Section	
Bench No.	

ECE110 Introduction to Electronics

Pre-lab 9 : Logical-AND Circuits

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Pre-lab 9: Logical-AND Circuits

Wheel Tuning plus Speed Control (Diode-Based Logic Circuit)

To attain a way in which to simultaneously control the balance between wheels and the overall speed control, we need a method to combine the two control signals. To simplify, we will just consider a single wheel, say, the left wheel. That wheel will be controlled by two voltage signals. Let's call them V_{bal} and V_{spd} for balance and speed control and we desire to combine them to produce the left motor-drive voltage, V_l. Being (binary) logical signals, each of these signals will, at any point in time, take on a voltage near 0 volts or a voltage near that of the battery, V_{bat}. To merge these two signals into a single control signal for the wheel, we will use a diode-based logical device often called a logical "AND". We desire a signal that is high only when V_{bal} andV_{spd} are both simultaneously high and otherwise low. This is illustrated in Figure 1 and Table 1.

V_{bal}	V_{spd}	V_l
0	0	0
0	V_{bat}	0
V_{bat}	0	0
V_{bat}	V_{bat}	V_{bat}

***Table 1**: Desired relationship between the left-wheel control signal and inputs V_{bal} and V_{spd}.*

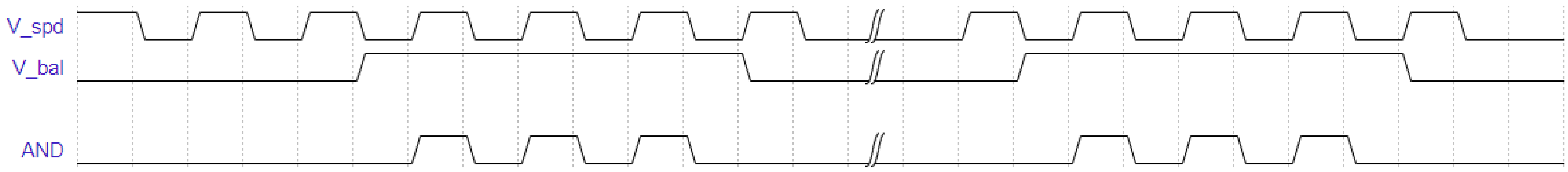

***Figure 1**: Example: Increasing the duty cycle of either V_{bal} or V_{spd} will change the output of the AND to drive the corresponding wheel at a higher speed.*

While this is the general behavior we want, we can tolerate some deviations from these voltages; they need not be exactly equal to 0 or $Vbat$ (with respect to the battery's negative terminal, of course).

Below is a proposed circuit to achieve this AND operation.

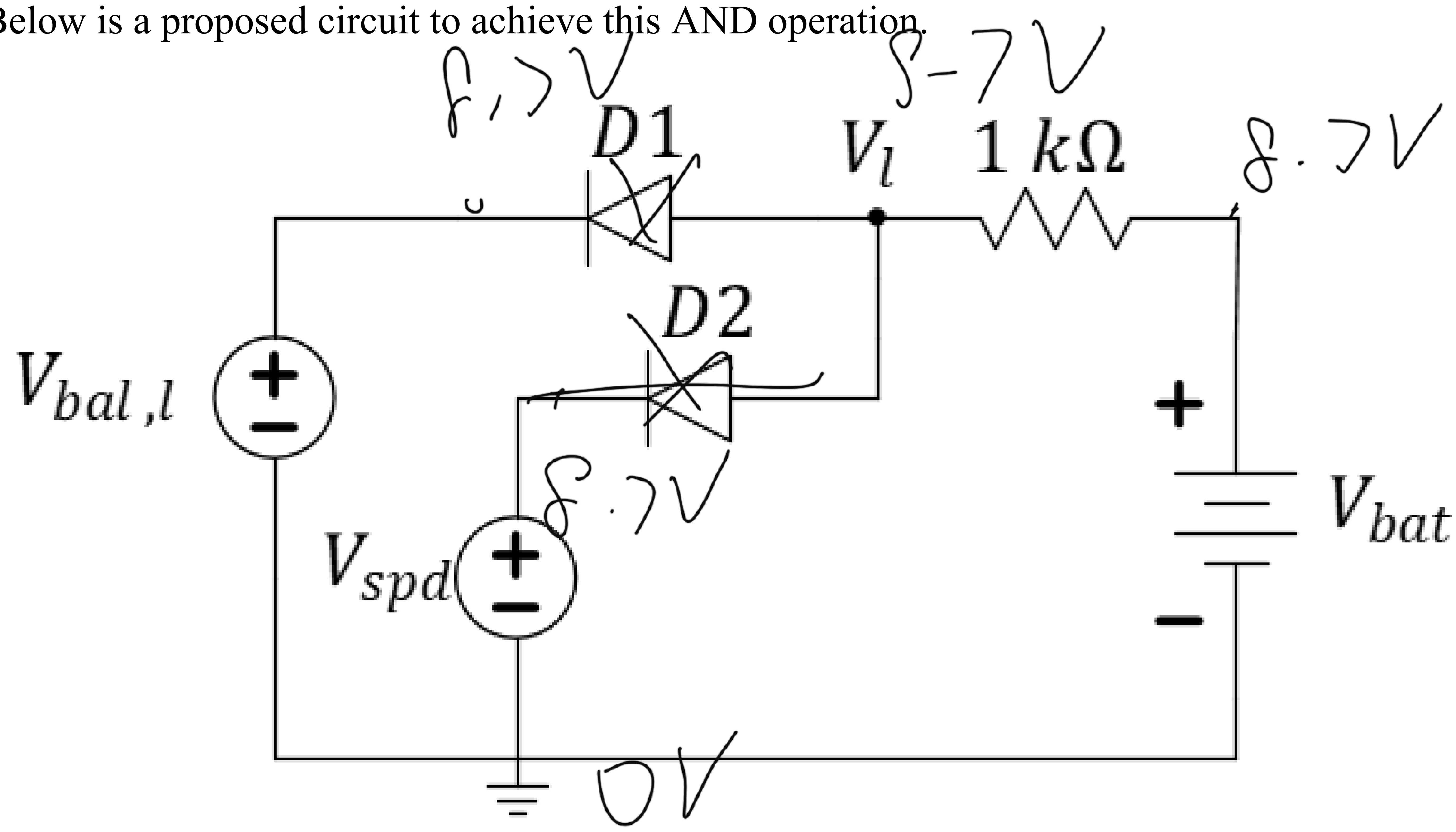

Figure 2: A diode-based logical-AND circuit for "joining" two PWM signals.

Question 1: Assume $V_{on} = 0.7\ V$ and $V_{bat} = 8.7\ V$. Use the circuit schematic to solve for the voltage V_l under the four conditions represented by each row.

$V_{bal,l}$	V_{spd}	V_l
0	0	0.7 V
0	8.7 V	0.7V
8.7 V	0	0.7V
8.7 V	8.7 V	8.7V

Table 2: Derived relationship between the left-wheel control signal and inputs V_{bal} and V_{spd} using the diode-based AND circuit.

We have built several circuits to do specific tasks. Examples include the oscillator to generate a PWM signal and the MOSFET- based motor-drive circuit. We have also learned that a cascade of circuits, a series of sub-circuits combined to achieve a "larger" goal, might require *buffering* elements to prevent loading effects. For example, suppose you want to record the voltage of a voltage divider, but the instrument you plan to use to collect this information has an internal resistance of 50 Ω. Figure 3 explains the issue in some detail.

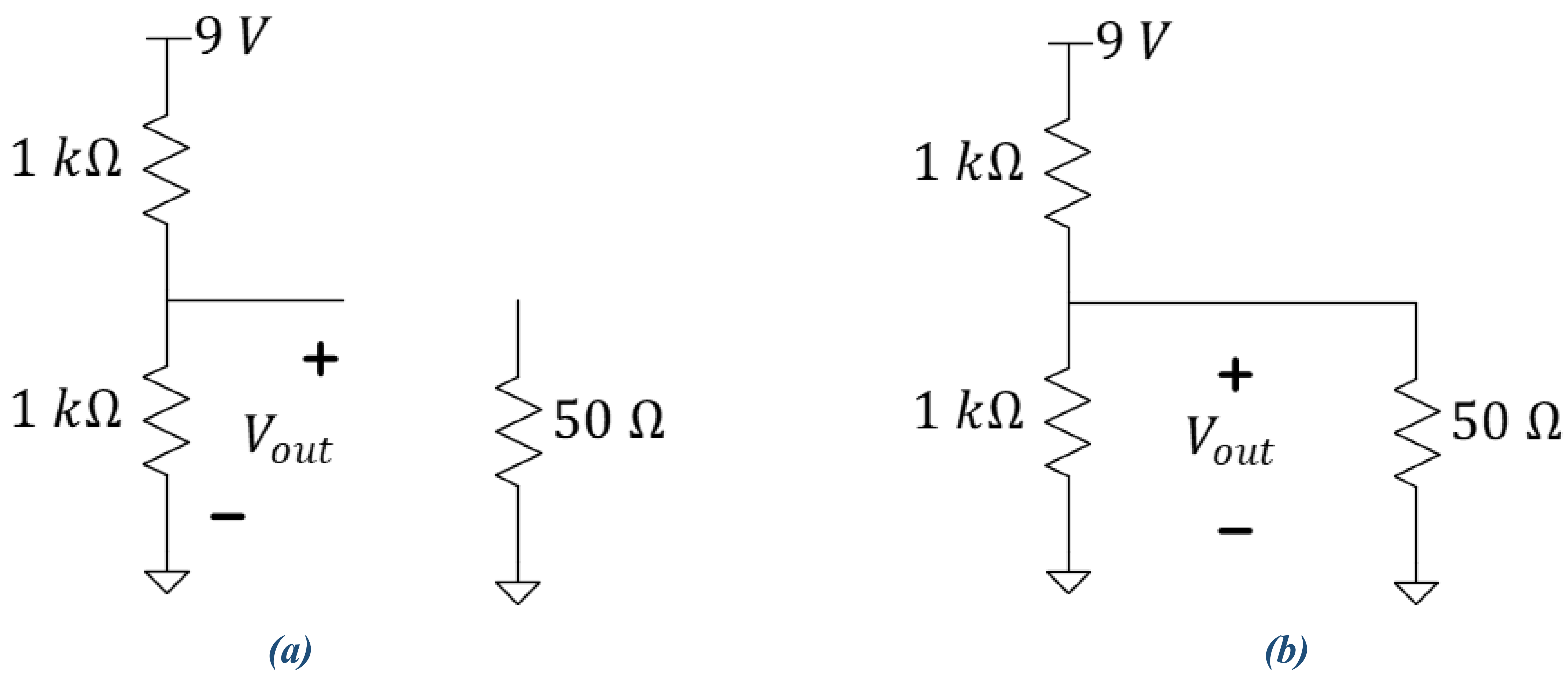

***Figure 3**: The voltage V_{out} changes from the intended value, 4.5 V in (a) to an unintended value of 0.4 V in (b) due to the lack of an appropriate "buffer" between the voltage divider circuit and the measurement device*

Recall this is why we used an extra inverter after our oscillator to protect the oscillation when connecting it to the voltage divider of the motor-drive circuit.

Other times, an intermediate circuit is required to strategically **combine** or couple two signals. This may involve, for example, simply adding a DC offset to a time-varying signal or merging two digital signals using Boolean-logic principles.

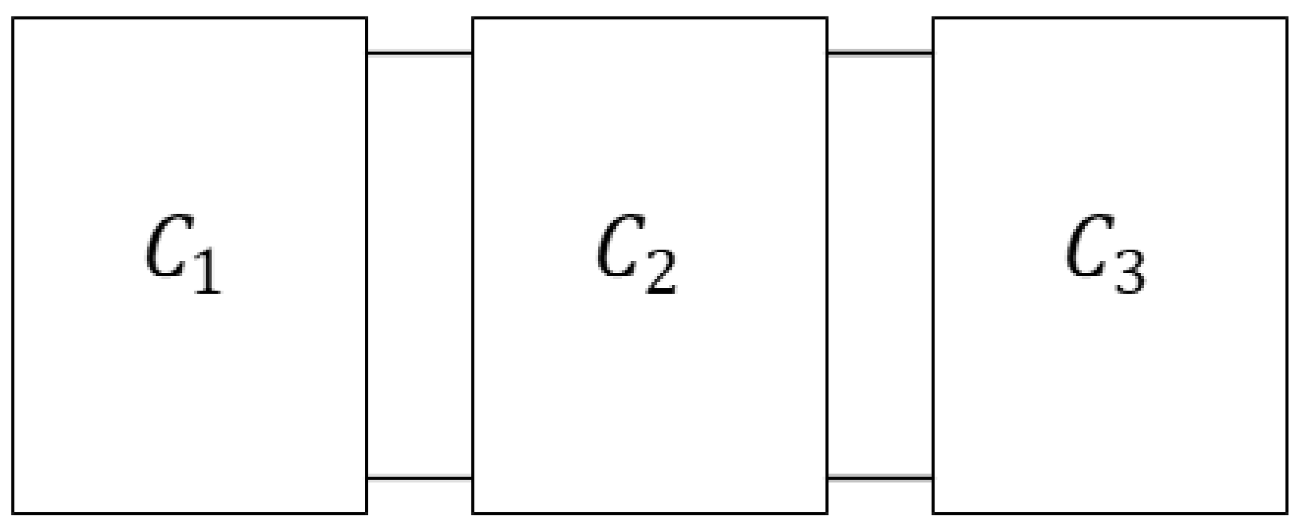

Figure 4: Coupling two circuits, C_1 and C_3, often requires the aid of a buffer or other coupling circuit, C_2.

Today, we will investigate one Boolean logic method of combining two inputs to control a single output. We will be using the logical AND circuit constructed in prelab to combine two signals into a single control signal for each of the two car wheels. The fact that we are dealing with binary (two) voltages only aides us in our task by allowing us to use simpler "logical" circuitry that does not require careful preservation of more-intricate voltage waveforms.

Now add the 1 $k\Omega$ resistor plus the pushbutton switches to imitate the two inputs. If there is only one pushbutton in your kit, it is okay to work with your lab partner and just produce one of these circuits in the breakout session.

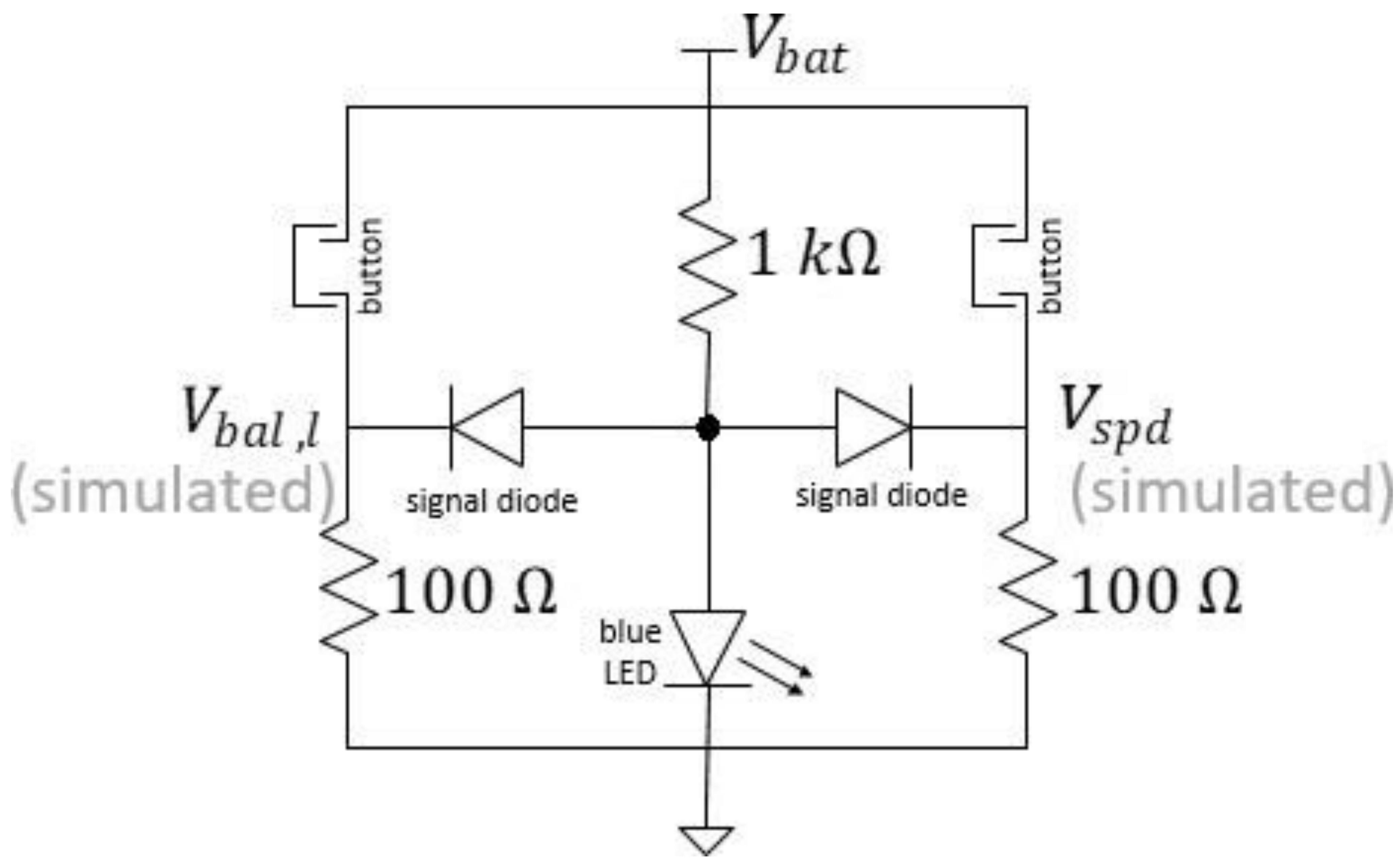

Figure 5: Circuit schematic of a two-input logical AND using buttons for inputs.

Question 2: Explain why the blue LED only illuminate when both buttons are pressed.

Because if we only press one button, the V_{LED} is only $\frac{100\Omega}{1000\Omega+100\Omega}$ Vbat $= \frac{1}{11}$ Vbat, It is too low to illuminate the LED

Only when both bottons are pressed can the voltage be Vbat to illuminate the blue LED

Learning Objectives

- Build a circuit by following the design specified on a circuit schematic
- Learn to control the duty cycle of a PWM signal using a turn pot and diodes
- Use observations of your circuit to discern the change of certain components.