
Lab 10: EMF and Drive Circuits

1. Introduction

When driving an inductive load, one has to consider the EMF (electromagnetic feedback) that occurs when the voltage source driving it is suddenly taken away. When the electromagnetic field collapses, the brief but large voltage spike that is created has to go somewhere. Sometimes it goes where we do not want it to go, like into a sensitive microcontroller. This can cause EOS, Electrical Over Stress, a.k.a “magic smoke”! And we all know that when the magic smoke is gone, you can’t put it back in!

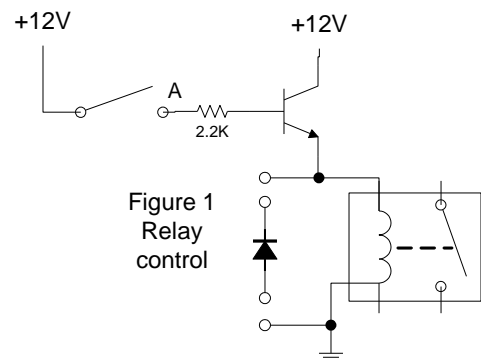
A motor, when the shaft is spun by some force, essentially becomes a generator. So when a motor is being driven by an electrical potential, and the potential is removed, if the motor continues to spin we can get potentially harmful feedback generated. This EMF principal is also useful in controlling the speed of the motor, but that is for another course.

2. Pre-Lab - Read the entire Lab text and document any questions you may have.

3. Experiment

3.1 Relay

Construct the circuit of Figure 1. Do NOT hook up the diode at this point. Use the 2N4400 transistor from your kit. Observe the signal on the emitter of the BJT with the oscilloscope. Set the trigger for a negative edge slope and set the trigger level to 8 volts. Set the time scale to 2mS/div and adjust the horizontal position so that the trigger point is one division from the left side of the screen. Your vertical scale should be 10V/div with ground set two divisions from the top of the screen. Your trigger mode should be set to normal or you will not capture the event.

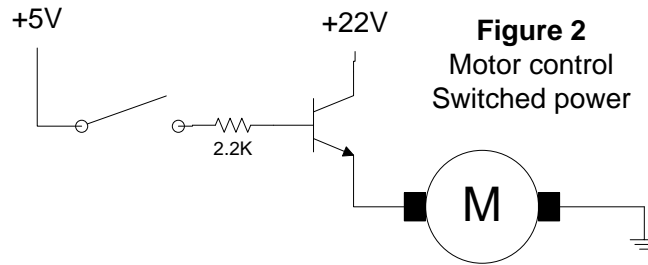


A relay uses an energized coil to electro-magnetically physically close or open a switch contact(s). Relays have a coil voltage rating and a contact voltage and current rating. The coil voltage is the required voltage to activate the relay. The contact ratings are the maximum amounts of voltage or current you can safely switch. For example, you could use a relay to switch 120VAC power with a 5V DC control source given that the relay used met those ratings.

Now you may close the switch. You should hear the relay contacts close with a “click”. This is the coil energizing and pulling the contact closed. Now open the switch. Your scope should have triggered and captured a very large negative spike. This is what is called EMF.

Insert a 1N4001 diode across the relay coil and repeat the procedure. This is often referred to as a flyback diode. What effect did the diode have on the circuit and the waveform?

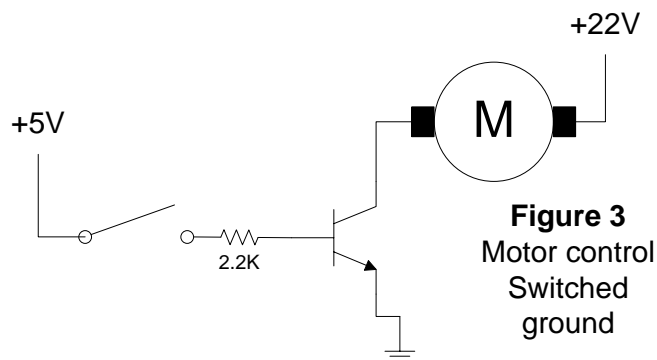
3.2 DC Motor – switched power



Connect the DC motor provided to +22V DC and observe the speed of rotation. Now replace the relay in figure 1 with the DC motor as shown in figure 2. **Note the changes in supply voltages.** Close the switch and observe the motor speed and compare it to the speed when hooked directly to the voltage source. The +5V and switch can be compared to controlling the circuit with a microcontroller. Why is the speed different? Measure the voltage at the emitter (V_E). Now measure V_B , V_{BE} and V_{CE} . From these measurements you should see that V_E is about 0.6V below V_B (your V_{BE} value). This is what should be expected due to the base-emitter junction characteristics. So if our motor is expecting 22V to operate we have a problem. Measure I_B with the motor running.

Increase the supply voltage to the switch to +22V. Does the motor run at full speed now? What is the value of V_E now? Problem solved right? But wait, if we still want to control the motor with our microcontroller we still have a problem. Microcontrollers are not capable of supplying that kind of voltage. In addition, we don't want to source or sink a lot of current thru a microcontroller. So we need some sort of buffer/amplifier between the microcontroller and our control circuit.

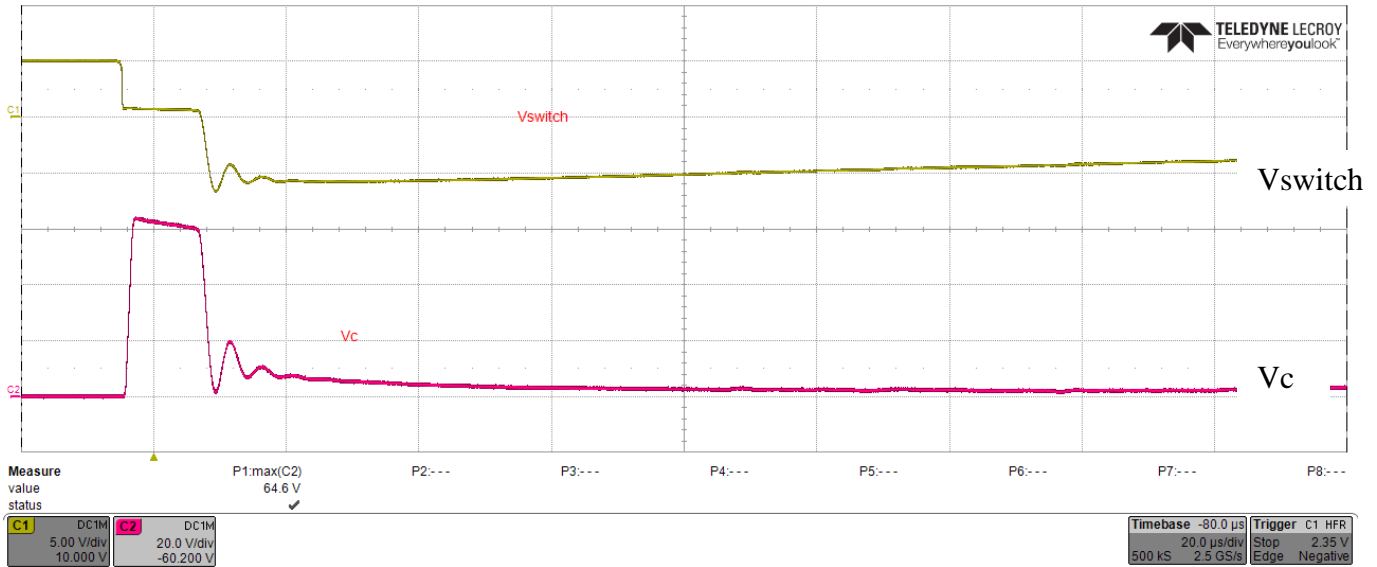
3.3 DC Motor – switched ground



Instead of switching the power to the motor, why don't we switch the ground? Let's try it. Modify your circuit to match figure 3. Does the motor rotate at the faster rate with this setup? How does V_B , V_E , and V_{BE} compare to the values of figure 2? Why is V_B different since the wiring of the base circuit is exactly the same? Measure I_B with the motor running to find the answer.

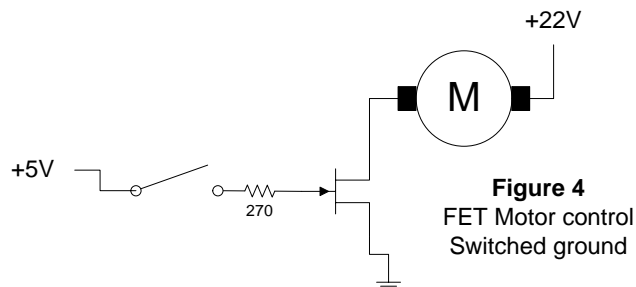
Look at the signal of V_C with the scope. To complete this task we need to trigger on the signal at the switch. So hook another channel to the resistor side of the switch, and trigger on it. You are looking for a negative edge at around 2V. Plus you will need to use the "High Frequency Reject" option in the trigger menu. Note where the trigger position is and the vertical and horizontal time scales from the example of Waveform 1.

Close the switch. The motor should run. Open the switch. Your scope should trigger and show you something like Waveform 1.



Where does this very large voltage come from? In most electric vehicles, this effect is used to recharge the batteries. In our case the spinning wheel is the only mass rotating at the end of our motor shaft to keep the motor spinning when it is switched off. But with the inertia of a car and the spinning of it's wheels, you can see how this large voltage could make a difference.

3.4 DC Motor – FET drive



Set up the circuit in figure 4. You will notice that the BJT is replaced by a MTP3055 FET and the base resistor has been replaced by a smaller gate resistor. Measure the actual value of this gate resistor before placing it in the circuit. **Before applying power:** 1. Ensure the switch is

open. 2. Temporarily short the switch side of the gate resistor to ground. Turn on the power supply and *then* remove the temporary ground from the gate. Close the switch and your motor should run. Open the switch. What happens? The motor continues to spin even with the switch open! This is due to the capacitance of the gate. We need a path for the charge that is built up on the gate to “bleed away”. This is called a “pull down” resistor. Close the switch again and measure I_G by measuring the voltage drop across the gate resistor. Now add a $1K\Omega$ resistor from the gate to ground. Try again, now when the switch is off, the motor will stop. What is the new value of current through the gate resistor? Is all this current going through the gate? Change the pull down to $1M\Omega$. What is your new I_{RG} ? Does your motor still turn off when the switch is opened? Which pull down would be best and why?

3.5 DC Motor – H bridge

So now you want to build that robot, but you don’t want him to just go forward. You want to back up. So you need to change the direction of the motor. You need something called a H-bridge. There are many different versions of this circuit. But we will focus on the simplest version. Figure 5 uses 4 NPN BJTs connected with the load in the middle. It looks like an H, thus the name. Notice the flyback diodes for each transistor. We are using a switch to simulate two output ports from a microcontroller.

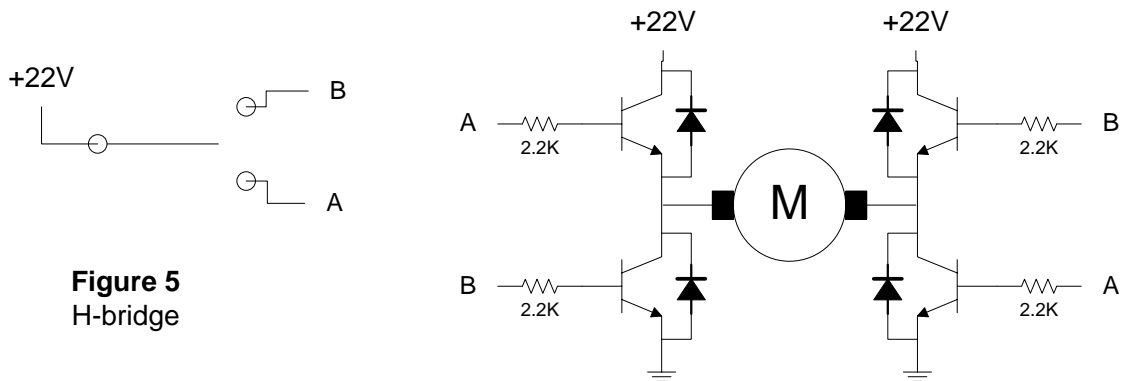


Figure 5
H-bridge

When the switch connects point A the motor will spin one direction, and when it connects to point B, it will spin the opposite direction. Note that we still have the same situation with the control signal. One would have to provide a buffer/amp stage between the microcontroller and the h-bridge to make it work correctly.

Construct the circuit of figure 5. Demonstrate your working circuit to a TA. Turn the motors back in to the TA.

4. Post Lab

You measured the current draw for both the BJT and FET motor drivers. Compare the two and discuss why one would be better than the other when driving from a microcontroller. What would happen in Figure 5 if power were applied to both inputs at the same time? Provide discussion and summary of the lab.