Section	
Bench No.	

ECE110 Introduction to Electronics

Pre-lab 8: Pulse-Width-Modulation (PWM)

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Date: ______________________________

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This part is reserved for your instructor

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Instructor Signature	
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Pre-lab 8: Pulse-Width-Modulation (PWM)

Background…Our story in Pictures (Circuit Schematics, that is!)

Let's reflect on the semester's progression. With little circuit knowledge, we learned that we could control a car by pulsing on and off the two wheels. Physical limitations on the switching rate (due to the switches, motors, and our own reaction time) made this kind of human-in-the-loop control system challenging to say the least.

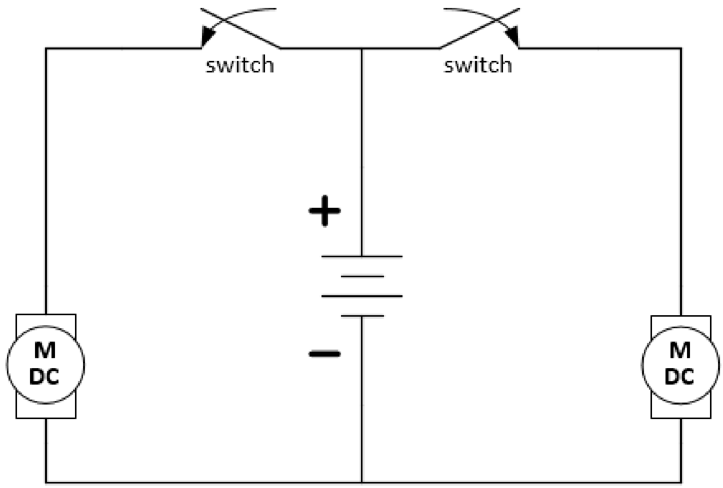

Figure 1: *Bang-bang control of the motors with a human-in-the-loop. Tough to control*

Next, we discovered that the motor speed could be reduced by utilizing current-limiting resistors in series with the motors. Careful selection of a network of resistors enabled us to both slow the wheels while safely dissipating excess power, but also to balance the speed between the wheels so that the car ran more-naturally straight.

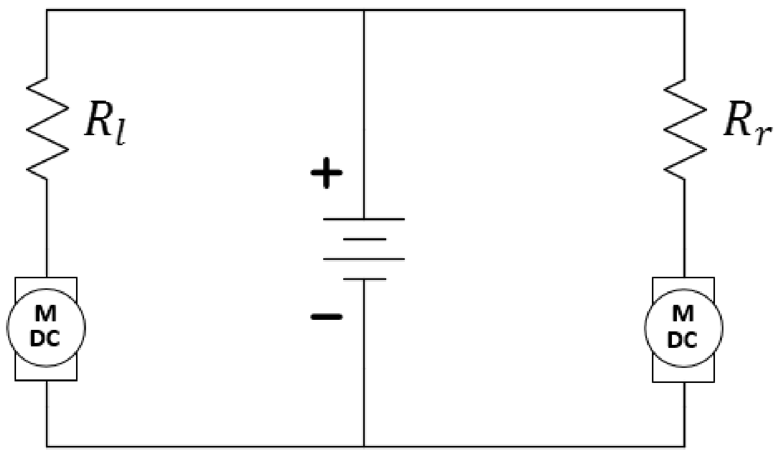

Figure 2: Current-limiting resistors when properly tuned, could make the car run straight without human control

We built upon this idea by controlling the resistive networks such that our switching action had lesser effect on the change in wheel speed and we found that we had improved control over the car.

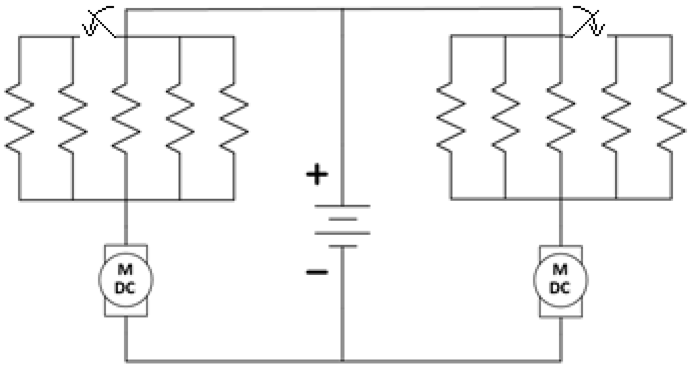

Figure 3: Fine switching differences of the current-limiting resistors improved human-in-the-loop control

At this point, we started to pay attention to efficiency. These resistive networks must be consuming power in proportion to that consumed by the motors. How inefficient were they? That was for you to calculate in the Unit 1 report.

The issue of efficiency was tackled by the use of a power MOSFET. Controlled by a voltage of our choosing, each MOSFET would allow current flowing through one motor. Why was the efficiency improved? Because the control voltage was being produced by a voltage divider that draws little current from the battery. Furthermore, that voltage was provided to the MOSFET with minimal current draw (a high equivalent resistance was seen looking into the MOSFET's "gate" terminal). How high was the efficiency? Answer it in question 1.

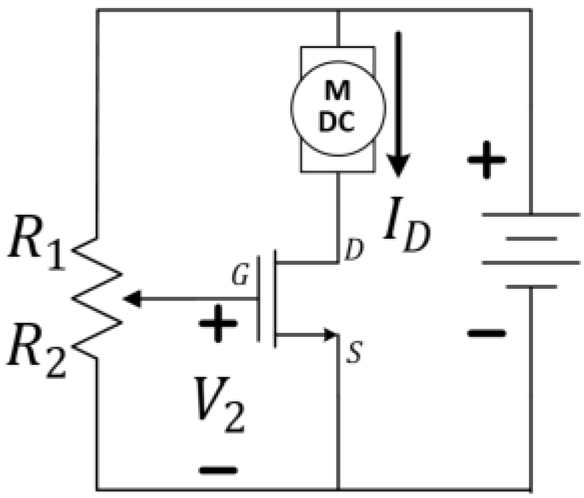

Figure 4: The use of MOSFETs and potentiometer-based voltage dividers leads to higher power efficiency and easy adjustment of straight-line vehicles

Question 1: What is the power dissipated on the resistor? Assuming the dissipation power of the MOSFET is ignored, what is the efficiency of the motor system? No specific numerical value, just use a formula to represent it.

While the speed of each wheel could be separately controlled by two voltage divider circuits, we found a way to control the overall car speed by pulsing the voltage divider's high-side voltage with a square-wave signal and did so using an oscillator that we built. This had the effect of slowing the car to nearly half of the "full-voltage" speed, but has another benefit. Square-wave signals are often used in motor-drive designs because they pulse the wheels at full voltage reducing the risk of stalling. We also became familiar with the idea of "buffering" our circuits to prevent one "sub-circuit" from "loading" another in way that our earlier circuit designs might fail. We used an extra inverter as this buffering element.

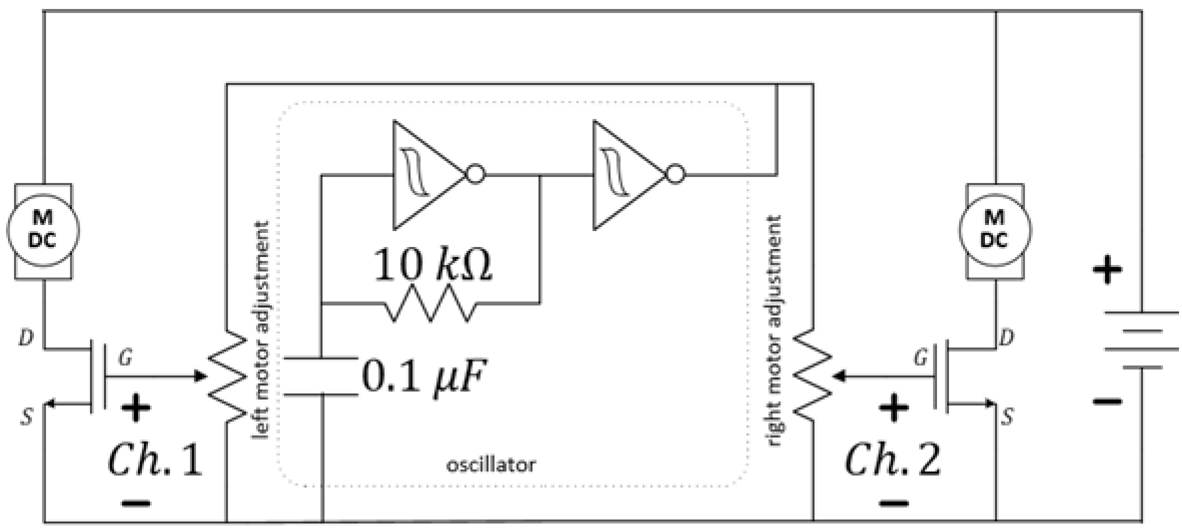

Figure 5: MOSFETs plus voltage dividers plus square wave pulses allow for efficient, tunable, slower straight-line vehicles.

Question 2: Analyze and build the circuit in Figure 5 on the Breadboard . **Save this circuit!** *Please take a picture of your circuit, and attach it here for grading.*

Moving away from speed control, we returned to the wheel-balance problem. Through the magic of diodes and the study of circuitry, **we discovered a way to create a square-wave signals with an adjustable duty cycle—a Pulse-Width Modulation (PWM) signal**. Using this signal and its "logical" inverse, we were able to balance the wheel speed with the turn of a single potentiometer and, therefore, get a car that would run remarkably straight.

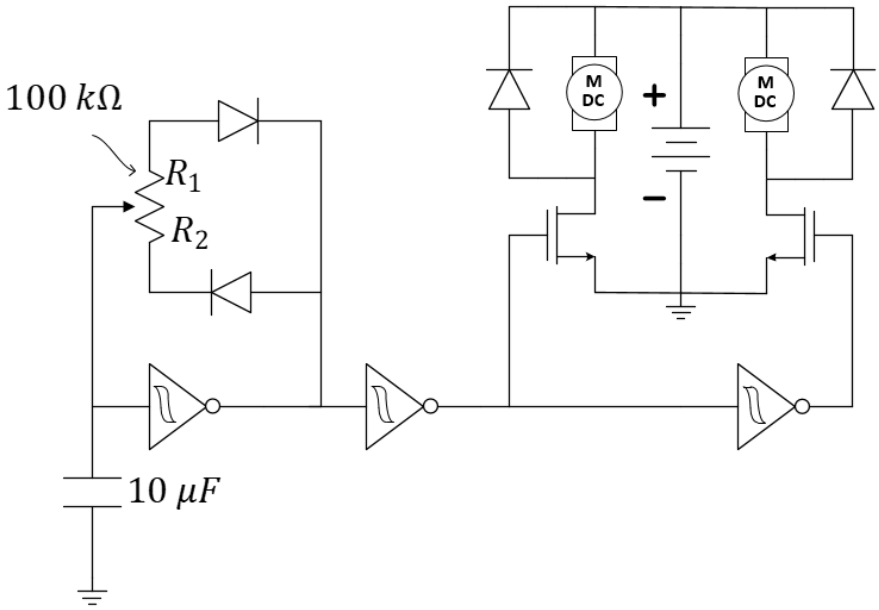

Figure 6: Replacing the two potentiometer-based wheel speed controllers with a single PWM-based wheel tuner

We now have two more objectives to bring our car to full autonomy. We will reintroduce speed control and we will reintroduce switches. *Different from last time*, we will not control our switches by hand. We will connect them to our vehicle in a manner which will allow the car to self-adjust and move away from obstacles (in this case, the wall) that might impede its progress.

If you have any questions about the circuits in Figures 5 and 6, bring your questions to the lab.