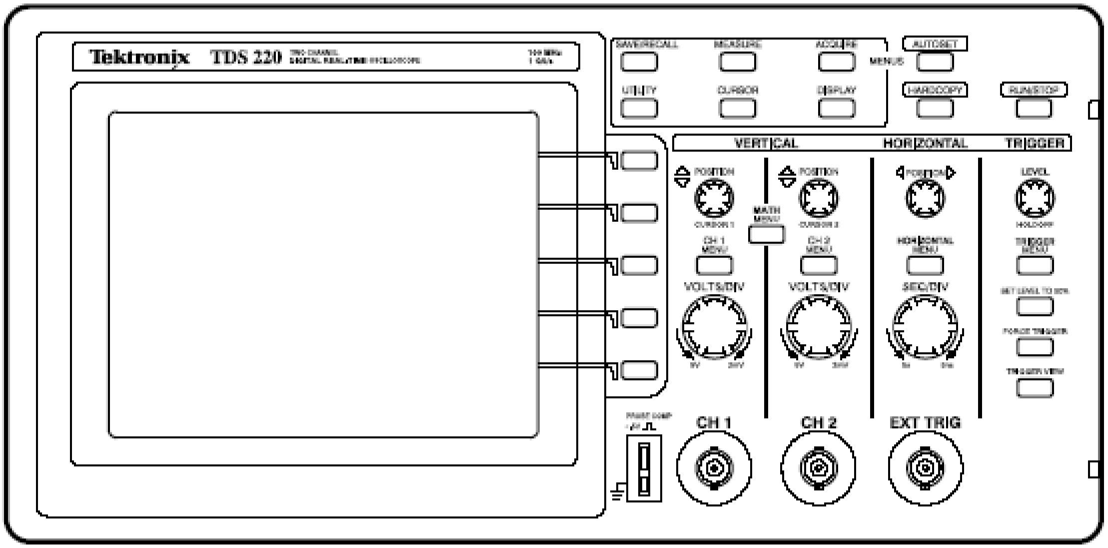
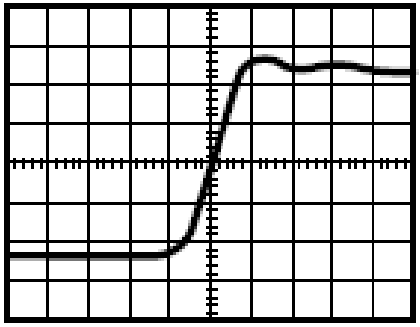
Introduction to oscilloscopes

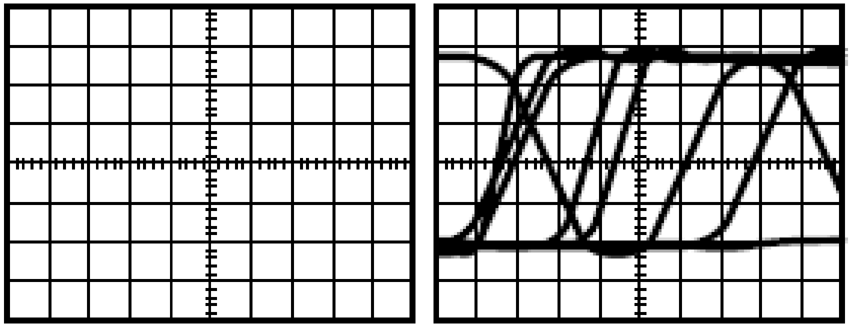


- *Triggering*
- *10x probes*
- *DC coupling vs AC coupling*
- *X-Y mode*

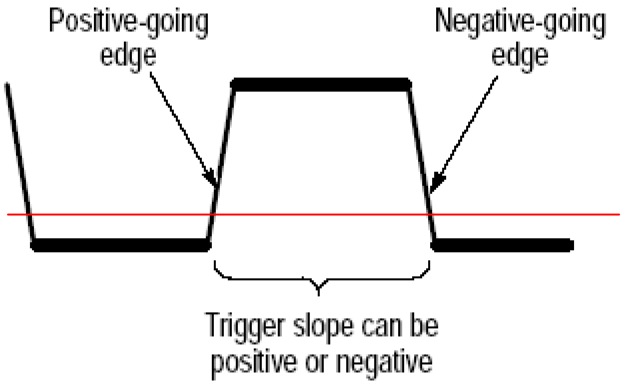
Triggering



Triggered waveform



Untriggered waveforms



Trigger Slope:

Positive/negative: rising or falling edge

Trigger source:

Ch 1

Ch 2

Ext/Ext 5

Line:

Trigger mode:

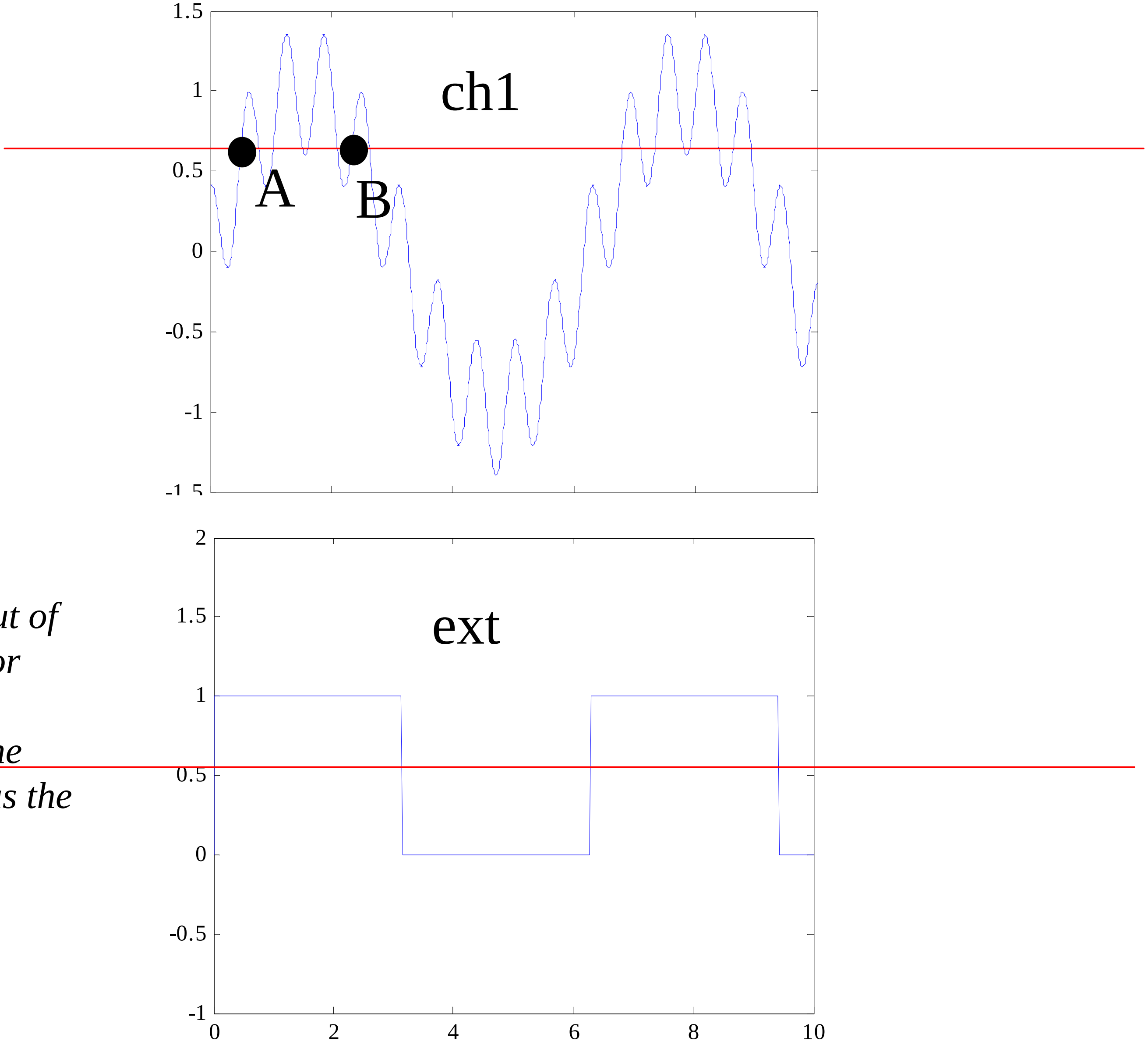
Normal: stops if cannot detect trigger

Auto: keeps going even if cannot detect trigger

Single: run/stop button

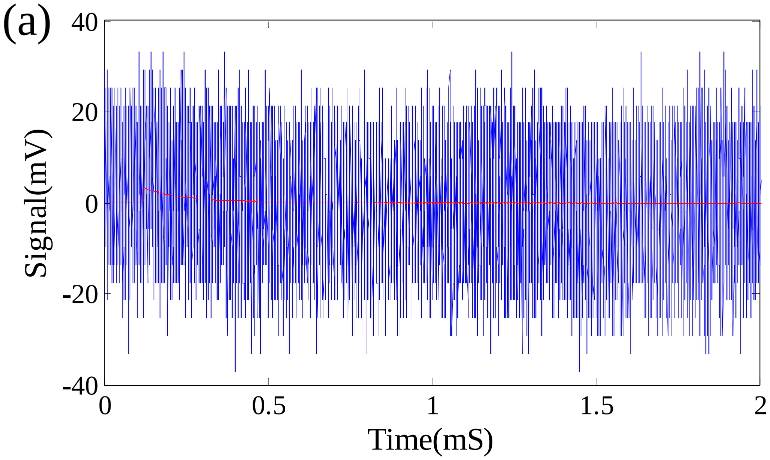
Triggering

$y = sin(t)+0.4cos(10t)$



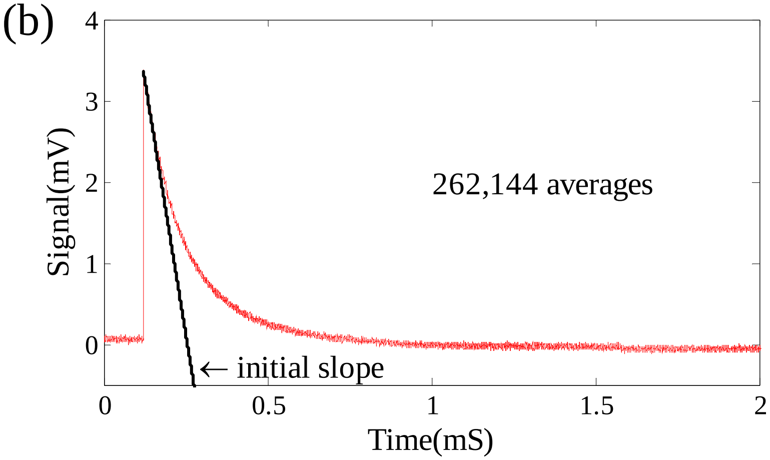
The "sync" output of function generator provides a clean square wave at the same frequency as the output

Importance of external trigger:
recovering signal from noise by averaging

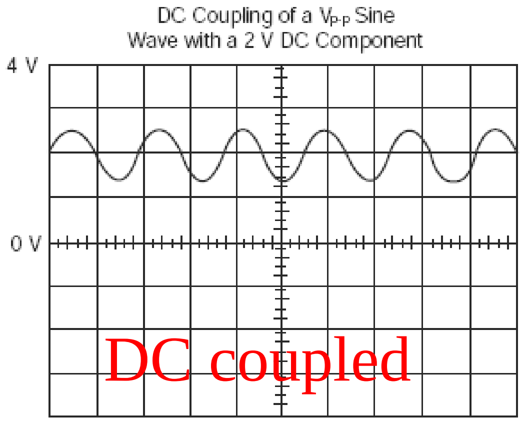


Blue = a single trace

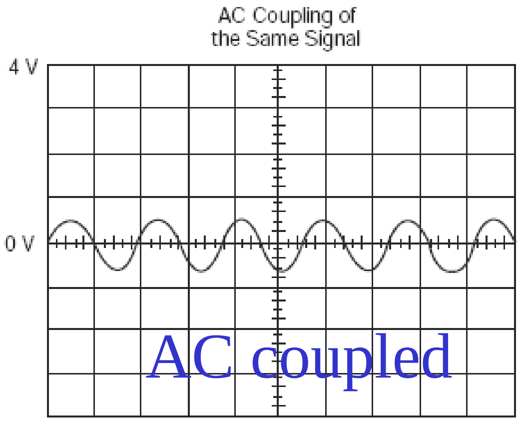
Red = 262144 averages



Coupling: DC vs AC



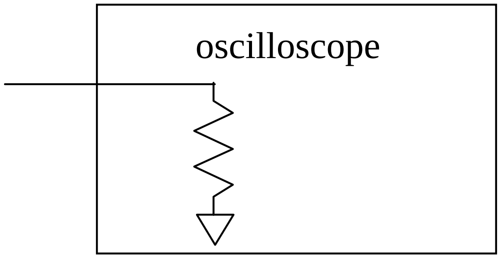
DC coupled

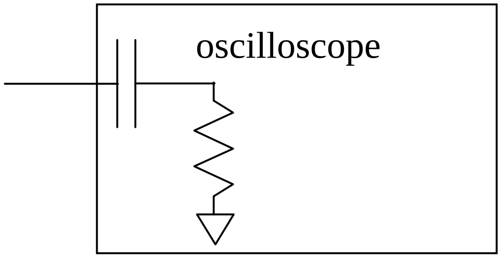


AC coupled

Removes all DC information

To observe small AC on top of large DC





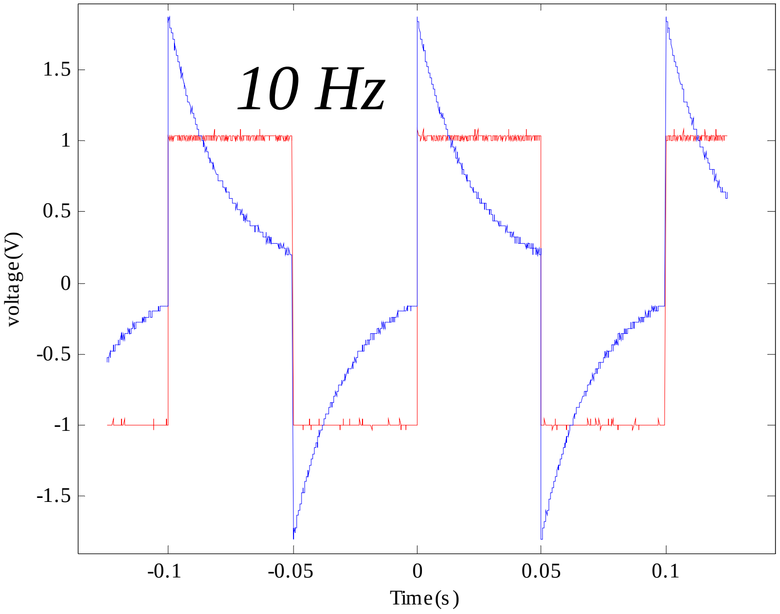
$z_c = 1/j\omega C$ $f_{3db} = 1/2\pi RC$

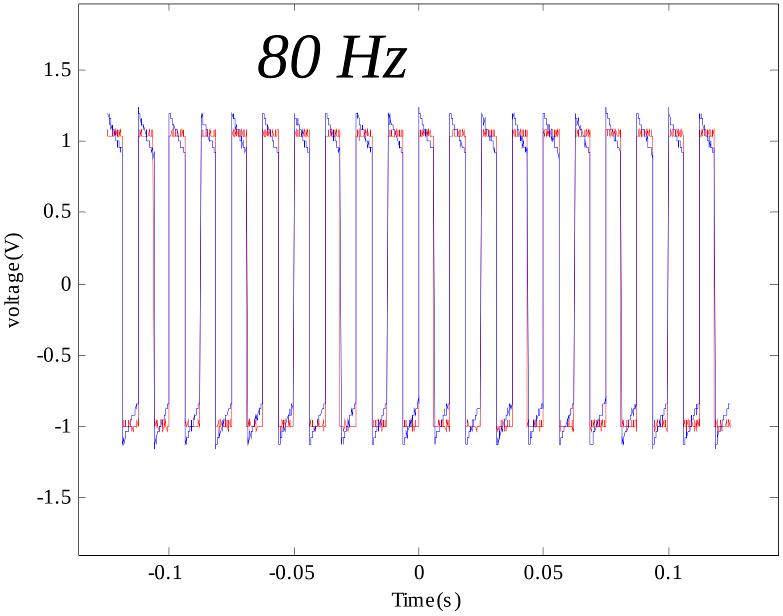
Coupling: DC vs AC

Low frequency waveforms can be severely distorted by the high pass filter

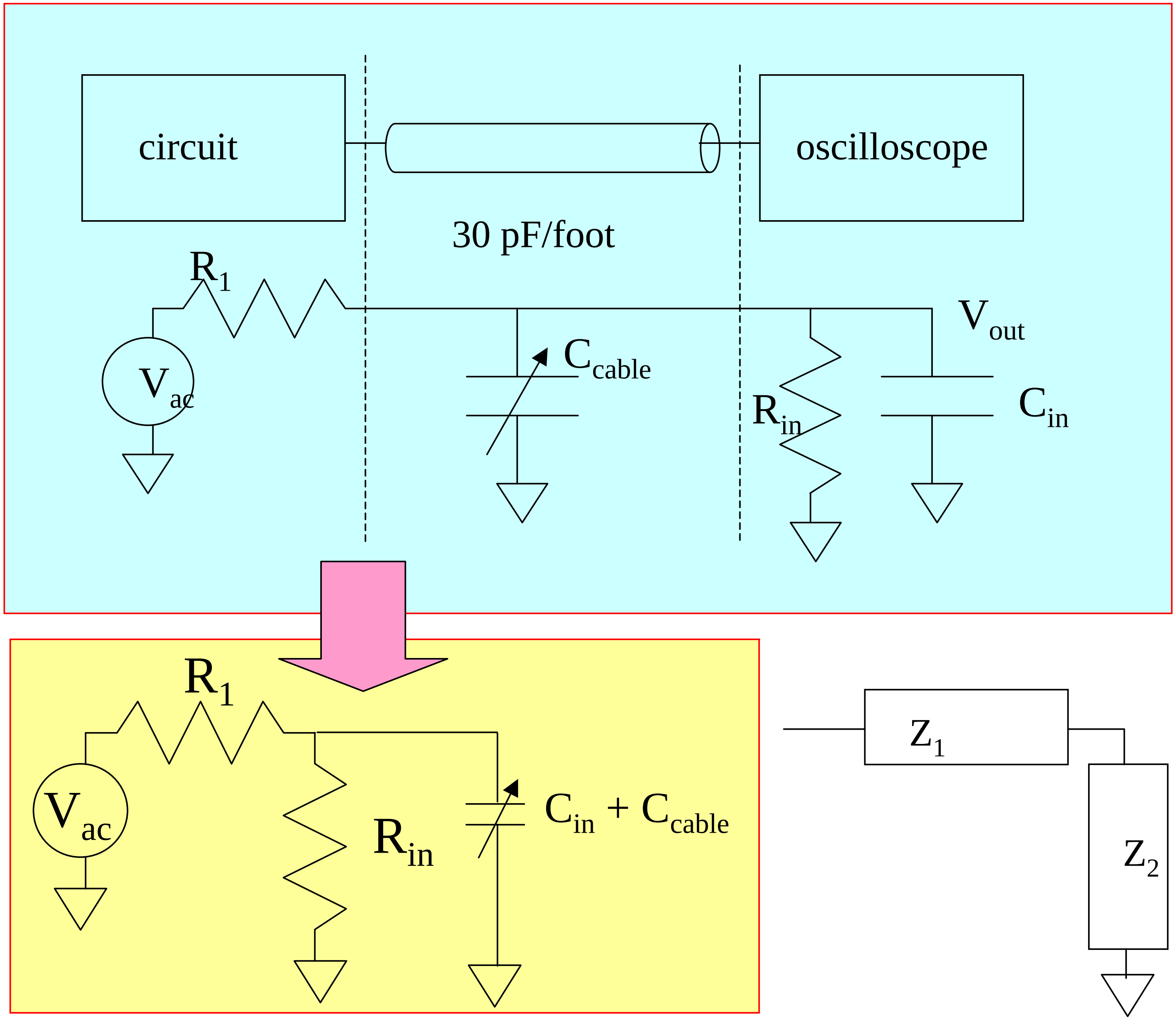
AC coupled

DC coupled





Oscilloscope probes



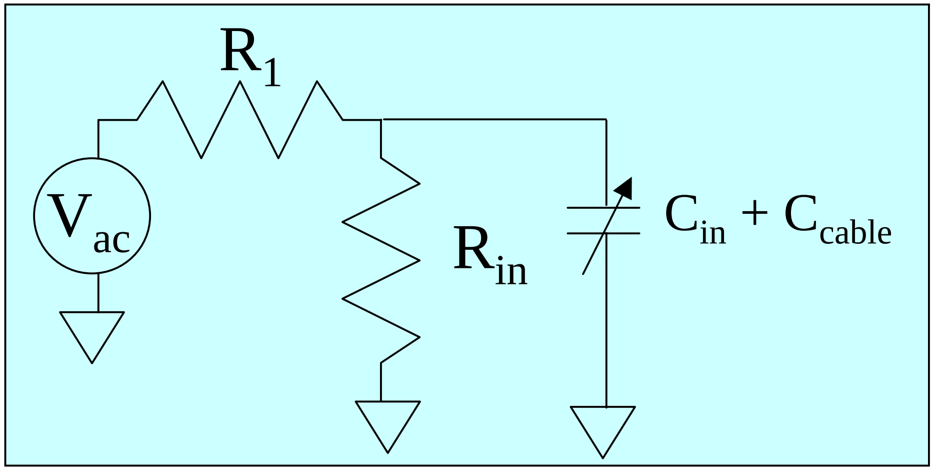
For scope:

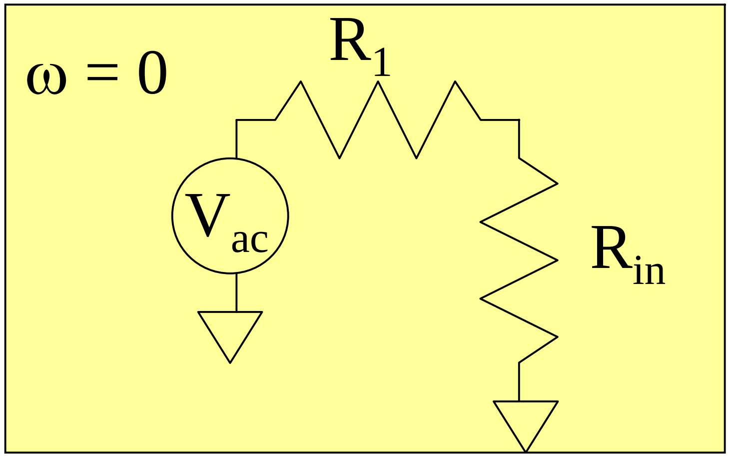
$R_{in} = 1\ M$

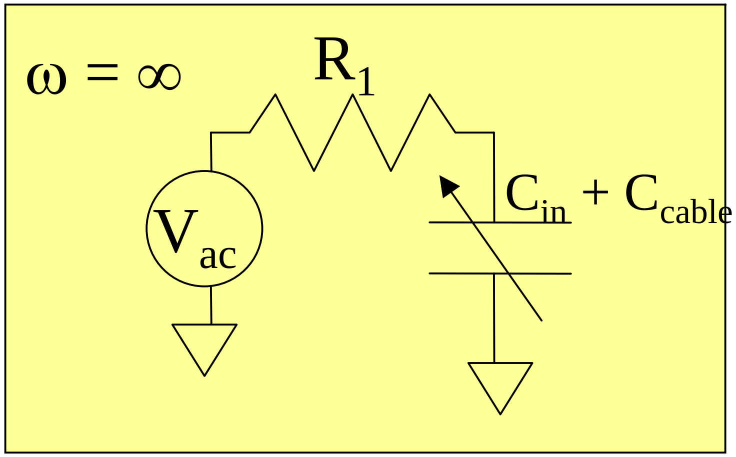
$C_{in} \sim 20\ pF$

Z_1 and Z_2 are frequency dependent and changes for each circuit

Oscilloscope impedance and stray capacitance can load the circuit







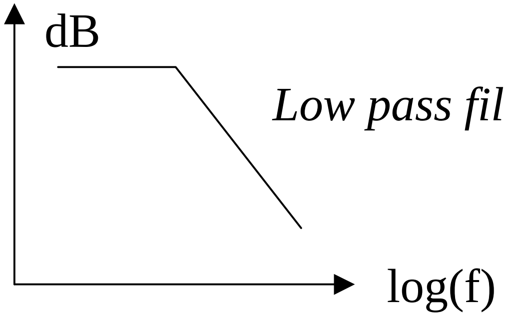
Example:

$R_1 = 10k$

$C = 50\ pF$

$f_{3db} = 1/2\pi RC$

$= 320\ kHz$

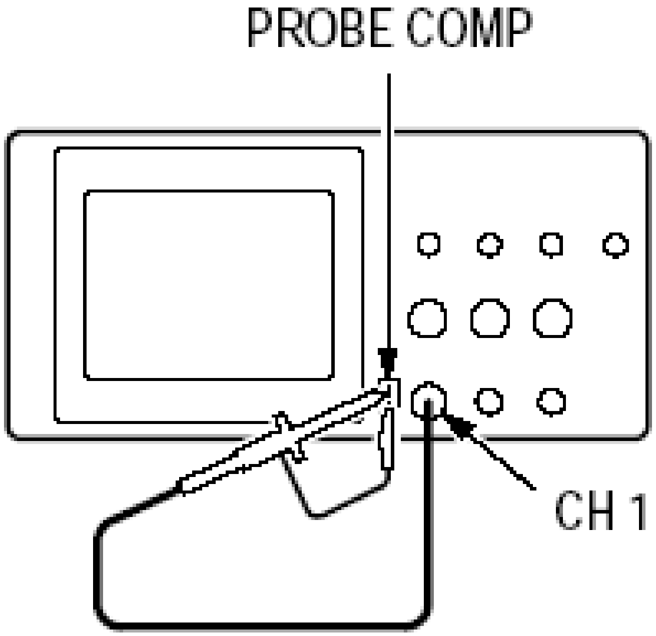


Low pass filter

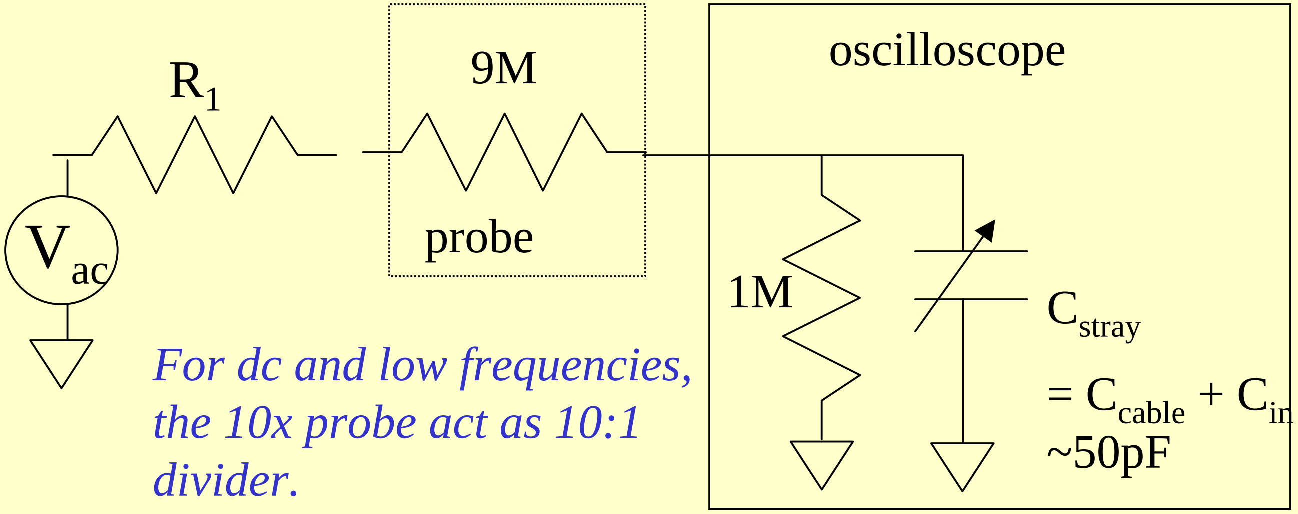
The signal is distorted!

Advantages of 10x probe

1. *Input impedance 10 times larger (reduce loading)*
2. *Frequency independent (almost, if tuned correctly)*



Resistive part:

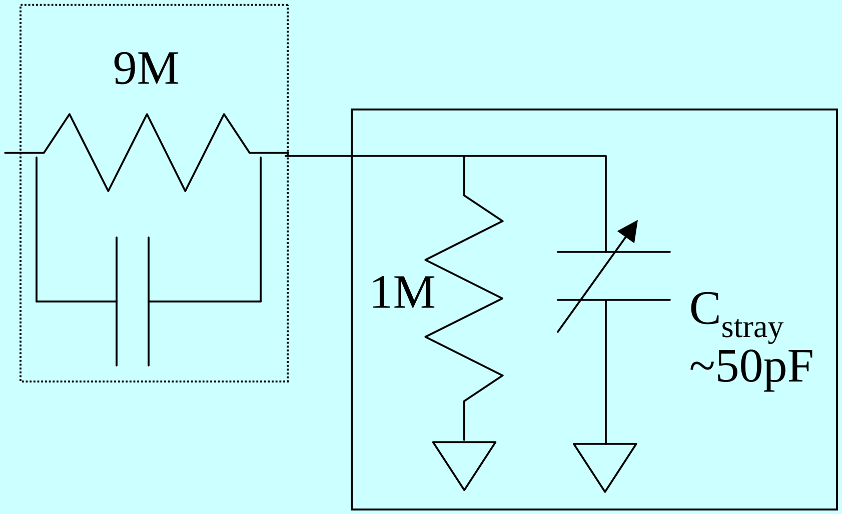


For dc and low frequencies, the 10x probe act as 10:1 divider.

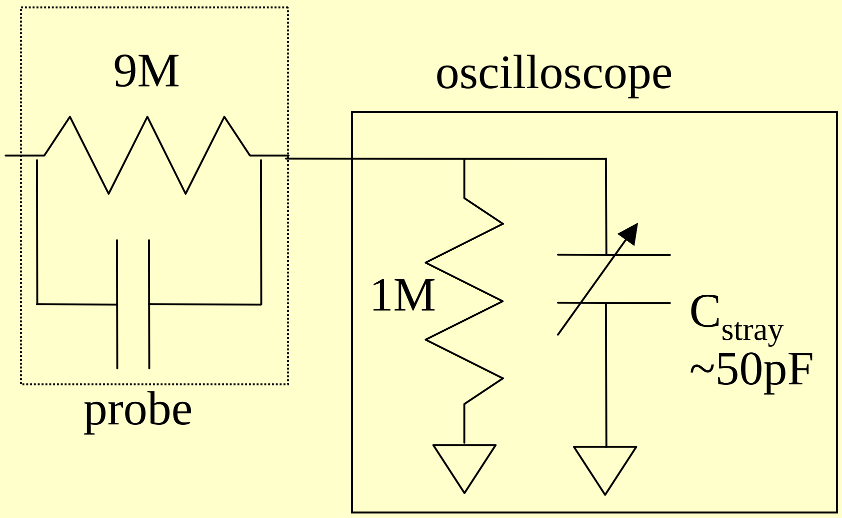
Input resistance is 10x higher.

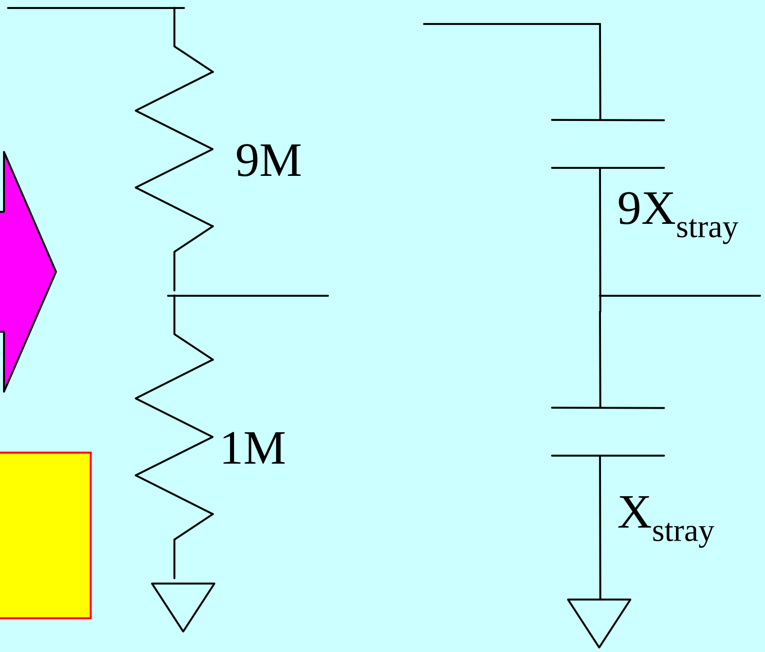
How to eliminate frequency dependence?

Add capacitor to probe



Consider the resistive and capacitive parts separately





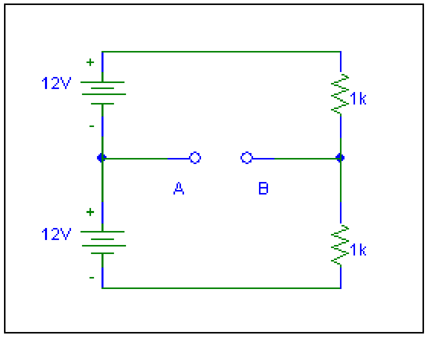
$$\frac{X_{stray}}{X_{stray} + 9X_{stray}}$$

$$\frac{1/j\omega\, C_{stray}}{1/j\omega\, C_{stray} + 9/j\omega C_{stray}}$$

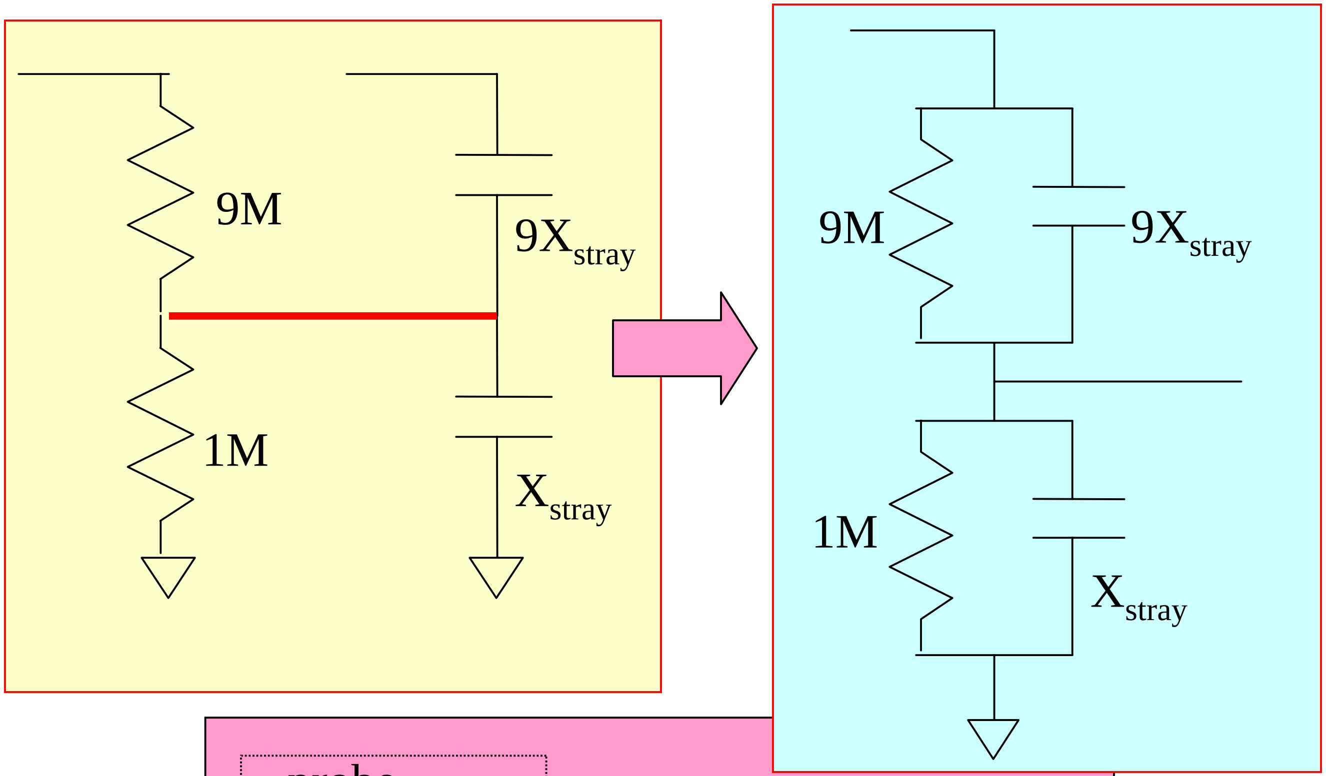
*Both dividers are 1:10, **independent** of frequency*

*They give the **same** output voltage*

Remember Quiz 1:



Both dividers give the ***same*** *output voltage ➔ can join the output*

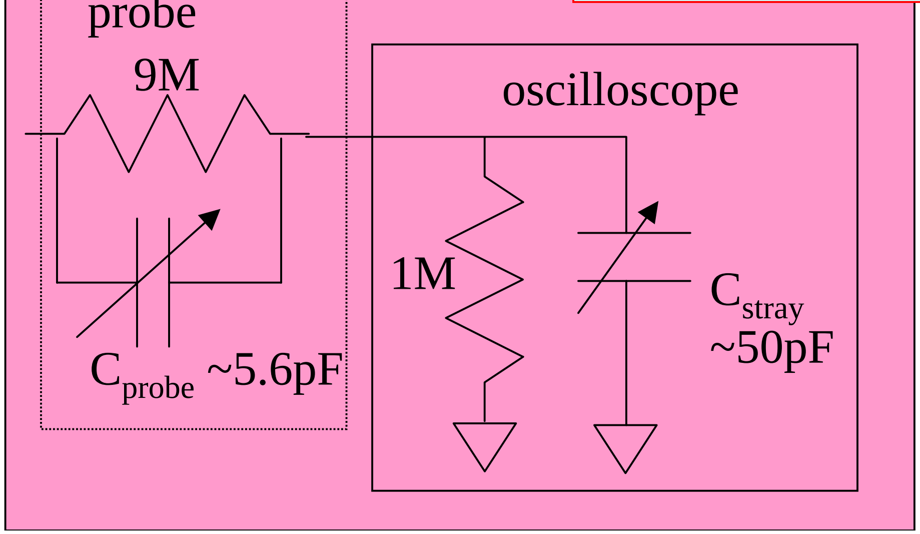


$X_c = 1/j\omega C$

$C_{probe} \sim 50pF/9$

$= 5.6$ pF

$C_{stray} \sim 50pF$



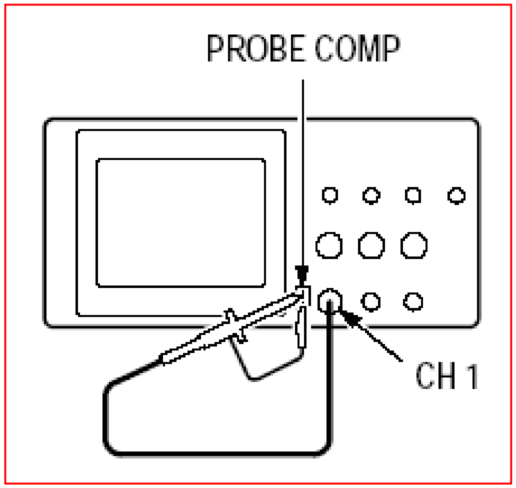
10x probe divides signal by 10. To display the actual signal, we need to tell the scope to multiply its measurement by 10.

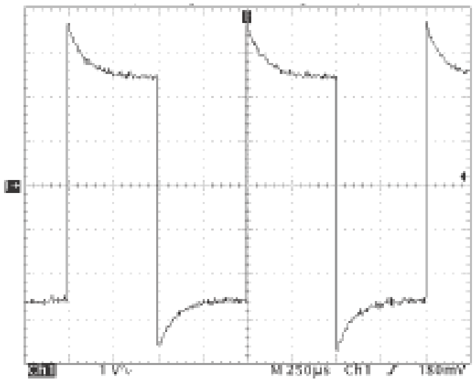
Tuning the probe

The oscilloscope provides a square wave output on its front panel, labeled as “probe adjust”

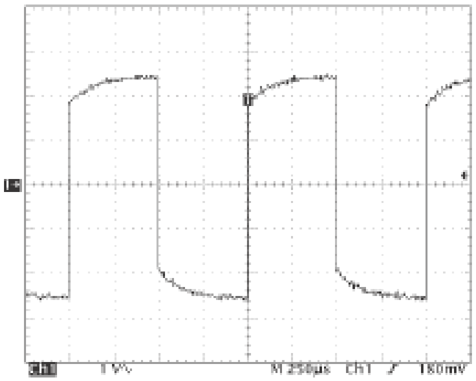
A square wave can be Fourier decomposed into a sum of many frequencies.

If the probe and scope attenuates all frequencies by 10, we should get back a square wave.

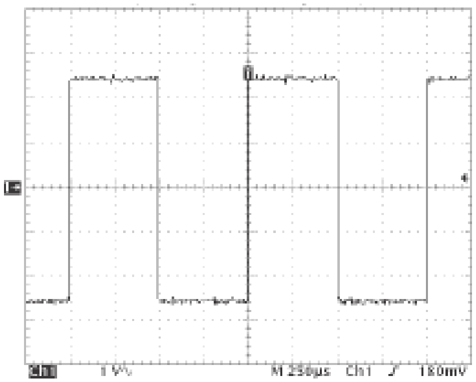




a. Overcompensated.

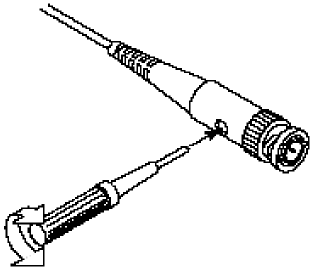


b. Under compensated.



c. Properly compensated.

Tune probe capacitance until the scope shows a good square wave.



Display:

YT: displays Ch1 and/or Ch2 as a function of time

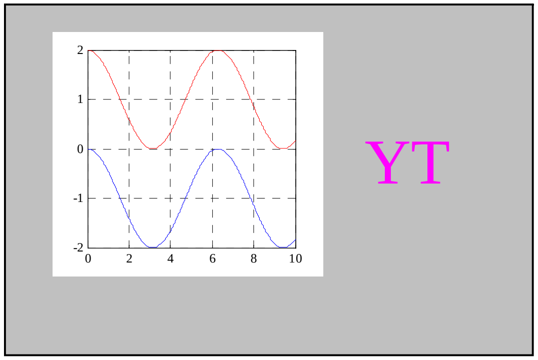
XY: displays Ch1 as a function of Ch 2

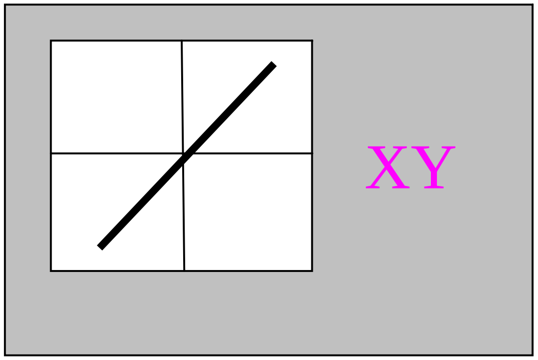
$$x(t) = A\cos(\omega_1 t - \delta_1)$$
$$y(t) = B\cos(\omega_2 t - \delta_2)$$

Example:

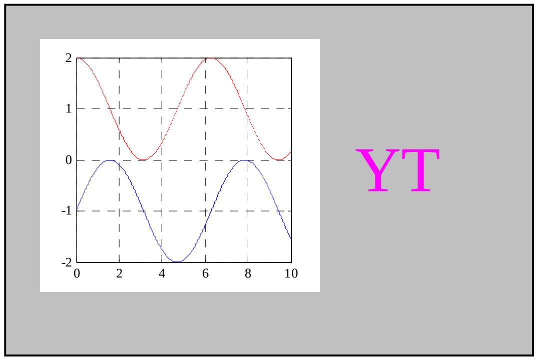
$$\omega_1 = \omega_2,\ \delta_1 = \delta_2$$

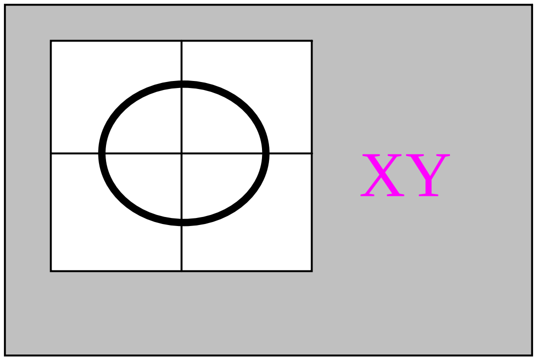
$$y = B/A\, x$$





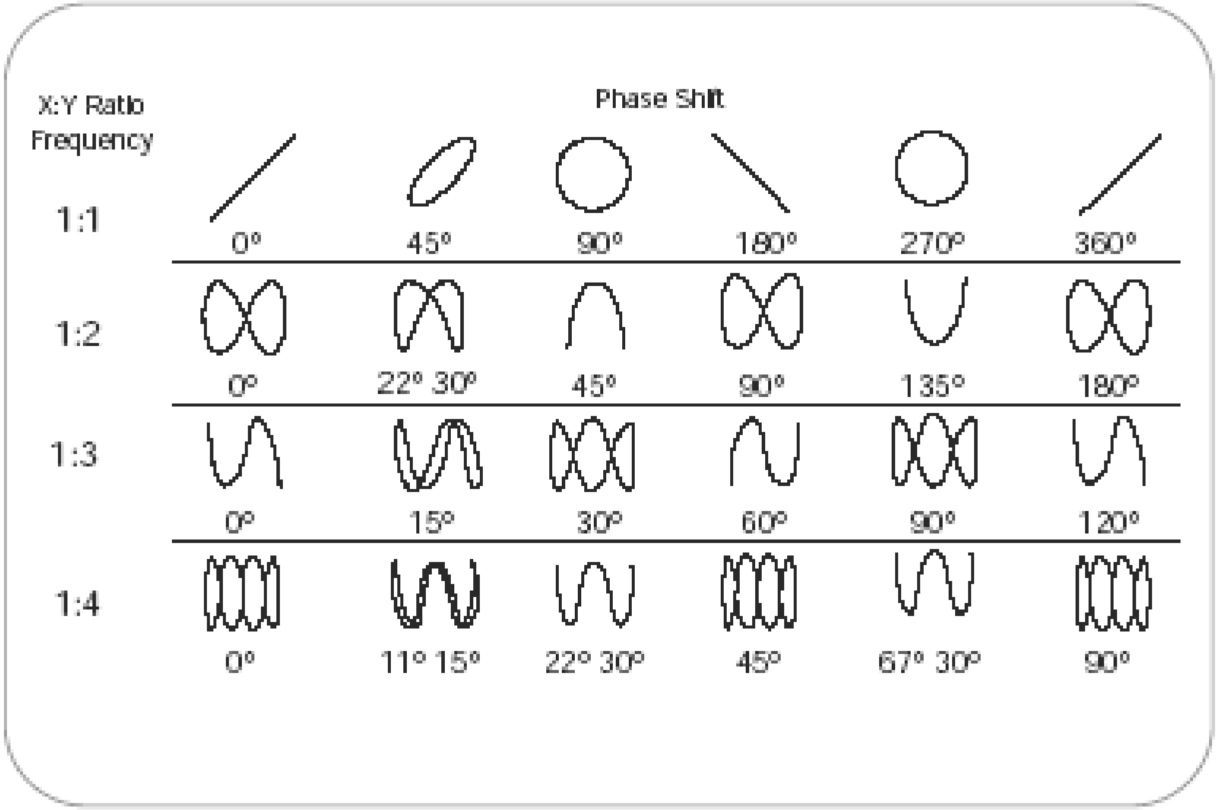
$$\omega_1 = \omega_2,\ \delta_2 = 0,\ \delta_1 = \pi/2$$
$$x(t) = A\cos(\omega_1 t)$$
$$y(t) = B\sin(\omega_1 t)$$

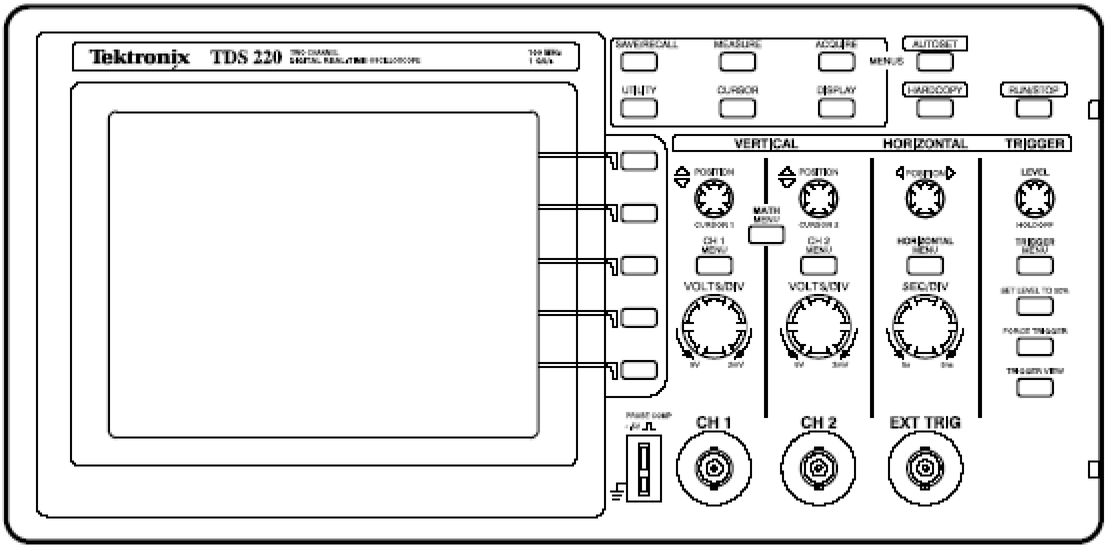




Lissajous Curves

$$x(t) = A\cos(\omega_1 t - \delta_1)$$
$$y(t) = B\cos(\omega_2 t - \delta_2)$$





Checklist for oscilloscope operation

1. *Make sure probe compensation is set to the correct value (1x, 10x)*
2. *If you cannot get signal on screen, press “autoscale”*
3. *Check DC/AC coupling*
4. *Check trigger source*