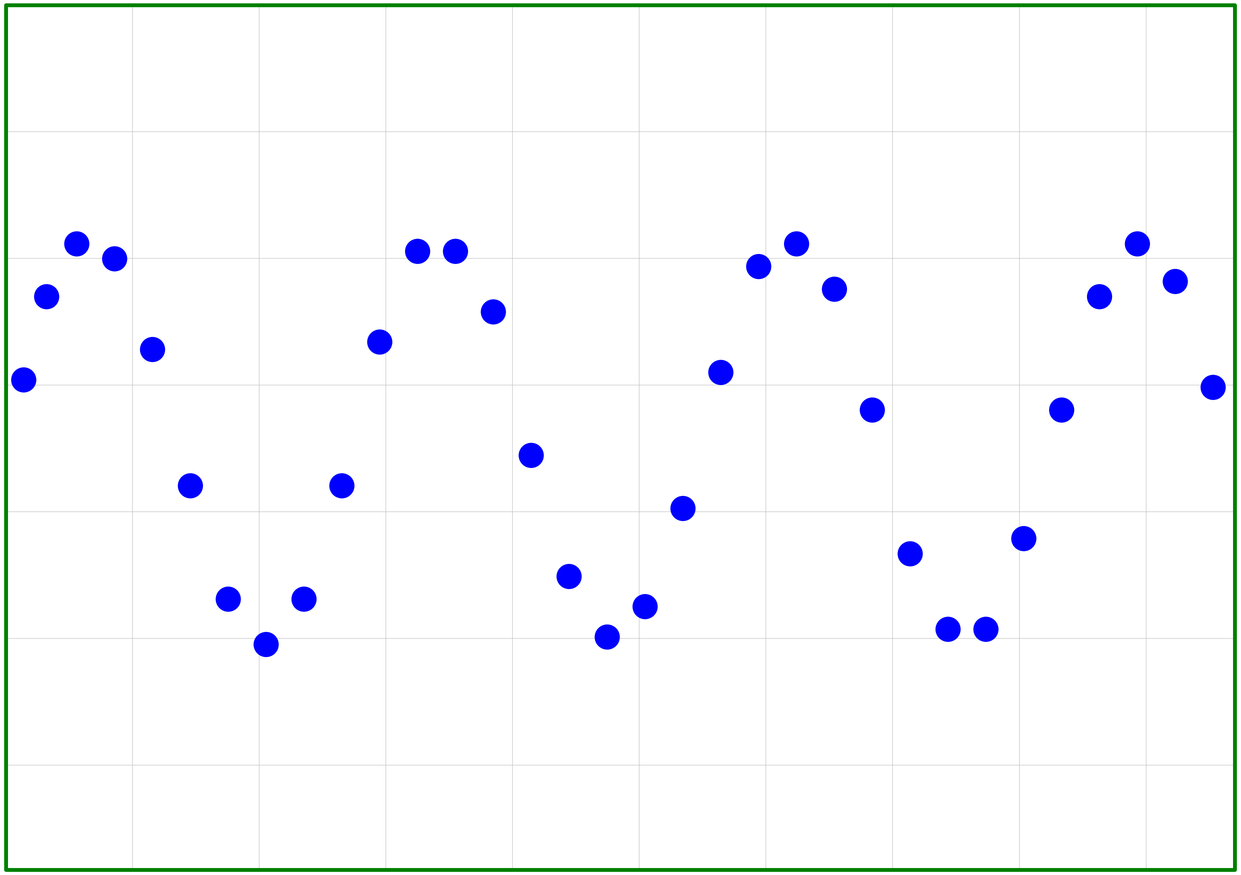

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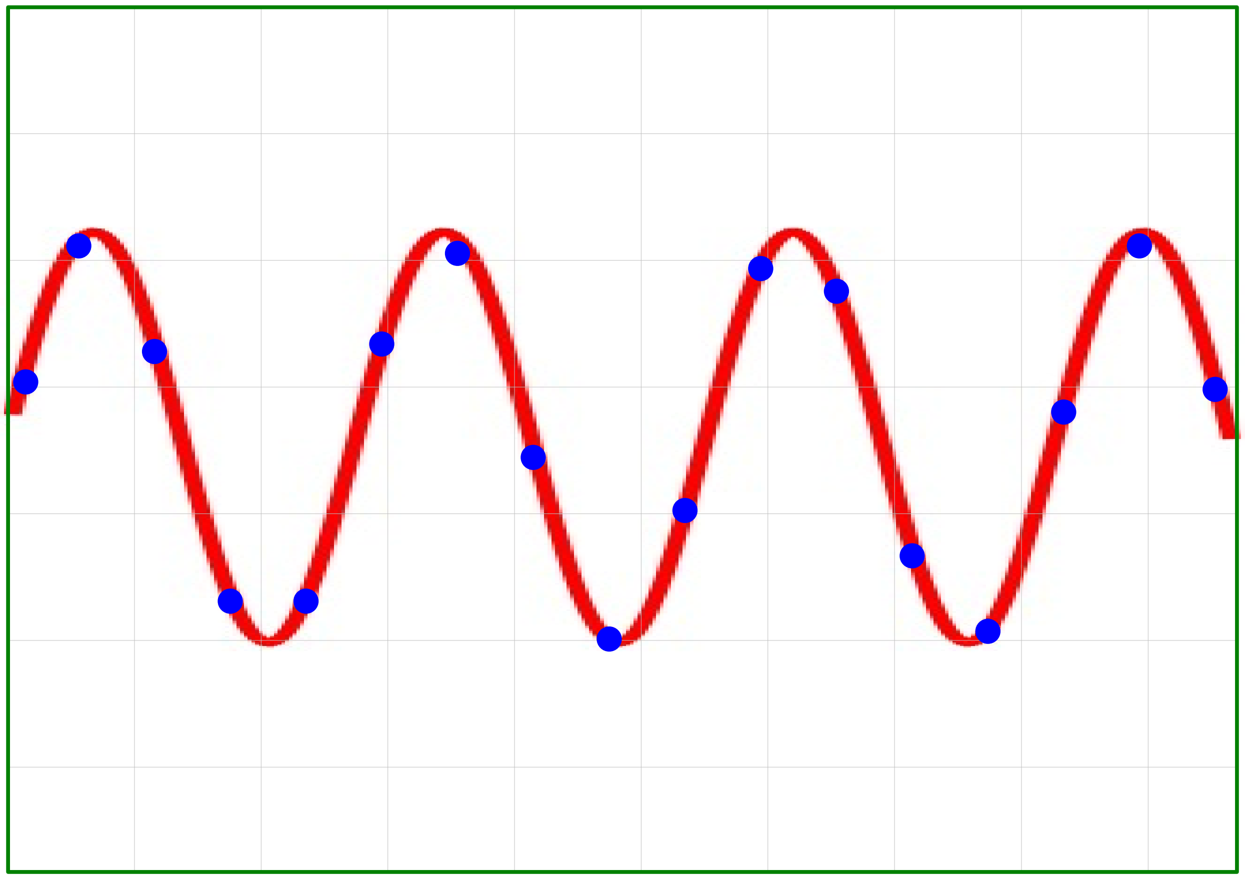
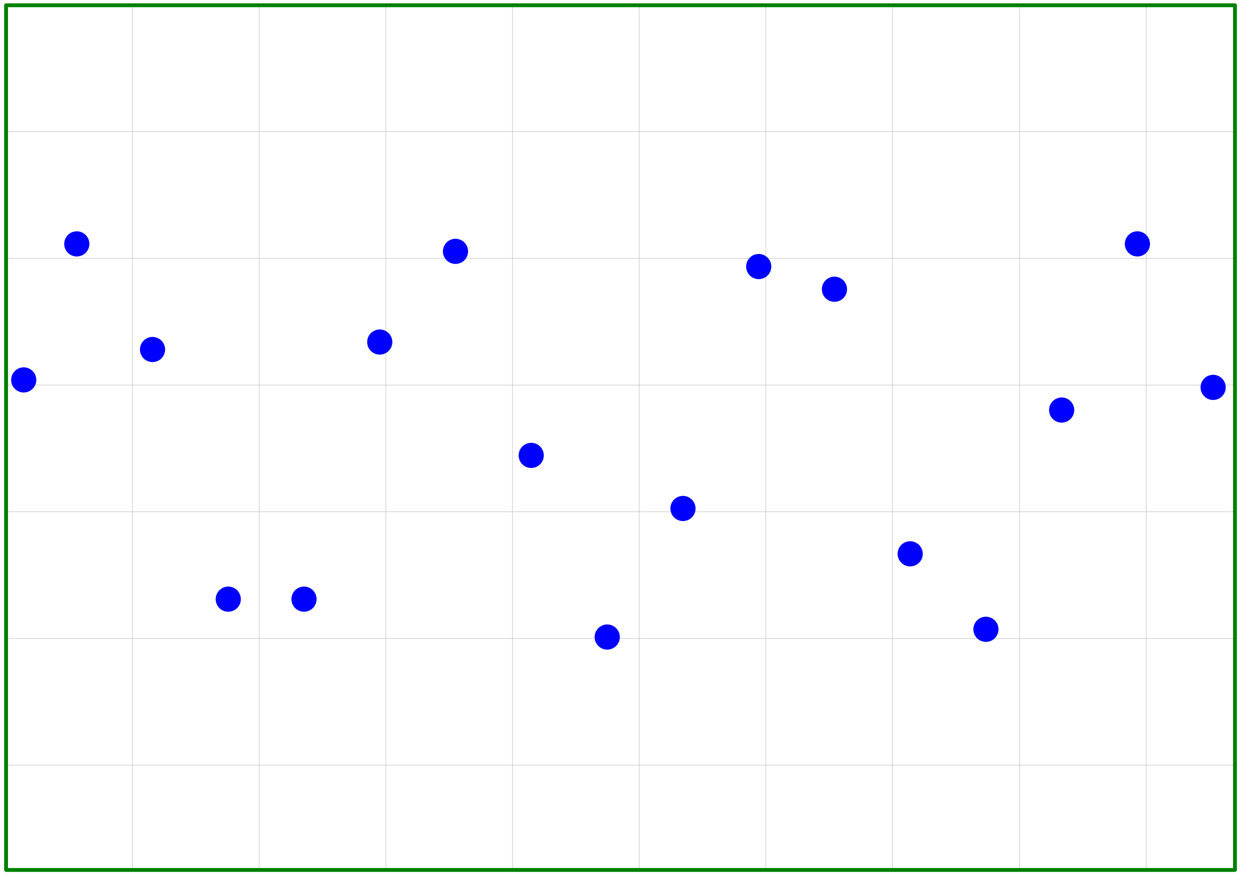


Reduce sample bandwidth 2x ⇨ Increase period 2x

SAMPLING BANDWIDTH



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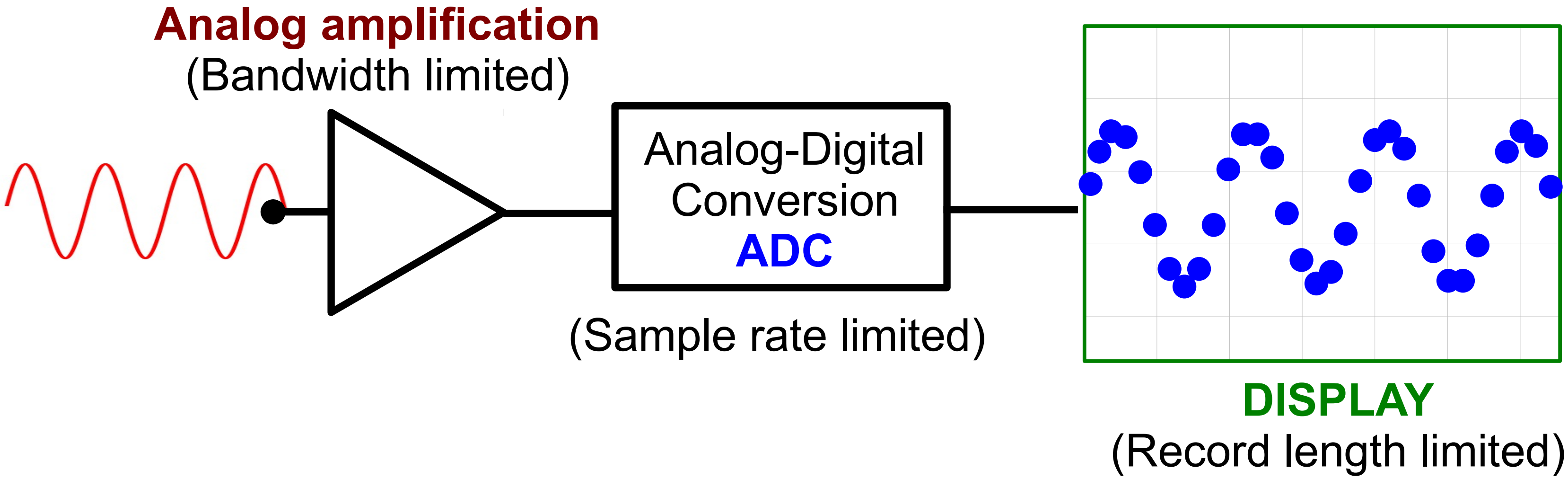
ANALOG BANDWIDTH ≠ SAMPLING BANDWIDTH



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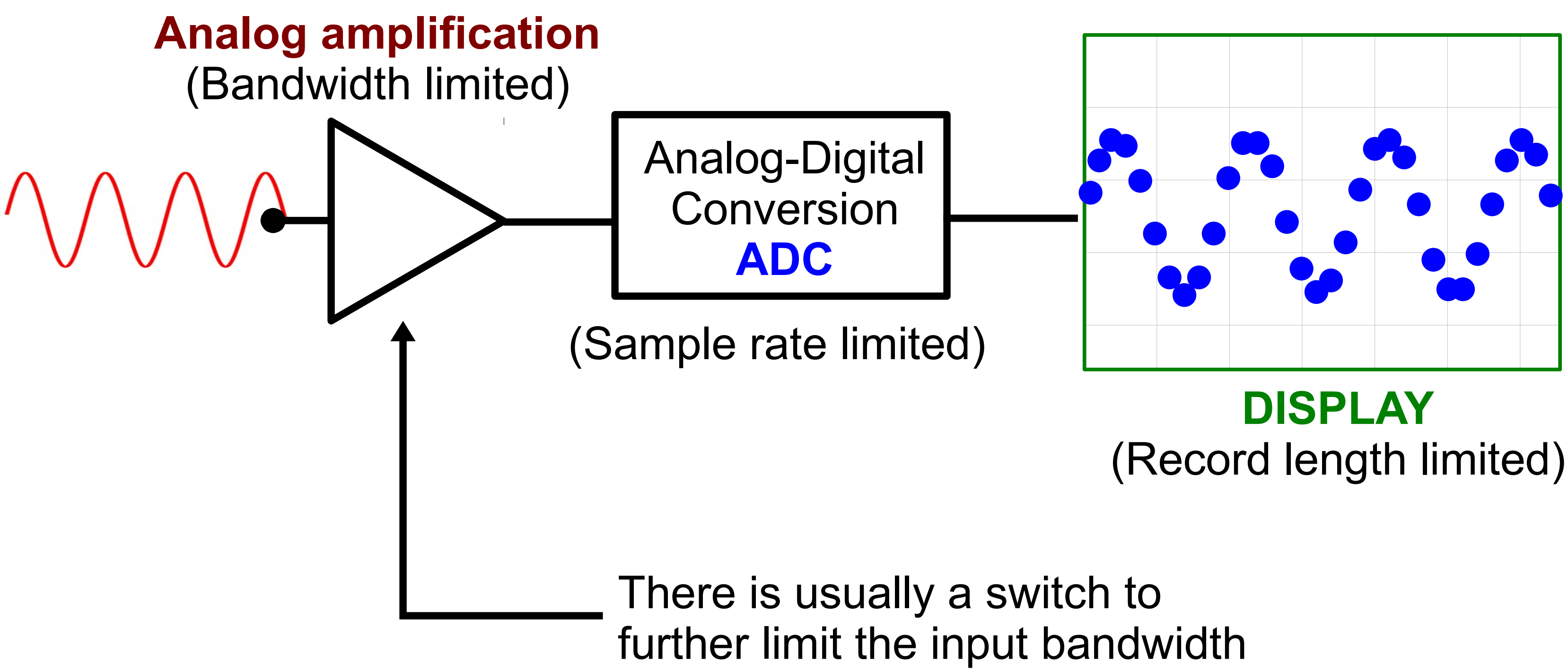
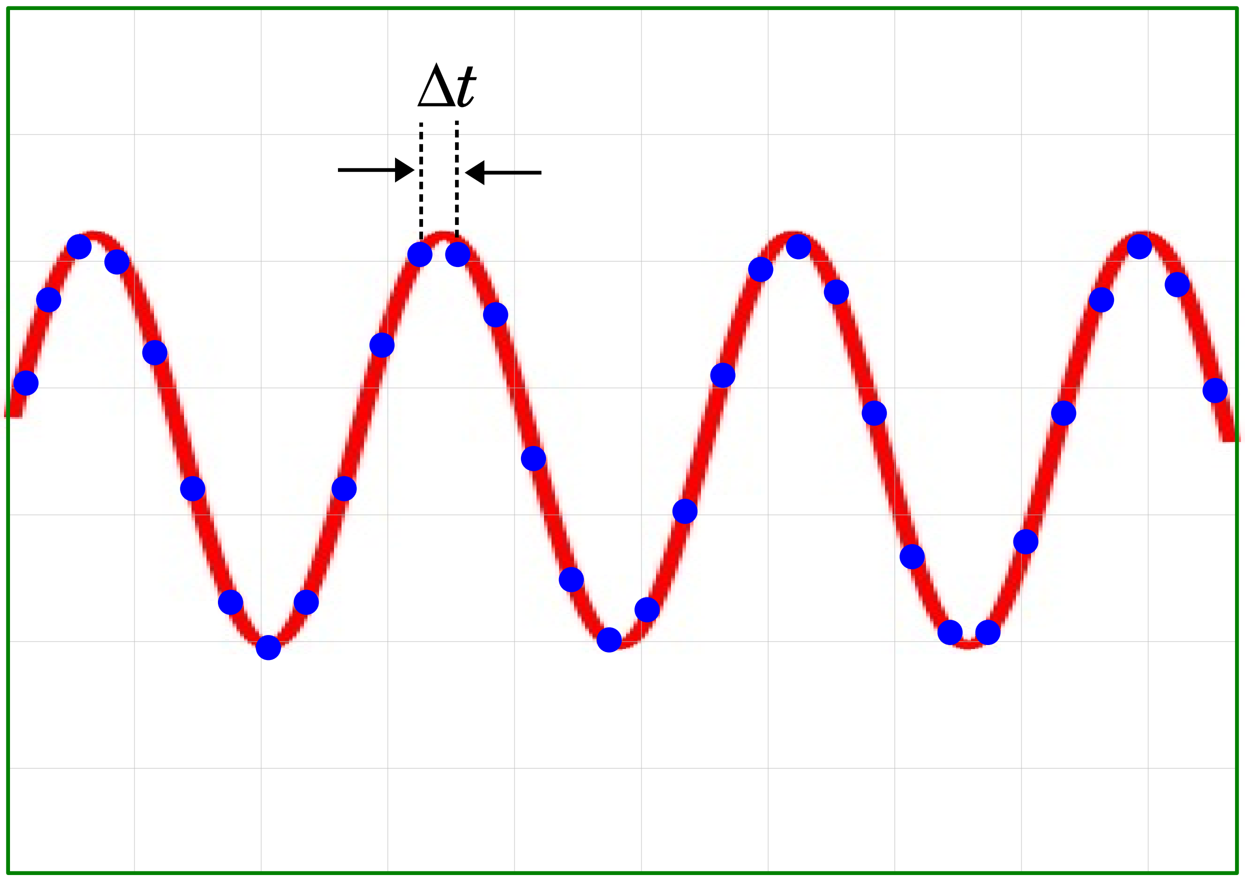


Nyquist theorem
Sampling theorem

Temporal spacing of signal sampling $\Delta t \leq \frac{1}{2\nu}$



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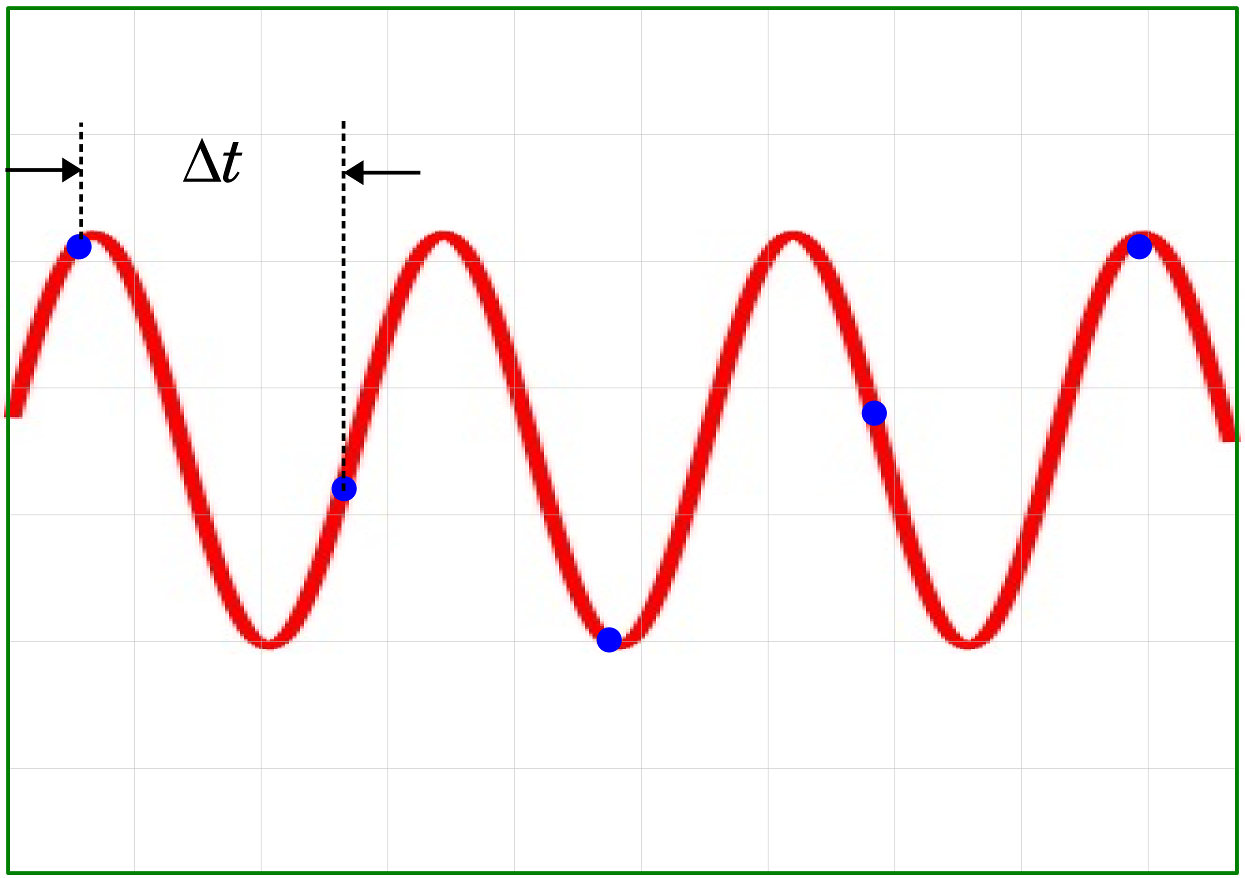

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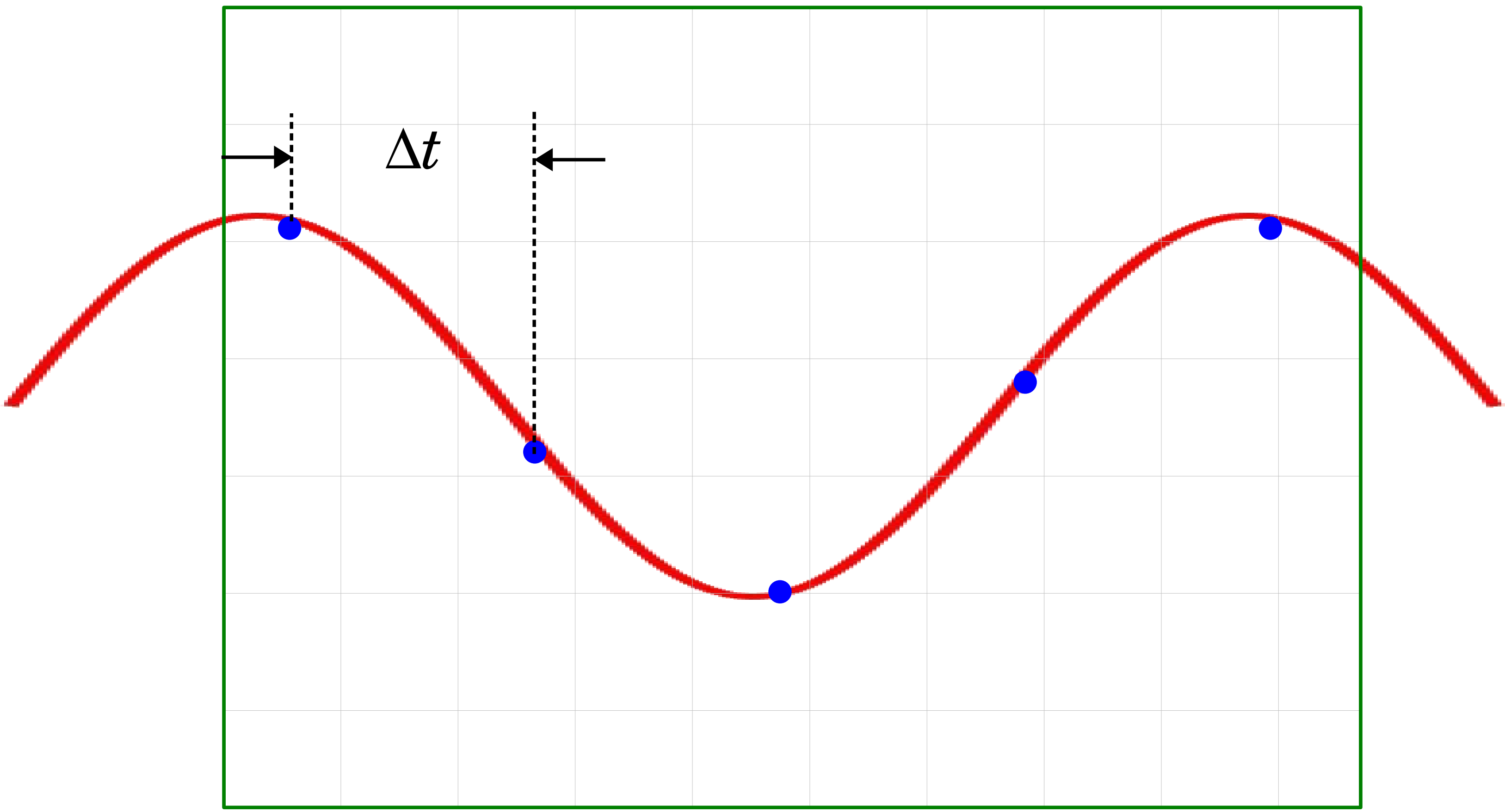

ALIASING

DIGITAL SCOPE: MEASUREMENT MENU

- Period
- Frequency
- Average amplitude
- Peak amplitude
- Peak-to-peak amplitude
- Rise time
- Fall time
- Duty cycle
- RMS
- Max/Min signals
- Horizontal and vertical adjustable cursors

DIGITAL SCOPE: MATH MENU

Channel addition

Channel subtraction

Fast Fourier Transform (FFT):
Observe frequency spectrum of time signal