Relating time-domain to frequency-domain circuit characteristics

Learning goals
- Physical meaning of frequency-domain transfer function
- Analyze sinusoidal circuits using frequency domain methods
  - Predict circuit behavior based on $H(s)$
    - Bode diagram as a tool
  - Compute sinusoidal signal output using $H(s)$
- Design simple RLC circuits using $H(s)$

Physical meaning
- Analyze circuits with sinusoidal signals
  - Frequency unchanged $\omega$
  - Compute output amplitude $|V_o|$
  - Compute output phase $\phi_o$
- Relate to $H(s)$
  - Gain = $|V_o|/|V_i| = |H(s)|$ at $s=\omega$
  - Phase shift = $\phi_o - \phi_i = \angle H(s)$ at $s=\omega$

Analysis procedure
- Find $H(s)$ of the circuit
- Write directly the expression for $V_{out}(t)$

Predict circuit behavior from $H(s)$
- Simple forms of $H(s)$: Bode plots
  - $1/(s+a)$: one pole at frequency $a$
  - $1/s$: one pole at zero frequency
  - $s+b$: one zero at frequency $b$
  - $s$: one zero at frequency zero
- More complex $H(s)$
  - MATLAB as a plotting tool

PSPICE AC analysis
- AC or AC analysis type
  - Specify input as AC with a magnitude and phase
- Sweep frequency over several decades
- Outputs:
  - Magnitude vs. frequency
  - Phase vs. frequency
Bandwidth concept

- 3-dB frequency, or “3-dB frequency”
  - Gain in dB decreases by 3 dB
  - “Half-power” bandwidth
- Bandwidth
  - Defined with respect to 3-dB frequency
  - Low-pass and band-pass cases

Applications

- RLC resonant circuits
  - Total reactance = 0 at resonance frequency $\omega_0$
  - Bandwidth BW
  - Q (quality factor)
  - $\text{BW} \cdot Q = \omega_0$
- Opamp frequency response
  - Opamp model: gain $A(\omega)$ from specs
  - Analyze circuit as usual with KVL, KCL, etc.

Design example: radio tuner

- Specifications for passive tuner:
  $$v_i(t) = \sin(2\pi \times 10^6 t + 135^\circ) + \sin(2\pi \times 10^5 t) + \sin(2\pi \times 1.4 \times 10^6 t + 300^\circ)$$
  $$v_o(t) = A \sin(2\pi \times 10^6 t + \theta)$$
- Translate to specifications for $|H|$
  - $|H| = 1$ @ $f = 10^6$ Hz
  - $|H| = 0$ @ 700 KHz and 1400 KHz
- Tuned circuit with $f = 10^6$ Hz
  - Pick $C = 0.001 \mu F$, compute $L = 25.33 \mu H$

Performance

- Pick Q
  - The higher the better, usual range 5-30
  - $Q = 15 \rightarrow R = 2.4 \text{ K}\Omega$
- “Noise” at 700 KHz and 1400 KHz
  - $|H| = 0.091$ (not 0) at 700 KHz
  - $|H| = 0.096$ (not 0) at 1400 KHz
- Need better more complex circuit to reduce $|H|$ at these frequencies