In DC steady state inductors "become" wires, and capacitors "disappear". Super/linked nodes can be made when there is a voltage source between the nodes. To measure current with a multimeter the rods need to be places together, and voltage one rod on either side of the resistor. Resisters Parallel: $R_1 * R_2 / R_1 + R_2$, Series: $R_1 + R_2$. Capacitors in s-land are 1/sC, and inductors are sL. Step response is voltage/s
Voltage divider formula: Vin[Ruse/Req], Current divider formula: Iin[Req/Req+Ruse]

$$V_{out}(s) = H(s)V_{in}(s)$$

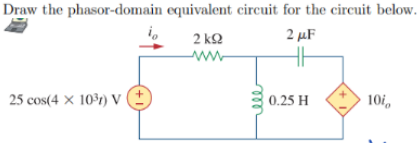
or, in steady-state,

$$V_{out}(j\omega) = H(j\omega)V_{in}(j\omega)$$

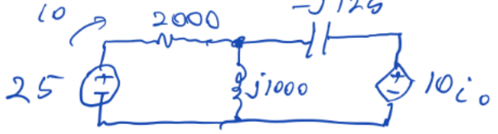
transfer function

Phasor:

3. Draw the phasor-domain equivalent circuit for the circuit below.



$$\frac{-j}{4000 \cdot 2\times10^{-6}} = \frac{-j1000}{8}$$



Different States:

Zero-State Models

t-domain	s-domain	s-domain Impedance
$v(t) = i(t) \cdot R$	$V(s) = I(s) \cdot R$	$Z_R = R$
$v(t) = \frac{1}{C}\int_{t_0}^{t} i(\tau)d\tau$	$V(s) = \frac{I(s)}{sC}$	$Z_C = \frac{1}{s \cdot C}$
$v(t) = L\frac{di(t)}{dt}$	$V(s) = Ls \cdot I(s)$	$Z_L = s \cdot L$

Steady-State Impedance Models

s-domain	Steady State @ ω R/s	Steady State @ f Hz
$Z_R = R$	$Z_R = R$	$Z_R = R$
$Z_C = \frac{1}{s \cdot C}$	$Z_C = \frac{1}{j\omega \cdot C}$	$Z_C = \frac{1}{j2\pi f \cdot C}$
$Z_L = s \cdot L$	$Z_L = j\omega \cdot L$	$Z_L = j2\pi f \cdot L$

Thevenin:

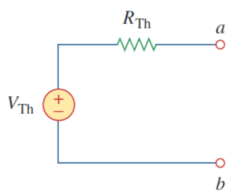


Figure 1: *Thevenin equivalent*

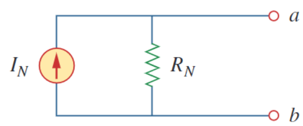


Figure 2: *Norton equivalent*

... and we also have the notion of **source transformation** - so that the simple equivalents are completely **interchangeable**.

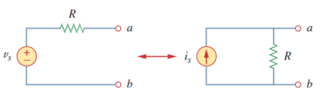


Figure 4.15
Transformation of independent sources.

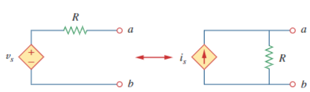


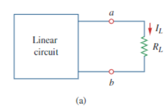
Figure 4.16
Transformation of dependent sources.

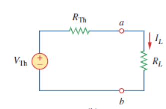
Op Amps:

Test Load Procedure:

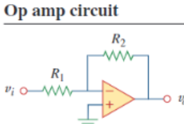
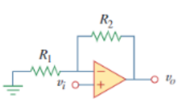
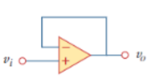
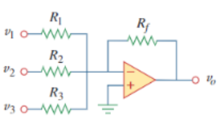
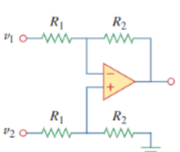
1. With the circuit *in-situ* and energized,
2. Measure the open-circuit voltage, obtain $V_{Th} = V_{OPEN}$.
3. Apply a reasonable load R_{LOAD} within range of the system specs **(NEVER A SHORT!)**
4. Measure the voltage, V_{LOAD}.
5. We can then find:

$$R_{Th} = -\frac{V_{OPEN} - V_{LOAD}}{I_{OPEN} - I_{LOAD}} = \frac{V_{OPEN} - V_{LOAD}}{I_{LOAD} - 0} = \frac{V_{OPEN} - V_{LOAD}}{V_{LOAD}/R_{LOAD}}$$





Closed-box system^

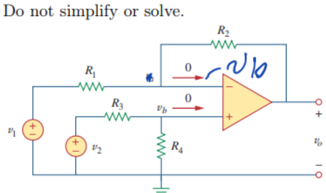
Op amp circuit	Name/output-input relationship
	Inverting amplifier $v_o = -\frac{R_2}{R_1}v_i$
	Noninverting amplifier $v_o = \left(1 + \frac{R_2}{R_1}\right)v_i$
	Voltage follower $v_o = v_i$
	Summer $v_o = -\left(\frac{R_f}{R_1}v_1 + \frac{R_f}{R_2}v_2 + \frac{R_f}{R_3}v_3\right)$
	Difference amplifier $v_o = \frac{R_2}{R_1}(v_2 - v_1)$

< Open-Box system

1. Replace *all independent sources with symbolic representations such as* V_{in} *or* I_{in}
2. Add a "test-load" resistor R_L across the specified terminals, $a - b$.
3. Use circuit analysis techniques to determine V_{a-b} in terms of V_{in} and R_L.
4. The result will be of the form: $V_{a-b} = \text{Input}_1 \cdot H_1 + \text{Input}_2 \cdot H_2$ with R_L in the expressions for the transfer functions.
5. Compute V_{a-b} as $R_L \to \infty$ to obtain $V_{Th} = V_{a-b}|_{R_L\to\infty} = \text{Input}_1 \cdot H_1^* + \text{Input}_2 \cdot H_2^*$.
6. If asked, find V_{Th} for specific values of V_{in} or I_{in}.
7. To find R_{Th}, select a second reasonable value for R_{LOAD}
8. Compute the voltage, $V_{LOAD} = V_{a-b}|_{R_L=R_{LOAD}}$.
9. Then find:

$$R_{Th} = \frac{V_{Th} - V_{LOAD}}{V_{LOAD}/R_{LOAD}}$$

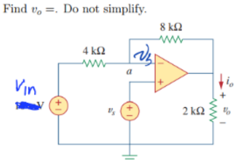
3. Write a node equation you would use to find v_o. Include any conveniently-labeled voltages. Do not simplify or solve.



$$\frac{(V_b - V_1)}{R_1} + \frac{(V_b - V_o)}{R_2} = 0$$

$$V_b = \frac{V_2 \cdot R_4}{R_3 + R_4}$$

4. Find v_o =. Do not simplify.



$$\frac{V_s - V_{in}}{4k} + \frac{V_s - V_o}{8k} = 0$$

$$V_o = V_s + \frac{(V_s - V_{in})}{4k} \cdot 8k$$

$$V_o = 3V_s - 2V_{in}$$

Transiate Responses: S-domain

$$v_{in}(t) \xleftrightarrow{\mathcal{L}} V_{in}(s) \longrightarrow \boxed{H(s)} \longrightarrow V_{in}(s) \cdot H(s) = V_{out}(s) \xleftrightarrow{\mathcal{L}} v_{out}(t)$$

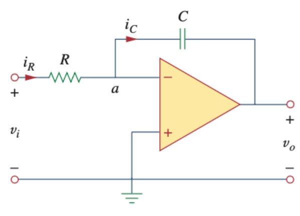
Figure 1: Transient Response Procedure for Zero-State Systems

Note: This is exactly the same procedure as for sinusoidal steady-state except we apply the s-domain input function to the transfer function $H(s)$!

1. Replace *all independent sources with symbolic representations such as* $V_{in}(s)$
2. Employ s-domain impedance models
3. Analyze the circuit using appropriate techniques to find the output: $V_{out}(s)$, or whatever output function is dictated by the problem
4. Find the transfer function: $H(s) = \frac{V_{out}(s)}{V_{in}(s)}$, or whatever input-output function is dictated by the problem
5. Find the output $V_{out}(s) = H(s) \cdot V_{in}(s)$, where $V_{in}(s) \xleftrightarrow{\mathcal{L}} v_{in}(t)$
6. Find the output $v_{out}(t) \xleftrightarrow{\mathcal{L}} V_{out}(s)$ using the inverse Laplace transform solver $v_{out}(t) = \text{ilaplace}(V_{out}(s))$
7. Plot $v_{out}(t)$ to observe the response of the system to that input

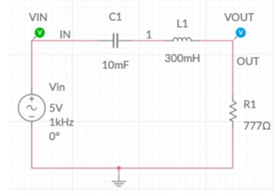
Misc

3. This circuit is a realization of (choose one): a) High-pass filter, $\boxed{\text{b) Low-pass filter,}}$ c) Band-pass filter.



more phasor/

1. Find the transfer function $H(s) = \frac{VOUT}{Vin}$. Do not simplify or compute.



$$H(s) = \frac{777}{777 + 300e^{-3}s + \frac{1}{10e^{-3}s}}$$

2. An analysis of a certain circuit yields transfer function $H(s) = \frac{vo}{Vin}$. If

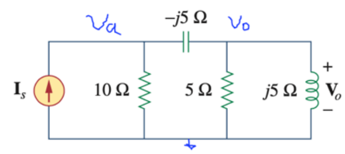
$Vin(t) = 20\cos(100t + 0.3)$

and

$H(j*100) = 0.6\angle 0.2$

Find vo(t) = $V_o(t) = 20 \cdot 0.6 \cos(100t + 0.3 + 0.2)$

4. Write a node equation at v_o. Do not write any other equations. Do not solve.



$$\frac{V_o}{5} + \frac{V_o}{j5} + \frac{(V_o - V_a)}{-j5} = 0$$

Sorry about the 5's.