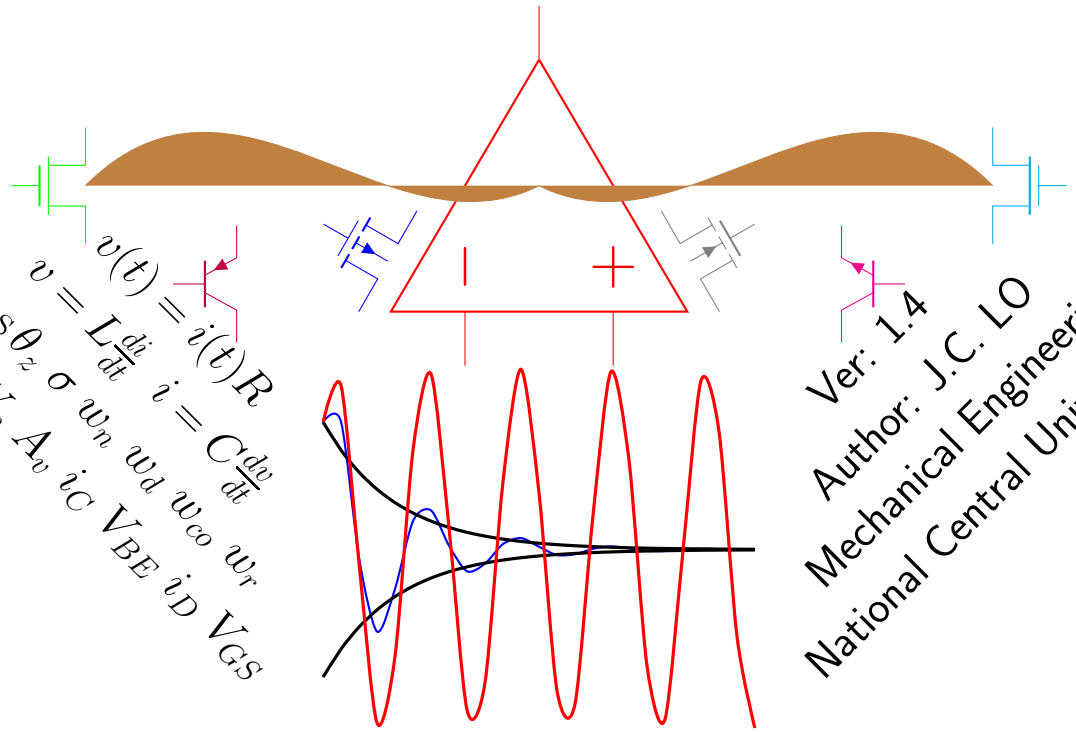
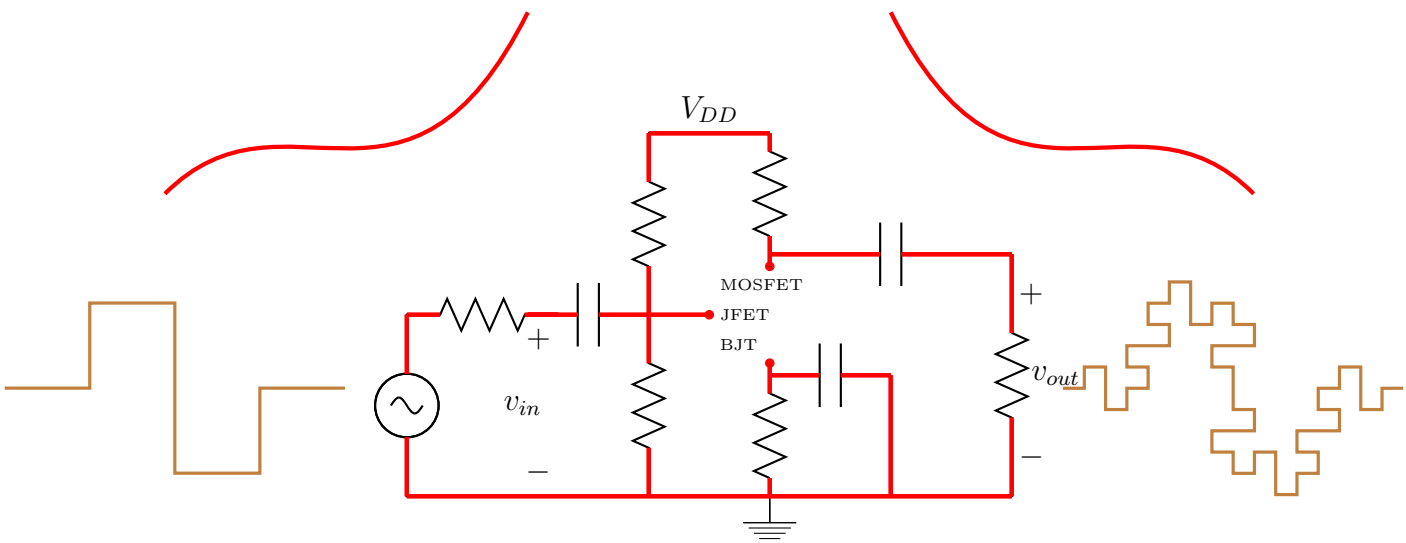


Ver: 1.4

Author: J.C. LO
Mechanical Engineering
National Central University, tw

eThinking in Circuits

with PSpice©



1 **Introduction**

2 **Circuit Laws**

3 **DC Circuits**

4 **AC Circuits**

5 **Transient Responses**

6 **Frequency Responses**

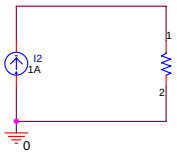
7 **Diodes**

8 **Operational Amplifiers**

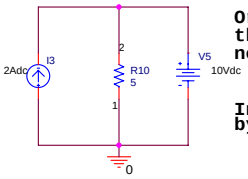
9 **Bipolar Transistors**

10 **Unipolar Transistors**

11 **PSpice Simulation Results**

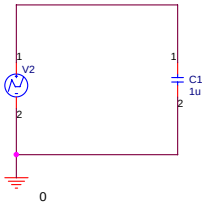


1. Construct the circuit on the left.
2. To verify Ohms' Law, open up the Simulation Settings and check DC Sweep/Primary Sweep, fill in the variable name I2, then Start value 0, End value 10, and increment 2 using linear scale.
3. Run the simulation by clicking the Big Blue Right Arrow.
4. When the probe window shows up, click Trace/Add Trace to find V1(R5) for output.
5. To find the numerical value of a particular point, click Trace/Cursor to get the cursor, move the cursor to the point you want, and click Plot/Label/Mark to add the numerical value on the graph.



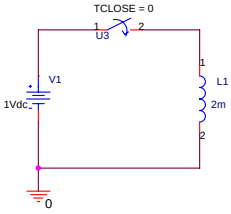
Or simply choose DC Bias Point analysis by editing Simulation Settings again. Then run the simulation. After that, click V and/or I to obtain the answer right away. But notice that this is valid only for one-time solution.

In the second example, there are two independent sources. You may explore the solution by using DC analysis again.



1. Construct the circuit on the left.
2. To verify Faradays' Law, open up the Simulation Settings and select Time Domain Transient analysis, set time period to 0.01ms.
3. Run the simulation.
4. When Probe window pops up, click Trace/Add Trace to select V1(V2) and I(C1), using comma to seperate them.

You may use the circuit above with C being replaced by L and voltage source replaced by IPWL, then verify the Henry's Law v=L di/dt. Or equivalently, check its intergral form as shown in the last circuit.



1. Construct the circuit on the left.
2. Open up the Simulation Settings, click Time Domain Transient and fill in Tstop=40ms.
3. Click the Blue Arrow.
4. When the Probe Window shows up, click Trace/Add Trace to add I(L1) and see the result.

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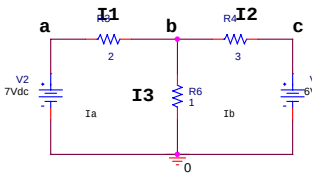
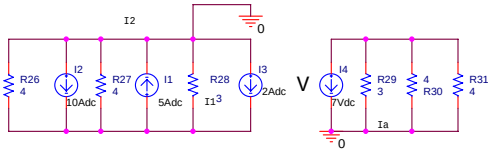
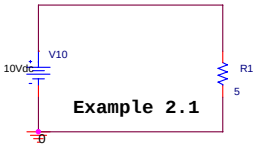
To solve DC circuits for current and voltage is to
1. Open up the Simulation Settings and select Bias Point analysis.
2. Run the simulation by clicking the Big Blue Arrow.
3. Once it is done, click V, I, W icons respectively to find solutions printed on the circuits.



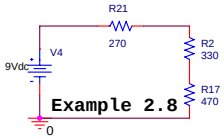
Example 2.5-2.7



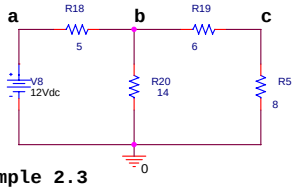
Example 2.13



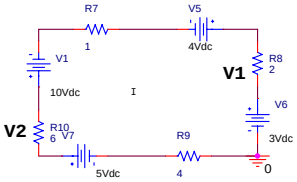
Example 2.1

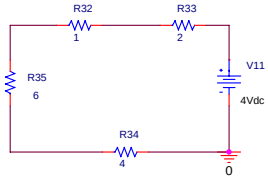


Example 2.8

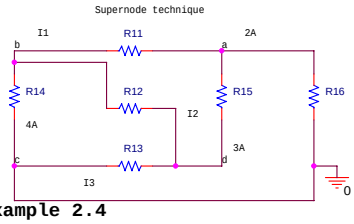


Example 2.3

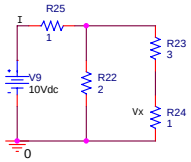




Example 2.10



Example 2.4



Example 2.12

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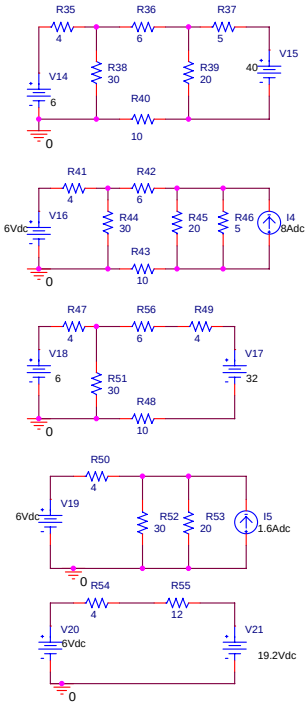
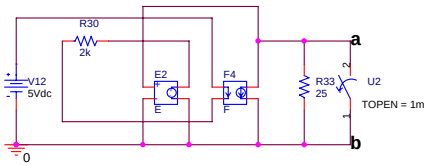
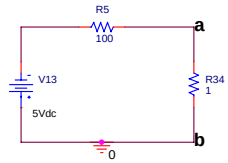
v-i Characteristics for Thevenin equivalent

1. **Construct the circuits below.**
2. **Open up the Simulation Settings, check the Time Domain Transient analysis, and set time period to 10ms.**
3. **Run the simulation. (it is noted that the switch yields short- and open-circuits)**
4. **Click Trace/Add Trace to select I(U?:2).for y-axis.**
5. **Since time domain t is the default x-axis, we need to change it. Click Plot/Axis Setting/Axis Variables to select x axis = V(U?:2). The slope is 1/R.**
6. **If one exahcnges x and y axis, then the slope is R.**

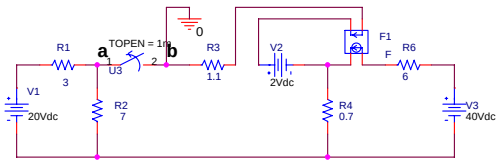


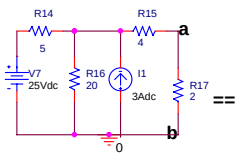
Example 3.2





Examples 3.5





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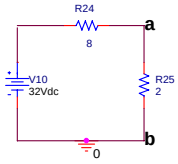
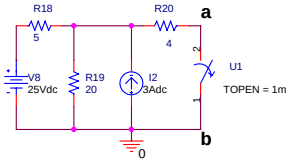


Examples 3.3-3.4



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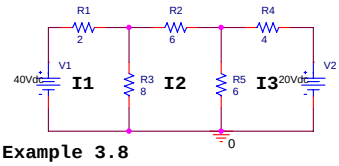
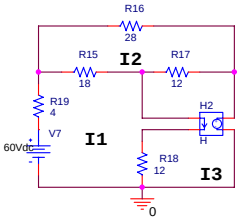
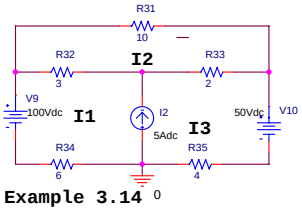
Loop-Current Approach
To find solutions for the the problems below is straightforward.
1. Open up Simulation Settings and choose Bias Point analysis.
2. Click the Big Blue Arrow to Run.
3. After simulation is complete, click V and I icon at the top of Capture menu.



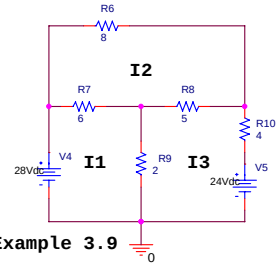
Example 3.8



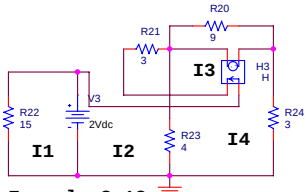
Example 3.11



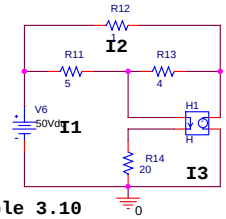
Example 3.14



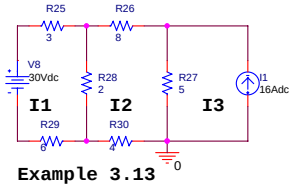
Example 3.9



Example 3.12



Example 3.10



Example 3.13

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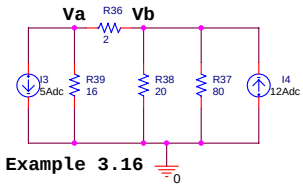
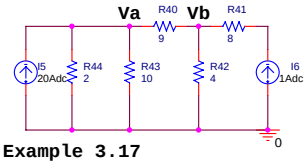
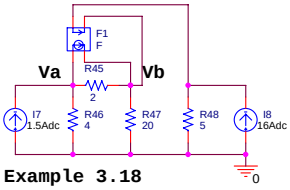
Node-Voltage Approach
To find solutions for the the problems below is straightforward.
1. Open up the Simulation Settings and choose Bias Point analysis.
2. Click the Big Blue Arrow to Run.
3. After simulation is complete, click V and I icon at the top of Capture menu.



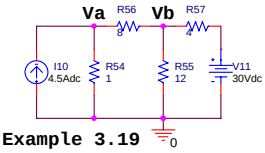
Example 3.16



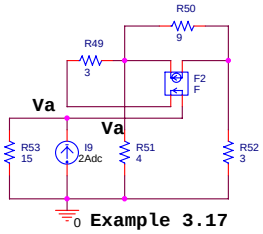
Example 3.17



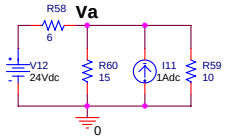
Example 3.18



Example 3.19



Example 3.17



Example 3.21

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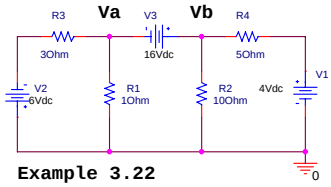
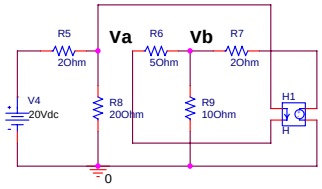
Node-Voltage Approach
To find solutions for the the problems below is straightforward.
1. Open up Simulation Settings and choose Bias Point analysis.
2. Click Run.
3. After simulation is complete, cick V and I icon at the top of Capture menu.

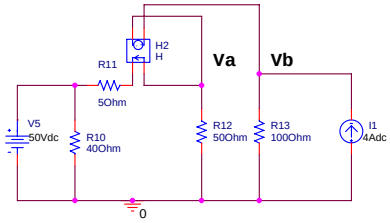
For supersition techniques
1. Basically this uses Bias Point analysis.
2. Replace on current source by an open circuit and replace an voltage source by an short circuit and leave only one active source to run.
3. Leave dependent sources alone.



Example 3.22

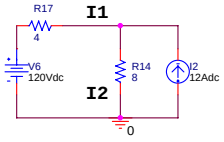


Example 3.23



Example 3.24

Superposition



Example 3.26

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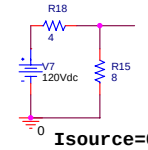

Isource=0

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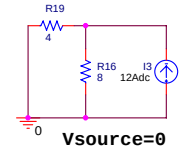
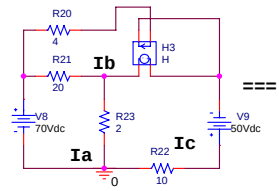


Vsource=0



Example 3.27

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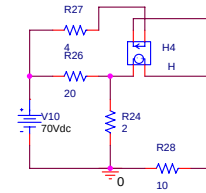

Vsource=0

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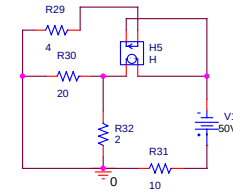

Vsource=0

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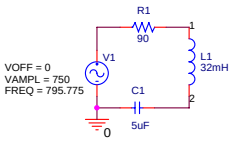
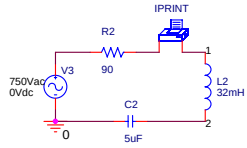
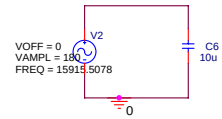


Example 4.3



Freq=5000/2pi=795.775

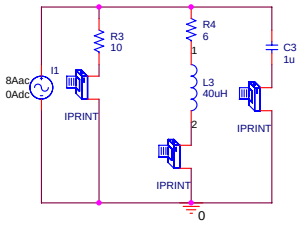


AC Power

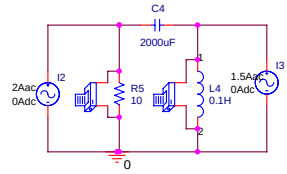
Real P=vi=180*180m/2=16.2W

Reactive P=vi=180*180*cos(-90/57.3)/2=0Var

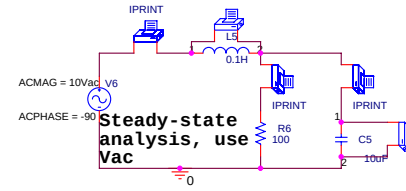
180cos(10^5t), R=1k, C=10u, L=10u



Example 4.4
Freq=200000/2pi=31831.015



Example 4.5
Freq=100/2pi=15.915



Steady-state analysis, use Vac

1. **To find transient response selects Vsin/Isin functions as sources.**
2. **draw the circuit.**
3. **Open up the Simulation Settings to select Time Domain Transient and fill in the time period.**
4. **Run the simulatiion.**
5. **When probe window appears, click Trace/Add Trace to add desired variables for plottings.**
5. **Actually, the steady-statee magnitude still can be found from the time trajectory.**

1. **To find steady-state response needs Vac/Iac functions**
2. **Select Simulation Settings/AC Sweep analysis and let Start = End frequency, using frequency in Hz, w=2\pi f, NOT in w.**
3. **Click PSpice/Markers/Advanced and select appropriate markers, connect them to the node.**
4. **Run the simulation.**
5. **Results will be shown on the probe window.**
6. **Another way is to place VPRINT2 and IPRINT in circuits and the outputs are saved in the output text fiile.**

Title: Steady-State Anlysis		
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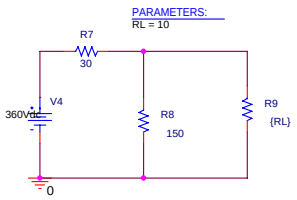

Maximum Power Transfer
1. Construct the circuit on the left.
2. Click R9 and fill in the value with {RL} (curly bracket is necessary)
3. Click Place Part/Special/PARAM and drag it to the place near R9.
4. Click the PARAMETERS to edit its property by adding a new column RL, insert a value except zero.
4. Click DC Sweep, check Global Parameter and give it a name RL, fill in (0:1:100) for sweeping range.
5. After Probe Window shows up, click Trace/Add Trace, select W(R9), to see the output vurve.

Title: Transient		
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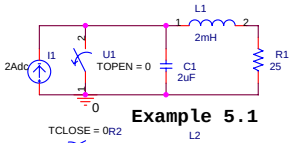
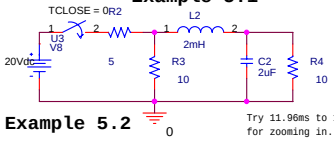
Tranisent simulation
1. Open up Simulation Settings and choose Time Domain Transient analysis.
2. Fill in the Stop time. (Some suggestions are given)
3. Click Run.
4. Clici Trace/Add Trace to select the variables of concern.
5 .Check if the time trajectory is what you expect.

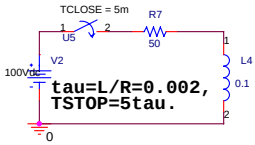


Example 5.1

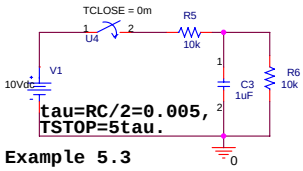


Example 5.2

Try 11.96ms to 12.06ms for zooming in.

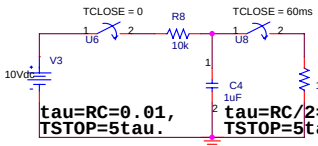


tau=L/R=0.002, TSTOP=5tau.



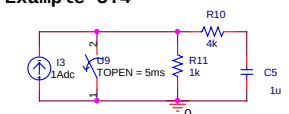
tau=RC/2=0.005, TSTOP=5tau.

Example 5.3



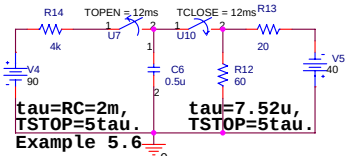
tau=RC=0.01, TSTOP=5tau. **tau=RC/2=0.005, TSTOP=5tau.**

Example 5.4



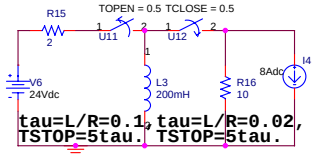
tau=(R1+R2)C=0.005, TSTOP=5tau.

Example 5.5



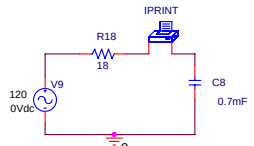
tau=RC=2m, TSTOP=5tau. **tau=7.52u, TSTOP=5tau.**

Example 5.6

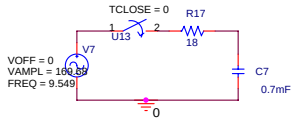


tau=L/R=0.1, TSTOP=5tau. **tau=L/R=0.02, TSTOP=5tau.**

Example 5.7



Steady-state selects Vac & AC sweep



tau=RC=0.0126,TSTOP=5tau. Noting cos should be changed to sin, adding 90 in phase.

Example 5.8

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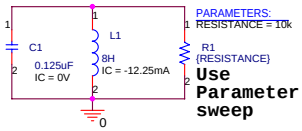
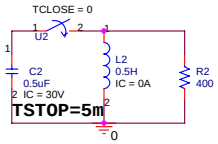
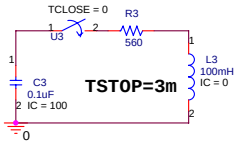


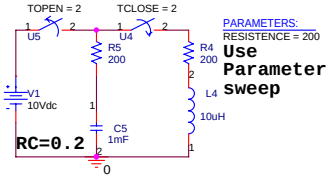
Examples 5.11-5.12



Example 5.13

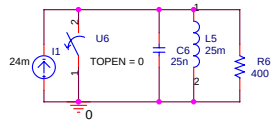


Example 5.14

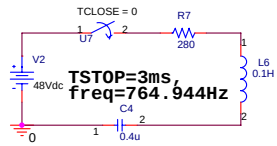


Example 5.15

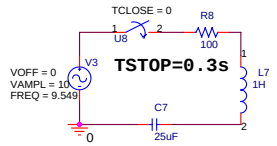
TSTOP=10. Also try 10uH for inductor whose charateristic equation is 10^-5s^2+400s+1000



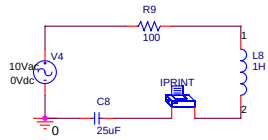
Example 5.16



Example 5.17



Example 5.18



Example 5.19

Tranisent simulation
1. Open up Simulation Settings and choose Time Domain Transient analysis.
2. Fill in the Stop time.
3. Click Run.
4. When Probe Window appears, click Trace/Add Trace to add variables of concerns to see the plot.

Parameter Sweep
1. Open up Simulation Settings and select Time Domain Transient/Parameter Sweep.
2. Fill in Parameter Name xxx. and select a Sweep type or key in a few values of interests in the List.
3. Go back to your circuit and click the element to name its value to be {xxx}
4. Click Run.
5. See the results.

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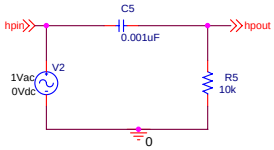
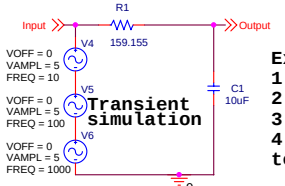


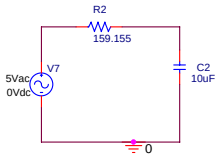
Example 6.2 -- Use VAC for frequency sweep
1. Construct the circuit on the left.
2. Click Simulation Settings, select Frequency Sweep, fill in (10:10:10E6).
3. When Probe Window appears, clcik Trace/Add Trace to add V(hpout) for linear scale or DB(V(hpout)) for log scale to generate the results.

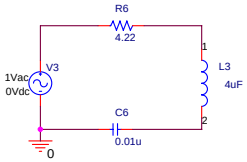


Example 6.3

Example 6.3
1. Construct the circuit on the left.
2. Open up Simulation Settings, select Time Domain Transient, fill in Stop time=100ms.
3. Run the Simulation.
4. When the Probe Window appears, click Trace/Add Trace to add V(output) and V(input) to see results, respectively.

For Bode Plot
1. Use VAC source.
2. Open up Simulation Settings, select AC Sweep and fill in frequency range (0.1:10:10E4).
3. When Probe Window appears, click Trace/Add Trace to add DB(V1(C2)) for log scale.





Example 6.4
1. Construct the circuit on the left.
2. Open up Simulation Settings, click AC Sweep, fill in (1K:10 10E6) and check log scale.
3. Run the Simulations.
4. When the Prob Windeow appears, click Trace/Add Trace to add DB(I(L3))
Freq=796159Hz<=>5002410rad/sec=w

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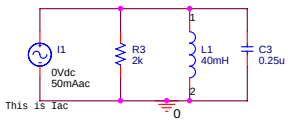
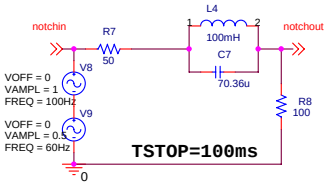
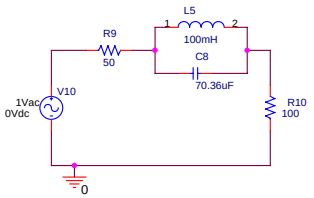


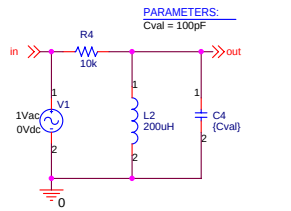
Example 6.6 -- Use IAC for frequency sweep
1. Construct the circuit on the left.
2. Click Simulation Settings, select Frequency Sweep, fill in (100:10:100K).
3. When Probe Window appears, clcik Trace/Add Trace to add I(R3) for linear scale or DB(I(R3)) for log scale to generate the results.



Example 6.7 Notch Filter
1. Construct the circuit on the left.
2. Open up Simulation Settings, select Time Domain Transient, fill in Stop time=100ms.
3. Run the Simulation.
4. When the Probe Window appears, click Trace/Add Trace to add V(notchout) and V(notchin)-V9 to see results, respectively.



For Bode Plot
1. Use VAC source.
2. Open up Simulation Settings, select AC Sweep and fill in frequency range (10:10:100).
3. When Probe Window appears, click Trace/Add Trace to add DB(V1(R10)) for log scale.



Example 6.9
1. Construct the circuit on the left.
2. Click C4 and fill in the value with {Cval} (the curly bracket is necessary)
3. Click Place Part/Special/PARAM and drag it to the place near C4.
4. Click the PARAMETERS to edit its property by adding a new column Cval, insert a value except zero.
5. Click dual AC Sweep, set (300K:10:3M) for primary, check Global Parameter and give it a name Cval, key in (100p, 200p, 300p) for Value list.
6. After Probe Window shows up, click Trace/Add Trace, select V(out), to see the output curve.

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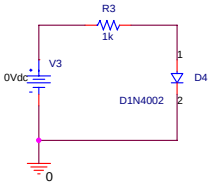
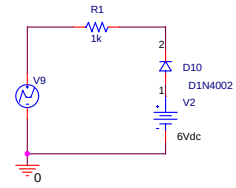
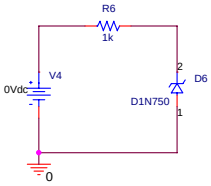


1. Construct the circuit diagram on the left.
2. Open up the Simiulation Settings by selecting DC Sweep where a dialog box will show up. Fill in sweep variable name V3 and sweep type (linear, start value -10, end value 2 and increments 0.1)
3. Run the simulation by clicking the blue solid right arrow.
4. After a blank graphic probe window appears, click Trace\Add Trace to add trace I(D4) for y-axis. Since the x-axis should be V(D4), we click Plot\Axis Settings to open up a dialog box and click axis variables to find V(D4:1).



1. Construct the circuit on the left.
2. Use Transient analysis. Set final time to10ms.
3. Run the simulation by clcking the big right arrow on the menu.
4. Click Trace\Add Trace to add input and output signals, V1(V9) and V2(D10)), respectively.
5. To find the transfer function, change x-axis in time to V1(V9).



1. Construct the circuit diagram on the left.
2. Edit simiulation settings by selecting DC sweep where a dialog box will show up. Fill in Sweep Variable name V4 and Sweep Type (linear, start value 0, end value 20 and increments 0.1)
3. Run the simulation by clicking the blue solid right arrow.
4. After a blank graphic probe window appears, click Trace\Add Trace to add trace -I(D6) for y-axis. Since the x-axis should be V(D6), we click Plot\Axis Settings to open up a dialog box and click axis variables to find V(D6:2).
5. Draw a load line by clicking Plot\Label\Line and then draw the line from y-axis to x-axis or vice versa.

6. Find cursor from Trace\Cursur and click the intersection Q-point. Once this is done, go back to Plot\Label\Mark to insert the numerical value of the load line.

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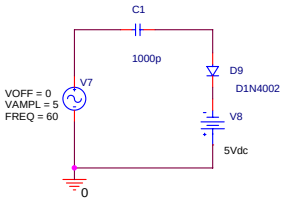
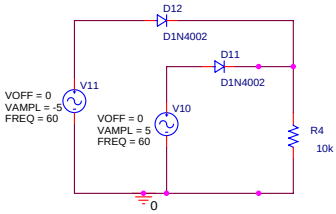
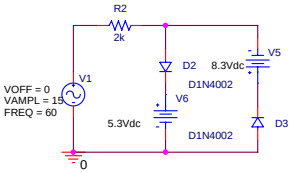


1. Construct the circuit on the left.
2. Use Transient analysis. Set final time to 33.33m.
3. Run the simulation by clcking the big right arrow on the menu.
4. Click Trace\Add Trace to add input and output signals, V1(V7) and V1(D9), respectively.



1. Construct the circuit on the left.
2. Use Transient analysis. Set final time to 33.33m.
3. Run the simulation by clcking the big right arrow on the menu.
4. Click Trace\Add Trace to add input and output signals, V1(R4).
5. Add one smoothing capacitor in parallel with the load.



1. Use Transient analysis. Set final time to 33.33m.
2. Run simulation by clcking the big right arrow on the menu bar.
3. Click Trace/Add Trace to find V1(V1) and V1(D2)+V1(V6) respectively.
4. To find the transfer function Vout/Vin, clcik Plot/Add Plot to Window to generate a new blank plot and then Plot/Plot Settings/Axis Variables V1(V1) as x-axis and Add/Add Trace V1(D2)+V(V6) as y axis.

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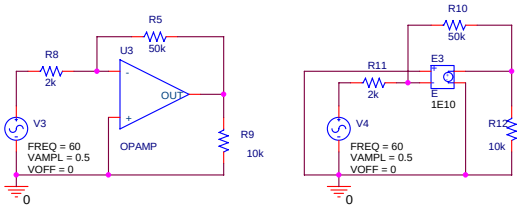
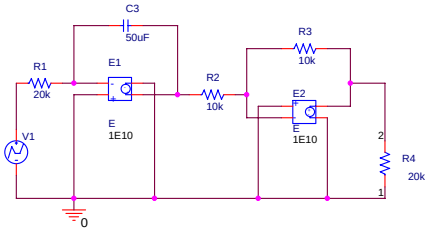
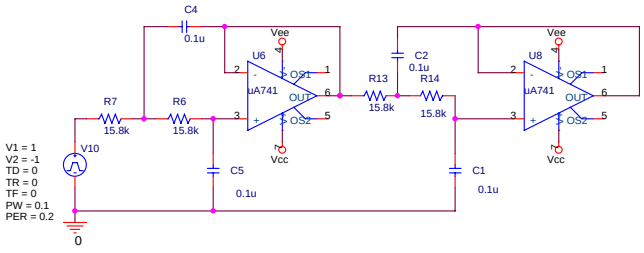


1. Construct the circuit on the left.
2. Open up the Simulation Settings and select the Traisnent analysis, setting simulation time period to 33.33ms.
3. Run the simulation.
4. Click Trace/Add Trace to add V1(R9) and V1(R12) to see identical plot, meaning VCVS = op-amp.
5. Click Trace/Cursor/Displace to find cursor and then click Plot/Label/mark to insert numerical values.



1. Construct the circuit on the left.
2. To verify integration, open up the Simulation Settings and select Time Domain Transient analysis, set time period to 4s. where pulse function of 4 second is given by VPWL.
3. Run the simulation.
4. When Probe window pops up, click Trace/Add Trace to select V1(V1) and V2(R2), using comma to seperate them.



To obtain Frequency response, use VAC
1. Construct the circuit on the left.
2. Open up Simulation Settings, click AC Sweep, fill in (1k:10:10K).
3. Click the Big Right Arrow to run the simulation.
4. When the Probe Window appears, click Trace/Add Trace to add V(U6out) and V(u8out) to see the Bode plot.

To find transient response, use VPULSE
2. Open up Simulation Settings, click AC Sweep, fill in (1k:10:10K).
3. Click the Big Right Arrow to run the simulation.
4. When the Probe Window appears, click Trace/Add Trace to add V(U6out) and V(U8out) to see the Bode plot.

VCC_CIRCLE can be found at GNG/CAPSYM

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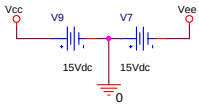
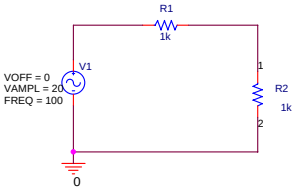
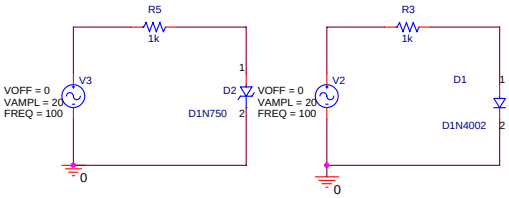




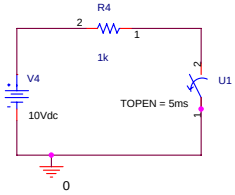
Linear element --- V-I characteristics

1. Construct the circuit on the left.
2. Open up the Simulation Settings, check the Time Domain Transient analysis, and set time period to 10ms.
3. Run the simulation.
4. Click Trace/Add Trace to select I(R2:1). A sine wave is shown.
5. Since time domain t is the default x-axis, we need to change it. Click Plot/Axis Setting/Axis Variables to select x axis =V(R2:1).



Nolinear element --- v-i characteristics

1. Construct the circuit on the left.
2. Open up the Simulation Settings, check the Time Domain Transient analysis, and set time period to 10ms.
3. Run the simulation.
4. Click Trace/Add Trace to select I(D1:1)
5. Since time domain t is the default x-axis, we need to change it. Click Plot/Axis Setting/Axis Variables to select x axis =V(D1:1).
5. Change D to D2, Zener v-i property is obtained.



v-i Characteristics for Thevenin equivalent

1. Construct the circuit on the left.
2. Open up the Simulation Settings, check the Time Domain Transient analysis, and set time period to 10ms.
3. Run the simulation. (it is noted that the switch yields short- and open-circuits)
4. Click Trace/Add Trace to select I(U1:2).
5. Since time domain t is the default x-axis, we need to change it. Click Plot/Axis Setting/Axis Variables to select x axis = V(U1:2).

Title: BJT		
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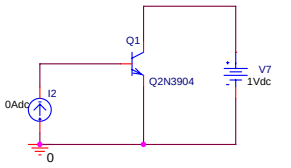
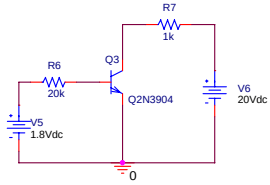
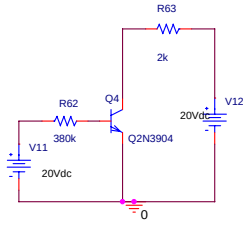


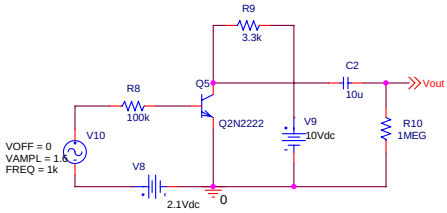
1. To find input characteristic Ib-Vbe, use DC sweep analysis by open up the Simulation Settings and select primary for current source I2(=Ib) using (0:10u:150u).
2. Run the simulation.
3. Click Trace/Add Trace to find IB(Q1) for y-axis.
4. Click Plot/Axis Settings/Axis Variable to find V(Q1:b) - V(Q1:e) for x-axis.
5. To find output characteristic Ic-Vce, use dual DC sweep where primary sweep is V7(=Vce) using (0:0.01:10) and the second sweep is I2(=Ib) using (0:10u:50u).
6. Click Trace/Add Trace to find IC(Q1) for y-axis.
7. Click Plot/Axis Settings/Axis Variable to find V1(V7) for x-axis.



To find input characteristic Ib-Vbe, use DC sweep on v5 (0:0.01:10)
To find output characteristic Ic-Vce, use dual DC sweep on v6 (0:0.1:10) and V5 (0:0.2:2)



To find Q point, simply run bias point analysis and click V and I button.



Title: BJT		
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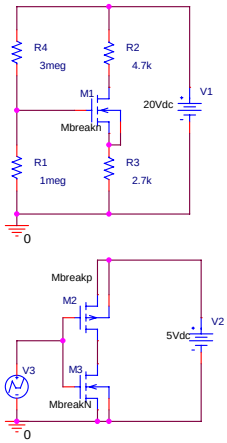

To verify input characteristic:
1. Click Place Part/Breakout/Mbreakn or Mbreakp, drag it to the place you favor. Click the Mbreakn once and from top menu, choose Edit/Model to add/copy the following
.MODEL Mbreakn NMOS (KP = 50E-6,Vto=2,lambda=0.01)
.MODEL Mbreakp PMOS (KP = 20E-6,Vto=-2,lambda=0.01)
to the model editor and then save it.
2. Click twice to edit NMOS, fill in W and L values.
3. Open up the Simulation Settings and select the Primary DC Sweep for V1 (1:1:5).
4. Run the Simulation by click the Big Blue Arrow.
5. When the probe window appears, click Trace/Add Trace and select ID(M1) for y-axis. Click Plot/Axis Setting/Axis Variables and select V(M1,g)-V(M1,s).
6. Click Plot/Label/Line to draw the load line. When drawing, change range of x- and y-axis if necessary.

To verify output characteristic:
1. Open up the Simulation Settings and use DC Dual Sweep. Let Primary Sweep be V2 (1:1:30) and secondarysweep be V1 (1:1:5).
2. Run the simulation.
3. When the probe window appears, click Trace/Add Traceand select ID(M1) for y-axis. Click Plot/AxisSetting/Axis Variables and select V(M1,d)-V(M1,s).
4. Click Plot/Label/Line to draw the load line. When drawing, change range of x- and y-axis if necessary.

DC Bias Point analysis
1. The easist way is to use Bias Point and then click the icons V and I to find Q point.

CMOS Inverter Gate
1. Construct the circuit on the left.
2. Open up Simulation Setting and choose Time Domain Transient analysis for 5 sec.
3. Run the simulation by clicking the big blue arrow.
4. After the probe window appears, click Trace/Add Trace to select V1(V3) and V(M2:d) for outputs.
5. Adjust range of y-axis for better presentation.

Title: MOSFET		
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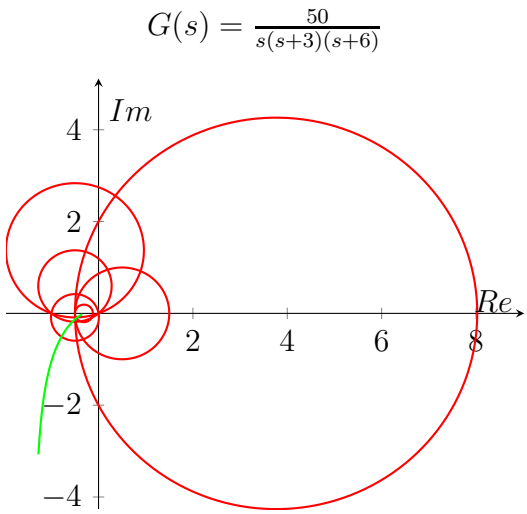

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