

Performance-based assessments for network analysis competencies

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The purpose of these assessments is for instructors to accurately measure the learning of their electronics students, in a way that melds theoretical knowledge with hands-on application. In each assessment, students are asked to predict the behavior of a circuit from a schematic diagram and component values, then they build that circuit and measure its real behavior. If the behavior matches the predictions, the student then simulates the circuit on computer and presents the three sets of values to the instructor. If not, then the student then must correct the error(s) and once again compare measurements to predictions. Grades are based on the number of attempts required before all predictions match their respective measurements.

You will notice that no component values are given in this worksheet. The *instructor* chooses component values suitable for the students' parts collections, and ideally chooses different values for each student so that no two students are analyzing and building the exact same circuit. These component values may be hand-written on the assessment sheet, printed on a separate page, or incorporated into the document by editing the graphic image.

This is the procedure I envision for managing such assessments:

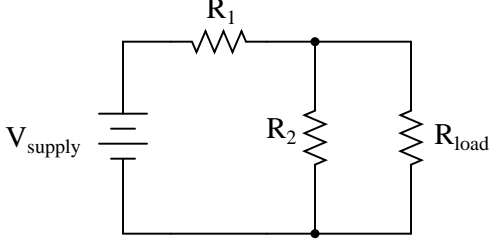
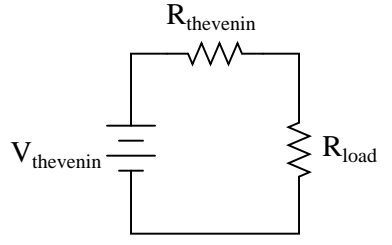
1. The instructor hands out individualized assessment sheets to each student.
2. Each student predicts their circuit's behavior at their desks using pencil, paper, and calculator (if appropriate).
3. Each student builds their circuit at their desk, under such conditions that it is impossible for them to verify their predictions using test equipment. Usually this will mean the use of a multimeter only (for measuring component values), but in some cases even the use of a multimeter would not be appropriate.
4. When ready, each student brings their predictions and completed circuit up to the instructor's desk, where any necessary test equipment is already set up to operate and test the circuit. There, the student sets up their circuit and takes measurements to compare with predictions.
5. If any measurement fails to match its corresponding prediction, the student goes back to their own desk with their circuit and their predictions in hand. There, the student tries to figure out where the error is and how to correct it.
6. Students repeat these steps as many times as necessary to achieve correlation between all predictions and measurements. The instructor's task is to count the number of attempts necessary to achieve this, which will become the basis for a percentage grade.
7. (OPTIONAL) As a final verification, each student simulates the same circuit on computer, using circuit simulation software (Spice, Multisim, etc.) and presenting the results to the instructor as a final pass/fail check.

These assessments more closely mimic real-world work conditions than traditional written exams:

- Students cannot pass such assessments only knowing circuit theory or only having hands-on construction and testing skills – they must be proficient at both.
- Students do not receive the “authoritative answers” from the instructor. Rather, they learn to validate their answers through real circuit measurements.
- Just as on the job, the work isn't complete until *all errors* are corrected.
- Students must recognize and correct their own errors, rather than having someone else do it for them.
- Students must be fully prepared on exam days, bringing not only their calculator and notes, but also their tools, breadboard, and circuit components.

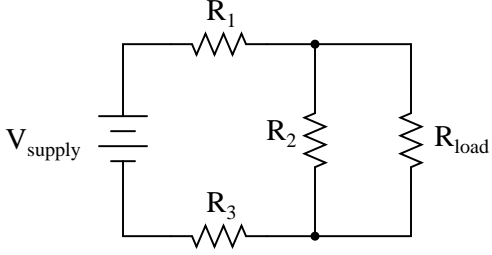
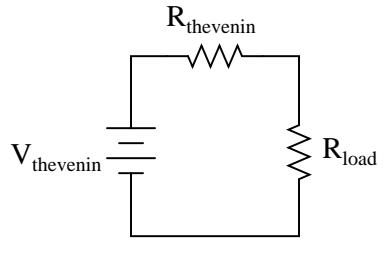
Instructors may elect to reveal the assessments before test day, and even use them as preparatory labwork and/or discussion questions. Remember that there is absolutely nothing wrong with “teaching to

the test" *so long as the test is valid*. Normally, it is bad to reveal test material in detail prior to test day, lest students merely memorize responses in advance. With performance-based assessments, however, there is no way to pass without truly understanding the subject(s).

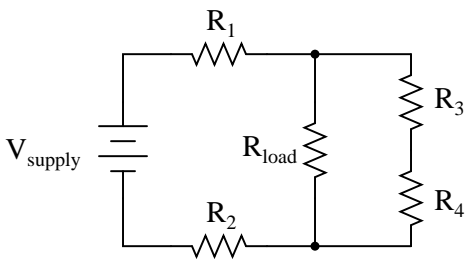
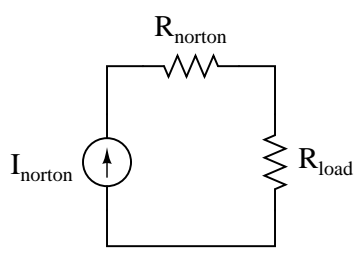
Competency: Thevenin's theorem	Version:		
Schematic			
<p><i>Original circuit</i></p> 	<p><i>Thevenin equivalent circuit</i></p> 		
Given conditions			
$V_{\text{supply}} =$	$R_1 =$	$R_2 =$	$R_{\text{load}} =$
Parameters			
<p style="text-align: center;">Predicted</p> <p>V_{thevenin} <input style="width: 80px; height: 25px;" type="text"/></p> <p>R_{thevenin} <input style="width: 80px; height: 25px;" type="text"/></p>	<p style="text-align: center;">Measured (in original circuit)</p> <p>V_{load} <input style="width: 80px; height: 25px;" type="text"/></p>	<p style="text-align: center;">Measured (in Thevenin equivalent circuit)</p> <p><input style="width: 80px; height: 25px;" type="text"/></p>	

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Schematic		
<p><i>Original circuit</i></p>	<p><i>Thevenin equivalent circuit</i></p>	
Given conditions		
$V_{\text{supply}} =$	$R_1 =$	$R_3 =$
	$R_2 =$	$R_{\text{load}} =$
Parameters		
Predicted		
V_{thevenin}	<input style="width: 100%;" type="text"/>	
R_{thevenin}	<input style="width: 100%;" type="text"/>	
Measured		
V_{load}	(in original circuit)	<input style="width: 100%;" type="text"/>
	(in Thevenin equivalent circuit)	<input style="width: 100%;" type="text"/>

Competency: Thevenin's theorem	Version:	
Schematic		
<p><i>Original circuit</i></p>	<p><i>Thevenin equivalent circuit</i></p>	
Given conditions		
$V_{\text{supply}} =$	$R_1 =$	$R_2 =$
	$R_3 =$	$R_{\text{load}} =$
Parameters		
Predicted		
V_{thevenin}	<input style="width: 100px; height: 20px;" type="text"/>	
R_{thevenin}	<input style="width: 100px; height: 20px;" type="text"/>	
Measured		
V_{load}	Measured (in original circuit)	Measured (in Thevenin equivalent circuit)
	<input style="width: 100px; height: 20px;" type="text"/>	<input style="width: 100px; height: 20px;" type="text"/>

Competency: Thevenin's theorem	Version:	
Schematic		
<p><i>Original circuit</i></p> 	<p><i>Thevenin equivalent circuit</i></p> 	
Given conditions		
$V_{\text{supply}} =$	$R_1 =$	$R_2 =$
	$R_3 =$	$R_{\text{load}} =$
Parameters		
Predicted		
V_{thevenin}	<input style="width: 100px; height: 20px;" type="text"/>	
R_{thevenin}	<input style="width: 100px; height: 20px;" type="text"/>	
Measured		
V_{load}	(in original circuit)	<input style="width: 100px; height: 20px;" type="text"/>
	(in Thevenin equivalent circuit)	<input style="width: 100px; height: 20px;" type="text"/>

Competency: Thevenin's theorem	Version:		
Schematic			
<p><i>Original circuit</i></p>	<p><i>Thevenin equivalent circuit</i></p>		
Given conditions			
$V_{\text{supply}} =$	$R_1 =$	$R_2 =$	$R_{\text{load}} =$
	$R_3 =$	$R_4 =$	
Parameters			
Predicted			
V_{thevenin}	<input style="width: 100%;" type="text"/>		
R_{thevenin}	<input style="width: 100%;" type="text"/>		
Measured (in original circuit)		Measured (in Thevenin equivalent circuit)	
V_{load}	<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>	

Competency: Norton's theorem	Version:		
Schematic			
<p><i>Original circuit</i></p> 	<p><i>Norton equivalent circuit</i></p> 		
Given conditions			
$V_{\text{supply}} =$	$R_1 =$	$R_2 =$	$R_{\text{load}} =$
	$R_3 =$	$R_4 =$	
Parameters			
Predicted			
I_{norton}	<input style="width: 100%;" type="text"/>		
R_{thevenin}	<input style="width: 100%;" type="text"/>		
Measured			
V_{load}	(in original circuit) <input style="width: 100%;" type="text"/>	(in Norton equivalent) <input style="width: 100%;" type="text"/>	

Competency: Voltage divider with limited range		Version:
Description		
Use simultaneous equations to calculate values for resistors R_1 and R_2 that will limit the range of voltage adjustment to the specified minimum and maximum values.		
Schematic		
Given conditions		
$V_{\text{supply}} =$	$R_{\text{pot}} =$	$V_{\text{out}} (\text{max}) =$ $V_{\text{out}} (\text{min}) =$
Parameters		
	Calculated	Measured
R_1	<input style="width: 100px; height: 20px;" type="text"/>	$V_{\text{out}} (\text{min})$
R_2	<input style="width: 100px; height: 20px;" type="text"/>	$V_{\text{out}} (\text{max})$
Equations		

Answers

Answer 1

Use circuit simulation software to verify your predicted and measured parameter values.

Answer 2

Use circuit simulation software to verify your predicted and measured parameter values.

Answer 3

Use circuit simulation software to verify your predicted and measured parameter values.

Answer 4

Use circuit simulation software to verify your predicted and measured parameter values.

Answer 5

Use circuit simulation software to verify your predicted and measured parameter values.

Answer 6

Use circuit simulation software to verify your predicted and measured parameter values.

Answer 7

Use circuit simulation software to verify your predicted and measured parameter values.

Notes 1

Use a variable-voltage, regulated power supply for $V_{thevenin}$, and a fixed-voltage supply for V_{source} . Specify standard resistor values, all between 1 k Ω and 100 k Ω (1k5, 2k2, 2k7, 3k3, 4k7, 5k1, 6k8, 10k, 22k, 33k, 39k 47k, 68k, etc.) for resistors in the original circuit. A decade box or potentiometer will suffice for $R_{thevenin}$.

In case it is not already crystal-clear, I want students to build *two different circuits* for this exercise: the "original" circuit and also a "Thevenin equivalent" circuit, then plug the exact same load resistor into both circuits (one at a time) to see that the voltage across it is the same in both cases. Many students seem to struggle with the basic concept of equivalent circuits, and I have found this exercise (once successfully completed) to be excellent for "making it real" to these students.

An extension of this exercise is to incorporate troubleshooting questions. Whether using this exercise as a performance assessment or simply as a concept-building lab, you might want to follow up your students' results by asking them to predict the consequences of certain circuit faults.

Notes 2

Use a variable-voltage, regulated power supply for $V_{thevenin}$, and a fixed-voltage supply for V_{source} . Specify standard resistor values, all between 1 k Ω and 100 k Ω (1k5, 2k2, 2k7, 3k3, 4k7, 5k1, 6k8, 10k, 22k, 33k, 39k 47k, 68k, etc.) for resistors in the original circuit. A decade box or potentiometer will suffice for $R_{thevenin}$.

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Notes 3

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Notes 4

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Notes 5

Thevenin's Theorem is tremendously useful for analyzing the performance of complex circuit networks. In particular, it is useful in transistor amplifier circuit design and analysis. Its power lies in the ability to reduce the complexity of a large network into nothing more than an equivalent voltage source and series resistance.

Use a variable-voltage, regulated power supply for $V_{thevenin}$, and a fixed-voltage supply for V_{source} . Specify standard resistor values, all between 1 k Ω and 100 k Ω (1k5, 2k2, 2k7, 3k3, 4k7, 5k1, 6k8, 10k, 22k, 33k, 39k 47k, 68k, etc.) for resistors in the original circuit. A decade box or potentiometer will suffice for $R_{thevenin}$.

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General concepts and principles to emphasize

- The internal resistance of ideal voltage sources (zero)
- The internal resistance of ideal current sources (infinite)
- Calculating the total resistance of a series-parallel resistor network
- Re-drawing circuits in simplified form as part of the analysis technique

Suggestions for Socratic discussion and experimentation

- Identify at least *two* different resistance values you could change in the original circuit to increase the Thevenin equivalent resistance as seen from the perspective of the load.
- Identify at least *two* different resistance values you could change in the original circuit to increase the Thevenin equivalent voltage as seen from the perspective of the load.
- Will an increase in Thevenin equivalent resistance result in a "firmer" or "softer" power source to the load (i.e. will the voltage delivered to the load be less or more dependent on how much current the load draws)?

Notes 6

Use a variable-voltage, regulated power supply for I_{norton} , and a fixed-voltage supply for V_{source} . Specify standard resistor values, all between 1 k Ω and 100 k Ω (1k5, 2k2, 2k7, 3k3, 4k7, 5k1, 6k8, 10k, 22k, 33k, 39k, 47k, 68k, etc.) for resistors in the original circuit. A decade box or potentiometer will suffice for R_{norton} .

An extension of this exercise is to incorporate troubleshooting questions. Whether using this exercise as a performance assessment or simply as a concept-building lab, you might want to follow up your students' results by asking them to predict the consequences of certain circuit faults.

Notes 7

The purpose of this exercise is for students to use simultaneous equations to arrive at values for fixed resistors R_1 and R_2 that will limit output voltage adjustment to the limits specified.

An extension of this exercise is to incorporate troubleshooting questions. Whether using this exercise as a performance assessment or simply as a concept-building lab, you might want to follow up your students' results by asking them to predict the consequences of certain circuit faults.