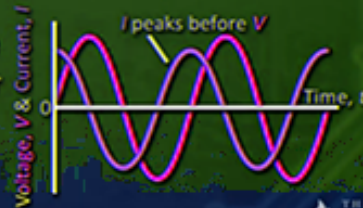


Electronics

Lecture 5 - Filters

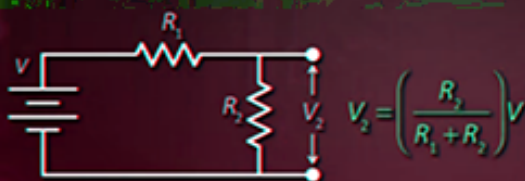
“OHM’S LAW” FOR CAPACITORS

- Capacitor acts **sort of** like frequency-dependent resistor
 - “Resistance” proportional to $1/\text{frequency}$
 - High frequency \rightarrow low “resistance” and vice versa
 - $f \rightarrow \infty$ (very high frequency): capacitor acts like short circuit
 - $f \rightarrow 0$ (very low frequency): capacitor acts like open circuit
- Why **sort of**?
 - Because capacitor changes **phase**
 - Current leads voltage in capacitor
 - Better name than “resistance”: *capacitive reactance*, X_c
 - X_c proportional to $1/fC$

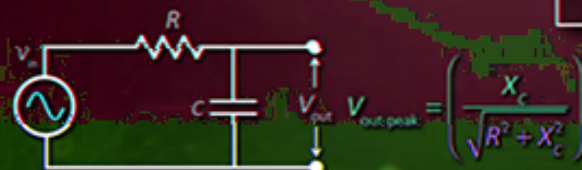


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MAKE IT A FILTER:

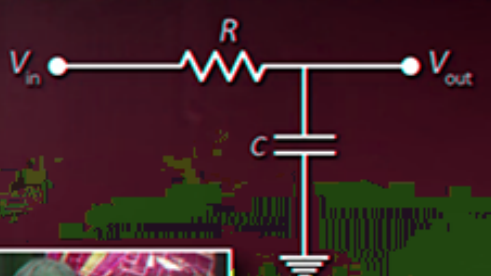


Still a voltage divider?
Sort of




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QUICK QUIZ: HIGH-PASS OR LOW-PASS FILTER?



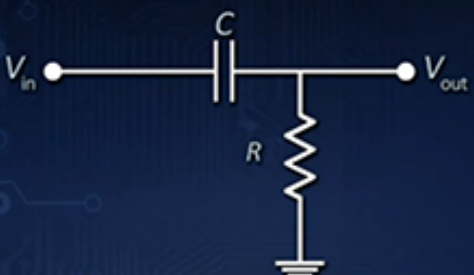
Low-pass filter

$$V_{\text{out peak}} = \left(\frac{X_C}{\sqrt{R^2 + X_C^2}} \right) V_{\text{in peak}} \quad X_C \propto \frac{1}{f}$$


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Above: Low pass filter in which the capacitor has high resistance for the low frequencies and therefore they pass through to V_{out} . This is functioning similar to a voltage divider in which the low frequencies will have very little attenuation, while higher frequencies have little resistance in the capacitor and are therefore filtered out to ground.

WHAT'S THIS?

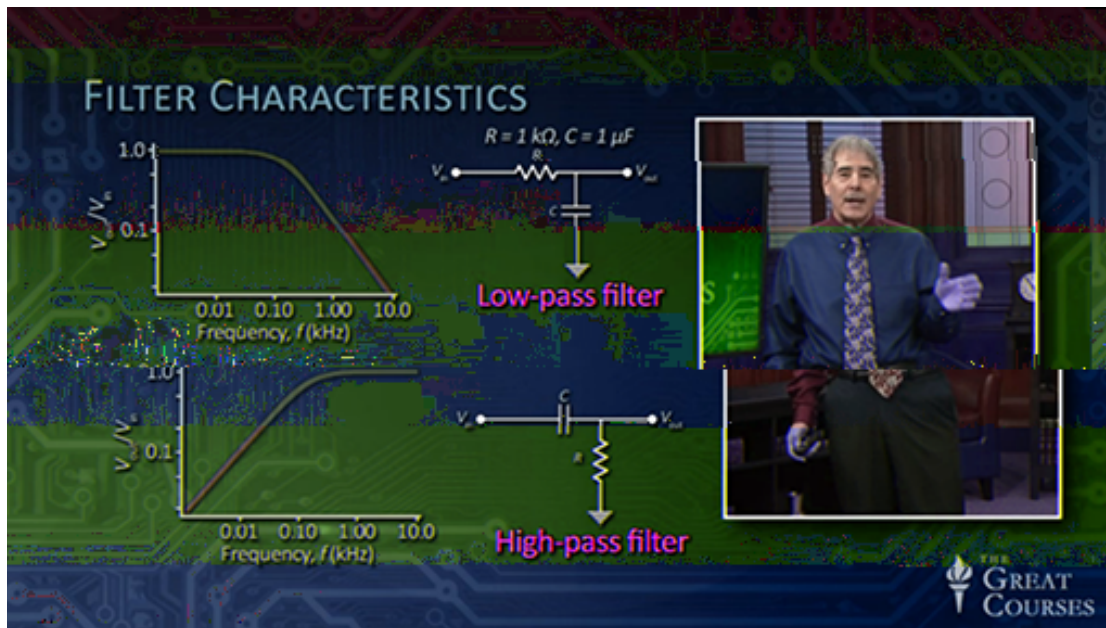


High-pass filter

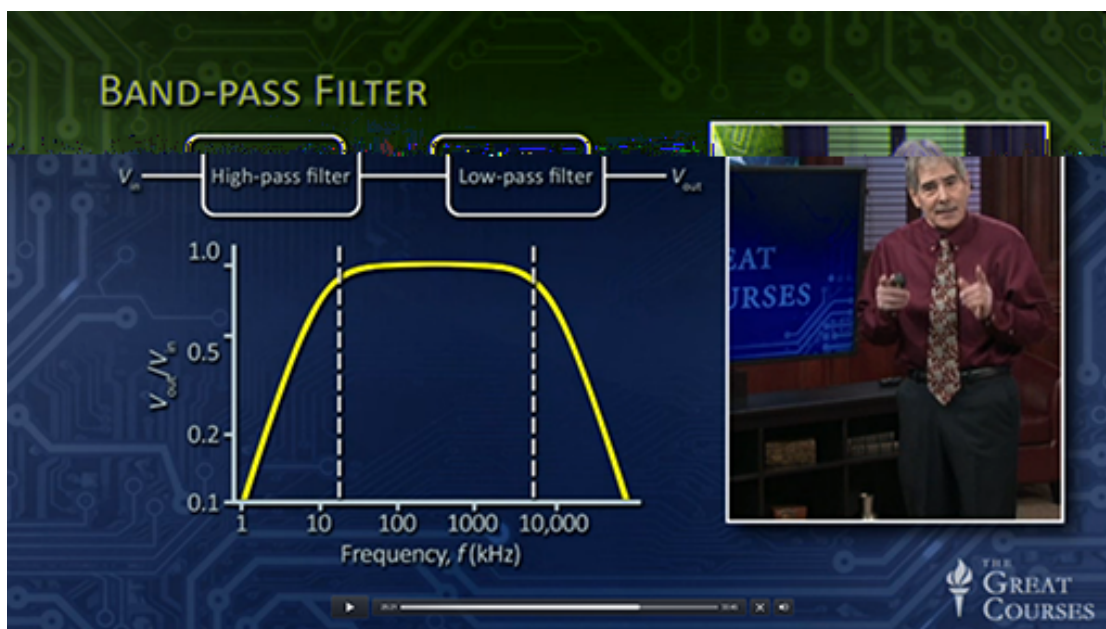
$$V_{\text{out peak}} = \left(\frac{R}{\sqrt{R^2 + X_C^2}} \right) V_{\text{in peak}} \quad X_C \propto \frac{1}{f}$$

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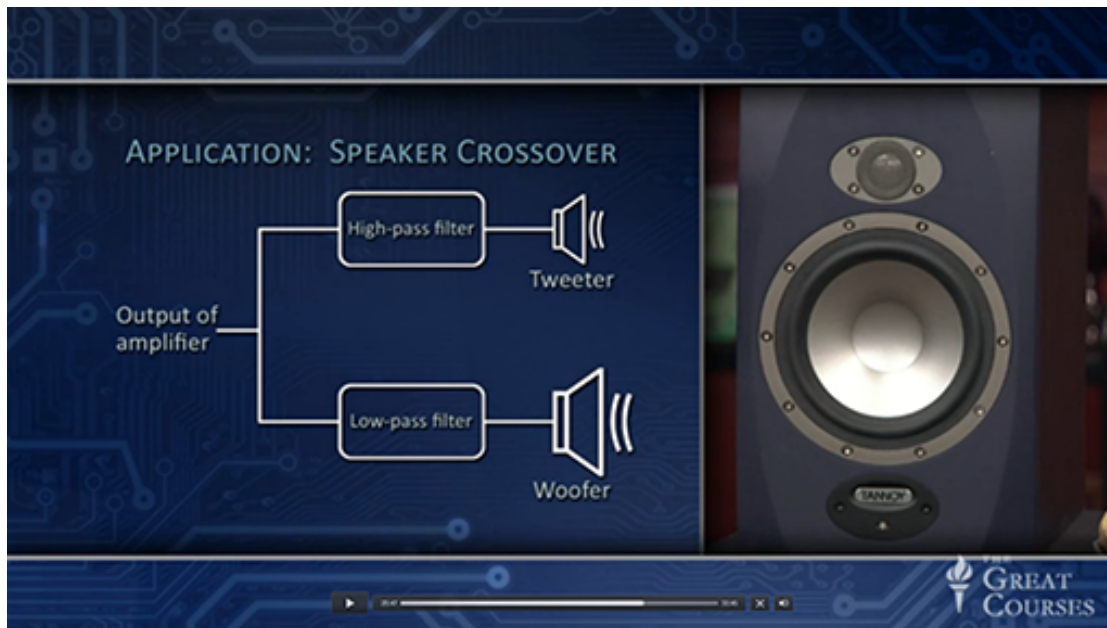
Above: a high-pass filter which blocks the lower frequencies (due to high resistance of the capacitor, but allows the high frequencies to pass (due to low resistance). From a voltage divider perspective the capacitor with its high resistance attenuates the low frequency voltage significantly, while the higher frequencies (and low capacitive reactance) have much less attenuation due to the ratio between the capacitors resistance (capacitive reactance) and the resistor.



Above: A logarithmic plot of the voltage relative to frequency for both low and high pass filters, using a $1\text{K}\Omega$ resistor and a $1\mu\text{F}$ capacitor.



Above: Band-Pass Filter. Using a high pass filter in combination with a low pass filter, filters out both the high and low frequencies allowing the middle frequencies to pass with much less attenuation.



Project

PROJECT: TWIN-T FILTER

Simulate the circuit shown, and explore its filter characteristics. Make a log-log plot of the ratio of output voltage to input voltage, over the frequency range $10 \text{ Hz} \leq f \leq 100 \text{ kHz}$.

- Straightforward: Use a voltage function generator (under *Signal Sources*) as the input. Use a fixed voltage, but different frequencies. Run a time-domain simulation for each f , and plot V_{out} .
- Extra Learning: Explore CircuitLab's Frequency Domain simulation.

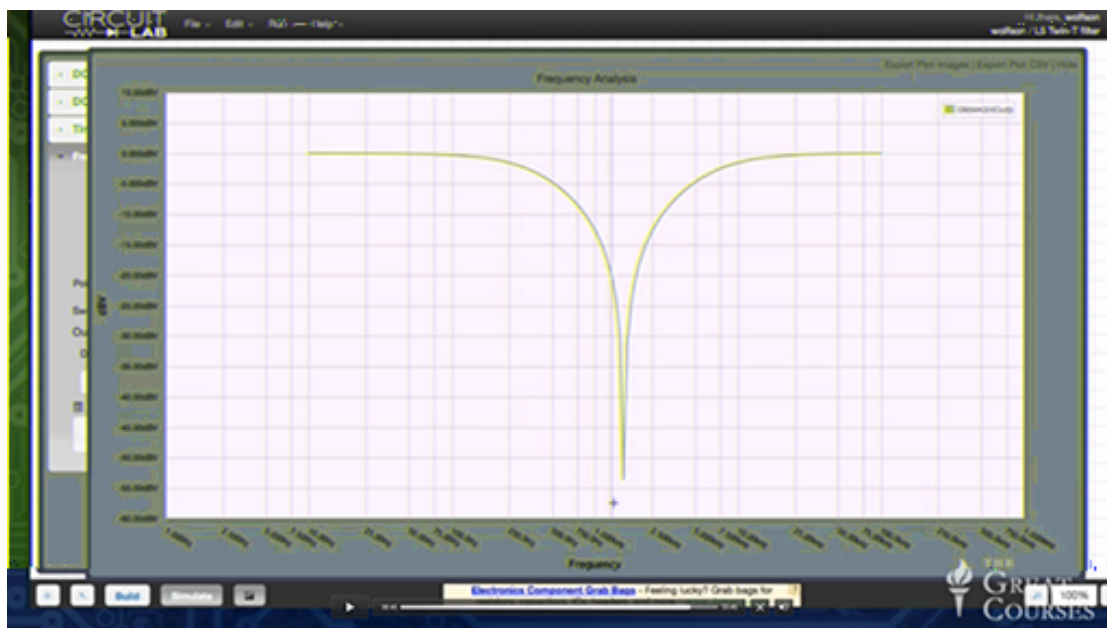
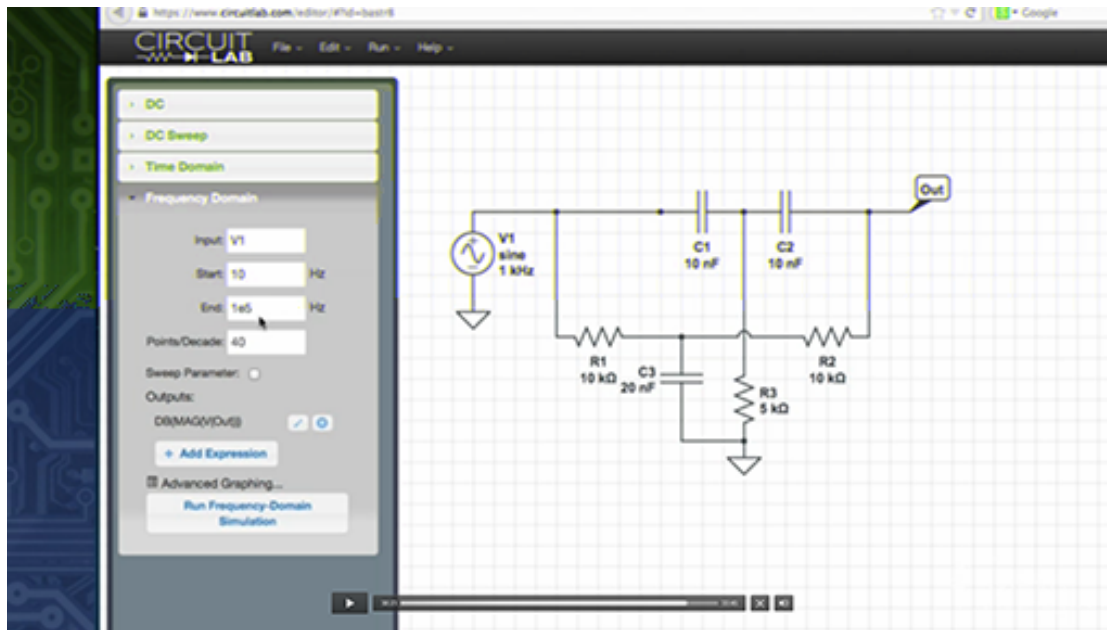
The circuit diagram shows an input 'In' connected to a network of resistors and capacitors. The output 'Out' is taken from the right side of the network. The circuit consists of two capacitors 'C' in series at the top, two resistors 'R' in series at the bottom, and a central branch with a capacitor '2C' in parallel with a resistor 'R/2' connected to ground.

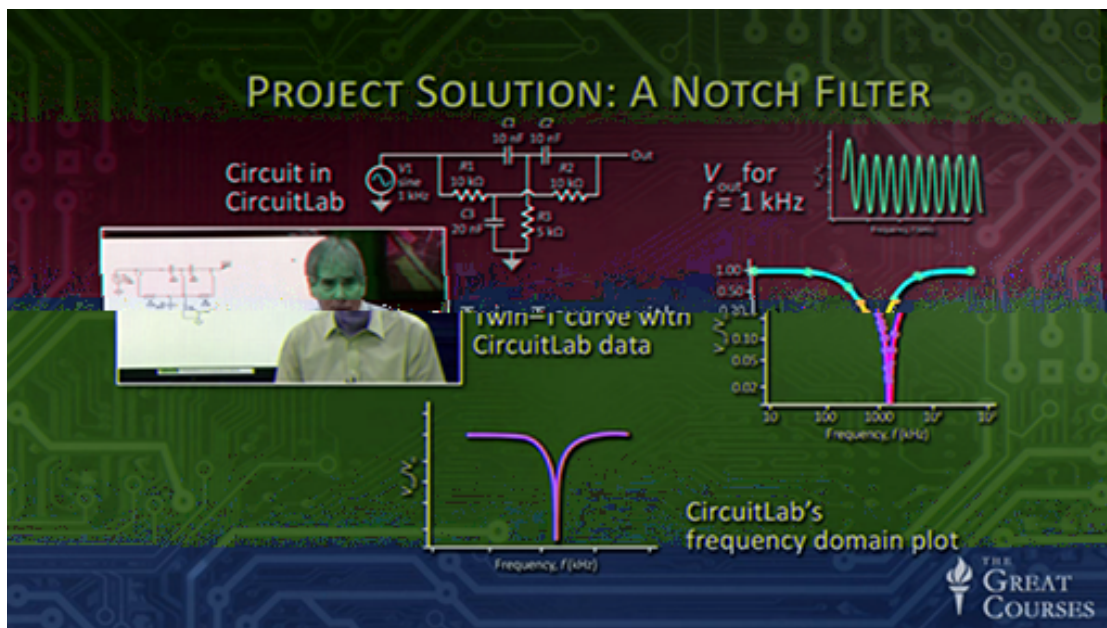
Component values:

$C = 0.01 \mu\text{F}$ (10 nF)

$R = 10 \text{ k}\Omega$

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In Docircuit

