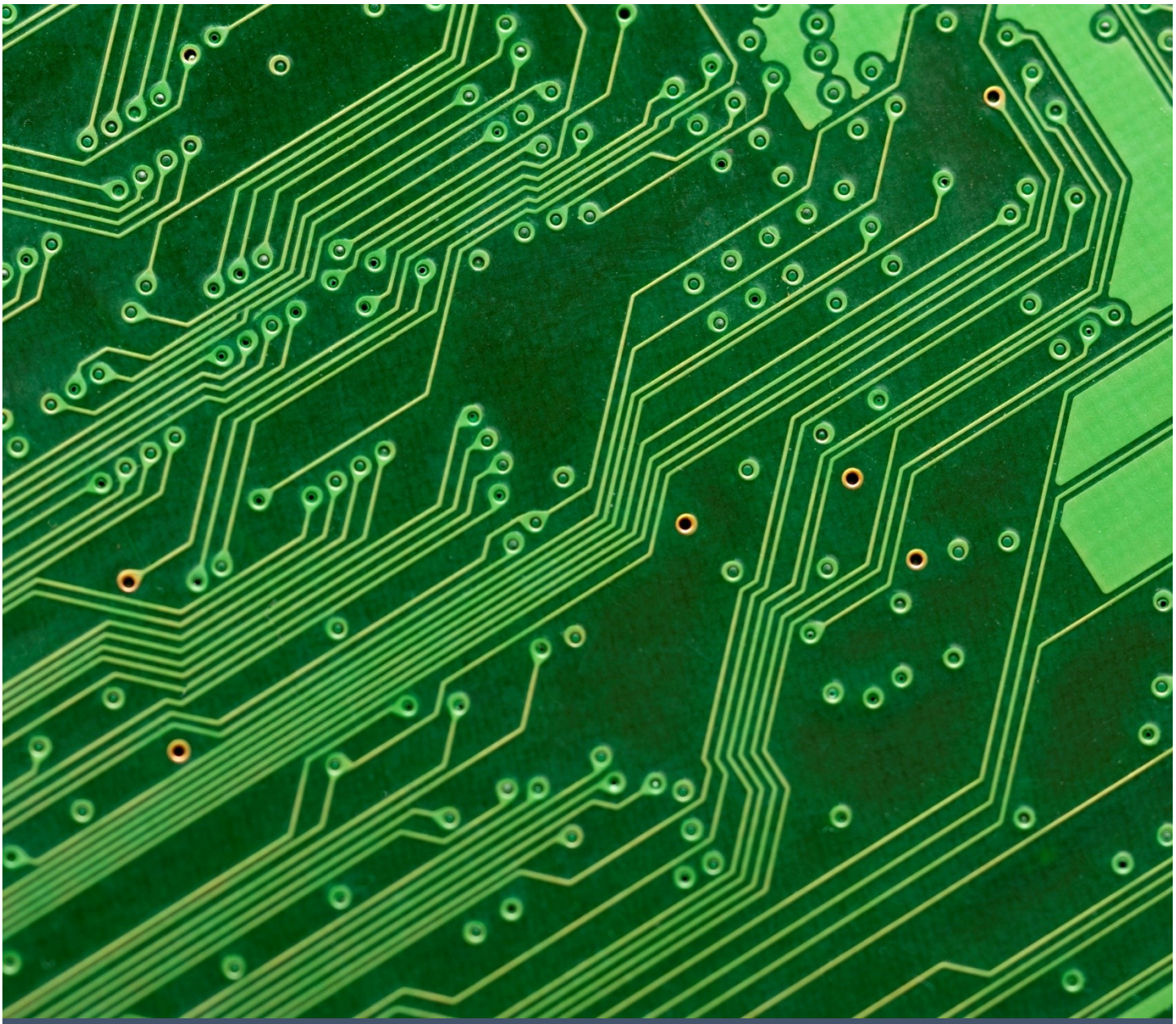

Free SPICE Software

Usability Test: LTspice Vs. QUCS

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ENGL 317

Table of Contents

Introduction

Two free SPICE (Simulation Program with Integrated Circuit Emphasis) based electrical circuit simulators are LTspice and QUCS (Quite Universal Circuit Simulator). This white paper presents the results of a usability test that compared how well the tools performed, targeting a novice SPICE user with a strong circuits background.

Methodology

Tasks

All tasks will be performed with both programs.

1. Create a new schematic with an AC voltage source (12 V, 60 Hz), resistor (1 kΩ), inductor (1 mH) and capacitor (1 µF).
2. Label every node; make the positive inductor node an output.
3. Run a transient simulation showing the voltage at each node and current through the circuit over 0.5 seconds.
4. Run an AC analysis from 1 Hz to 1000 Hz, 100 points per decade. Plot the inductor voltage.
5. Insert a transistor (basic NMOS model) in the circuit. Use a 5 V square wave as the gate voltage to switch the current on and off at 4 Hz.
6. Subtract two waveforms – plot the capacitor voltage from task 3 (transient simulation).
7. Plot the power consumed by the capacitor.
8. Add a SPICE directive statement – set initial inductor current to 1 mA and plot current over time.
9. Label all nodes.
10. Export a graph and the schematic as an attractive and readable image.

Test Environment

The 3/15/19 update of LTspice XVII and version 0.0.19 of QUCS were tested on a Windows 10 laptop, using the built in keyboard and trackpad. The tester already was familiar with LTspice and was new to QUCS but attempted to be nonbiased, as if he were new to both.

No real circuits were available to verify the output of the simulations. It is assumed that the user will only use Google to figure out how to complete a task as a last resort. The tests were done at a desk in a quiet room at the tester’s home. Mousotron was used to measure how long each task took in each program and count the numbers of keystrokes and clicks.

Rating Scale

Each task will be rated on a Likert Scale for each of the criteria below:

1. Effective: The task was completed.
2. Efficient: The task was completed quickly with reasonably few clicks and keystrokes.

3. Engaging: The design of the interface made completing the task a pleasant experience.
4. Error tolerant: There were no failed attempts to complete the tasks. The program warned of mistakes in advance.
5. Easy to learn: It was simple to learn how to complete the task.

Strongly Disagree	Somewhat Disagree	Neutral	Somewhat Agree	Strongly Agree
1	2	3	4	5

Additional notes will be made as necessary.

Results

Task 1

Task 1 was creating a new schematic and creating a series circuit with an AC voltage source, resistor, capacitor and inductor. Both QUCS (Fig. 2) and LTspice (Fig. 1) let me complete this. It took slightly less time in LTspice, but required more total keystrokes and clicks, and the interface was much less intuitive. A new user likely would have needed to Google how to insert a voltage source.

Criteria	**LTspice**	**QUCS**
Effective	5	5
Efficient	4	4
Engaging	2	4
Error Tolerant	3	3
Easy to Learn	3	4
Total	17	20

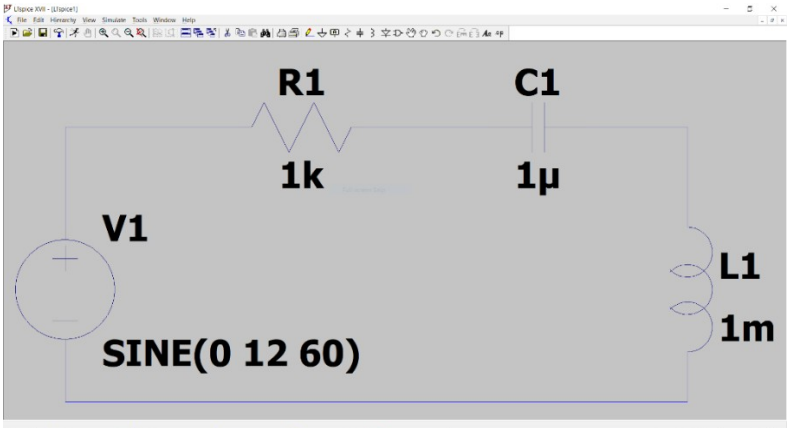


Figure 1: LTspice Schematic

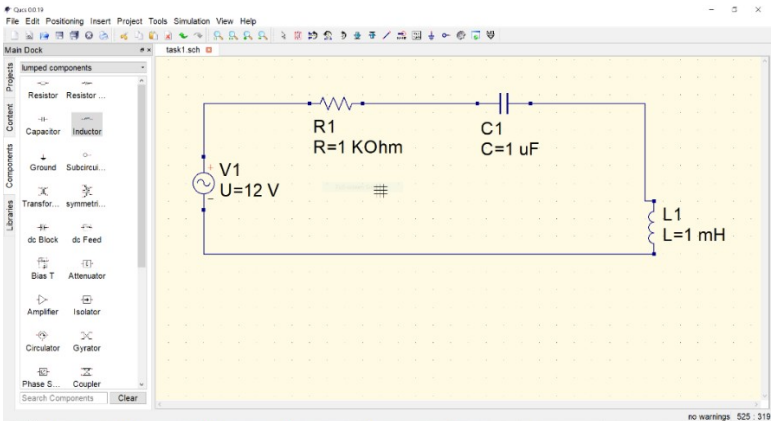


Figure 2: QUCS Schematic

In LTspice, I made a few errors drawing wires, and undo is F9 instead of ctrl+z so I had to use the menu. The voltage source is not in an obvious location. Once it is found, the properties (Fig. 3) are a little overwhelming. Properties are opened by a double click, instead of right click. I forgot to put in a ground – I repeated this in QUCS. The programs should catch this error in later steps.

In QUCS, I did not have to create a new schematic – it opened with one. It was easier to find voltage sources and other elements with menu on the left side (see Fig. 2). It is easier to change values without opening an options window by just clicking the text on the schematic. Properties are opened by double click. Wire drawing is slightly more intelligent than in LTspice. The wires snap into position with fewer clicks, but this is a minor concern. As usual, ctrl+z is undo. The relatively simple voltage source properties dialog is shown in Fig. 4.

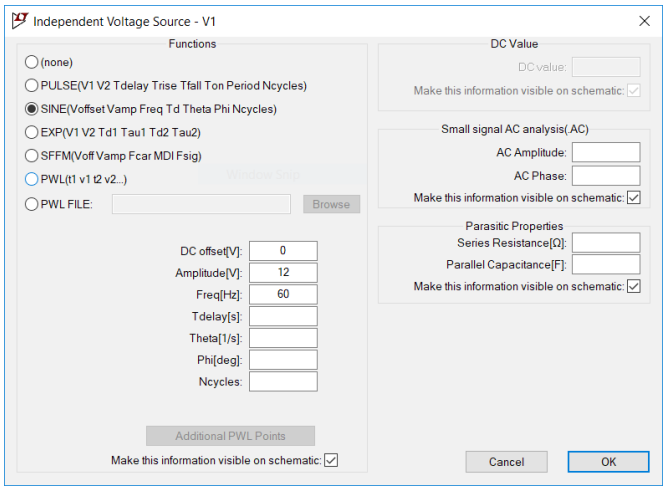


Figure 3: LTspice add voltage dialog

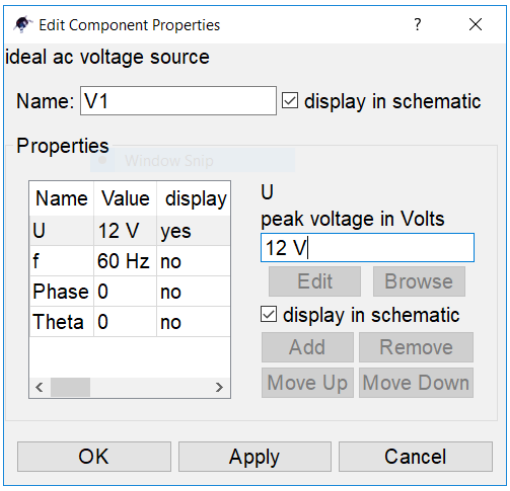


Figure 4: QUCS add voltage dialog

Overall, creating the schematic in QUCS is more straightforward for a new user.

Task 2

Task 2 was to label every node, specifying node 3 (above the inductor) as an output.

Criteria	LTspice	QUCS
Effective	5	5
Efficient	4	4
Engaging	3	2
Error Tolerant	2	2
Easy to Learn	5	3
Total	19	16

In LTspice, this was straightforward. I selected “label nets” in the menu, then entered the net name. Doing this every time was inconvenient (having to go back into the menu for each new name). Within the right click dialog, I could set node 3 to be an output. All of this is shown in Fig. 5. There is an annoying issue where dragging toward the edge of the visible schematic makes it quickly scroll away – but that is occasionally convenient. There were no warnings when I had all the nodes labeled the same, which should be a major problem.

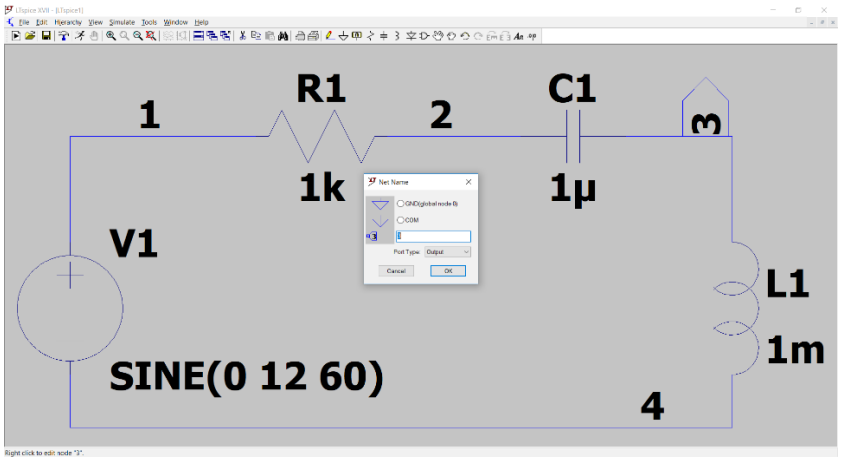


Figure 5: LTspice with labeled nets and dialog

QUCS would not accept numbers for net names and did not give a warning or explanation, the numbers just did not show up, so I used a-d instead of 1-4. The label tool itself was in a similar place as LTSpice. Every click made a dialog pop up to name the net which is a lot more convenient than LTspice. All of that is shown in Fig. 6. Fig. 7 shows the separate tool that is used to set the output. I created a port, and then changed the settings to make it an output. This was rather less clear than LTspice.

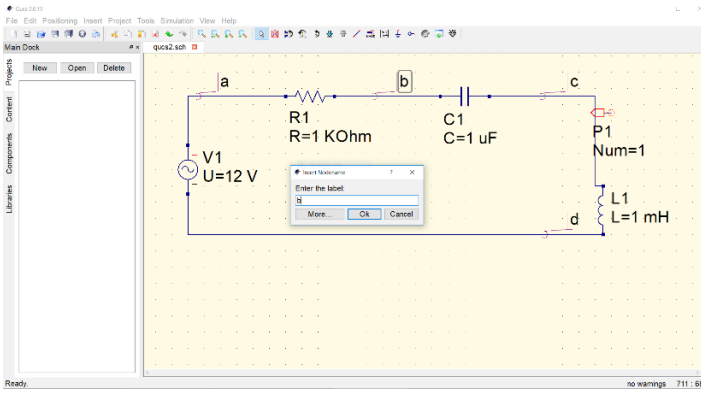


Figure 6: QUCS with labeled nets and dialog

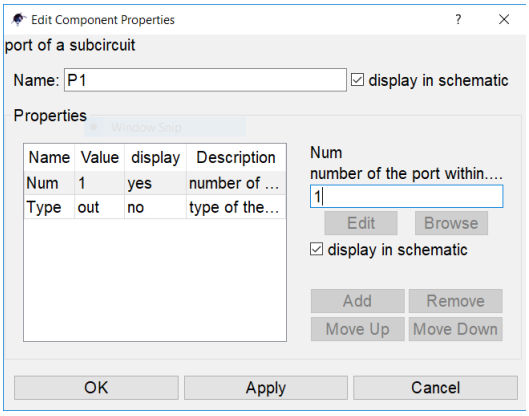


Figure 7: QUCS port dialog

Because of the requirement to use multiple tools and the relatively complicated interface in QUCS, LTspice is overall the better option.

Task 3

Task 3 was to show all the outputs of a transient simulation.

Criteria	LTspice	QUCS
Effective	5	5
Efficient	5	4
Engaging	5	2
Error Tolerant	4	2
Easy to Learn	4	3
Total	23	16

LTspice makes simulations and plotting very easy once the user learns the method. Setting up the simulation was simple – there is a button in the menu bar. A warning popped up about the missing ground, so I added one. The simulation command is added to the schematic, and the setup dialog is shown in Fig. 8. The plot is blank at first which may confuse users, but adding voltages is as simple as clicking on nodes, and currents is as simple as clicking on components. The only issue is that the default blue on black is hard to see. The schematic remains in view, and the plot appears above, as shown in Fig. 9.

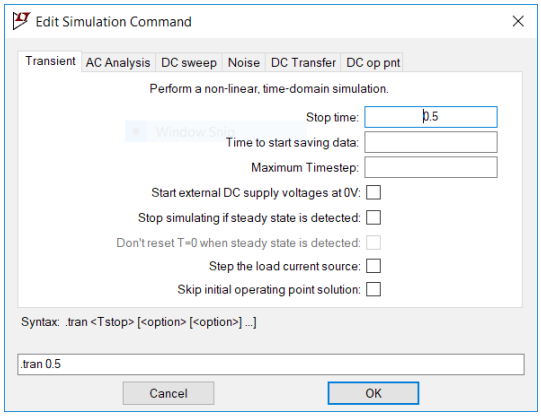


Figure 8: LTspice simulation dialog

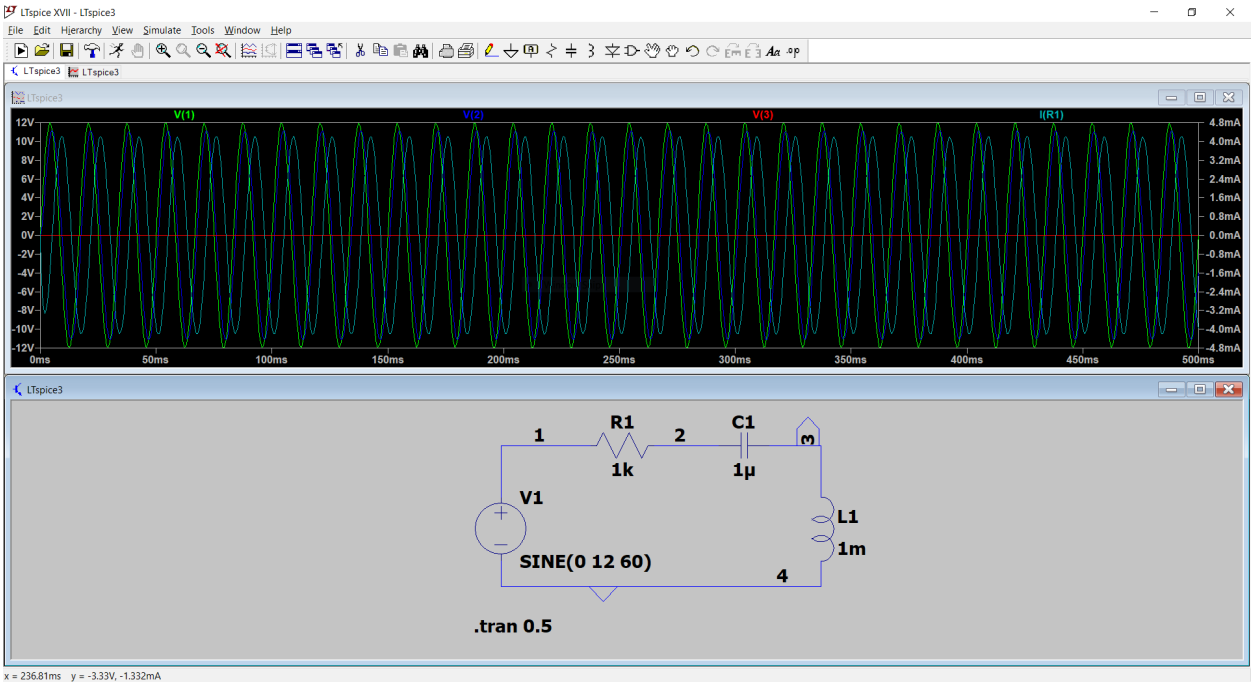
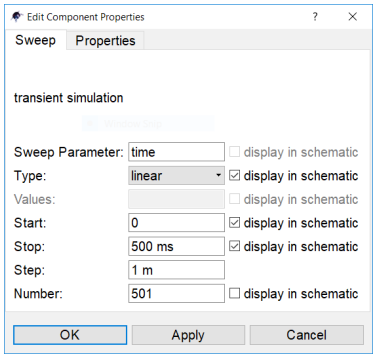
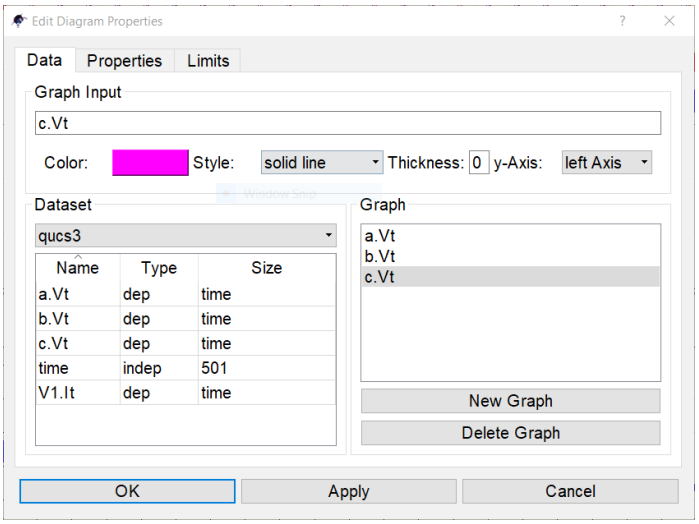


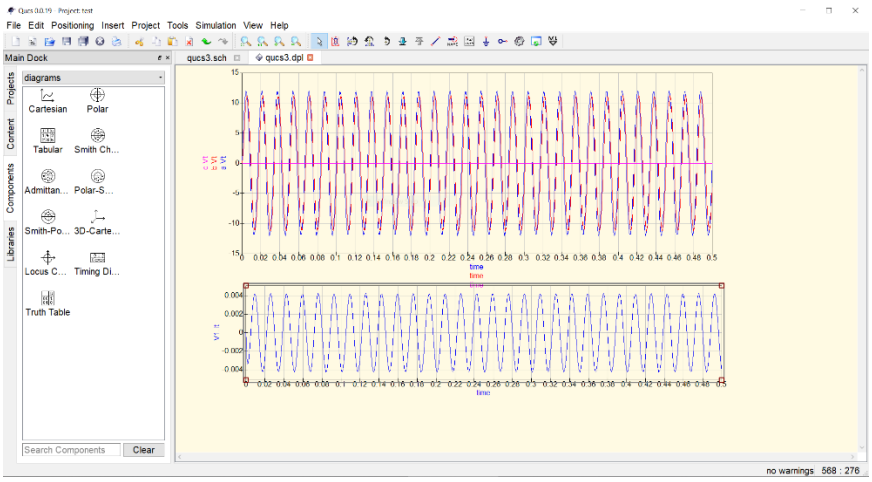
Figure 9: LTspice window with schematic and plot

QUCS handles simulation set up differently. The simulation button was in an obvious location but it was not clear how to set up a simulation. Finally I figured out it was in



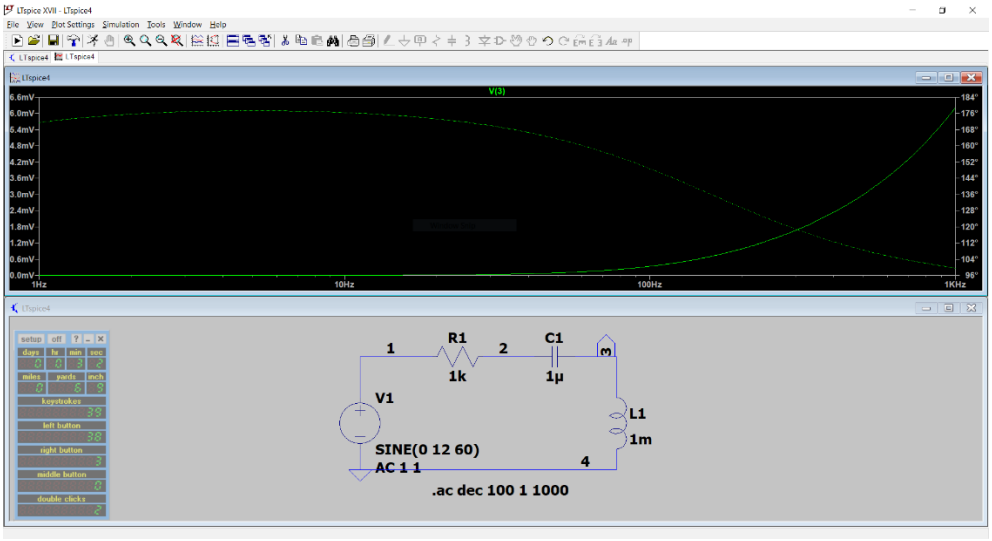
the side menu and had to be added as an object. This does make sense, so I did not dock many points for that. The setup dialog is shown in Fig. 10. What is more frustrating is that plots must be also individually added. Then there was an error in the simulation. I had to look around and ended up using Google. I had simply used a capital KOhm instead of kOhm, but QUCS gave no warning. After fixing that, the simulation ran, but got stuck – it had not warned me about the ground I forgot in Task 1. The simulation worked after putting that in, but inserting a plot must be done on a different worksheet in another tab, and is done through the dialog shown in Fig. 11.

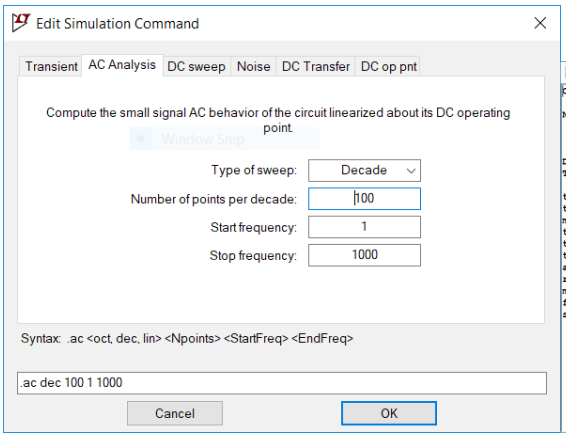


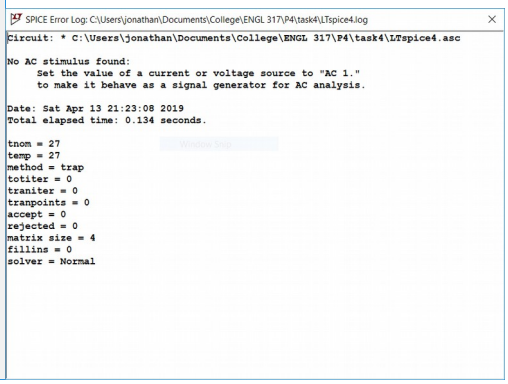


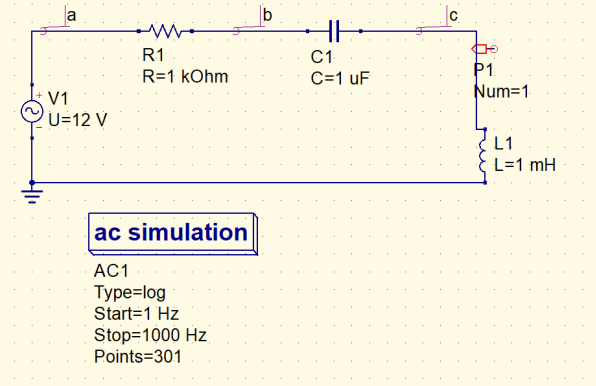
LTspice makes simulating and plotting very straightforward once the user knows where the buttons are and is the clear winner for this taks.

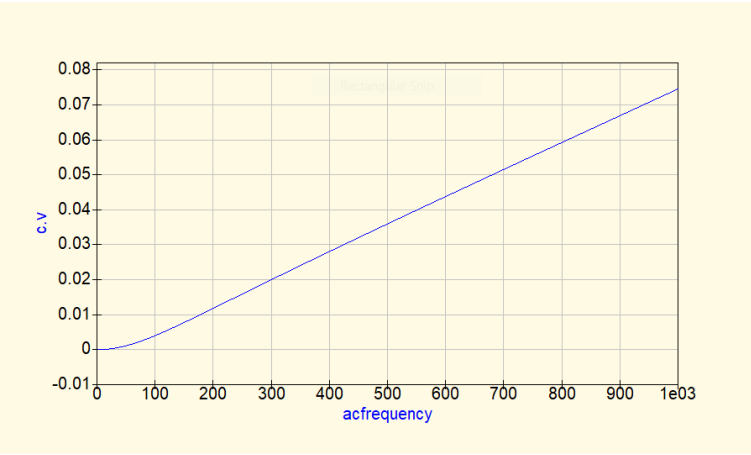
Task 4

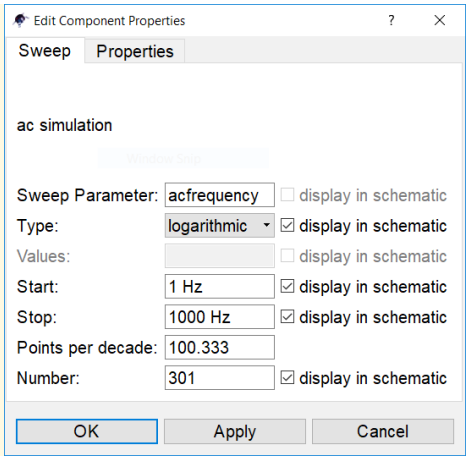

LTspice XVII - LTspice4
File View Plot Settings Simulation Tools Window Help
V(3)
6.6mV
6.0mV
5.4mV
4.8mV
4.2mV
3.6mV
3.0mV
2.4mV
1.8mV
1.2mV
0.6mV
0.0mV
184°
176°
168°
160°
152°
144°
136°
128°
120°
112°
104°
96°
1Hz
10Hz
100Hz
1KHz
R1
C1
1
2
1k
1µ
V1
L1
1m
SINE(0 12 60)
AC 1 1
4
.ac dec 100 1 1000


Edit Simulation Command
Transient
AC Analysis
DC sweep
Noise
DC Transfer
DC op pnt
Compute the small signal AC behavior of the circuit linearized about its DC operating point.
Type of sweep:
Decade
Number of points per decade:
100
Start frequency:
1
Stop frequency:
1000
Syntax: .ac <oct, dec, lin> <Npoints> <StartFreq> <EndFreq>
.ac dec 100 1 1000
Cancel
OK

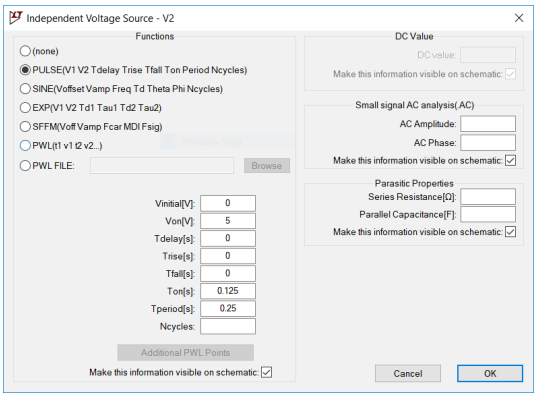

SPICE Error Log: C:\Users\jonathan\Documents\College\ENGL 317\P4\task4\LTspice4.log
Circuit: * C:\Users\jonathan\Documents\College\ENGL 317\P4\task4\LTspice4.asc
No AC stimulus found:
Set the value of a current or voltage source to "AC 1."
to make it behave as a signal generator for AC analysis.
Date: Sat Apr 13 21:23:08 2019
Total elapsed time: 0.134 seconds.
tnom = 27
temp = 27
method = trap
totiter = 0
traniter = 0
tranpoints = 0
accept = 0
rejected = 0
matrix size = 4
fillins = 0
solver = Normal

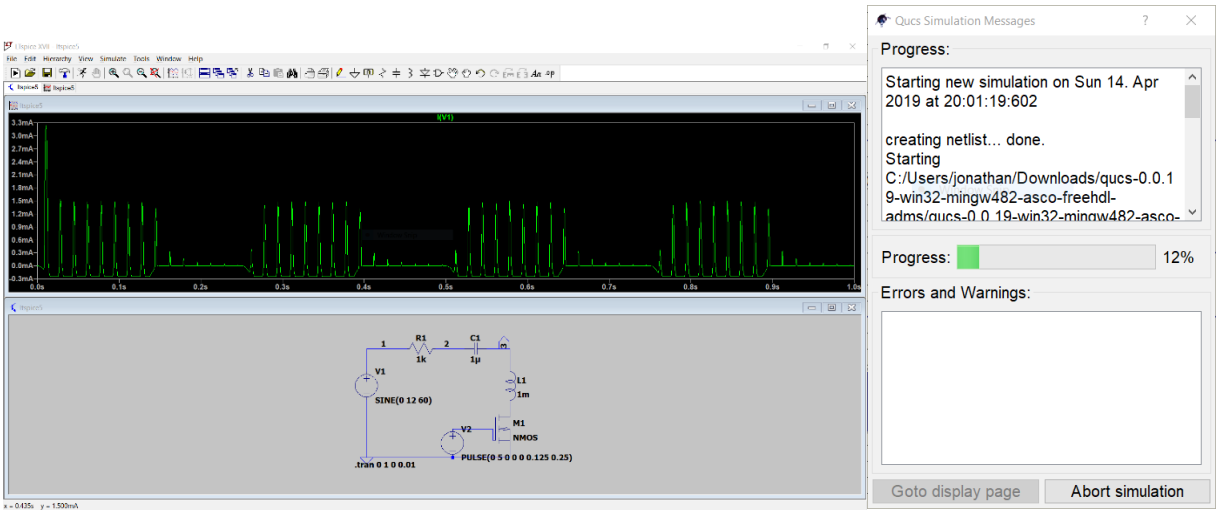

a
b
c
R1
R=1 kOhm
C1
C=1 uF
P1
Num=1
V1
U=12 V
L1
L=1 mH
ac simulation
AC1
Type=log
Start=1 Hz
Stop=1000 Hz
Points=301

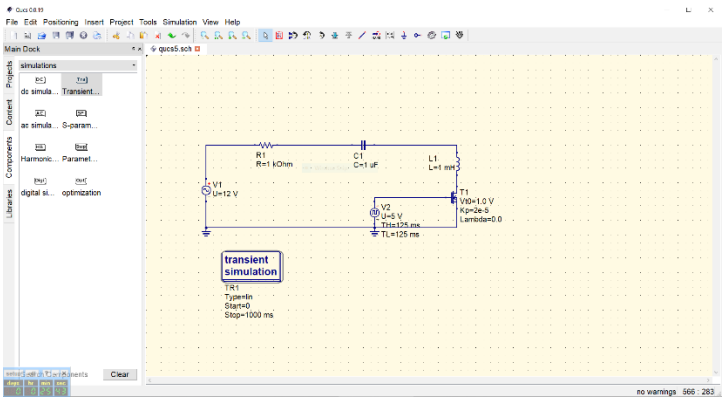

0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
c.v
0
100
200
300
400
500
600
700
800
900
1e03
acfrequency


Edit Component Properties
Sweep
Properties
ac simulation
Sweep Parameter: acfrequency
display in schematic
Type: logarithmic
display in schematic
Values:
display in schematic
Start: 1 Hz
display in schematic
Stop: 1000 Hz
display in schematic
Points per decade: 100.333
Number: 301
display in schematic
OK
Apply
Cancel

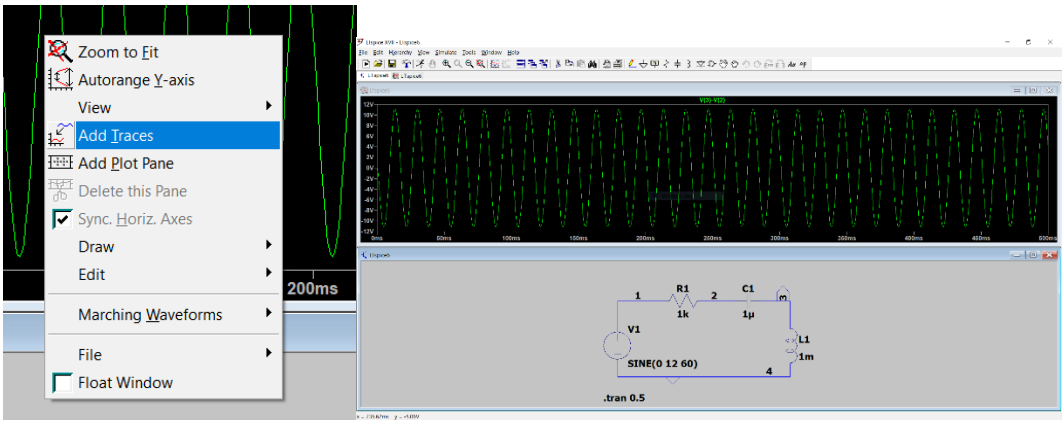
Task 5

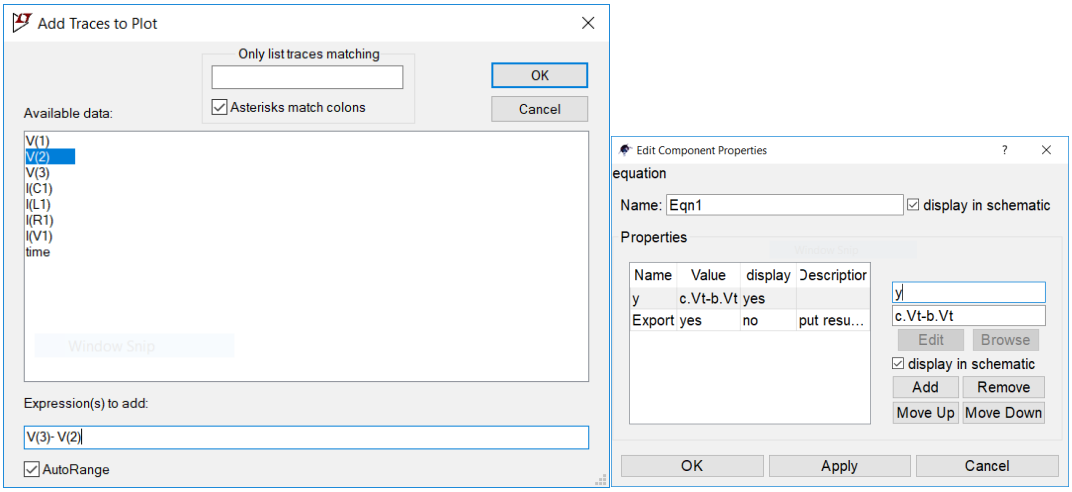

Independent Voltage Source - V2
Functions
(none)
PULSE(V1 V2 Tdelay Trise Tfall Ton Period Ncycles)
SINE(Voffset Vamp Freq Td Theta Phi Ncycles)
EXP(V1 V2 Td1 Tau1 Td2 Tau2)
SFFM(Voff Vamp Fcar MDI Fsig)
PWL(t1 v1 t2 v2...)
PWL FILE:
Browse
Vinitial[V]: 0
Von[V]: 5
Tdelay[s]: 0
Trise[s]: 0
Tfall[s]: 0
Ton[s]: 0.125
Tperiod[s]: 0.25
Ncycles:
Additional PWL Points
Make this information visible on schematic:
DC Value
DC value:
Make this information visible on schematic:
Small signal AC analysis(AC)
AC Amplitude:
AC Phase:
Make this information visible on schematic:
Parasitic Properties
Series Resistance[Ω]:
Parallel Capacitance[F]:
Make this information visible on schematic:
Cancel
OK

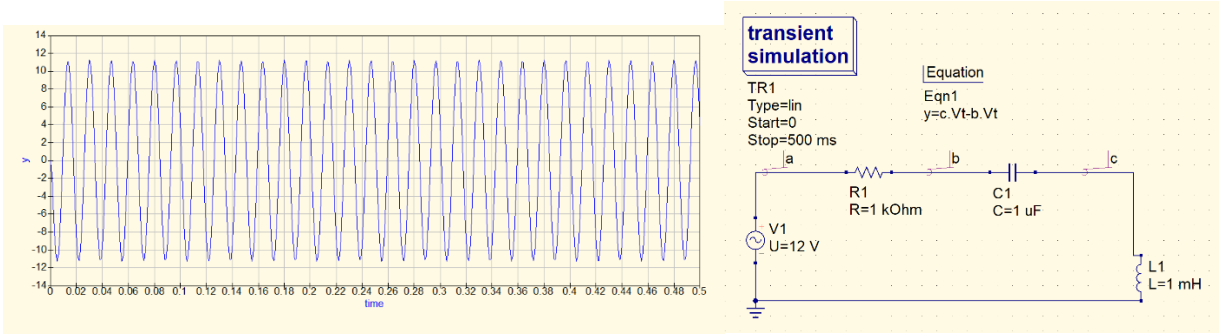

I(V1)
R1
1k
C1
1µ
V1
SINE(0 12 60)
L1
1m
V2
M1
NMOS
PULSE(0 5 0 0 0 0.125 0.25)
.tran 0 1 0 0.01
Qucs Simulation Messages
Progress:
Starting new simulation on Sun 14. Apr 2019 at 20:01:19:602
creating netlist... done.
Starting C:/Users/jonathan/Downloads/qucs-0.0.19-win32-mingw482-asco-freehdl-adms/qucs-0.0.19-win32-mingw482-asco-
Progress:
12%
Errors and Warnings:
Goto display page
Abort simulation


File Edit Positioning Insert Project Tools Simulation View Help
Main Dock
qucs5.sch
simulations
Transient...
S-param...
optimization
R1
R=1 kOhm
C1
C=1 uF
L1
L=1 mH
V1
U=12 V
V2
U=5 V
TH=125 ms
TL=125 ms
T1
Vt0=1.0 V
Kp=2e-5
Lambda=0.0
transient simulation
TR1
Type=lin
Start=0
Stop=1000 ms
Clear
no warnings 566 : 283

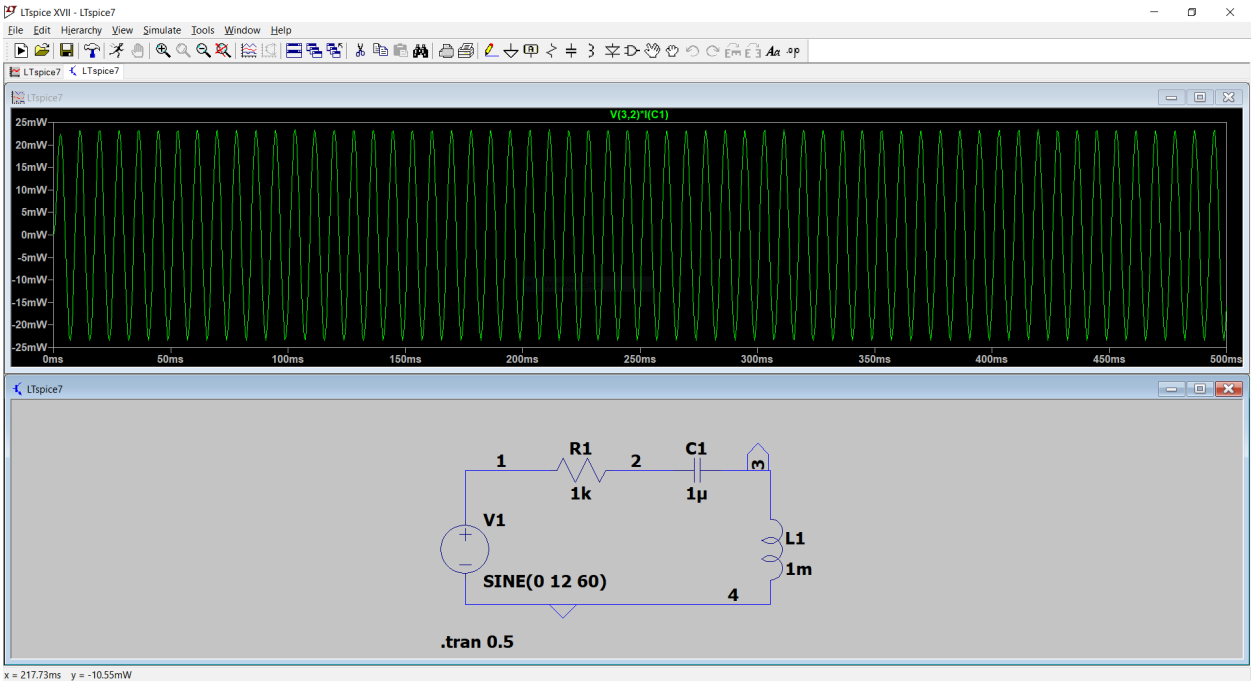
Task 6


Zoom to Fit
Autorange Y-axis
View
Add Traces
Add Plot Pane
Delete this Pane
Sync. Horiz. Axes
Draw
Edit
Marching Waveforms
File
Float Window
200ms
R1
1k
C1
1µ
V1
SINE(0 12 60)
L1
1m
.tran 0.5

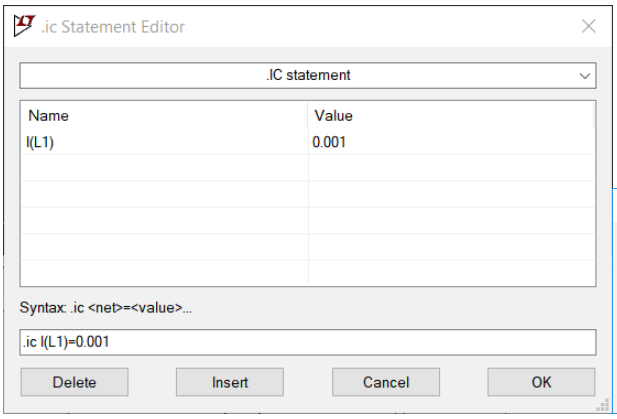

Add Traces to Plot
Only list traces matching
Asterisks match colons
OK
Cancel
Available data:
V(1)
V(2)
V(3)
I(C1)
I(L1)
I(R1)
I(V1)
time
Expression(s) to add:
V(3)- V(2)
AutoRange
Edit Component Properties
equation
Name: Eqn1
display in schematic
Properties
Name
Value
display
Description
y
c.Vt-b.Vt
yes
Export
yes
no
put resu...
Edit
Browse
display in schematic
Add
Remove
Move Up
Move Down
OK
Apply
Cancel

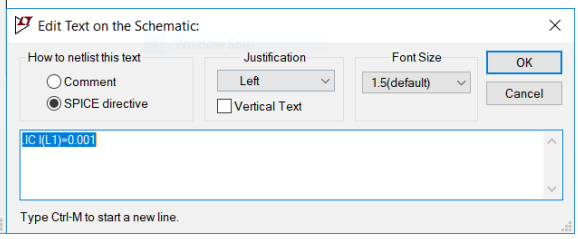

transient simulation
TR1
Type=lin
Start=0
Stop=500 ms
Equation
Eqn1
y=c.Vt-b.Vt
a
b
c
R1
R=1 kOhm
C1
C=1 uF
V1
U=12 V
L1
L=1 mH
y
time

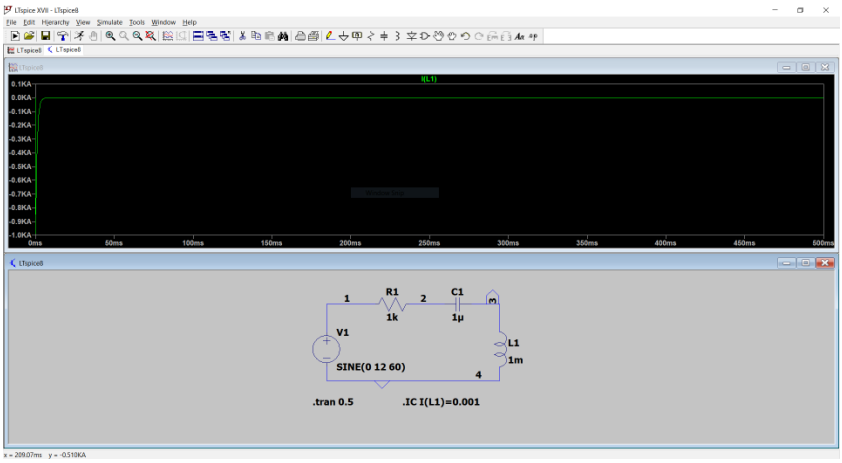
Task 7


LTspice XVII - LTspice7
File Edit Hierarchy View Simulate Tools Window Help
V(3,2)*I(C1)
25mW
20mW
15mW
10mW
5mW
0mW
-5mW
-10mW
-15mW
-20mW
-25mW
0ms 50ms 100ms 150ms 200ms 250ms 300ms 350ms 400ms 450ms 500ms
LTspice7
R1
1k
C1
1µ
V1
L1
1m
SINE(0 12 60)
1
2
3
4
.tran 0.5
x = 217.73ms y = -10.55mW

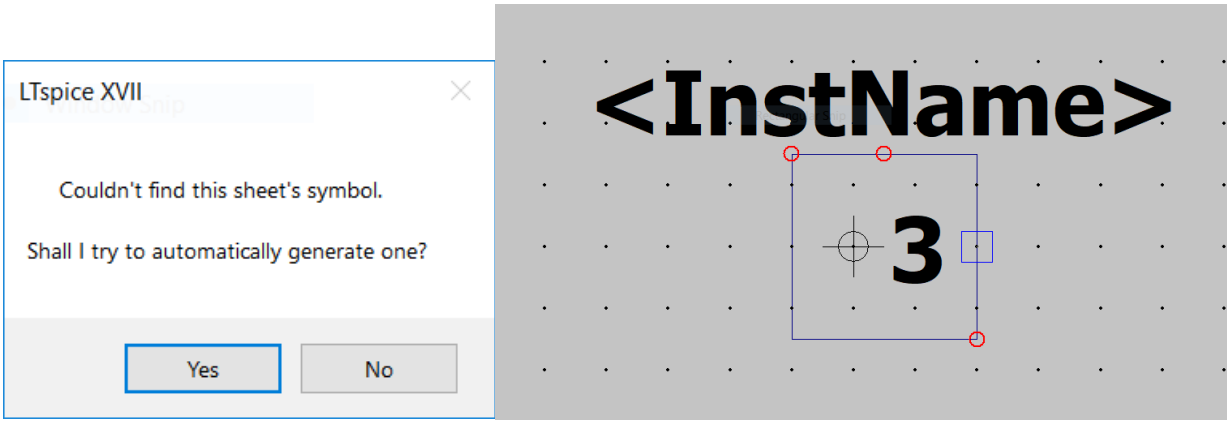
Task 8

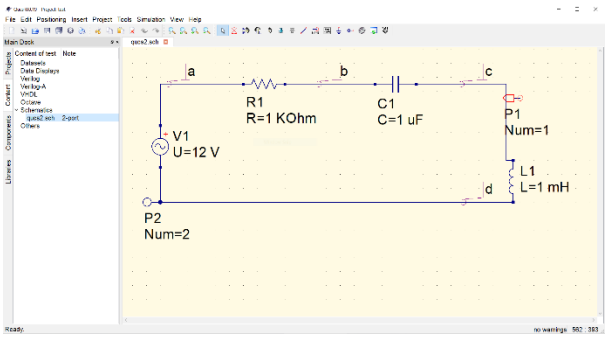

.ic Statement Editor
.IC statement
Name
Value
I(L1)
0.001
Syntax: .ic <net>=<value>...
.ic I(L1)=0.001
Delete
Insert
Cancel
OK


Edit Text on the Schematic:
How to netlist this text
Comment
SPICE directive
Justification
Left
Vertical Text
Font Size
1.5(default)
OK
Cancel
IC I(L1)=0.001
Type Ctrl-M to start a new line.

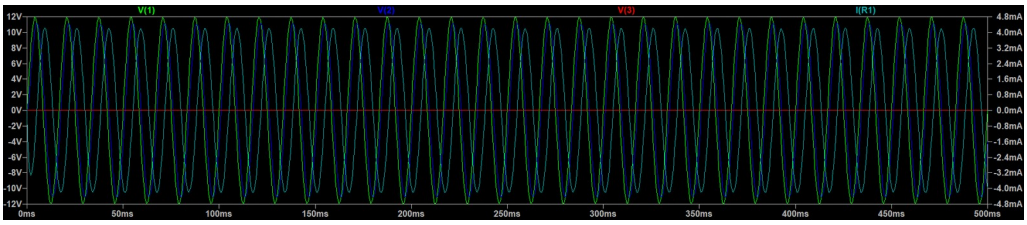

I(L1)
R1
1k
C1
1µ
V1
L1
1m
SINE(0 12 60)
.tran 0.5
.IC I(L1)=0.001

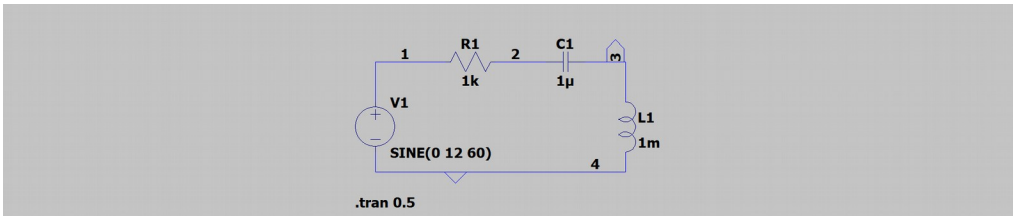
Task 9

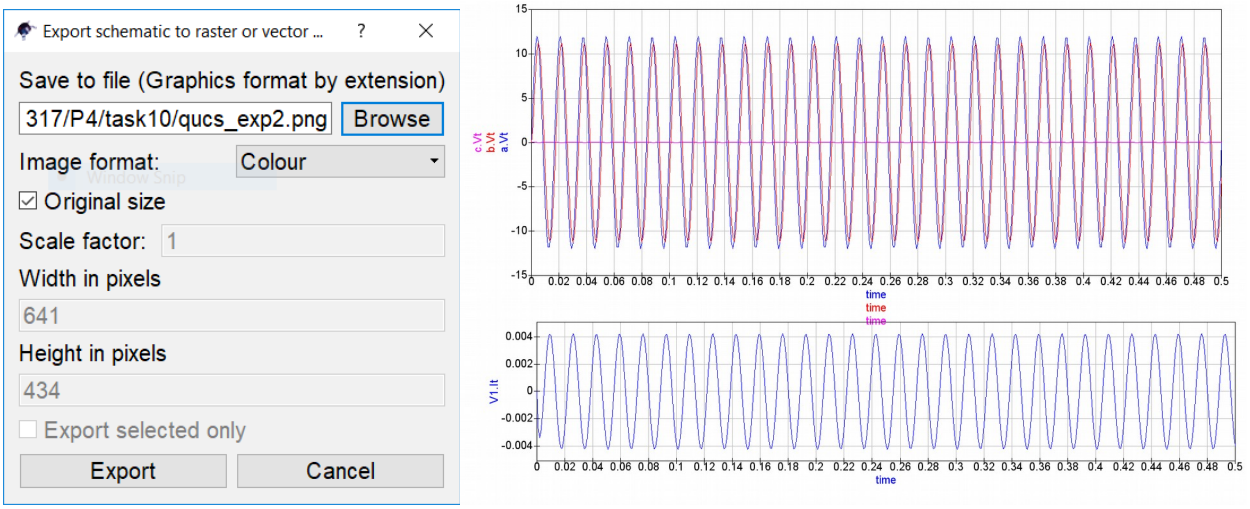


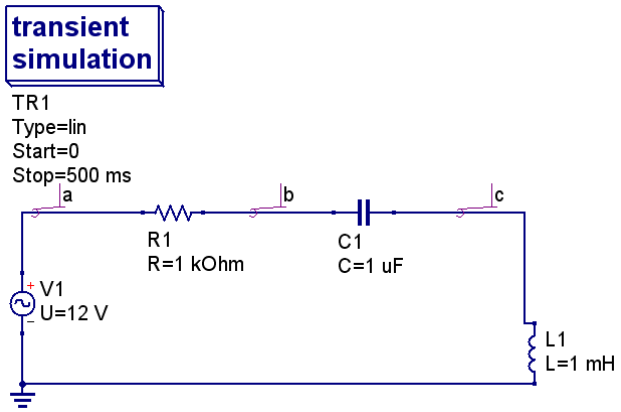


Task 10









Recommendations

Total score: [graph showing totals for effectiveness, efficiency, etc]

I strongly recommend LTspice for individuals new to simulating circuits with SPICE. QUCS has a lot of powerful features, but a newer user who just needs to quickly run simulations will be able to jump into LTspice much more easily and ultimately accomplish much more.

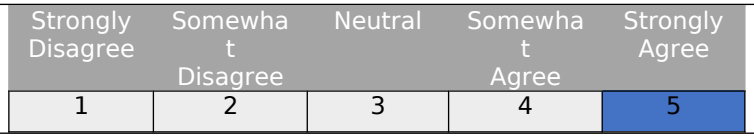
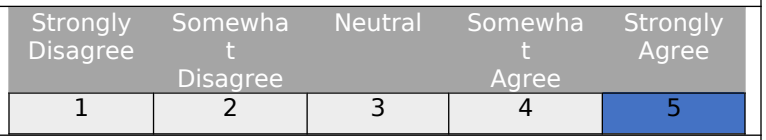
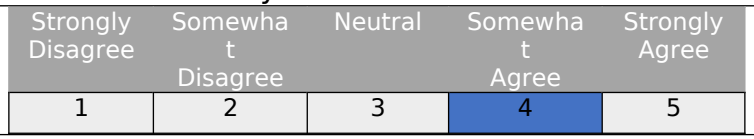
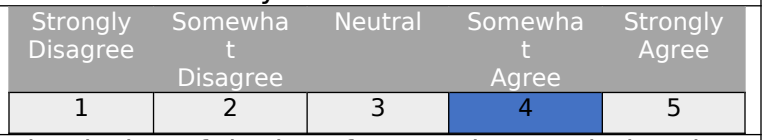
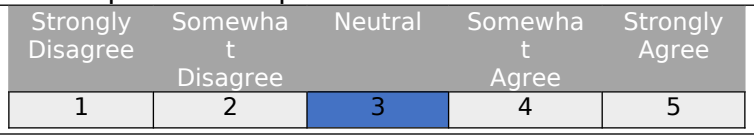
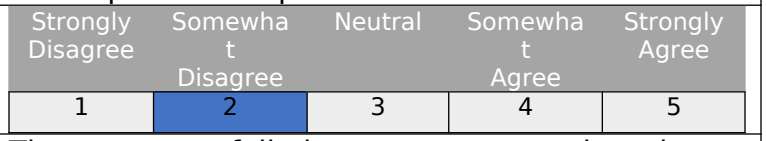
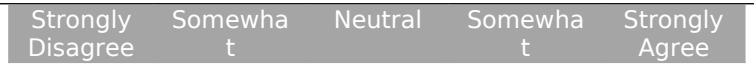
Bibliography

http://qucs.sourceforge.net/

https://www.analog.com/en/design-center/design-tools-and-calculators/ltspice-simulator.html

Appendix

Tasks	LTspice	QUCS
Task 1	**Create a new schematic with an AC voltage source (12 V, 60 Hz), resistor (1 kΩ), inductor (1 mH) and capacitor (1 µF).**	**Create a new schematic with an AC voltage source (12 V, 60 Hz), resistor (1 kΩ), inductor (1 mH) and capacitor (1 µF).**
Effective	The task was completed	The task was completed
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / 4 / **5**	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / 4 / **5**
Efficient	The task was completed quickly with reasonably few clicks and keystrokes	The task was completed quickly with reasonably few clicks and keystrokes
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / **4** / 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / **4** / 5
Engaging	The design of the interface made completing the task a pleasant experience	The design of the interface made completing the task a pleasant experience
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / **2** / 3 / 4 / 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / **4** / 5
Error Tolerant	There were no failed attempts to complete the tasks. The program warned of mistakes in advance	There were no failed attempts to complete the tasks. The program warned of mistakes in advance
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / **3** / 4 / 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / **3** / 4 / 5
Easy to Learn	It was simple to learn how to complete the task	It was simple to learn how to complete the task
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / **3** / 4 / 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / **4** / 5

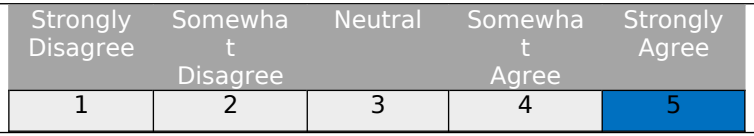
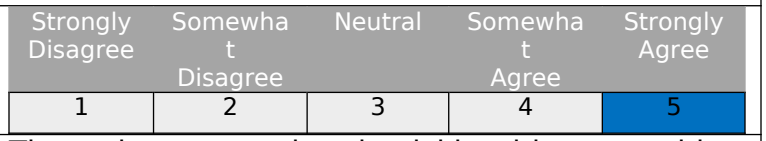
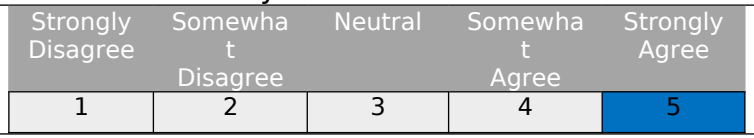
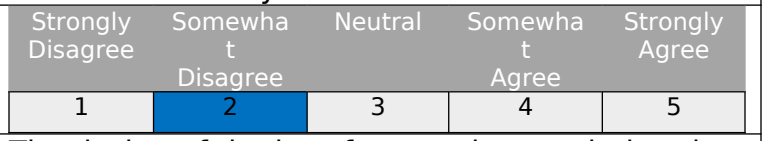
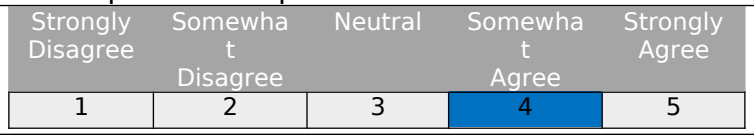
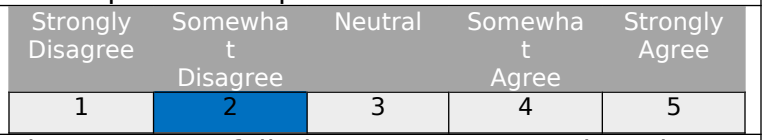
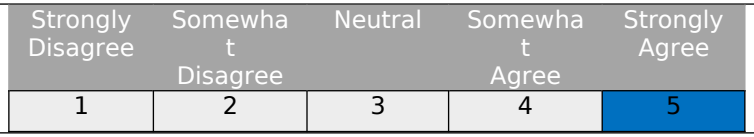
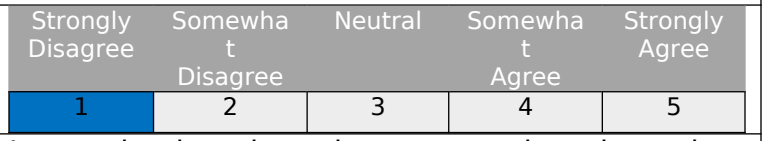
Additional Notes	Completed task in 3:30, 45 clicks and 48 keystrokes (93 total). Made a few errors drawing wires, and undo is F9 instead of ctrl+z so I had to use the menu. The voltage source is not in an obvious location. Properties are opened by a double click. I forgot to put in a ground.	Completed task in 4:30, 58 clicks and 32 keystrokes (90 total). Didn't have to create a new schematic – it opened with one. Starting the program was harder though since it doesn't install normally. Easier to find voltage sources and other elements with menu on the side. Easier to change values without opening an options window. Properties are opened by double click. Wire drawing is slightly more intelligent. Tested, ctrl+z is undo. I forgot to put in a ground.
Tasks	**LTspice**	**QUCS**
Task 2	**Label every node; make the positive inductor node an output.**	**Label every node; make the positive inductor node an output.**
Effective	The task was completed	The task was completed
		
Efficient	The task was completed quickly with reasonably few clicks and keystrokes	The task was completed quickly with reasonably few clicks and keystrokes
		
Engaging	The design of the interface made completing the task a pleasant experience	The design of the interface made completing the task a pleasant experience
		
Error Tolerant	There were no failed attempts to complete the tasks. The program warned of mistakes in advance	There were no failed attempts to complete the tasks. The program warned of mistakes in advance
		

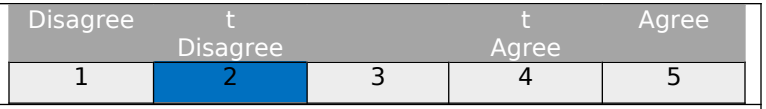
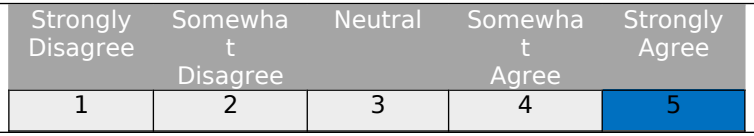
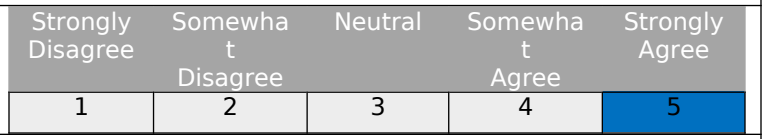
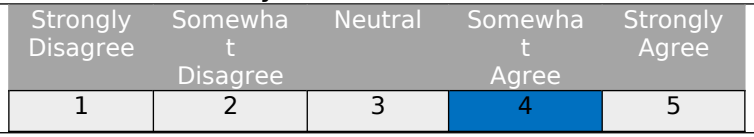
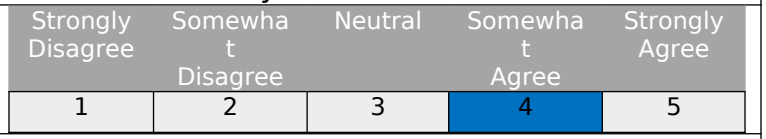
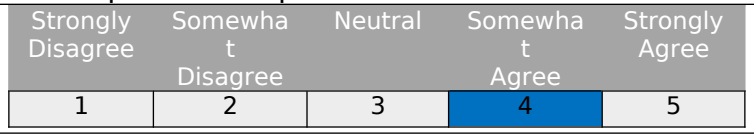
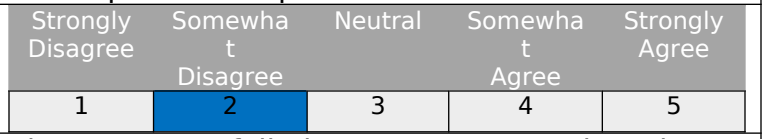
	Disagree / Agree 1 **2** 3 4 5	Disagree / Agree 1 **2** 3 4 5
Easy to Learn	It was simple to learn how to complete the task	It was simple to learn how to complete the task
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 2 3 4 **5**	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 2 **3** 4 5
Additional Notes	Completed in 1:28, 25 clicks, 11 keystrokes. Straightforward. Selected label nets in menu, then put in net name. Then clicked wire I wanted to label. Clicked the other wires, then went back and right clicked to change the label. Within the right click dialog, I could set node 3 to be an output. There is an annoying issue where dragging toward the edge of the visible schematic makes it quickly scroll away – but that is occasionally convenient. There were no warnings when I had all the nodes labeled the same.	Completed in 1:35, 30 clicks, 15 keystrokes. Would not accept numbers for net names, just did not register. Label tool was in a similar place as LTSpice. Every click made a dialog pop up to name the net. A separate tool is used to set the output. I created a port, and then changed the settings to make it an output. This was rather less clear than LTspice.
Tasks	**LTspice**	**QUCS**
Task 3	**Run a transient simulation showing the voltage at each node and current through the circuit over 0.5 seconds.**	**Run a transient simulation showing the voltage at each node and current through the circuit over 0.5 seconds.**
Effective	The task was completed	The task was completed
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 2 3 4 **5**	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 2 3 4 **5**
Efficient	The task was completed quickly with reasonably few clicks and keystrokes	The task was completed quickly with reasonably few clicks and keystrokes
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 **2** 3 4 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 **2** 3 4 5

Engaging	The design of the interface made completing the task a pleasant experience	The design of the interface made completing the task a pleasant experience
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / 4 / **5**	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / **2** / 3 / 4 / 5
Error Tolerant	There were no failed attempts to complete the tasks. The program warned of mistakes in advance	There were no failed attempts to complete the tasks. The program warned of mistakes in advance
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / **4** / 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree **1** / 2 / 3 / 4 / 5
Easy to Learn	It was simple to learn how to complete the task	It was simple to learn how to complete the task
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / **4** / 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree **1** / 2 / 3 / 4 / 5
Additional Notes	Completed in 1:30, 18 clicks, 5 keystrokes. A warning popped up about the missing ground, so I added one. The simulation command is added to the schematic. Setting up the simulation was simple. The plot is blank at first which may confuse users, but adding voltages is as simple as clicking on nodes, and currents is as simple as clicking on components. The default blue on black is hard to see.	Completed in 17:30, 266 clicks and 50 keystrokes. Simulation button was obvious but it was not clear how to set up a simulation. Finally figure out it was in the side menu and had to be added as an object. Plots must be also individually added. Then there was an error in the simulation. Had to look around and Google; I used a capital KOhm instead of kOhm. Then sim ran, but got stuck – I had not put in a ground. It worked after putting that in, but required much more manual intervention and set up to see a plot. QUCS help seems extensive.
Tasks	**LTspice**	**QUCS**
Task 4	**Run an AC analysis from 1 Hz to 1000 Hz, 100 points per decade. Plot the inductor voltage.**	**Run an AC analysis from 1 Hz to 1000 Hz, 100 points per decade. Plot the inductor voltage.**

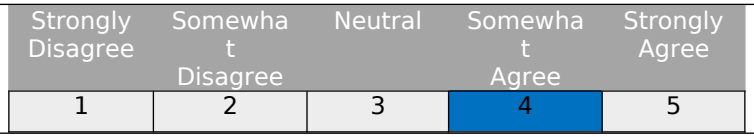
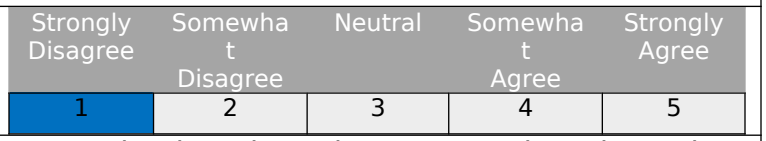
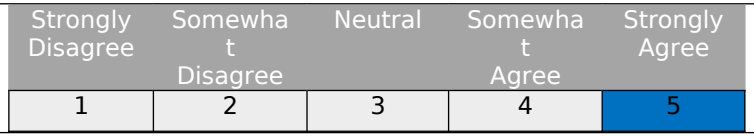
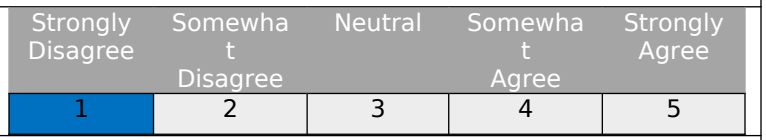
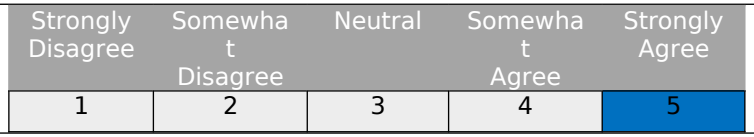
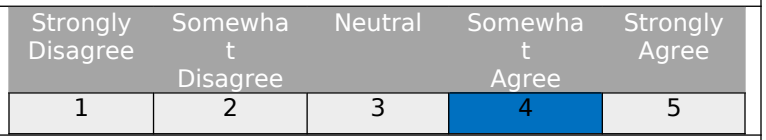
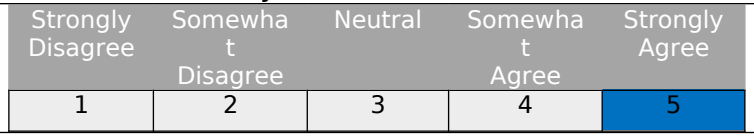
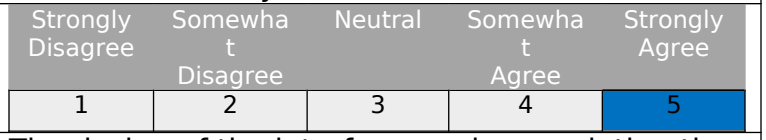
Efficient	The task was completed	The task was completed
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / 4 / **5**	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / **4** / 5
Effective	The task was completed quickly with reasonably few clicks and keystrokes	The task was completed quickly with reasonably few clicks and keystrokes
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / 4 / **5**	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / **4** / 5
Engaging	The design of the interface made completing the task a pleasant experience	The design of the interface made completing the task a pleasant experience
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / 4 / **5**	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / **3** / 4 / 5
Error Tolerant	There were no failed attempts to complete the tasks. The program warned of mistakes in advance	There were no failed attempts to complete the tasks. The program warned of mistakes in advance
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / **4** / 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / **4** / 5
Easy to Learn	It was simple to learn how to complete the task	It was simple to learn how to complete the task
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / 4 / **5**	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / 4 / **5**
Additional Notes	Completed in 3:02, 41 clicks, 39 keystrokes. Needed to set AC source value specifically but it warned about it. Simulation setup was straightforward, like task 3.	Completed in 3:30, 60 clicks, 26 keystrokes. Fairly easy after figuring out task 3, but the interface is still more intimidating than LTspice. No clear option for plotting phase.
Tasks	**LTspice**	**QUCS**

Task 5	**Insert a transistor (basic NMOS model) in the circuit. Use a 5 V square wave as the gate voltage to switch the current on and off at 4 Hz.**	**Insert a transistor (basic NMOS model) in the circuit. Use a 5 V square wave as the gate voltage to switch the current on and off at 4 Hz.**
Efficient	The task was completed	The task was completed
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / 4 / **5**	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / **2** / 3 / 4 / 5
Effective	The task was completed quickly with reasonably few clicks and keystrokes	The task was completed quickly with reasonably few clicks and keystrokes
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / **4** / 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / **2** / 3 / 4 / 5
Engaging	The design of the interface made completing the task a pleasant experience	The design of the interface made completing the task a pleasant experience
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / **4** / 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / **2** / 3 / 4 / 5
Error Tolerant	There were no failed attempts to complete the tasks. The program warned of mistakes in advance	There were no failed attempts to complete the tasks. The program warned of mistakes in advance
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / 4 / **5**	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree **1** / 2 / 3 / 4 / 5
Easy to Learn	It was simple to learn how to complete the task	It was simple to learn how to complete the task
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / 2 / 3 / **4** / 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 / **2** / 3 / 4 / 5
Additional Notes	Completed in 3:45. 38 keystrokes, 61 clicks. Verified by plotting current over time. Voltage source options for square wave (“pulse”) are not	Gave up after 25:43, 165 keystrokes, 355 clicks. Added transistor in relatively simply; it is nice that it immediately presents more options than

	very straightforward, necessarily, but actually are simple – most fields can be ignored.	LTspice. Took a while to find rectangular voltage source; was looking in AC source. Inserted transient simulation for testing, but could not get it to run. Just hung at 12%, no errors. Help and google search did not solve.
Tasks	**LTspice**	**QUCS**
Task 6	**Subtract two waveforms – plot the capacitor voltage from task 3 (transient simulation).**	**Subtract two waveforms – plot the capacitor voltage from task 3 (transient simulation).**
Efficient	The task was completed	The task was completed
		
Effective	The task was completed quickly with reasonably few clicks and keystrokes	The task was completed quickly with reasonably few clicks and keystrokes
		
Engaging	The design of the interface made completing the task a pleasant experience	The design of the interface made completing the task a pleasant experience
		
Error Tolerant	There were no failed attempts to complete the tasks. The program warned of mistakes in advance	There were no failed attempts to complete the tasks. The program warned of mistakes in advance
		
Easy to Learn	It was simple to learn how to complete the task	It was simple to learn how to complete the task
		

		
Additional Notes	Completed in 0:35, 1 keystroke, 9 clicks. Run like task 3, just instead of clicking in circuit to add plots, right click empty plot, add trace, and do voltage of node 3 minus node 2. Very simple, though the add trace option will not be immediately apparent to beginners.	Completed in 4:22, 55 keystrokes and 66 clicks. Could not add a math trace as easily as LTspice; needed to add an equation to the schematic. Had to look at help and only indirectly figured it out. But it went as smoothly as task 3 once that was figured out. There were no errors when trying to plot the wrong things; it just did not work.
Tasks	**LTspice**	**QUCS**
Task 7	**Plot the power consumed by the capacitor.**	**Plot the power consumed by capacitor.**
Efficient	The task was completed	The task was completed
		
Effective	The task was completed quickly with reasonably few clicks and keystrokes	The task was completed quickly with reasonably few clicks and keystrokes
		
Engaging	The design of the interface made completing the task a pleasant experience	The design of the interface made completing the task a pleasant experience
		
Error Tolerant	There were no failed attempts to complete the tasks. The program warned of mistakes in advance	There were no failed attempts to complete the tasks. The program warned of mistakes in advance
		

	1 **2** 3 4 5	1 2 3 **4** 5
Easy to Learn	It was simple to learn how to complete the task	It was simple to learn how to complete the task
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree **1** 2 3 4 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 **2** 3 4 5
Additional Notes	Completed in 5:42 with 96 keystrokes and 51 clicks. First wanted to do math like Task 7, but couldn't figure out complex conjugate – it warned that it did not understand the conj function. Ended up being simple (but had to Google it, not found in help): hold alt and click component and power is plotted.	Completed in 1:19 with 22 keystrokes and 38 clicks. Complete like Task 7 using "conj" function – seems to work correctly.
Tasks	**LTspice**	**QUCS**
Task 8	**Add a SPICE directive statement – set initial inductor current to 1 mA and plot current over time.**	**Add a SPICE directive statement – set initial inductor current to 1 mA and plot current over time.**
Efficient	The task was completed	The task was completed
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 2 3 4 **5**	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree **1** 2 3 4 5
Effective	The task was completed quickly with reasonably few clicks and keystrokes	The task was completed quickly with reasonably few clicks and keystrokes
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 2 3 **4** 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree **1** 2 3 4 5
Engaging	The design of the interface made completing the task a pleasant experience	The design of the interface made completing the task a pleasant experience
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 2 3 4 **5**	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree **1** 2 3 4 5

Error Tolerant	There were no failed attempts to complete the tasks. The program warned of mistakes in advance	There were no failed attempts to complete the tasks. The program warned of mistakes in advance
		
Easy to Learn	It was simple to learn how to complete the task	It was simple to learn how to complete the task
		
Additional Notes	Completed in 0:56, 33 keystrokes, 6 clicks. A little confusing to find where to click – the .op button, but after that, putting in the directive is straightforward.	Realized this is impossible after 7:36 and 46 keystrokes and 73 clicks.
Tasks	**LTspice**	**QUCS**
Task 9	**Make the circuit into a subcircuit.**	**Make the circuit into a subcircuit.**
Efficient	The task was completed	The task was completed
		
Effective	The task was completed quickly with reasonably few clicks and keystrokes	The task was completed quickly with reasonably few clicks and keystrokes
		
Engaging	The design of the interface made completing the task a pleasant experience	The design of the interface made completing the task a pleasant experience
		

	1 2 3 **4** 5	1 2 3 **4** 5
Error Tolerant	There were no failed attempts to complete the tasks. The program warned of mistakes in advance	There were no failed attempts to complete the tasks. The program warned of mistakes in advance
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 2 3 4 **5**	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 **2** 3 4 5
Easy to Learn	It was simple to learn how to complete the task	It was simple to learn how to complete the task
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 2 **3** 4 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 **2** 3 4 5
Additional Notes	Completed in 1:05 with 18 clicks. Just need to go into hierarchy menu and view symbol. Then it offers to automatically generate it, and it pops up with the single output.	Completed in 4:34, 29 keystrokes, 79 clicks. Required a google search since subcircuits work differently in QUCS. Needed to add the circuit to the project, then it automatically shows up as a subcircuit if there are ports on it (which there were and I added another). Easy when you know what to expect.
Tasks	**LTspice**	**QUCS**
Task 10	**Export the plot from task 3 and the schematic as attractive and readable images**	**Export the plot from task 3 and the schematic as attractive and readable images**
Efficient	The task was completed	The task was completed
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 2 3 **4** 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 2 3 4 **5**
Effective	The task was completed quickly with reasonably few clicks and keystrokes	The task was completed quickly with reasonably few clicks and keystrokes
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree

	1 2 3 4 **5**	1 2 3 4 **5**
Engaging	The design of the interface made completing the task a pleasant experience	The design of the interface made completing the task a pleasant experience
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 **2** 3 4 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 2 3 **4** 5
Error Tolerant	There were no failed attempts to complete the tasks. The program warned of mistakes in advance	There were no failed attempts to complete the tasks. The program warned of mistakes in advance
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 2 3 **4** 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 2 3 **4** 5
Easy to Learn	It was simple to learn how to complete the task	It was simple to learn how to complete the task
	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 2 **3** 4 5	Strongly Disagree / Somewhat Disagree / Neutral / Somewhat Agree / Strongly Agree 1 2 3 4 **5**
Additional Notes	Completed in 1:53, 7 keystrokes, 32 clicks. There's no way to export to an image exactly, only print. Can save as emf, but don't know what to do with that. Can also easily copy to clipboard as bitmap and paste into a Word processor in tools which works well. The colors are the only issue. This is also kind of awkward if you want the image file.	Completed in 1:21, 12 keystrokes, 25 clicks. There is an export to image option in the file menu, which includes several options for exporting to jpg. Can also do monochrome, change size, etc.