Sim Lab 6 – DC Motor in LTspice

Prerequisites

- Please make sure you have completed the following:
  - Lab 7 LTspice tutorial parts 1-4
  - Simulation Lab 8 Part 1- MATLAB

Learning Objectives

1. Import a realistic DC Motor model to LTspice
2. Study the IV Characteristic of DC Motor in simulation
3. Study the back EMF effect of DC Motor in simulation

1. Import DC Motor Component

1. Import DC Motor Component

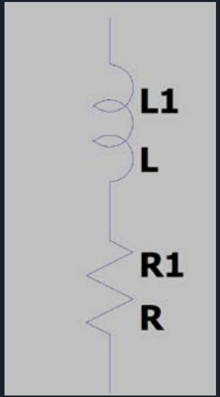


Figure 1..

- As you have seen in the tutorials , LTspice allows you to add a wide range of components to your schematic in LTspice, including voltage source, resistor, capacitor, etc. However, a DC motor like the ones that we used for our cars in previous labs, is not on the list of components innately provided by LTspice. We need to model a DC motor using components offered in LTspice.
- One simple model of motor would be a simple resistor + inductor design, as shown in figure 1. This model of motor considers that the motor not only has resistance, but also a “coil” of wire that operates as an electromagnet and offers a significant amount of inductance. While current flows, energy is stored in the form of a magnetic field. This DC motor model, while better than a simple resistive model, still ignores mechanical properties like inertia. Therefore, its simulation will poorly reflect real-world operation.
- If you wish to know more on the characterization of a DC motor, you should read [this article](#).

1. Import DC Motor Component

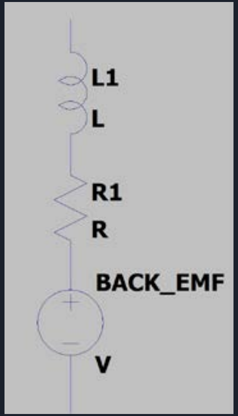


Figure 2..

- There are many mechanical properties of a DC motor, such as internal friction, non-zero turn-on voltage, etc. In this lab, our DC motor model considers the back EMF effect of DC motors, as briefly mentioned in lab 5. A model of the DC motor that considers back EMF is illustrated in figure 2.

- Note that this illustration is a simplification as it does not show how the voltage output of the voltage source 'BACK_EMF' is determined. However, this detail can be left behind for now, since your TAs have created the model of DC motor for you. If you are curious about how this model works internally, you can read all about it in this article and this article.

- Now, please download the DC motor model that we created for you from ECE110 Lab Procedures called dc_motor.asc and dc_motor.asy. Next, we are going to show you how to import this customized model to LTspice

1. Import DC Motor Component

- After the file is downloaded, unzip the file to extract the following two files:

```
dc_motor.asc: LTspice schematic for the DC motor component
dc_motor.asy: LTspice symbol for the DC motor component
```

- Now, place *both* files into the following directory:

```
C:\Users\[yourUserName]\Documents\LTspiceXVII\lib\sym
```

Note:

- The directory shown above may vary depending on where you install LTspice. Ask a TA for help if you are having trouble finding this directory on your computer.
- If you are not sure how to unzip the files, check out this link.

1. Import DC Motor Component

- Save any work and close out of LTspice if it is open. This will force it to read the symbol folder again.
- Open LTspice and open a new schematic by pressing `ctrl + n`.
- Then, press the component symbol  and then search for `dc_motor` in the search bar. You should see something similar to figure 3. Click ok to place the motor component on your schematic.

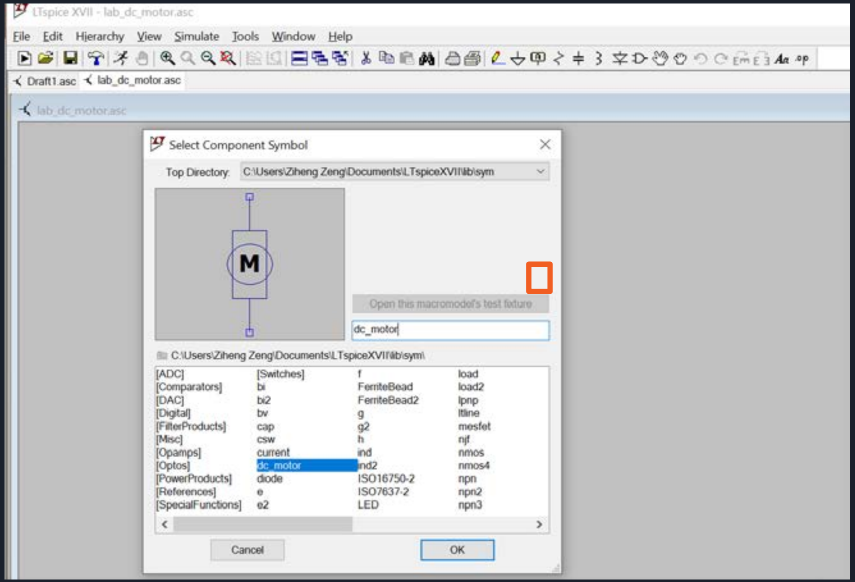


Figure 3.

2. IV Characteristics of the DC Motor in simulation

2. IV Characteristic of DC Motor in simulation

- To understand how the DC motor in simulation differs from your DC motor of your lab car chassis, let's do a quick analysis of the IV characteristic of the DC motor component.
- Similar to what we have done in lab 6, build the circuit shown in figure 4 in LTspice.

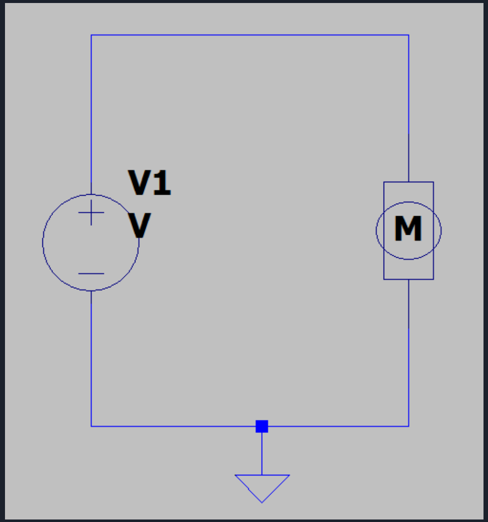


Figure 4..

2. IV Characteristic of DC Motor in simulation

- Now, we will sweep the voltage of the voltage source from 0V to 6V in 6s and obtain the current and voltage signal.
- First, edit the voltage source. Right click on the voltage source and select `Advanced.`

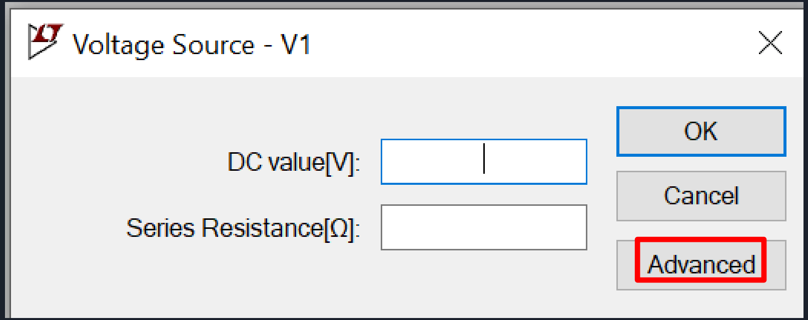


Figure 5..

2. IV Characteristic of DC Motor in simulation

- Under ‘Functions’, select PWL… (Piecewise Linear) and enter the settings as shown in figure 6. That is, sweep from 0 to 6 volts in 0 to 6 seconds.
- The voltage supplied by V1 will ramp up from 0V to 6V in the span of 6s in simulation.

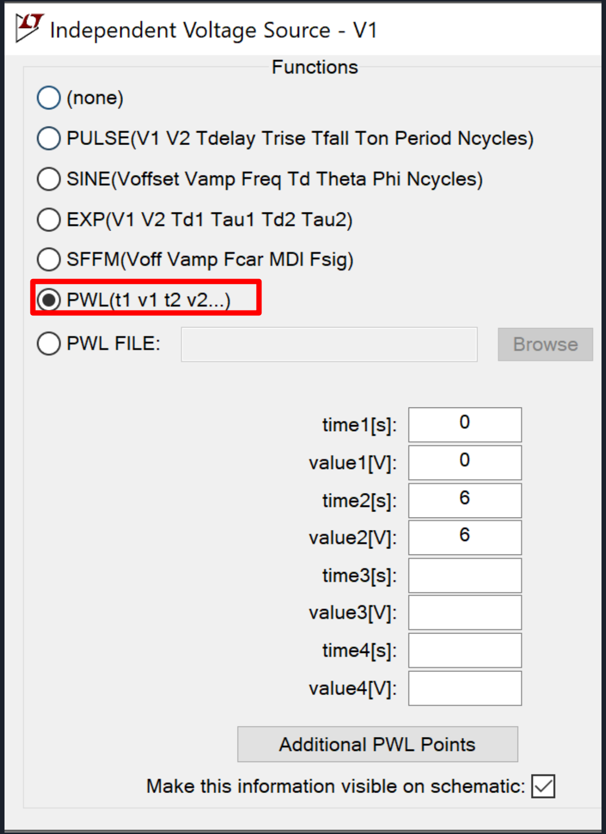


Figure 6.

2. IV Characteristic of DC Motor in simulation

- Now, we will add simulation. Click on the `Simulate` tab and then select `Edit Simulation Cmd`, as shown in figure 7.
- Next, enter the Stop time of 6s as shown in figure 8 and then click ‘OK’.

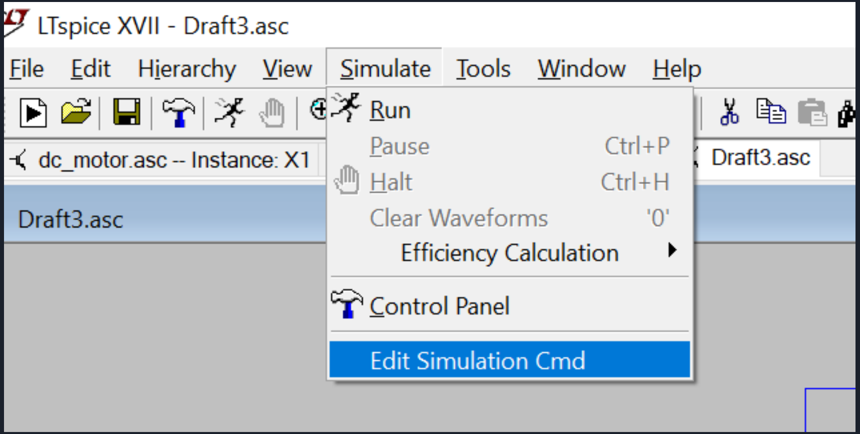


Figure 7..

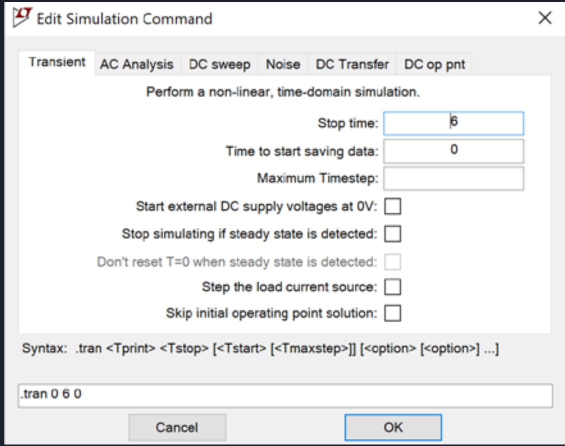


Figure 8..

2. IV Characteristic of DC Motor in simulation

- In simulation, probe the *voltage* output from the voltage source, as shown in figure 9. The voltage waveform should show up as ‘`V(n001)`’.
- Also, probe the *current* entering the motor, as shown in figure 10. The current waveform should show up in simulation as ‘`Ix(x1:INPUT)`’
  - To measure current, make sure to click on the connection point of the wire and the motor input. You should see the symbol in the orange box shown in figure 10 instead of the red probe in figure 9 .

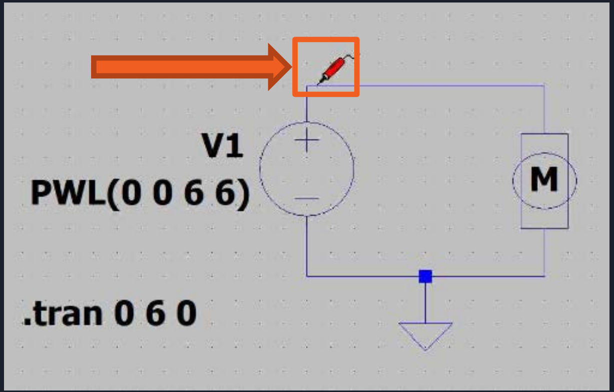


Figure 9..

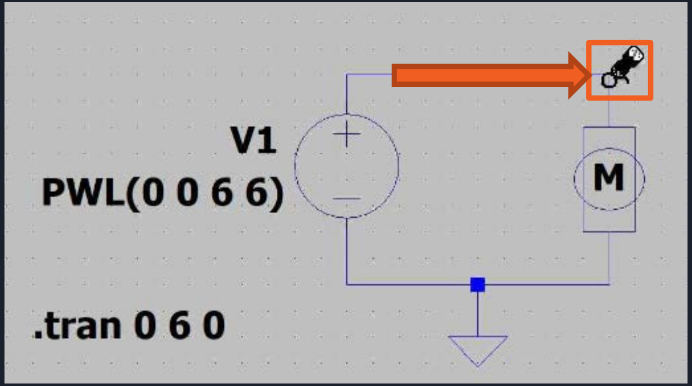


Figure 10..

2. IV Characteristic of DC Motor in simulation

- For the current waveform, you should be able to see current for a ‘while stalled’ portion and a ‘while moving’ portion, similar to the ‘approaching turn-on’ curve that is shown in figure 11.

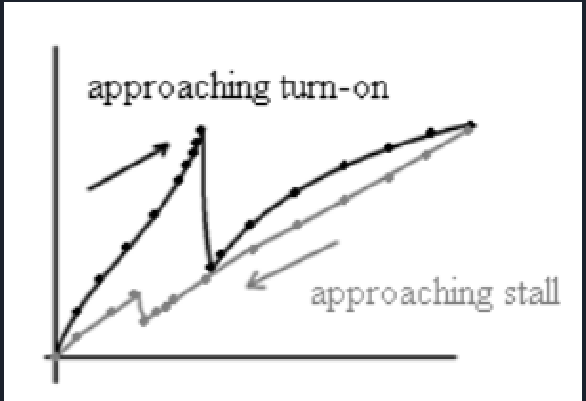


Figure 11..

2. IV Characteristic of DC Motor in simulation

- **Question 1:** From the waveforms, determine the ‘turn-on’ voltage of the motor, i.e., the voltage when motor stop stalling and start moving.
- **Question 2:** Export the voltage and current data and plot the IV curve in MATLAB. Perform a linear curve-fit to the “while moving” portion of this data.
    - For exporting data and plotting in MATLAB, see the tutorial at the Lab Procedure webpage.
- **Question 3:** Determine a linear equation (slope-intercept form) corresponding to your linear curve-fit generated from your simulated model.
    - While Moving: `I = ________ V + ________`
- **Submission:** Submit the schematic for this part. Also, submit waveforms and the answers to question 1 to 3.

3. Back EMF Effect of DC Motor in sim ulation

3. Back EMF Effect of DC Motor in simulation

- We have seen the back EMF effect of DC motors from lab 5. Read the paragraph before Lab 5 Question 10 if you forgot what back EMF is.
- Now, we will observe the back EMF effect of the DC motor component in simulation.

3. Back EMF Effect of DC Motor in simulation

- Open up a new schematic and build the circuit shown below in figure 12. Read ahead for some hints on building the circuit.

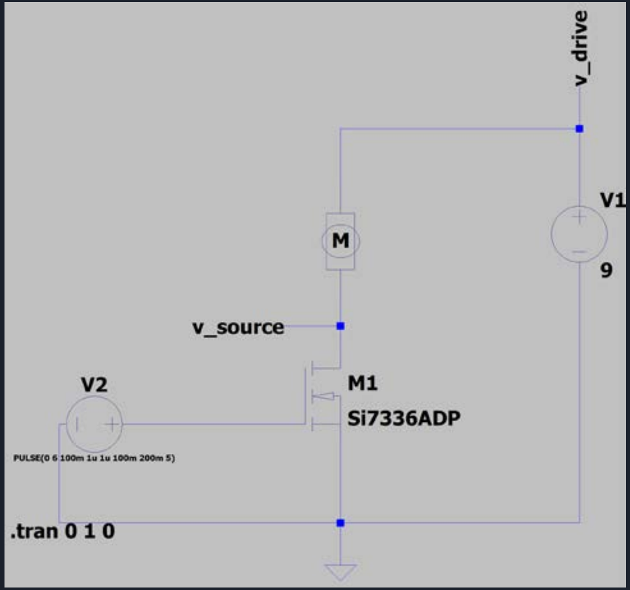
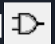
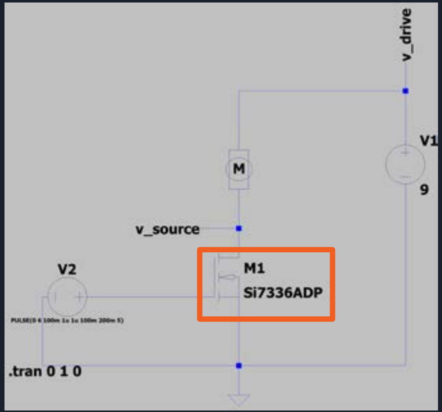


Figure 12..

3. Back EMF Effect of DC Motor in simulation

- How to add MOSFET to the circuit.
  - Click component symbol  , and then search `nmos` in the search bar as shown in figure 13. Then, click ‘OK’.
  - Right click on MOSFET component, then click `Pick New MOSFET`; pick the first option `Si7336ADP`, then click ‘OK’. See figure 14.



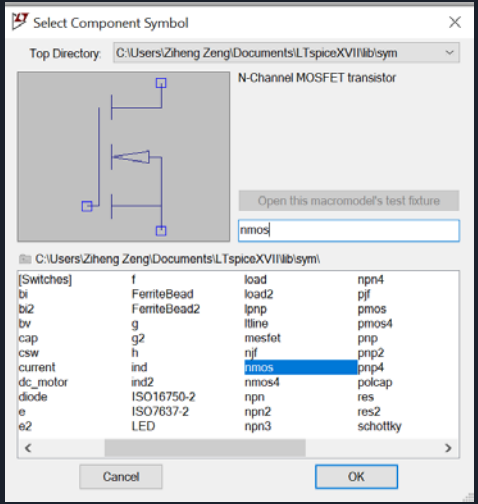


Figure 13..

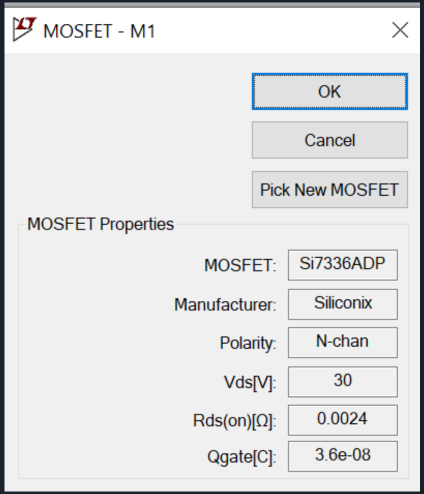
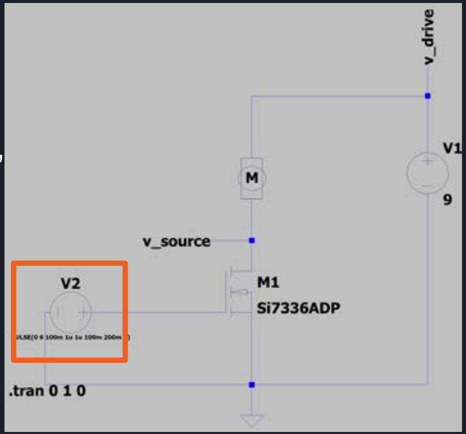
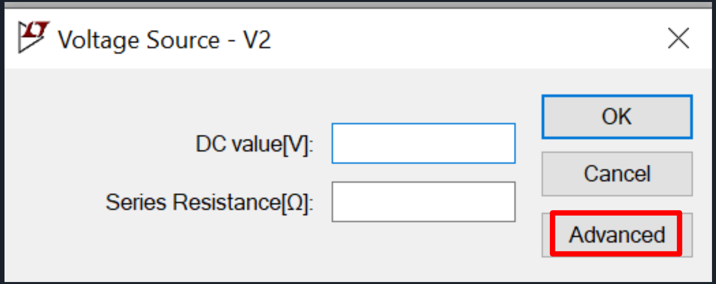


Figure 14..

3. Back EMF Effect of DC Motor in simulation

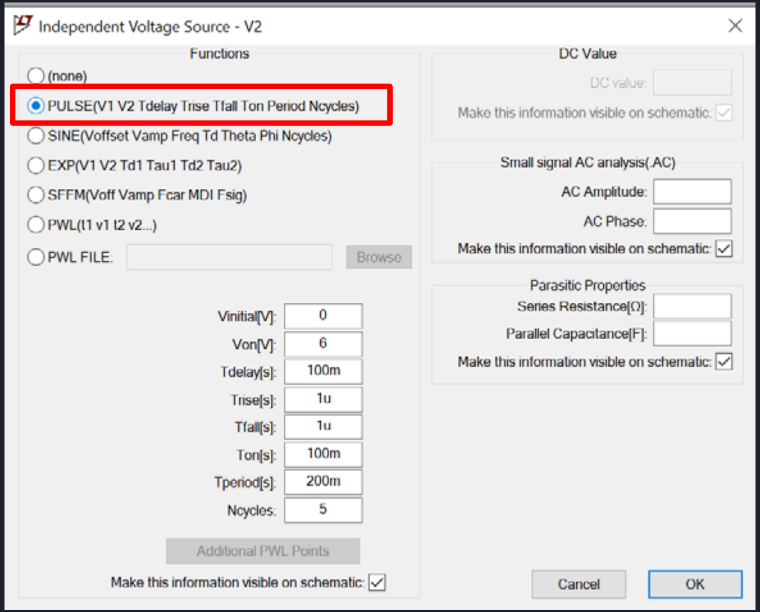
- How to add a squared-wave power supply (V2)
    - Add a voltage source (shown as V2 in the figure to the right). Then, right click on the voltage source and click `Advanced`





3. Back EMF Effect of DC Motor in simulation

- How to add a squared-wave power supply (V2) (cont'd)
  - Under 'Functions', select PULSE... and enter the settings as shown in figure 15.



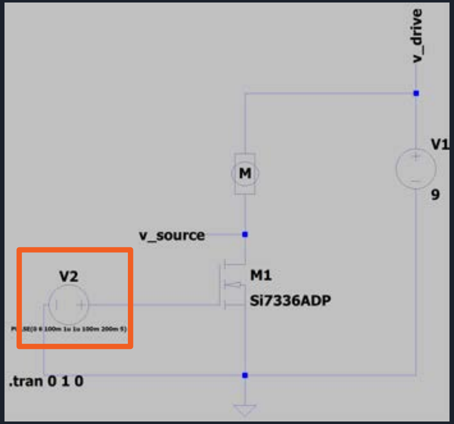
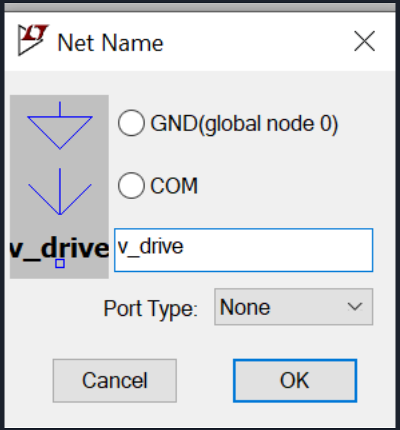


Figure 15.

3. Back EMF Effect of DC Motor in simulation

- How to add a node
    - Click on from the menu bar and then type `v_drive` or `v_source` in the bar as shown in the figure 16 below. Click ‘OK’.
    - After adding the node, use wire to connect the node to the circuit.



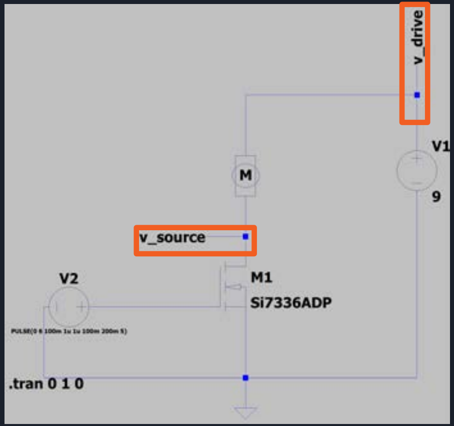


Figure 16..

3. Back EMF Effect of DC Motor in simulation

- **Question 4:** After completing the circuit, run simulation with `Stop time=1` and `Time to start saving data=0`. Probe the voltage at node `v_source` and `v_drive` as shown in figure 17. Save and submit the resulting simulation waveforms and write down your observations.
- **Question 5:** Compare the above waveform to the waveform you sketched in Lab 5 Question 10. How do they compare? Do you see large spikes at node `v_source` from your simulation waveform?

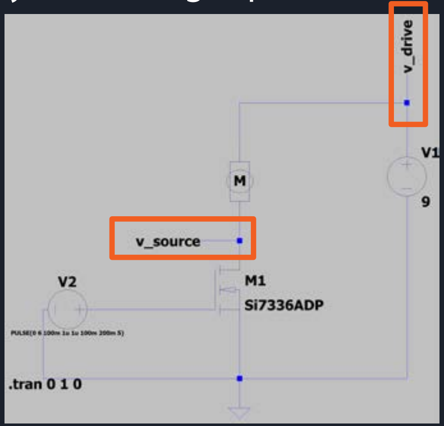


Figure 17.

3. Back EMF Effect of DC Motor in simulation

- Now, let’s try to suppress the large spikes produced by back EMF with a diode.
- Add a diode by clicking on  left to the ‘component’ button on the menu bar.
- Set the diode values by right clicking the diode. Then, click `Pick New Diode` and pick the first option as shown in figure 18. Click ‘OK’.

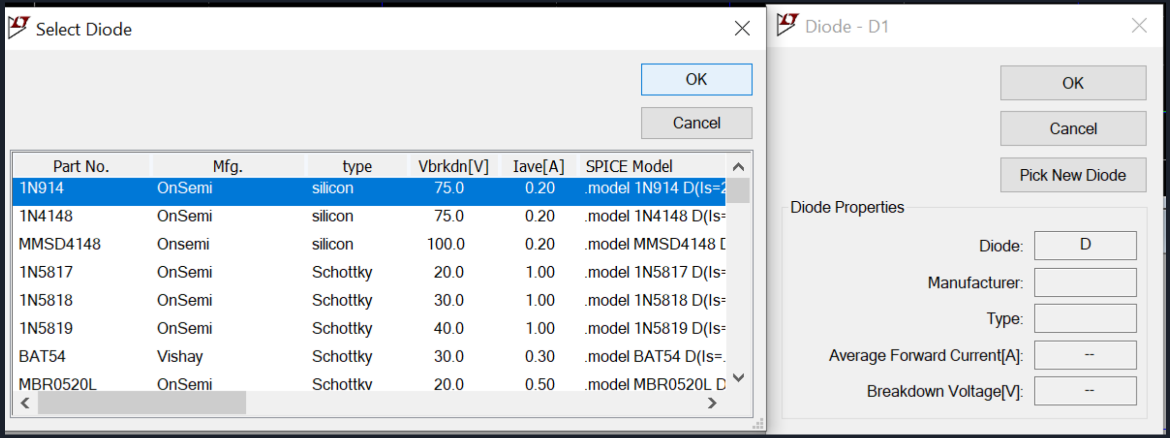


Figure 18.

3. Back EMF Effect of DC Motor in simulation

- Connect the diode to the rest of the circuit as shown in figure 19.

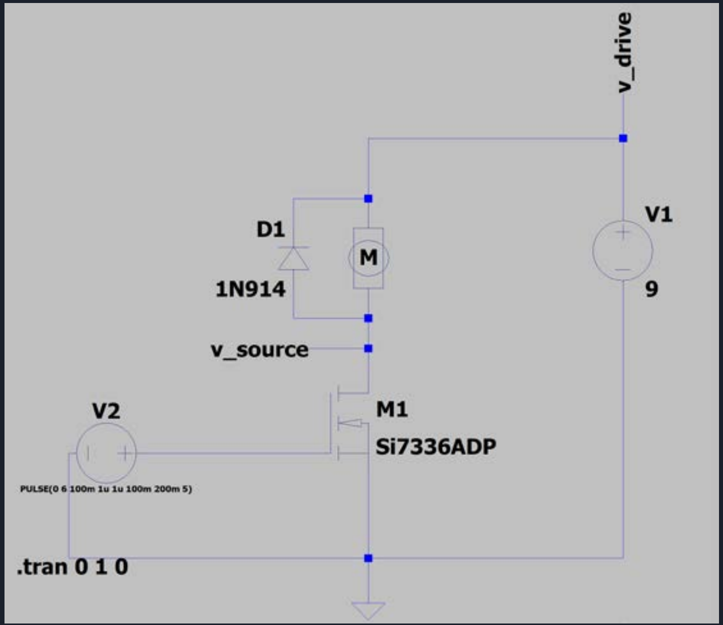


Figure 19..

3. Back EMF Effect of DC Motor in simulation

- **Question 6:** After completing the circuit, run simulation as in question 4 and again probe the voltage at node `v_source` and `v_drive` as shown in figure 16. Save and submit the resulting simulation waveforms. and write down your observations.
- **Question 7:** Compare the waveform from question 6 and question 4. Does the diode suppressed the voltage spikes? Explain.
- **Submission:** Submit your answers to question 4-7. Submit the schematic used for question 6 and the waveforms from question 4 & 6.