Section	LA1
Bench No.	5

ECE110 Introduction to Electronics

Experiment 6: Improved Motor Modeling

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This part is reserved for your instructor

Score	
Instructor Signature	
Date	

Experiment 6: Improved Motor Modeling

Laboratory Outline

Up until this point, we've used devices that can be treated as ideal for most practical purposes. Yet, even non-ideal devices are very practical in many applications, and these will prove useful in your final design challenge as well as a host of projects you might take on after ECE 110. Motors and batteries are two such devices. As engineers, we must recognize non-ideal behavior and ask pertinent questions…Does a motor behave like a resistor? No, clearly our oscilloscope measurements revealed behaviors that are clearly not Ohmic. What is a better model? Can our battery provide enough current to drive two motors and the rest of the circuitry for any extended amount of time? You'll now understand some of the limitations of these devices when used in a circuit.

The DC power supply on your bench can be treated as an ideal voltage source for a great deal of its voltage range with typical circuits used in class. This is not the case with batteries. In the prelab, you characterized how our battery pack behaved under a load and you used a simple linear approximation of a battery that allows us to analyze this non-ideal device by modelling with a perfectly linear IV curve.

Motors convert electrical energy into kinetic energy. Today we'll characterize the chassis motor by varying the voltage that is applied to the motor terminals. In addition, we'll develop a linear model that approximates the motor's behavior over a range of input voltages. This will simplify analysis for the motor-drive circuit.

Learning Objectives

- Measure, analyze, and model the IV characteristics of the motor, noting that hysteresis (different behaviors in two different stimulus directions) requires two Thevenin models.
- Make note of the current drawn by the motor in normal operation and at a stall point.
- Estimate the waste power (large percentage!) for an inefficient voltage-divider-style motor speed controller.

At your Bench

Today we'll look at the voltage-current relationship of a DC motor and see how it differs from resistors and develop a simplified linear model of the motor that we can use for basic circuit analysis.

Experimental Setup

Connect the circuit as shown in Figure 1, using the power (voltage) supply and one of the drive motors on your car.

- ✓ Make sure that the output on the power supply is set to “off” when you are constructing or making changes to your circuit. Use the + and − ports of the +6V supply on the DC power supply.
- ✓ The DC motor in the diagram is one of the drive motors on your car chassis. You do not need to remove the motor from the chassis. Instead, use the small block as a “car lift” to keep the wheels off the ground.

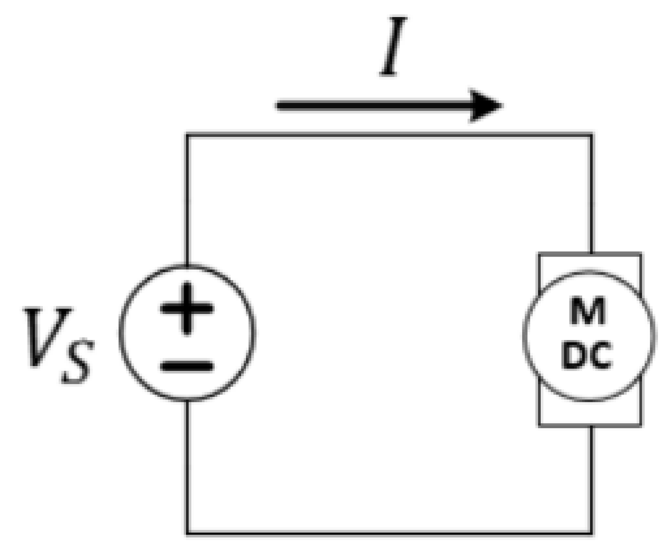


Figure 1: Circuit schematics of the variable voltage source motor drive method.

Run your motor at 6 volts for 2 minutes to warm it up. This should help you get more consistent results in your measurements.

Before we begin taking measurements using our motor, it’s good practice to perform a quick test run with our circuit. In this case, we want to collect as many measurements as possible just before and just after the motor begins to turn (or stops turning).

You will find that when the supply voltage is too low, the motor will remain stopped due largely to static friction and inertia. When the voltage is increased enough, the motor will turn on. Once the motor is moving and the voltage is decreased, the motor will not stop (stall) at the same turn-on voltage level because of the different kinetic friction and inertia. Starting from 0 V, the motor will fight internal friction. To find the turn-on voltage, it is important that you always collect your data with increasing voltage. If you need to go back and collect a certain data point, you need to start over from a voltage that produces a stalled position. Likewise, the stall voltage can only be found by starting from a higher voltage where the wheel is moving and reducing the voltage until the stall occurs. Below you will find an example of the motor IV data. Your figure may look a bit different.

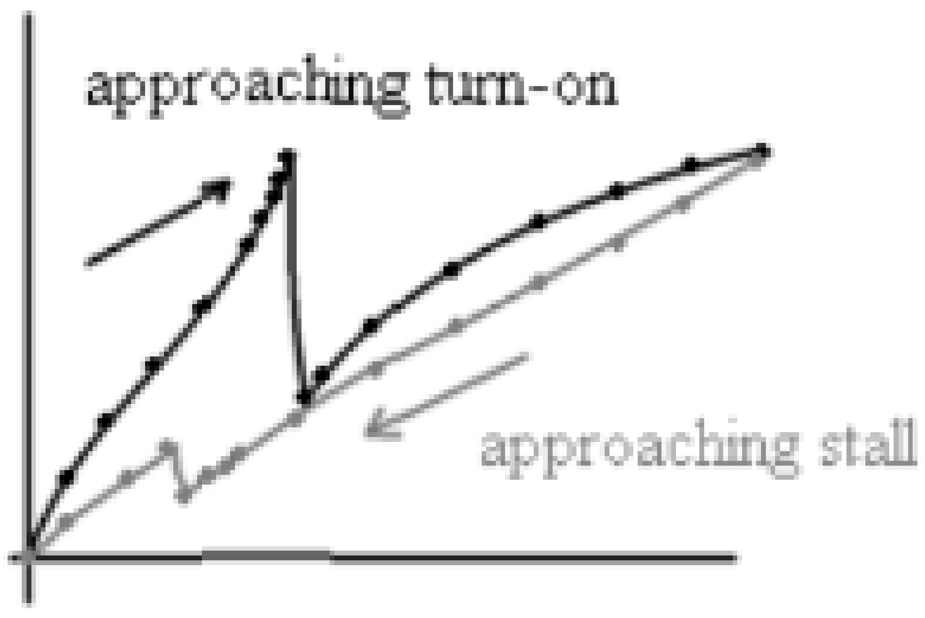


Figure 2: Example motor IV data without curve fits.

When we sweep the voltage from high to low, kinetic friction of the motor is less than the static friction. The inductance of the motor windings may also play a role in keeping the motor rotating. Eventually, we will reach a stall voltage that is generally lower than the turn-on voltage.

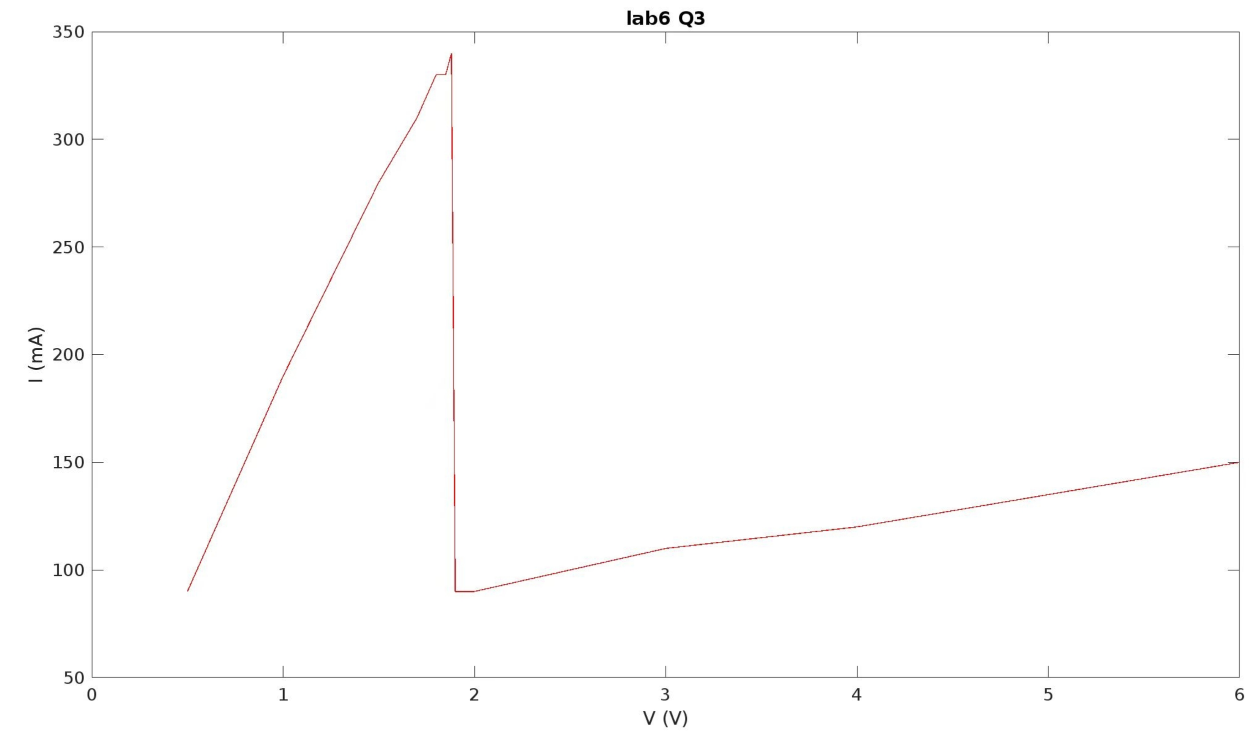
Question 1: Starting at zero volts, sweep the voltage of the power supply up to 6V and make note of the approximate “turn-on” voltage at which the motor begins to spin. Once you have hit 6V, sweep the voltage back down and make another note of the approximate voltage at which the motor stops or “stalls”. Record your approximate turn-on and stall voltages here. These two numbers should be different.

Voltage(V)	Current	Notes:
1.9V	0.09A	
0.5V	0.09A	

Table 1: Current flow for the motor for increasing, then decreasing, DC voltage with comments.

Question 2: Manually sweep of the power supply. Start at zero volts and sweep the voltage of the power supply up to 6V. Record all the voltage and current values. Next, decrease the voltage from 6V to 0, record all the voltage and current values at the tables below. (Please record all the data in the Table 2 and Table 3 of ***Attachment 1***）

Question 3: Use MATLAB to generate a graph of IV data from Table 2.



Question 4: F g” portion of this data (labeled on Figure3). In MATLAB, you might use the polyfit command to do a first order (n=1) fit to that data. Include the polyfit figure below.

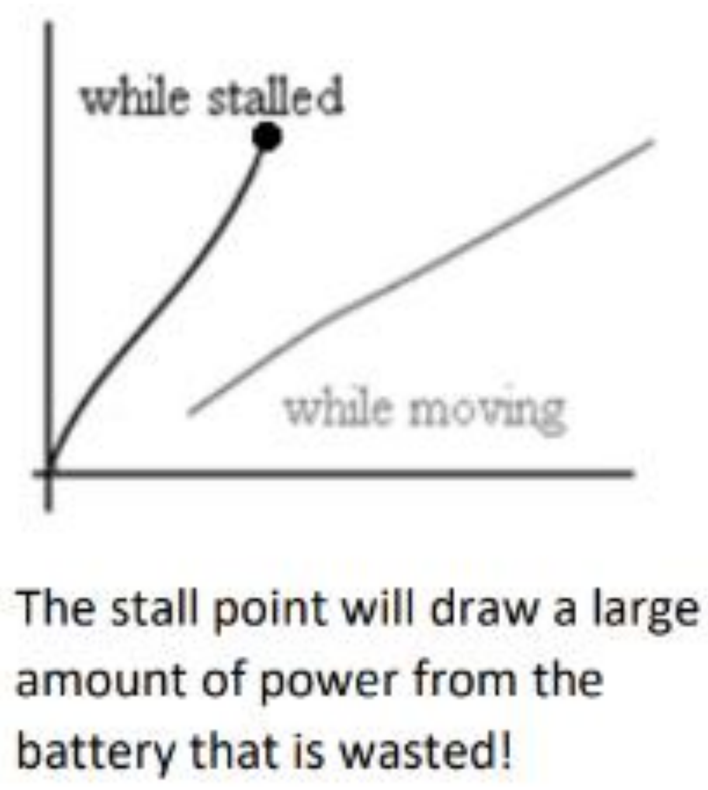
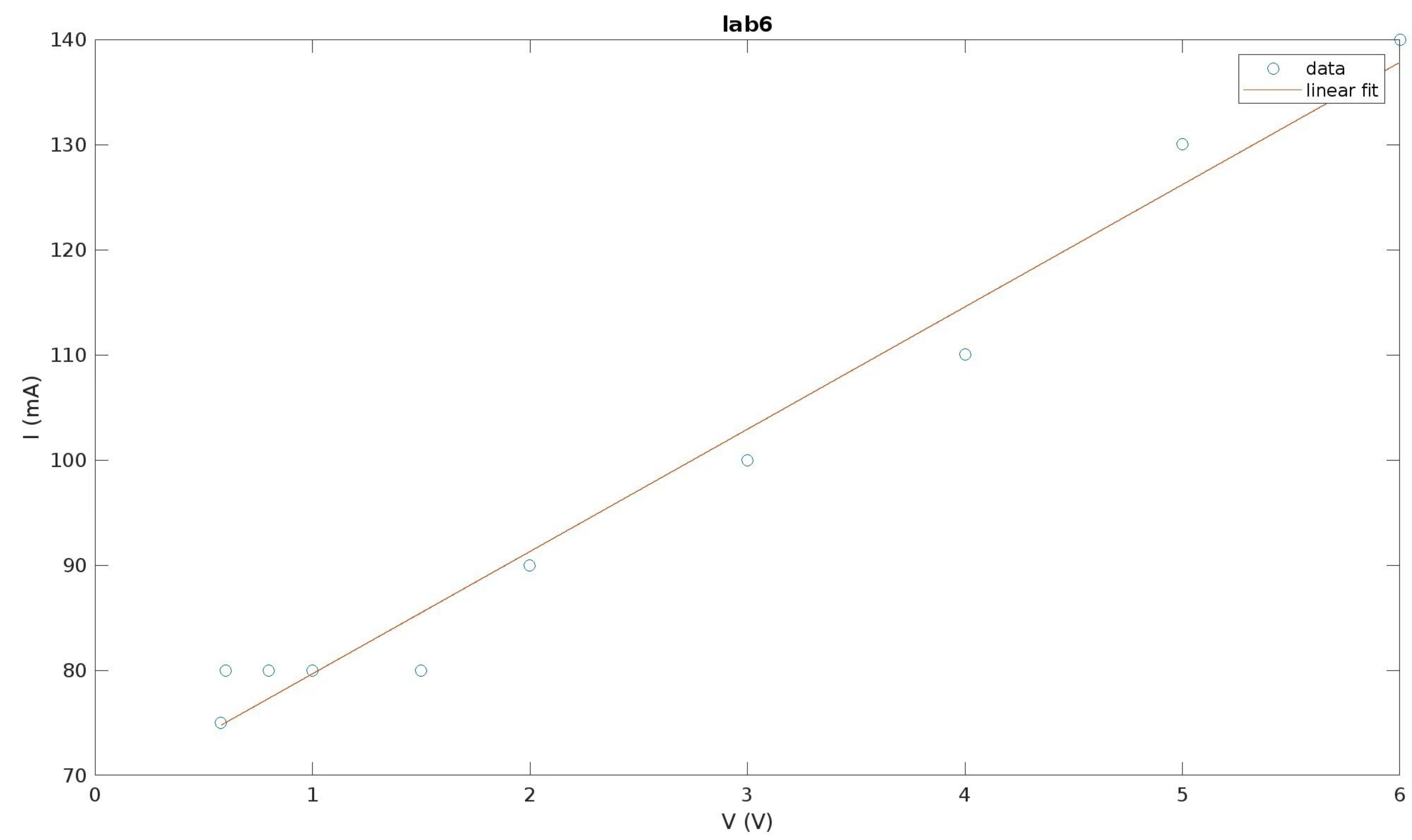


Figure 3: The ideal IV curve of the motor



Question 5: Determine a linear equation (slope-intercept form) corresponding to the linear curve-fit generated. Explain how you found the missing values below.

While Moving: I = 11.633 V + 68.023 (mA)

Question 6: Using this equation, determine a Thevenin-equivalent circuit for your motor to model it when it's moving. Show your work.

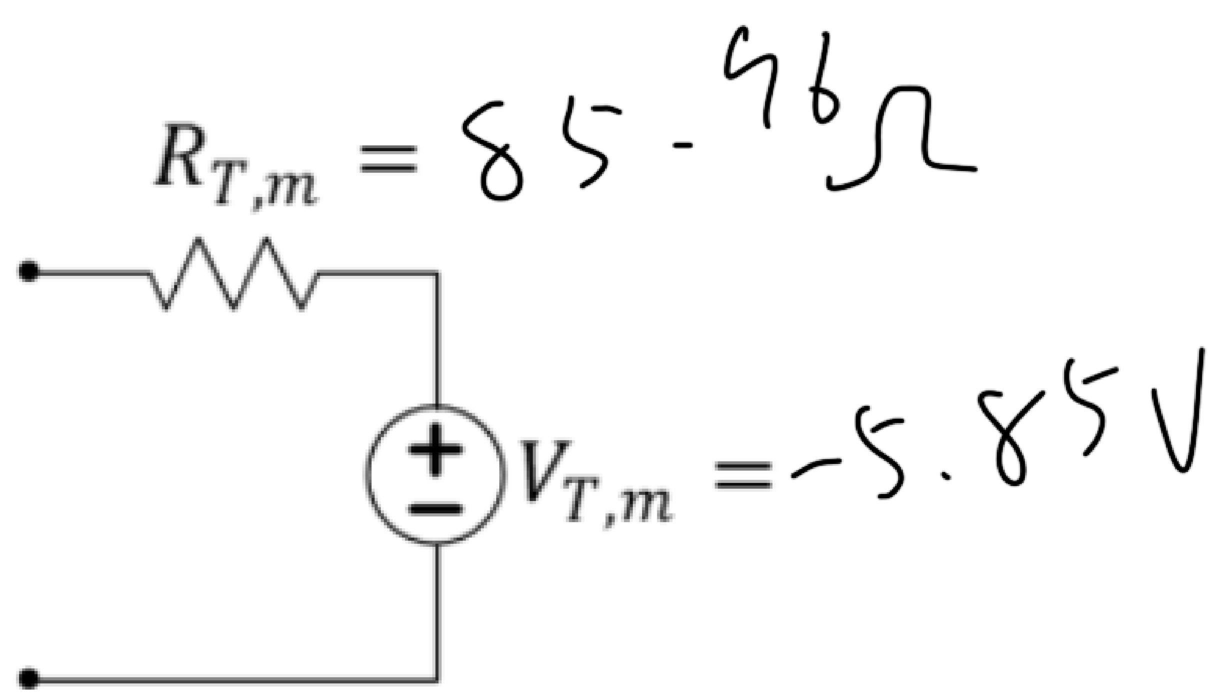
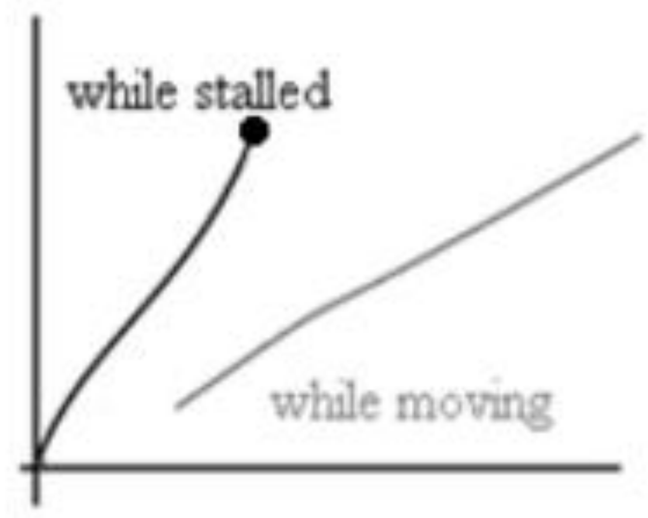


Figure 4: Record your estimate of $R_{T,m}$ and $V_{T,m}$ for the Thevenin model of the moving motor in the figure above.

Question 7: How much power is drawn from the power supply just below the turn-on voltage (while still stalled)? See the operating point suggested in the figure below but use the data you collected.

$I = 340mA$

$P = UI = 0.6392W$



The stall point will draw a large amount of power from the battery that is wasted!

Question 8: When installed, all energy from the battery is wasted. How long will your battery last if it were to sit continuously just below the turn-on state? Recall that the battery is rated at 2800 mAh. You measured the current drawn just below turn-on!

8.116 h

Explore More! Modules

The instructor will provide you with their preferences for this week's ***Explore More! Modules***. Continue with below **with your choice.** Remember, at the end of the semester, you will earn points towards your total semester lab score by completing at least 6 modules. If you wish to be eligible for a Course Aide position in the future, please consider doing more and impressing us with your command of the material and your ability to aid your classmates.

Attachment 1:

Voltage (V)	Current(mA)	Voltage(V)	Current(mA)
0.5	90		
1	190		
1.5	280		
1.7	310		
1.8	330		
1.85	330		
1.88	340		

1.90	90		
2	90		
2.5	100		
3	110		
4	120		
5	135		
6	150		

Table 2: Current flow for the motor for increasing DC voltage from 0 to 6V.

Voltage (V)	Current(mA)	Voltage(V)	Current(mA)
6	140		
5	130		
4	110		
3	100		
2	90		
1.5	80		
1	80		
0.8	80		
0.6	80		
0.58	75		
0.55	100		
0.5	90		
0.4	70		
0.2	40		

Table 3: Current flow for the motor for decreasing DC voltage from 6V to 0.