Phase Measurements. Grounding.

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See https://mviordache.name/EEGR2051 for more information.

Review—Amplitude Measurements

- Based on the volts/div setting (vertical sensitivity) of the oscilloscope, amplitude measurements can be easily performed.

Example 1: *If channel 2 (CH2) has 2V/div, then the peak-to-peak amplitude of the CH2 signal is*

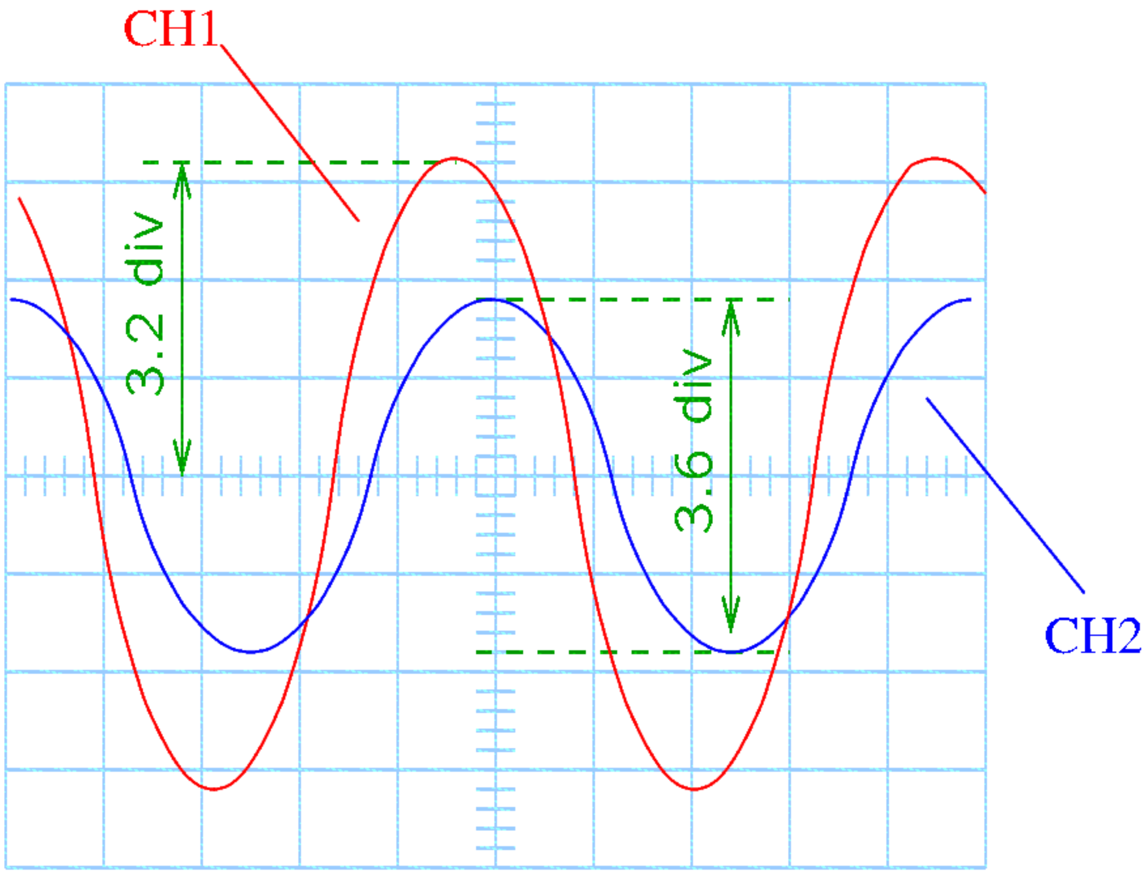
$$V_{pp2} = 3.6\,div \times 2\,\frac{V}{div} = 7.2\,V.$$

Example 2: *If channel 1 (CH1) has 1V/div, then the peak-amplitude of the CH1 signal is*

$$V_{p1} = 3.2\,div \times 1\,\frac{V}{div} = 3.2\,V.$$

The RMS value of the AC component on CH1 is

$$V_{rms1} = \frac{3.2}{\sqrt{2}} = 2.26\,V.$$



Review—Frequency Measurements

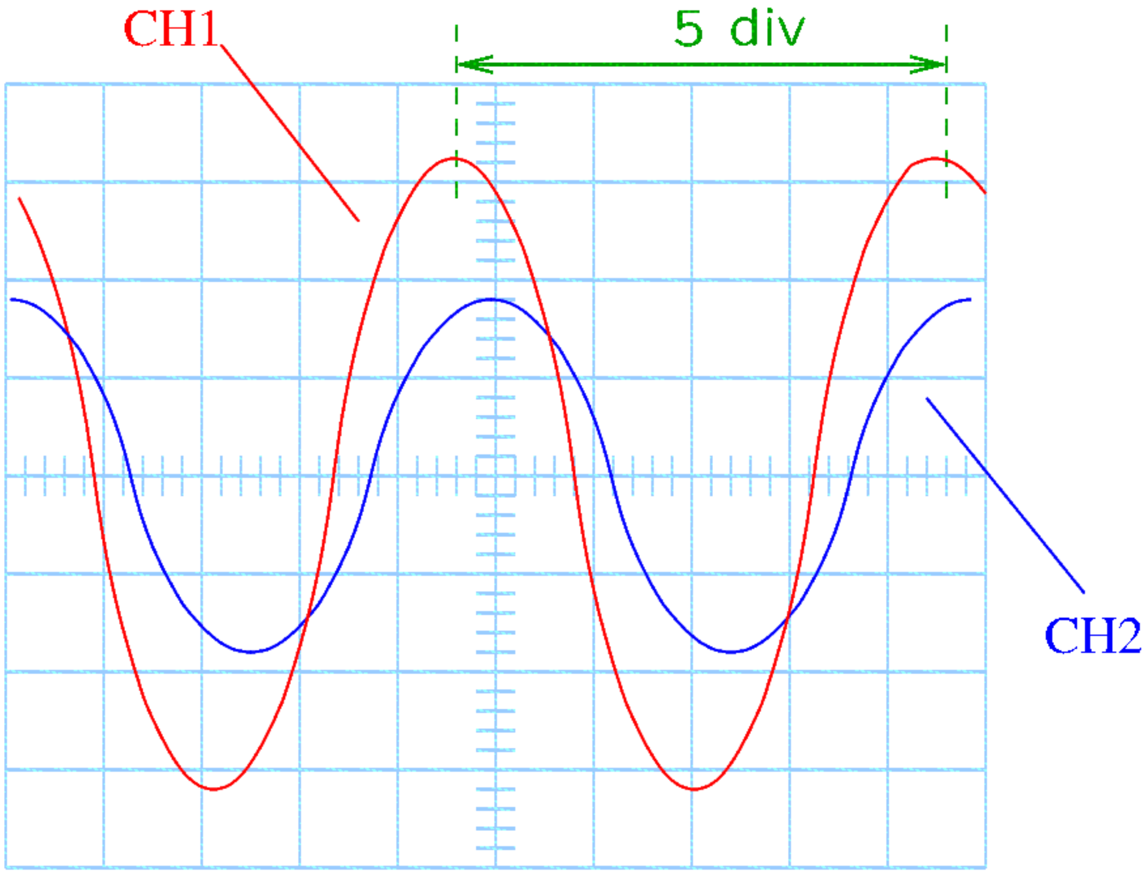
- Based on the time/div setting (horizontal sensitivity) of the oscilloscope, time measurements can be easily performed.

Example: *Assuming a horizontal sensitivity of* $5\ \mu s/div$*, the period of the two signals is*

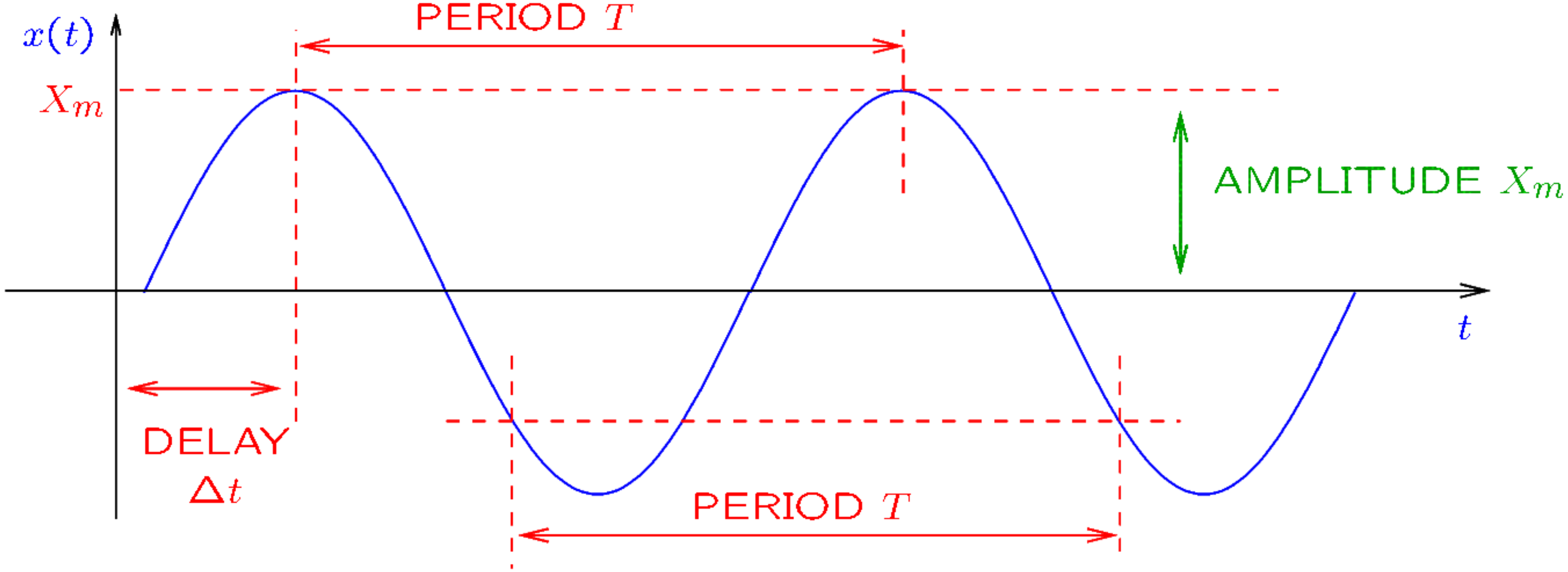
$$T = 5\ div \times 5 \frac{\mu s}{div} = 25\ \mu s.$$

The frequency is

$$f = \frac{1}{T} = 40\ kHz.$$



The Sinusoidal Function

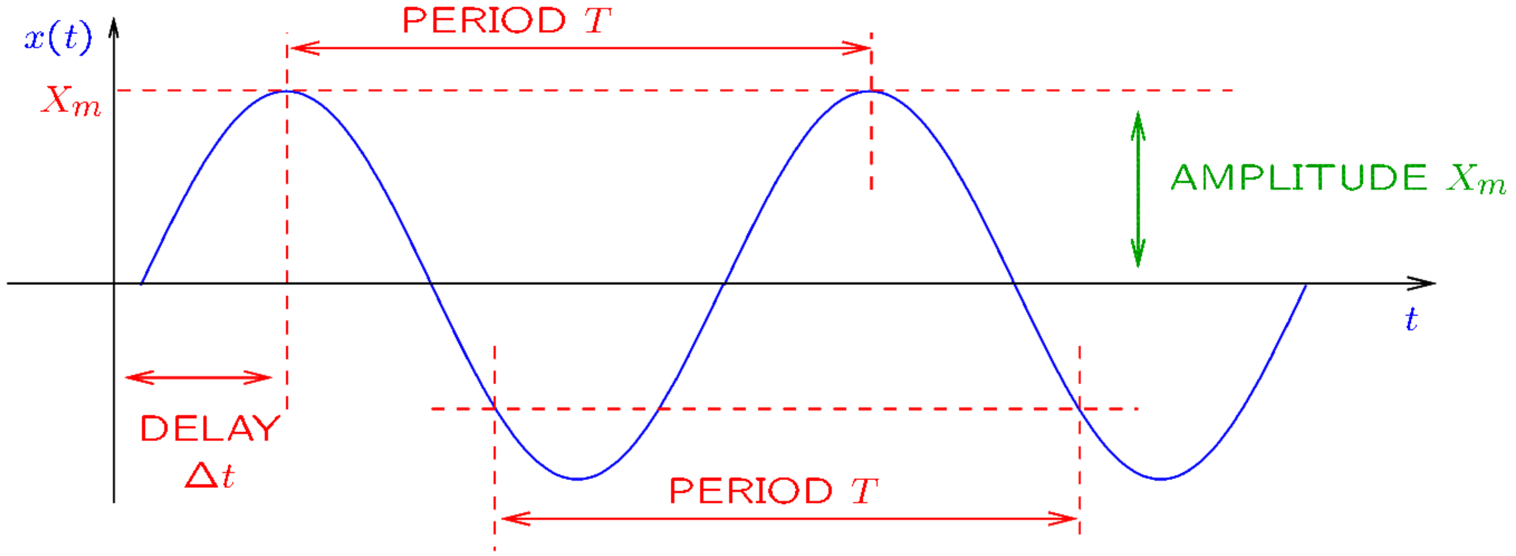


- The figure shows a delayed cosine, $x(t) = X_m \cos(\omega(t - \Delta t))$.
- Let $\alpha = -\omega \Delta t$.
- Then $x(t) = X_m \cos(\omega t + \alpha)$

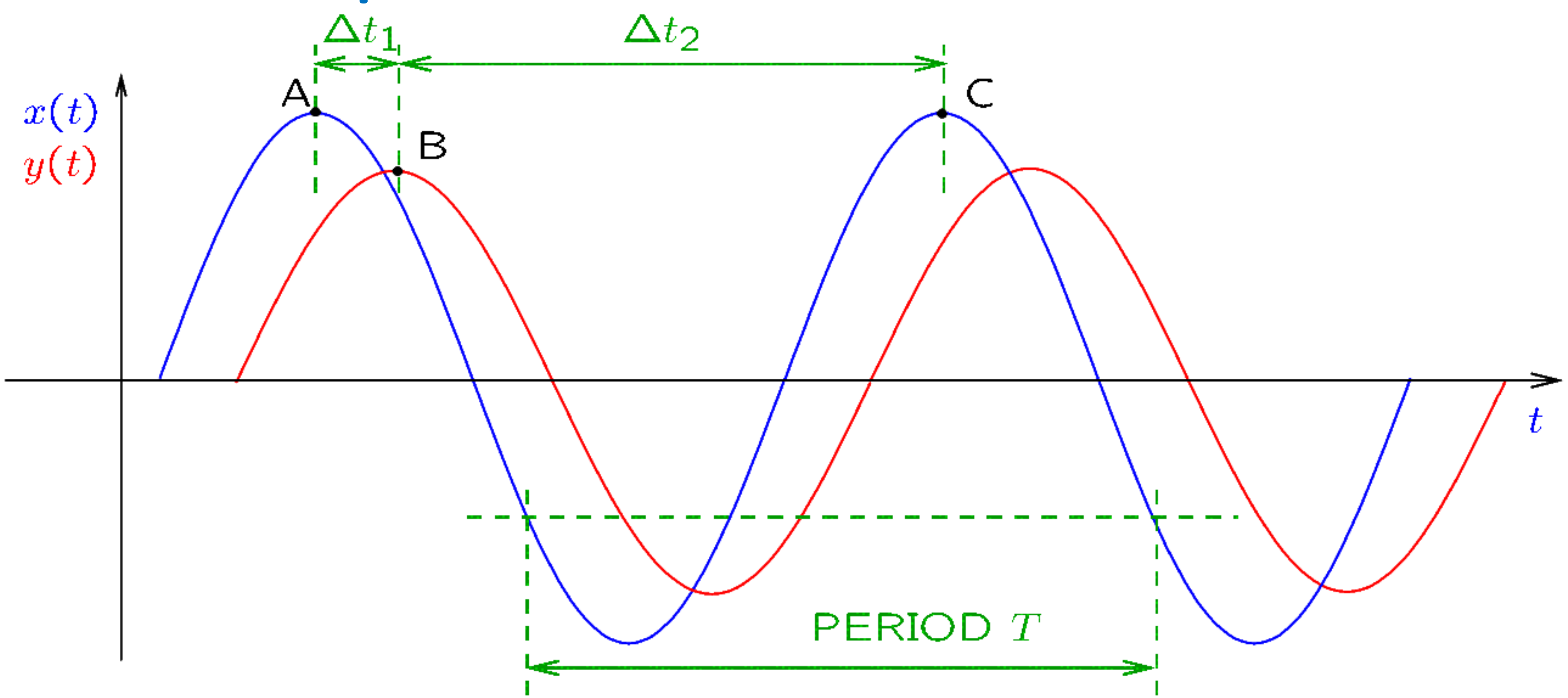
The Sinusoidal Function

Given $x(t) = X_m \cos(\omega t + \alpha)$ of period T:

- $\omega = \frac{2\pi}{T}$ is the angular frequency; it is measured in rad/s.
- $f = \frac{1}{T}$ is the frequency; it is measured in Hz.
- α is the phase angle; it is measured in degrees or radians.
- X_m is the peak amplitude.

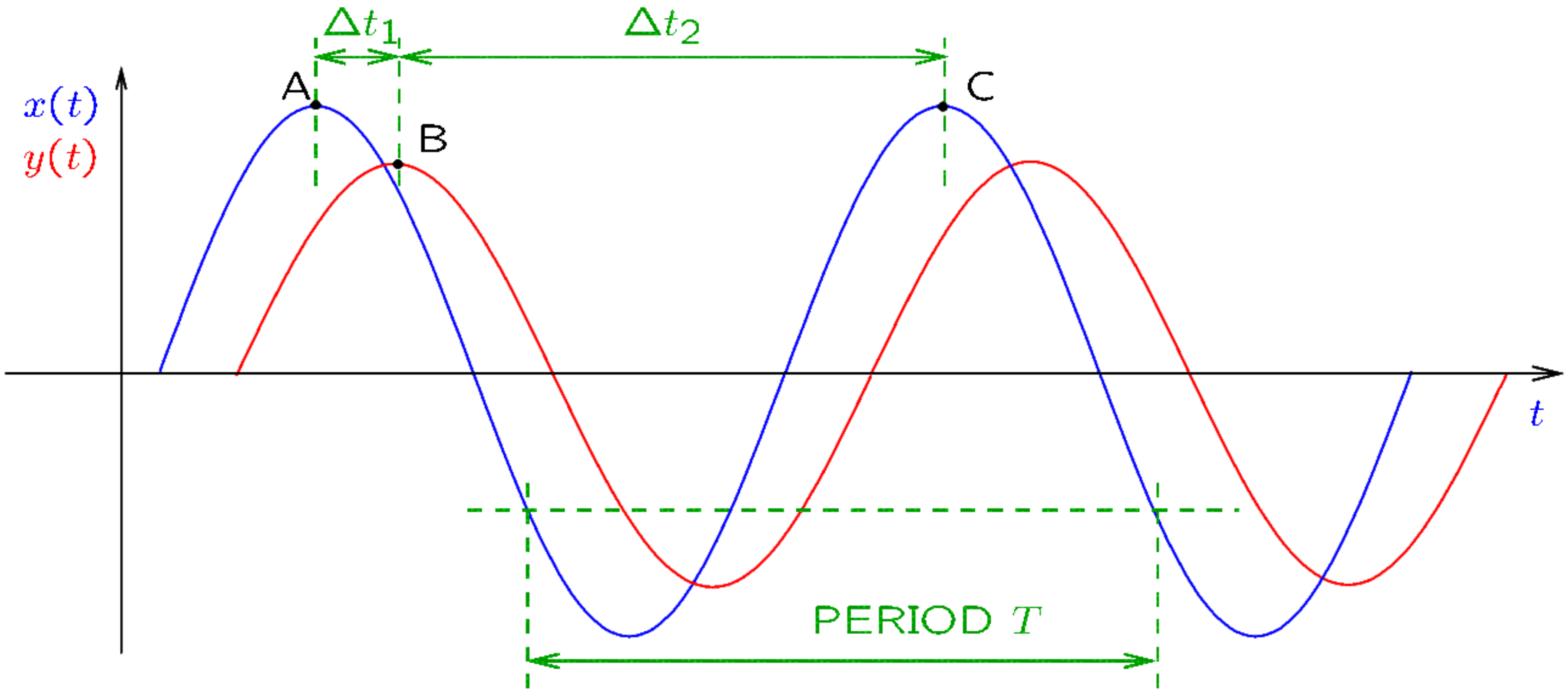


Lead/Lag Relationships



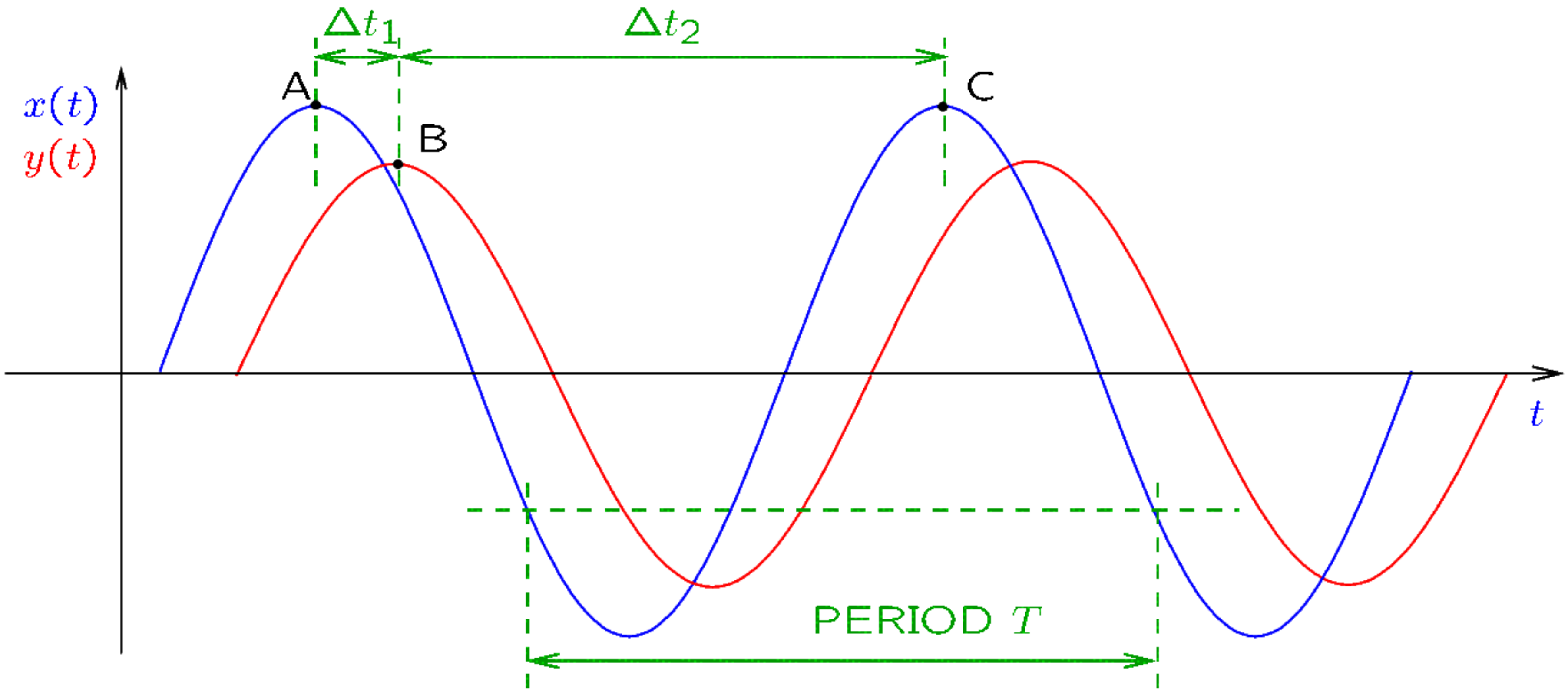
- When two signals have the same frequency, their phase can be compared.
- Note that $x(t)$ reaches the peak A before $y(t)$ reaches its peak B.
- Thus, $x(t)$ leads $y(t)$ by Δt_1 and $y(t)$ lags $x(t)$ by Δt_1.

Lead/Lag Relationships



- A signal $a(t)$ leads (lags) $b(t)$ if it leads (lags) by less than half of a period.
- In the figure, though $y(t)$ leads $x(t)$ by Δt_2, we cannot say that $y(t)$ leads $x(t)$ because $\Delta t_2 > T/2$.

Phase Difference



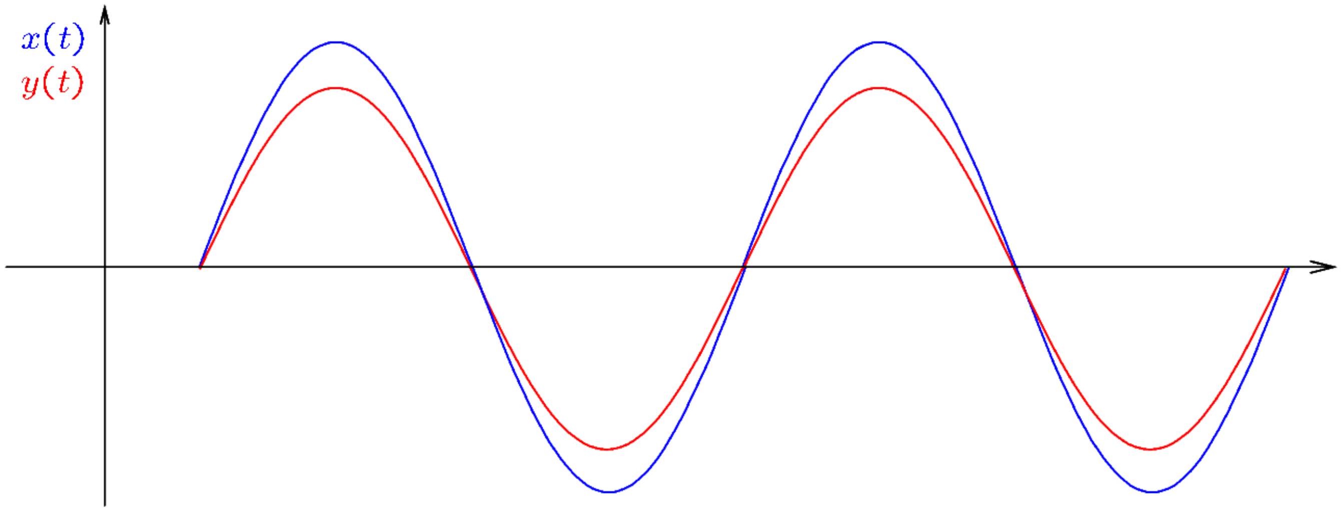
- We will express the lead/lag relationship in terms of the phase difference

$$\theta = \omega \Delta t_1 = 360° \cdot \Delta t_1 / T$$

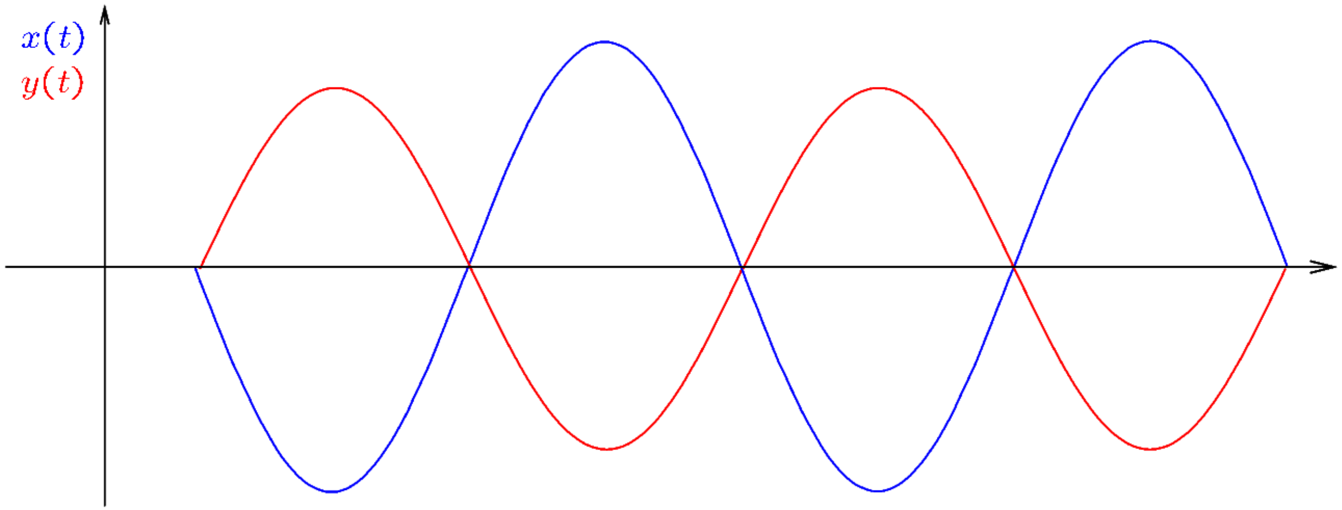
- $x(t)$ leads $y(t)$ by $\Delta\varphi$ and $y(t)$ lags $x(t)$ by θ.

Phase Difference

- When $\theta = 0$ the signals are in phase.



- When $\theta = 180°$ the signals are $180°$ out of phase.

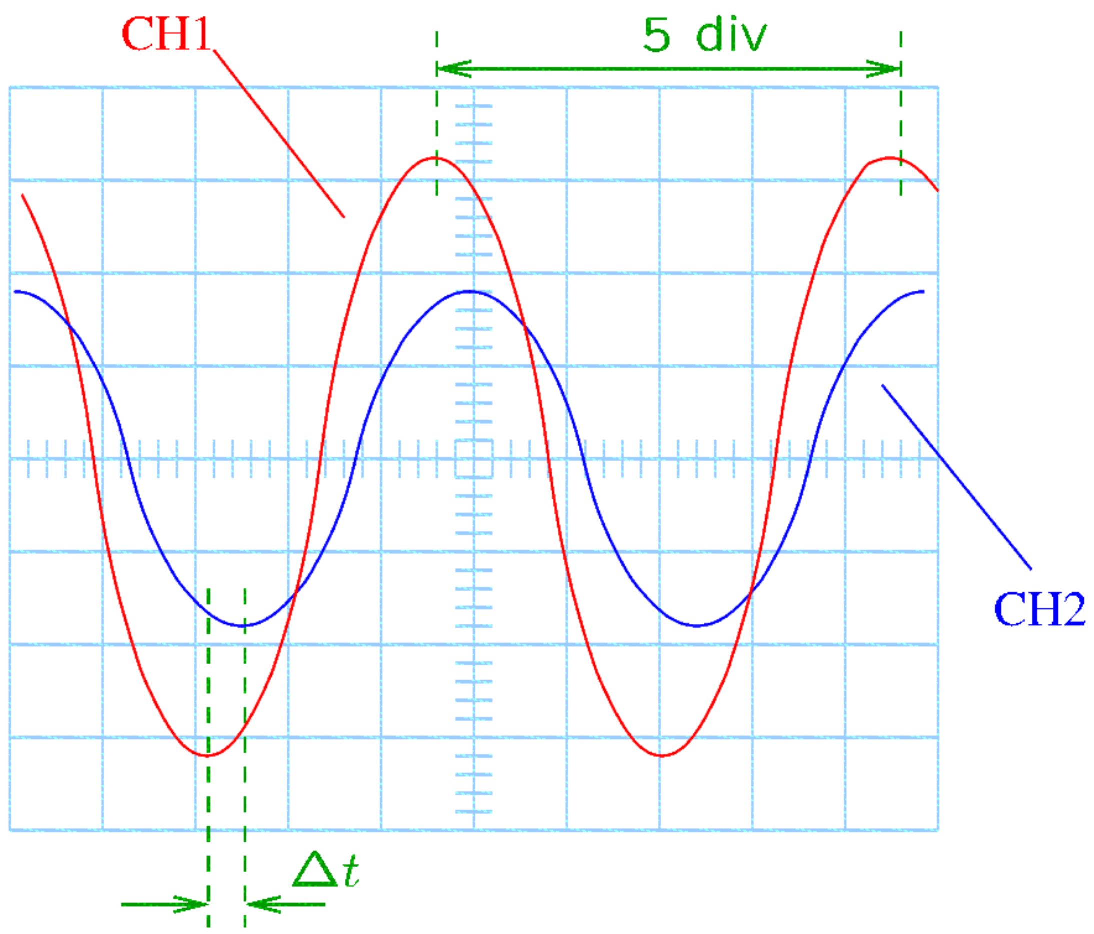


Phase Measurements—Example

- Note that CH1 leads CH2.
- The phase difference is

$$\theta = 360° \cdot \Delta t/T$$
$$= 360° \cdot \frac{0.4\, div}{5\, div}$$
$$\Rightarrow \theta = 28.8°$$

- If CH1 has $x(t) = X_m\cos(\omega t)$, then CH2 has $y(t) = Y_m\cos(\omega t - \theta)$, where *the minus sign preceding θ indicates that $y(t)$ lags $x(t)$ by θ*.
- In other words, if $y(t) = Y_m\cos(\omega t)$, then $x(t) = X_m\cos(\omega t + \theta)$, where the plus sign indicates that $x(t)$ leads.



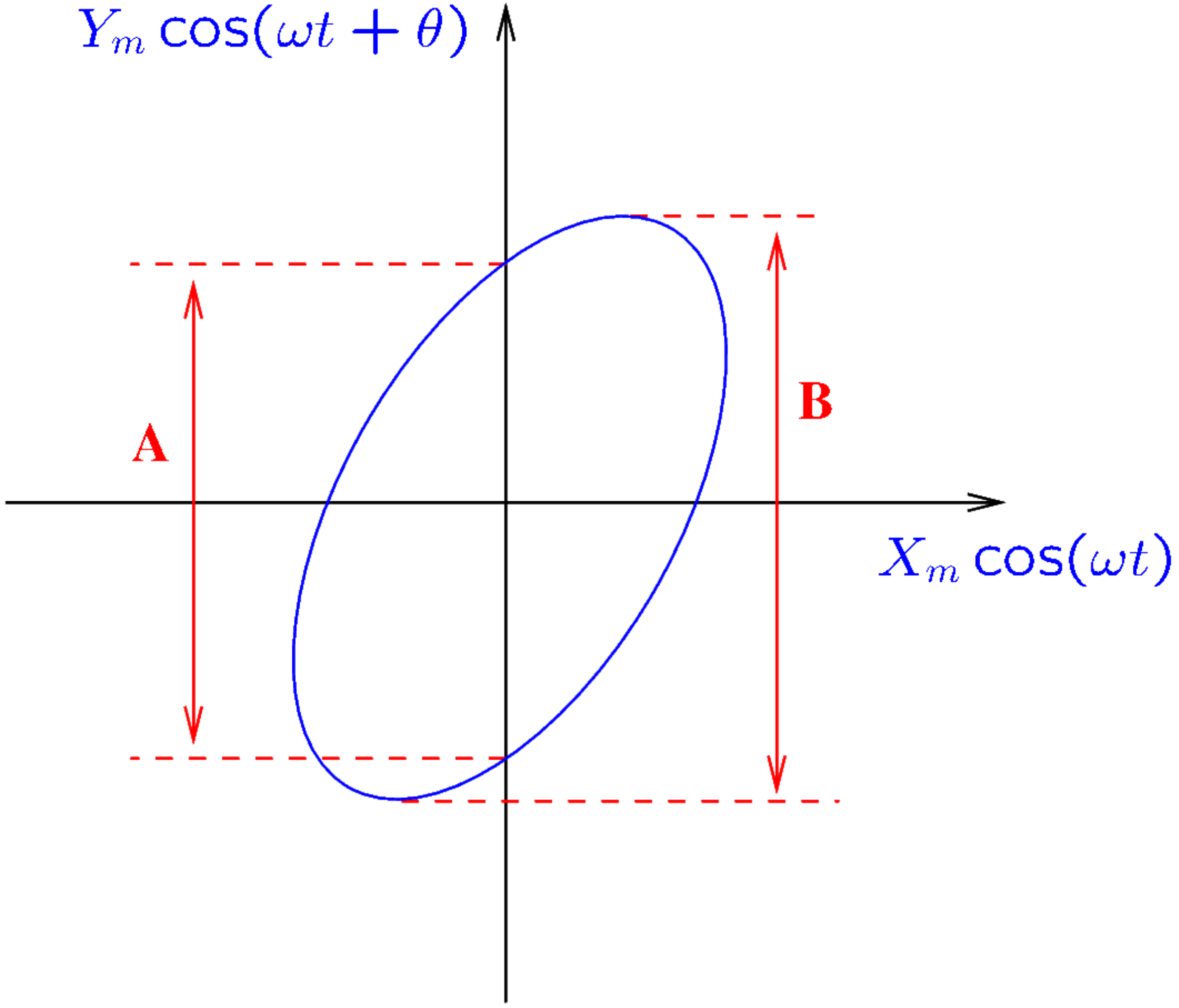
Phase Measurements—The Lissajous Pattern Method

- Let $x(t) = X_m \cos(\omega t + \theta)$ be applied to CH1 and $y(t) = Y_m \cos(\omega t)$ to CH2.
- When the oscilloscope is in *XY mode*, it will display the position of the points (x, y) in the *XY* plane for all t.
- Curves such as the one to the right will be displayed.
- In the figure,

$$A = 2Y_m |\sin\theta|$$
$$B = 2Y_m$$

- By measuring A and B, we find

$$\theta = \pm \sin^{-1}\left(\frac{A}{B}\right)$$

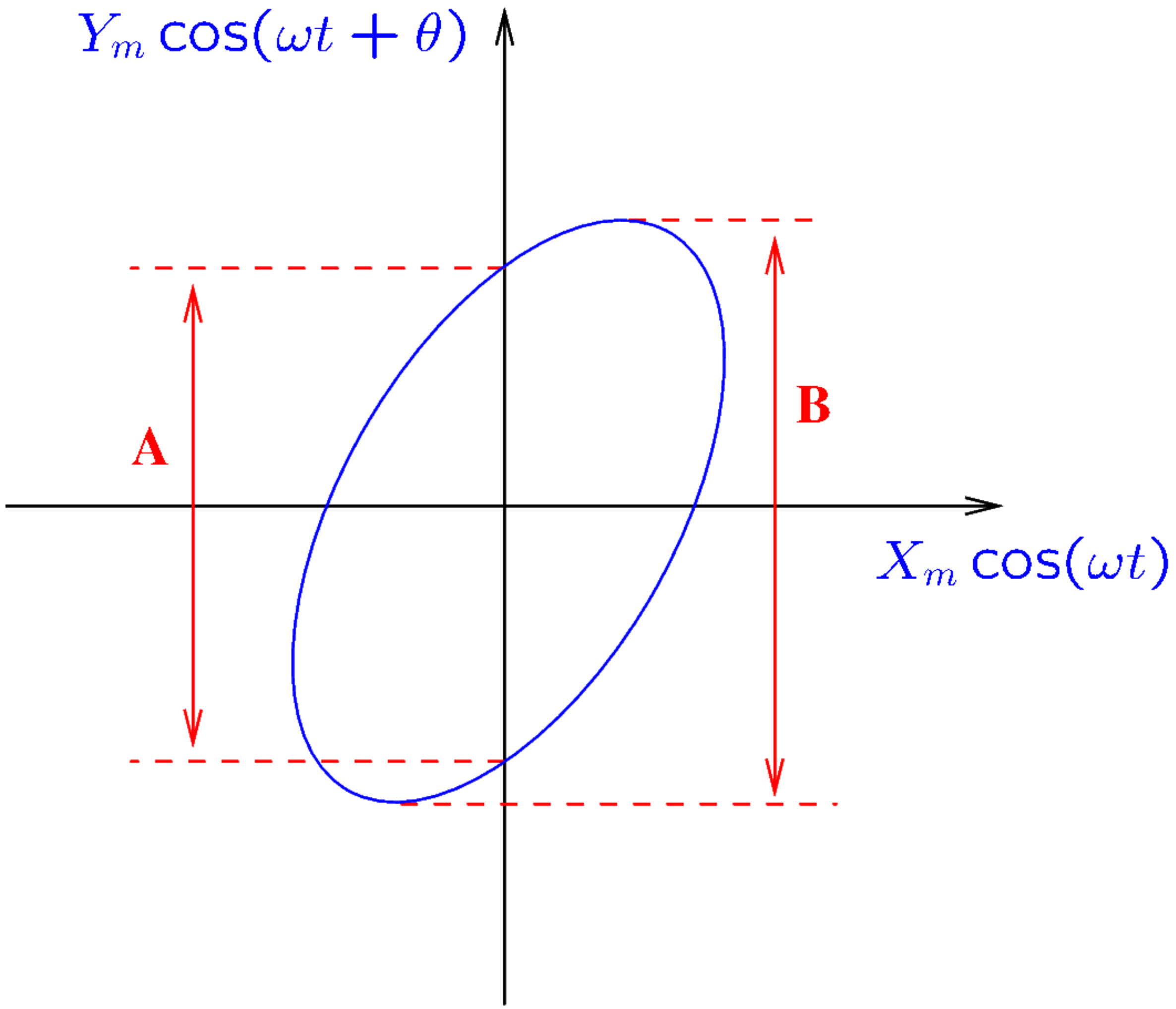


Phase Measurements—The Lissajous Pattern Method

- By measuring A and B, we find

$$\theta = \pm \sin^{-1}\left(\frac{A}{B}\right)$$

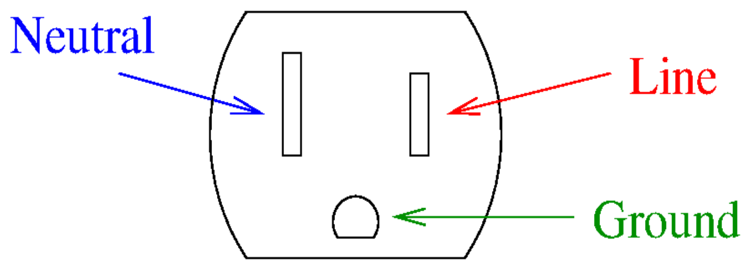
- The curve by itself does not indicate whether $x(t)$ leads or lags $y(t)$.
- It can be verified that if $\theta > 0$ the points (x, y) move clockwise along the curve, but counterclockwise if $\theta < 0$.
- If $\theta = 0$ the signals are in phase and the curve becomes a straight line.



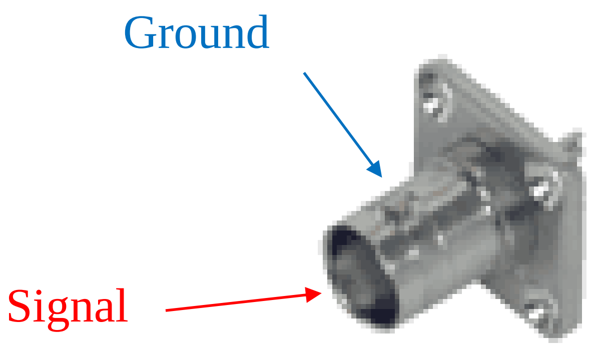
Grounding

Grounding

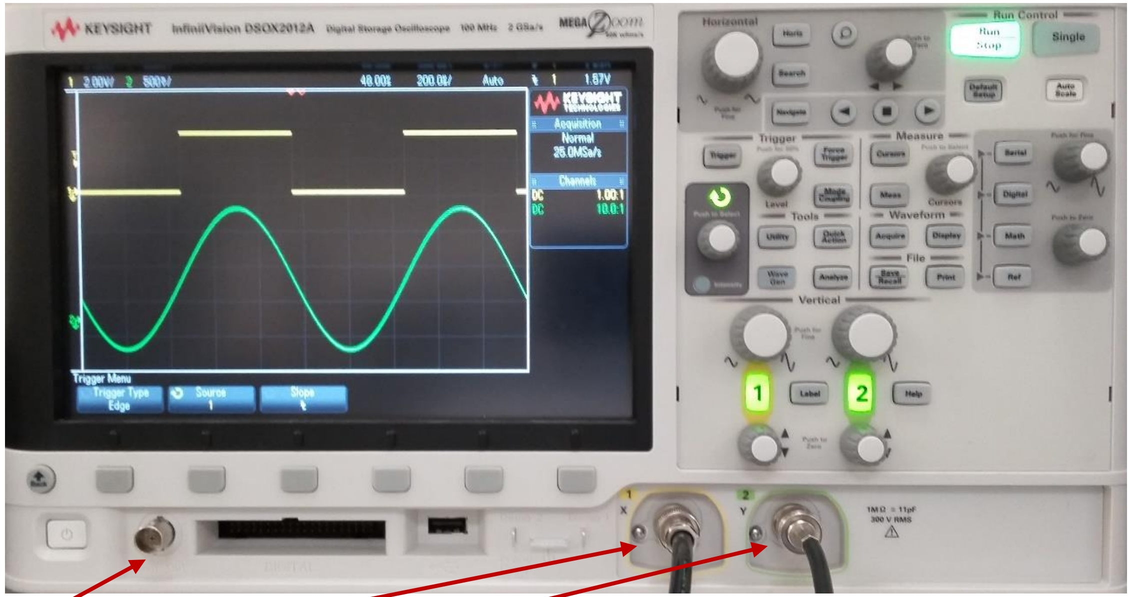
- Various instruments generate or measure voltage with respect to earth ground.
- They are connected to earth ground by means of the ground terminal of the wall outlet.



- Circuits connected to earth ground are said to be *grounded*.
- Circuits that are not connected to earth ground are said to be *floating*.
- For example, the oscilloscope and some waveform generators are grounded.
- The BNC connectors of a grounded instrument will have the shield connected to ground.



Grounding

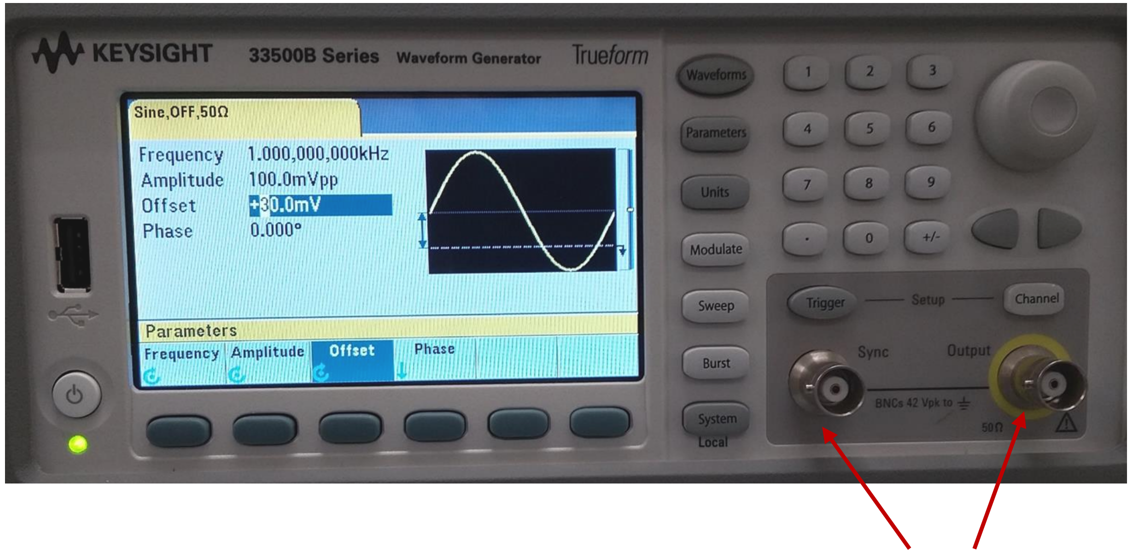


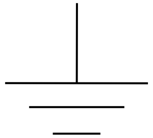
earth ground

- As soon as a grounded instrument is plugged into the wall outlet, the shield of its BNC connectors becomes earth ground.
- Floating instruments do not connect input or output terminals to earth ground.
- For example, any battery powered instrument is floating; some waveform generators are floating; DMMs and DC power supplies are floating.

Grounding

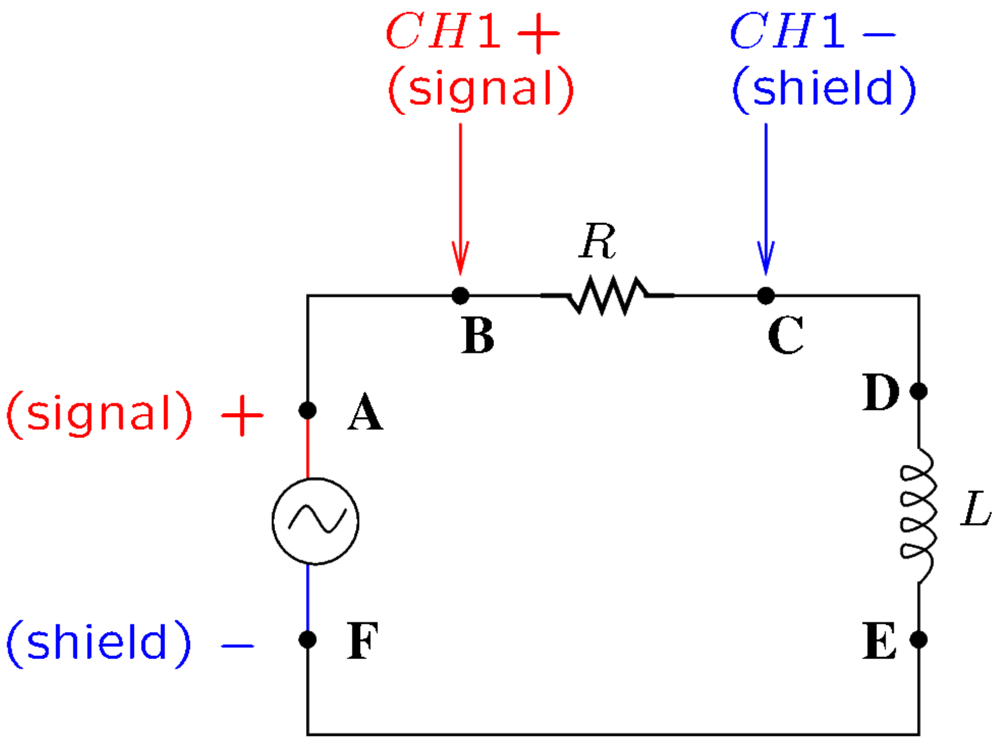
- Floating instruments also have a common point of reference, called ground, though this ground is not connected to earth ground.
- The shield of the BNC connectors is normally connected to the ground reference.



- When a floating instrument is connected to a grounded instrument, the ground references will also be connected, and thus the ground of the floating instrument will become earth ground.
- *Since multiple instrument terminals are connected to the same ground reference, an inadequate connection of the instruments to a circuit may result in short-circuits!*
- The ground is abbreviated GND and has the symbol 

Example 1

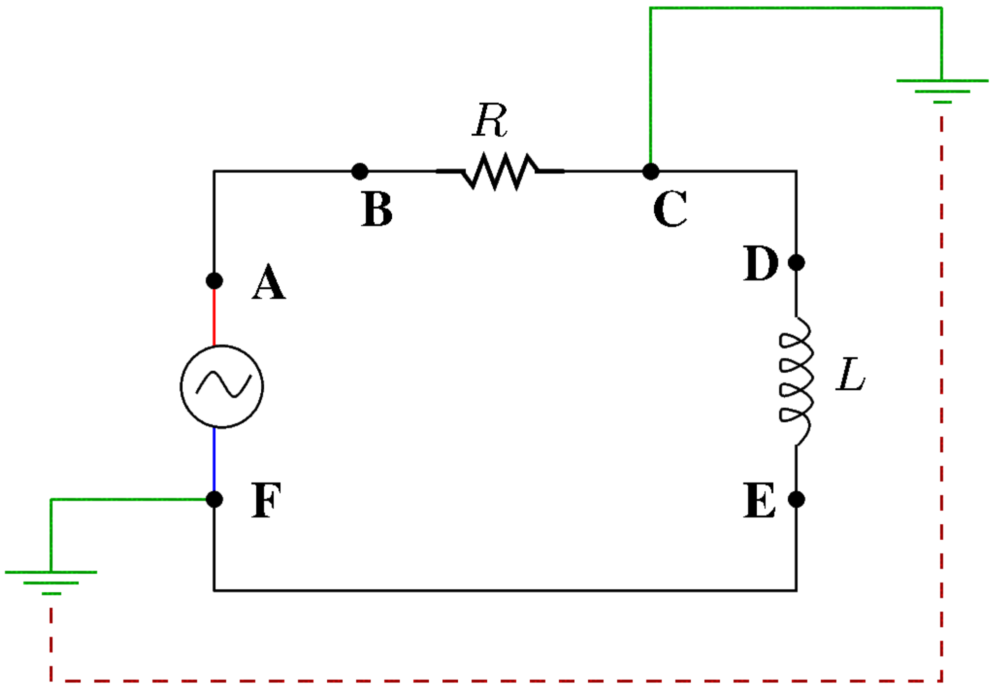
- *The circuit consists of a resistor R, an inductor L, and a waveform generator connected between the points **A** and **F**.*
- *Channel 1 of the oscilloscope is connected to the circuit as shown in the figure.*
- *Both the oscilloscope and the waveform generator are grounded.*



- *The waveform generator outputs $5\ V$ peak-to-peak.*
- *What voltage will the oscilloscope measure?*
- *Are the instruments connected correctly?*

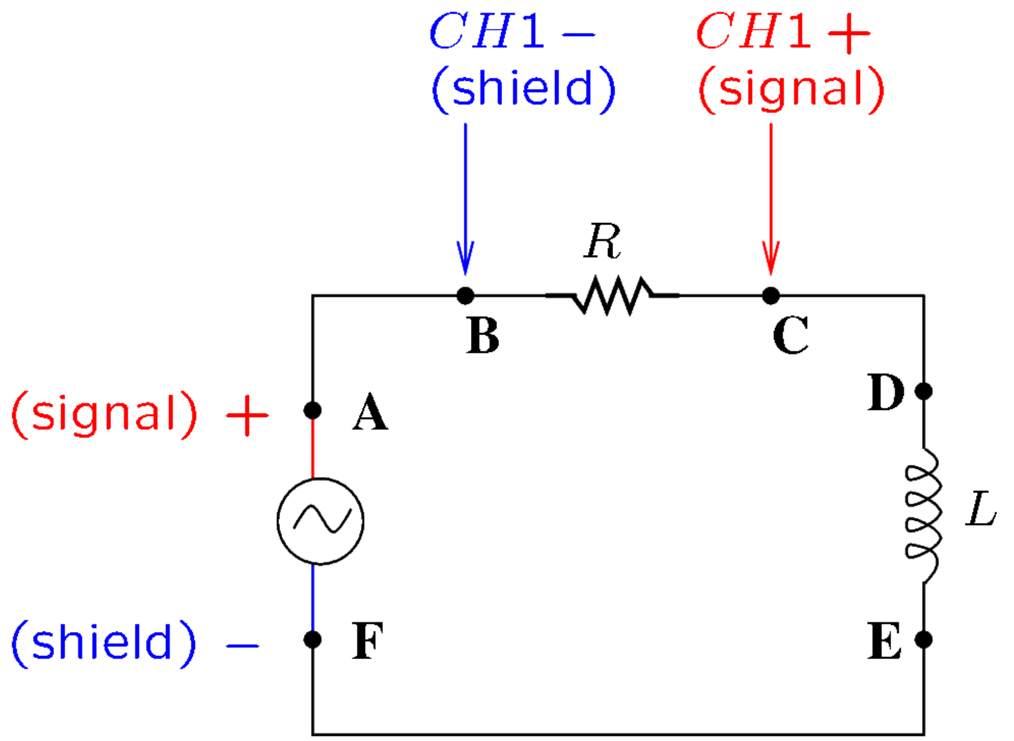
Example 1—Solution

- *Since both instruments are grounded, the shield is connected to earth ground for both instruments:*
  - *Point **F** is connected to the GND terminal of the wall outlet of the waveform generator.*
  - *Point **C** is connected to the GND terminal of the wall outlet of the oscilloscope.*
  - *The GND terminals of the wall outlets are connected together to the same GND.*
  - *Therefore, points **C** and **F** are connected!*
- *Therefore, the inductor is short-circuited.*
- *Therefore, the entire voltage of the source will be on the resistor.*
- *The oscilloscope will measure* $5\ V_{pp}$.
- *The oscilloscope is connected incorrectly to the circuit because it short-circuits the inductor!*



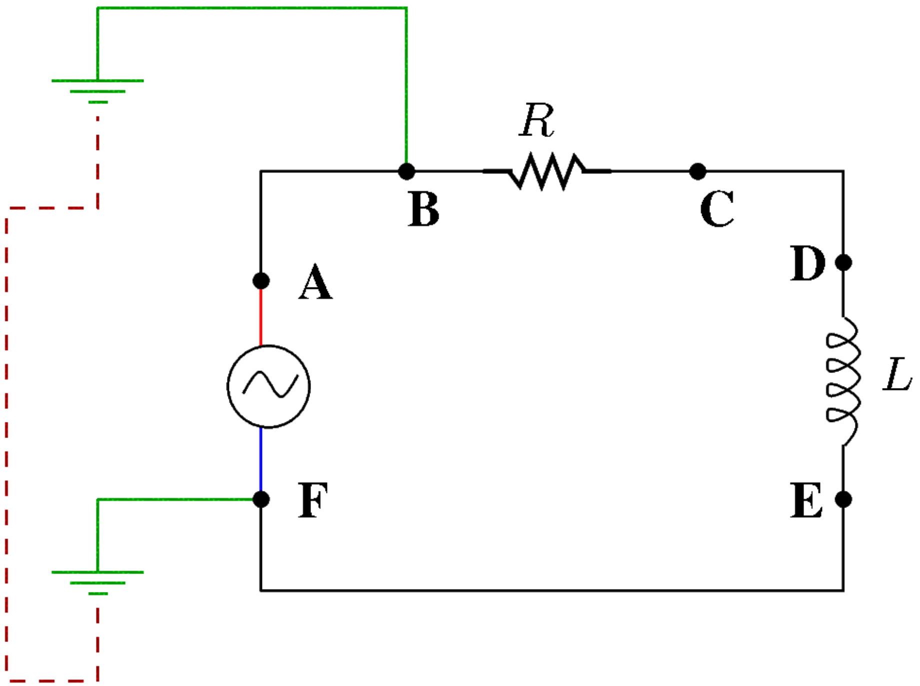
Example 2

- *Consider the previous circuit with the oscilloscope connections interchanged.*
- *What voltage will the oscilloscope measure?*
- *Are the instruments connected correctly?*



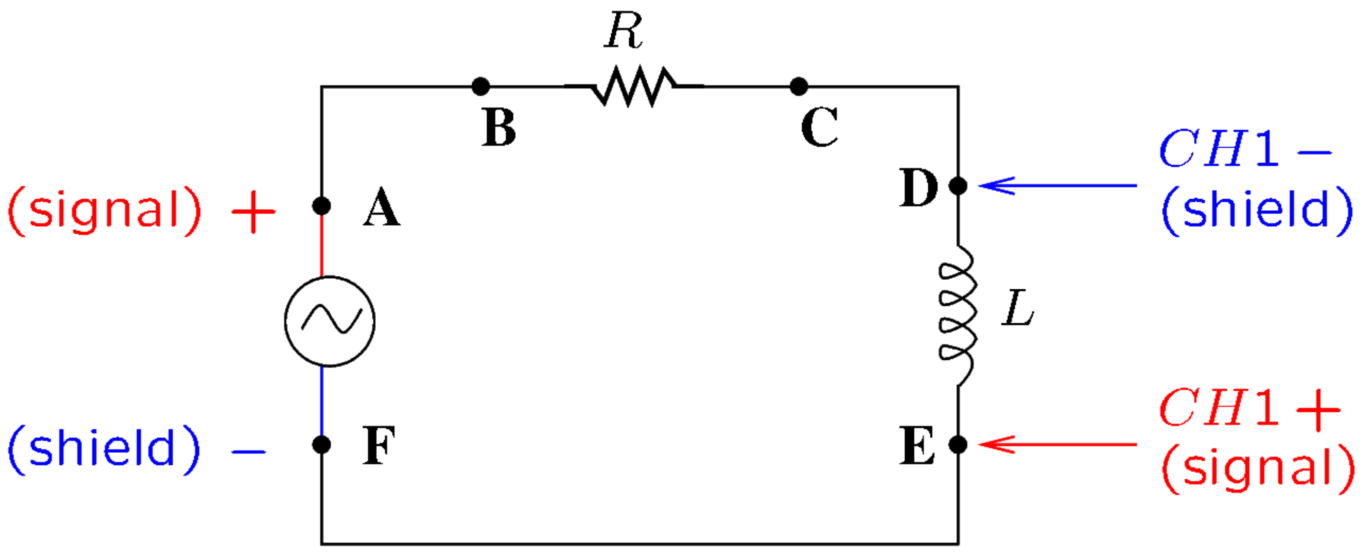
Example 2—Solution

- *Since both instruments are grounded, the shield is connected to earth ground for both instruments:*
  - *Point **F** is connected to the GND terminal of the wall outlet of the waveform generator.*
  - *Point **B** is connected to the GND terminal of the wall outlet of the oscilloscope.*
  - *The GND terminals of the wall outlets are connected together to the same GND.*
  - *Therefore, points **C** and **F** are connected!*
- *Therefore, the waveform generator is short-circuited.*
- *Therefore, the circuit will not be powered.*
- *The oscilloscope will measure $0\ V_{pp}$.*
- *The oscilloscope is connected incorrectly to the circuit because it short-circuits the waveform generator!*



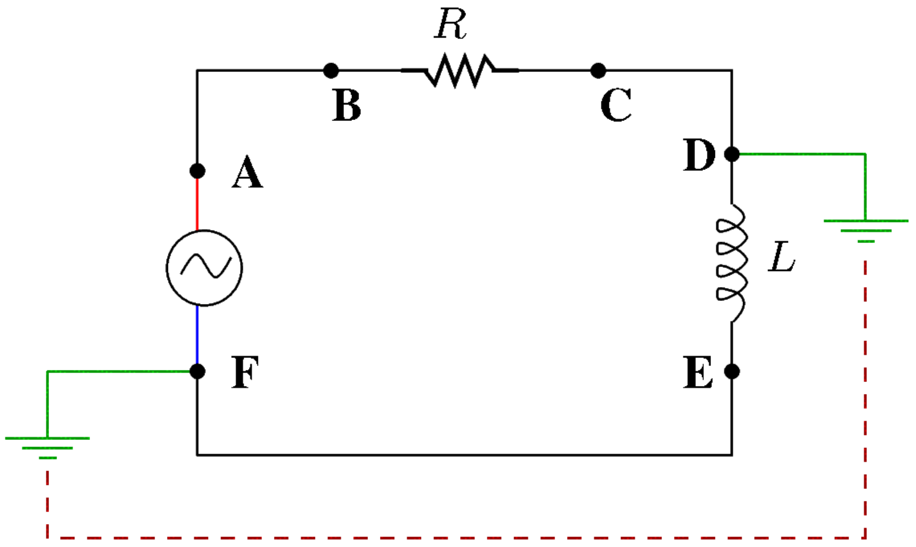
Example 3

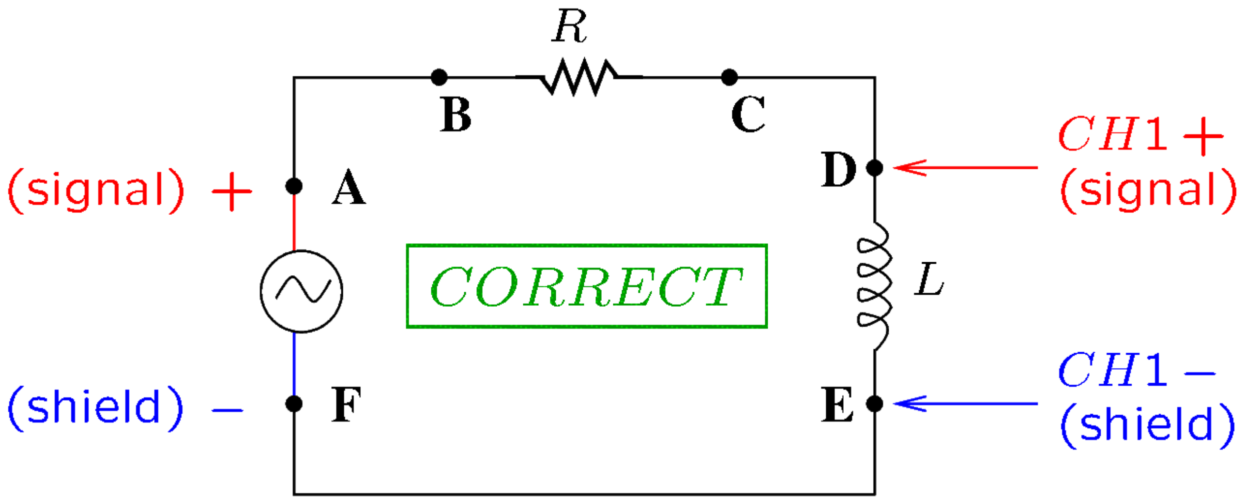
- *Consider the previous circuit.*
- *Suppose that the voltage of L should be measured.*
- *Indicate whether the oscilloscope is connected correctly.*
- *If the oscilloscope is connected incorrectly, show how to connect it correctly.*

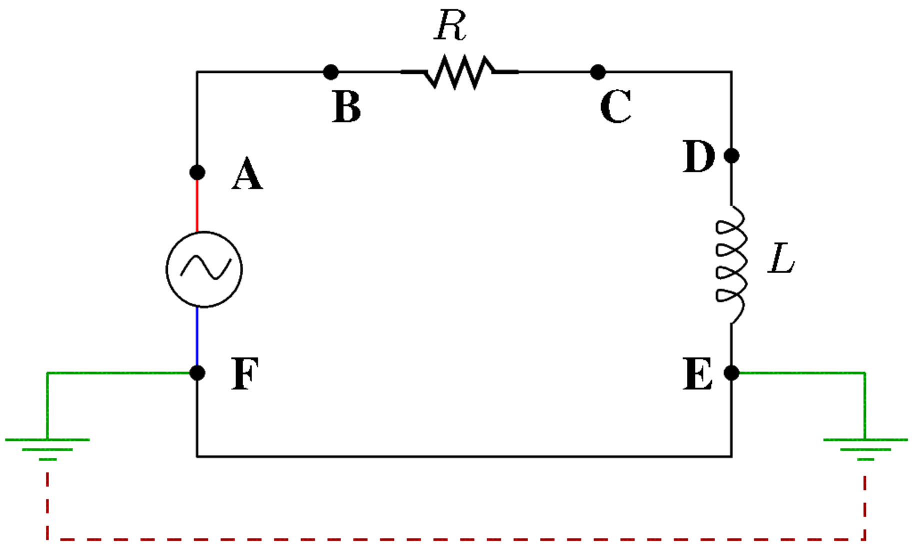


Example 3—Solution

- *The oscilloscope is connected incorrectly, because it short-circuits L.*
- *By interchanging the connections of the oscilloscope, the voltage is measured correctly.*
- *The ground connection connects now two points of the circuit belonging to the same node, so there is no problem.*

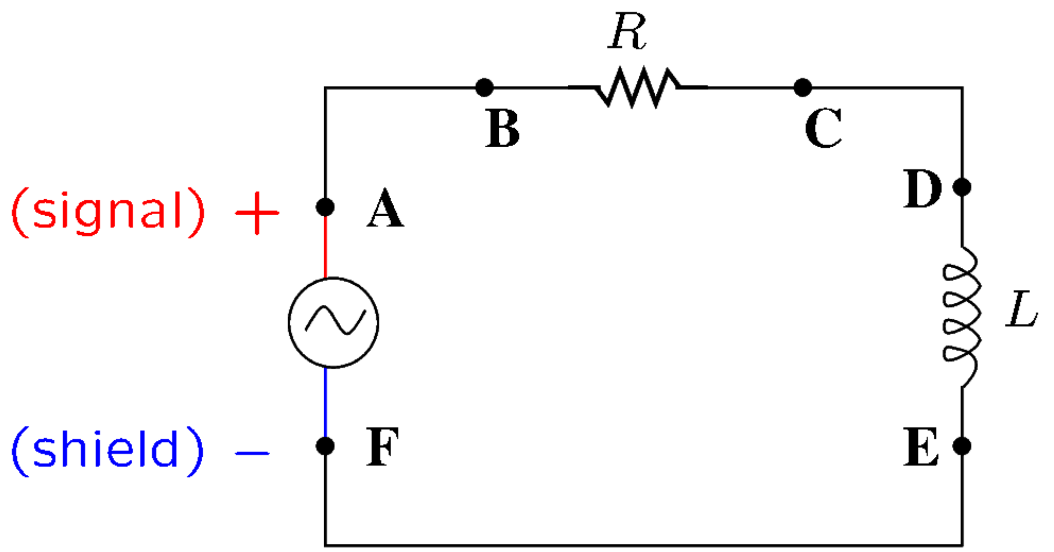






Example 4

Indicate how to measure correctly the voltage on R with the oscilloscope.

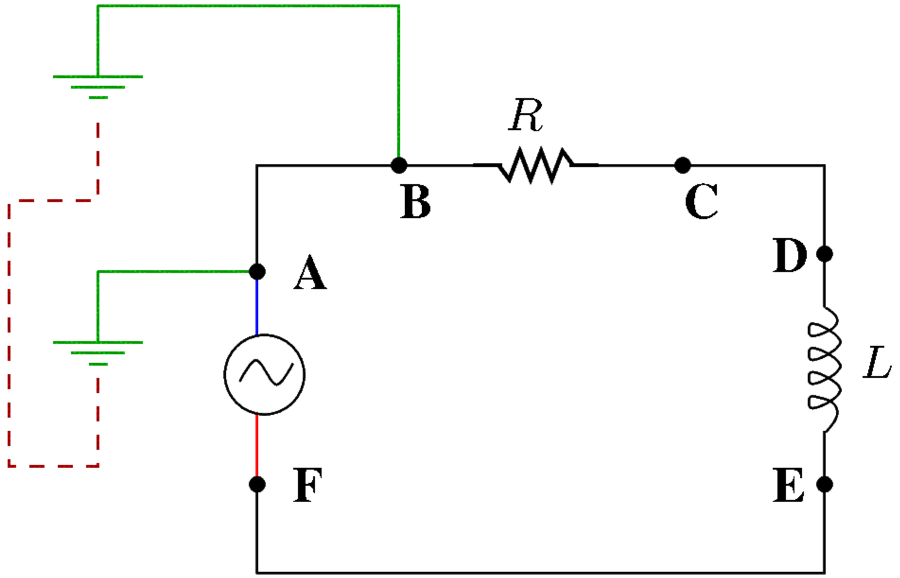


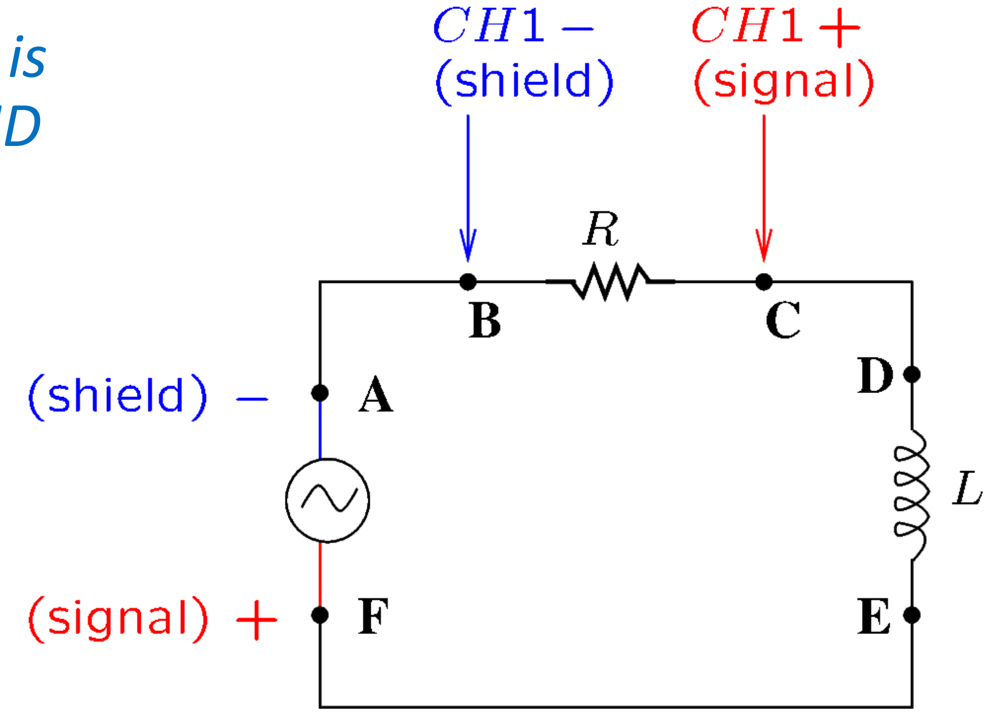
Several solutions are possible:

- *Method 1: Interchange connections of waveform generator.*
- *Method 2: Reorder series components so that R has a terminal connected to the GND of the source.*
- *Method 3: Perform a differential measurement.*
- *Method 4: Use a ground adapter.*
- *Method 5: Isolate the source from the circuit with a transformer.*

Solution 1—Interchange Source Connections

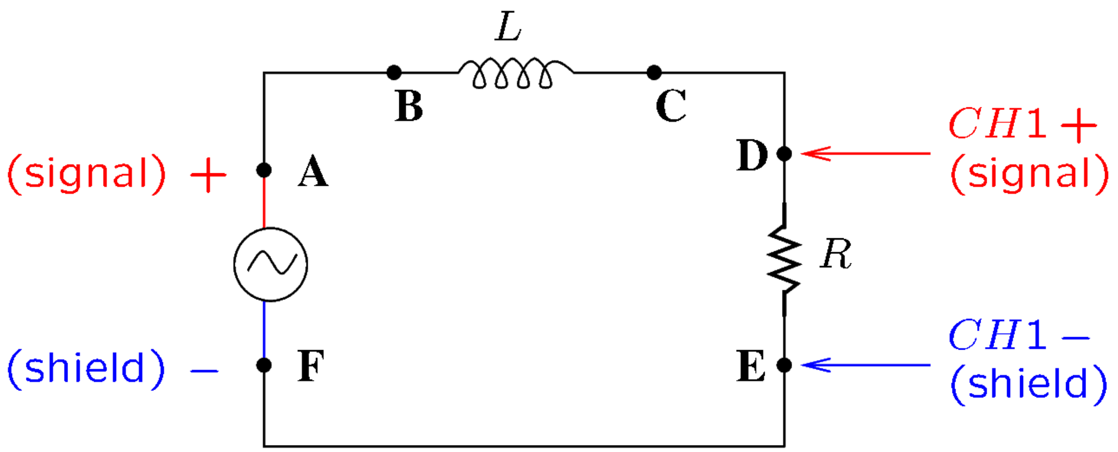
- *After interchanging the source connection, it is possible to connect the shield of CH1 (the GND terminal) at the point **B**.*
- *The ground connection connects now two points of the circuit belonging to the same node, so there is no problem.*

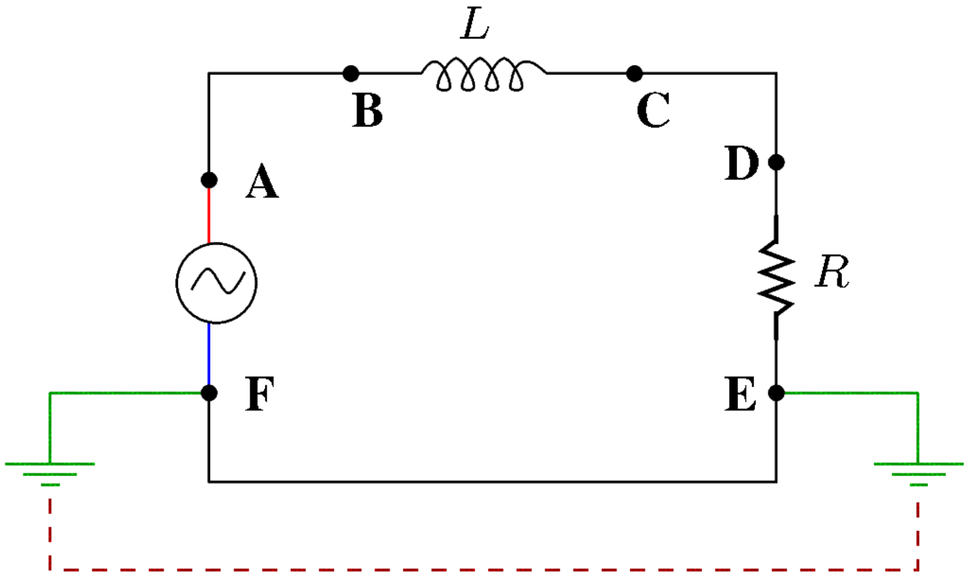




Solution 2—Interchange *R* and *L*

- *After interchanging R and L, the voltage between the points* ***D*** *and* ***E*** *is the voltage of R.*
- *The ground connection connects now two points of the circuit belonging to the same node, so there is no problem.*





Other Solutions

- *Perform a differential measurement.*
  - *Measure on CH1 the source voltage.*
  - *Measure on CH2 the voltage on the inductor L.*
  - *Display on the oscilloscope the difference $CH1 - CH2$.*
  - *Drawback: The resolution of $CH1 - CH2$ might be an issue if the difference is small.*

- *Use a three-prong/two-prong adapter.*
  - *This adapter could be used to disconnect the source or the oscilloscope from the GND of the wall outlet.*
  - *This method is unsafe and is not recommended.*

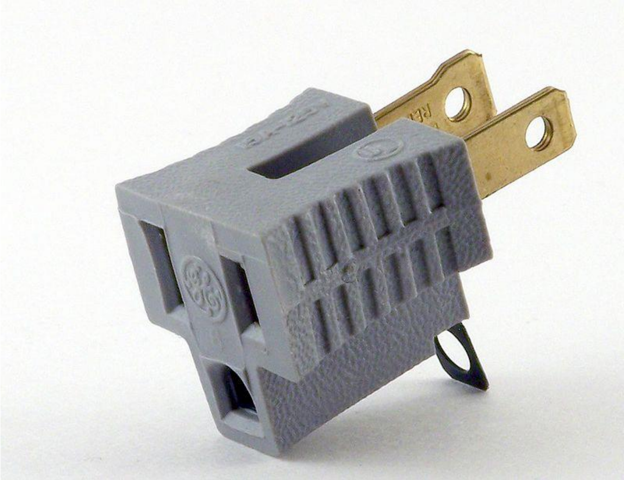


Image from https://en.wikipedia.org/wiki/File:Cheater_plug_edited.jpg

- *Use a transformer to isolate the source from the circuit.*
  - *Transformers will be discussed later in our class.*