Lilo

Problem set: RC circuits as signal filters—FFTs and the Bode plot

Worksheet

Part I: Viewing signals through time and 1/time domains

The FFT uses a *relative* amplitude of the voltages using the decibel (dBV).

$$dBV = 20 \cdot log_{10}\left(\frac{V}{V_{ref}}\right)$$

For our case, the 1V ("Carrier" signal amplitude) is the V_{ref}

How pure is Wavegen's 1kHz signal?

What do you notice about the frequency composition of Wavegen's 1kHz signal?

spike near 1kHz, noisy at greater frequencies
^ up to 0 dBV

What are the amplitude (volts) and frequency (kHz) of the largest signal that is not 1 kHz? (Use 2 significant figures).

250kHz → −75 dB$\tilde{V}$

The dimensions of frequency are hertz, 1 Hz = 1 cycle/second. What is the "cycle" that the Hz is referring to?

sine wave voltage.

Effects of adding two signals

First remove both "FM" and "AM" and restart the Scope.

Now add in "FM" 20kHz signal. What happens to the FFT?

spike 1: 1kHz → 0 dB$\tilde{V}$

spike 2: 19kHz → −32 dB$\tilde{V}$

spike 3: 21kHz → −34 dB$\tilde{V}$

What accounts for signals that appeared in the FFT that are not 20kHz?

when adding the two signals together, the 1kHZ acts as a kind of offset. with a 1kHz carrier, 20 kHz has a max of 21 kHz and a minimum of 19kHz, explaining the spikes. also, the spikes at 38kHz and 42kHz are echoes of the signal at double the frequency/an octave because it resonates and creates harmonics

Now add in "AM" (50kHz). What do you observe in the FFT output?

1kHz, 0 dBṼ
19kHz, −32 dBṼ
21kHz, −34 dBṼ
29kHz, −40 dBṼ
31kHz, −38 dBṼ
49kHz, −5 dBṼ
51 kHz, −6 dBṼ
69kHz, −38 dBṼ
71 kHz, −40 dBṼ

Now that you've had a little experience with FFTs, how do you imagine that they can help you build a filter?

filter out any frequencies that are less than x amount of dBṼ to get rid of noise and only look at the spikes

Part 2. The RC filter and its behavior

For the RC circuit, describe what you see happening to the signal amplitude in when the input goes from low frequency (~100Hz) to high frequency (100 kHz).

at low freq the channel 2 mirrors ch1 at higher freq, ch2 never has any spikes above ~ −15dBṼ. It caps it, filtering out some of the high frequencies

Compute the phase shift at the characteristic frequency. This phase shift should be the same for all filters at the characteristic frequency.

$$f = \frac{1}{2\pi RC} = \frac{1}{2\pi\, 1.58\cdot 10^{3}\cdot 0.1\cdot 10^{-6}} = \frac{10^4}{9.93} = 1007\ \text{Hz} = 1.007\ \text{kHz}$$

$$\boxed{120\ \mu s}$$

What does the Bode plot tell you about changes in the RC filter's response from low to high frequency input signals? (Is this the same as what you've observed?)

as freq ↑ dB magnitude decreases
it's a low pass filter

What does the Bode plot illustrate about the phase shifts for low and high frequency input signals?

$\text{atan}\left(\frac{1}{RC\omega}\right)$

the phase of the waves has an inflection point around the characteristic frequency

What is the expected A, when $RC\omega = 1$?

$A = \frac{1}{\sqrt{2}} = 0.707$ $\quad 2\pi f$

Recall, $A = \frac{V_{out}}{V_{in}} = \frac{1}{\sqrt{1+(RC\omega)^2}}$ = voltage gain.

$\omega = \frac{1}{RC} = \frac{2\pi}{2\pi RC} = 2\pi \cdot 1.007\,kHz$

$= 6.324\,kHz$

Use the Waveform cursor tool to look up the value of A for the RC filter:

$10^{\left(\frac{-15.4004}{20}\right)} = 0.169$

Part 2. The RC filter and its behavior: The Bode plot

What does the Bode plot tell you about the performance of the CR circuit at low and high frequencies?

at high freq they are uninterupted

at low freq they are decreased

(high pass filter)

Use the Waveform cursor tool to look up the value of A for the RC filter:

Why do you think *f (Hz or cycles/second)* $\cong \frac{1}{2\pi RC}$ is known as the "cutoff frequency."

Let's name these circuits! Match the names below with a good name for each circuit:

Naming options:

High pass filter (allows "high" frequencies to pass through)	**Low pass filter (allows "low" frequencies to pass through)**	**band pass filter (allows a limited band of frequencies to pass through)**