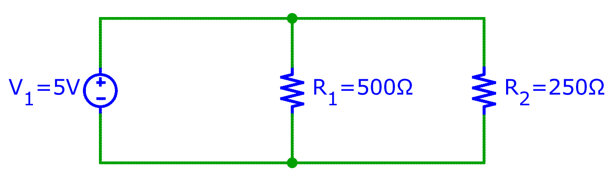
1. Binary signals represent one of two possible states, e.g. 0 or 1, yes or no, current or no current, etc. In electronic systems binary signals can be represented by a voltage on a wire, e.g. 0 V or 3.3 V. Each binary signal carries one "Bit" of information, the unit of information. Answer the questions below:
   a) How many bits (wires carrying binary signals) are required to represent the output of a motion detector, "motion" or "no motion" detected?
   b) How many bits are required to represent integers (whole numbers) 0 . . . 63?
   c) How many bits are required to represent integers (whole numbers) 0 . . . 100?
   d) The output voltage of a sensor varies between 0 V and 5 V. How many bits are required to represent that output with a resolution of 1 mV? I.e. the output voltage is rounded to the nearest mV value before representation as a binary signal.

2. The Huzzah32 microcontroller board includes a Lithium battery charger circuit. Per the schematic it is based on an MCP73831 chip. Find the datasheet for this part and answer the following questions:
   a) What are the minimum and maximum values of the supply voltage of the MCP73831?
   b) What are the typical, minimum, and maximum battery charging currents in "fast charge constant-current mode" with a 10 kΩ programming resistor connected between the PROG and VSS terminals?
   c) When the chip's "junction temperature" (i.e. its internal temperature) exceeds a threshold, internal circuitry reduces the charging current to avoid damage (clever!). What is the approximate temperature threshold above which the charging current starts decreasing?

3. The series resistance of an ideal ammeter is zero. Practical DMMs insert a small resistor to measure current. In this problem you are going to evaluate the resulting measurement error and determine if and when it matters.



   a) Calculate the currents through R_1 and R_2 in the circuit shown above.
   b) Now suppose you are in the lab and measure these same currents. To measure current, your DMM inserts a 1 Ω resistor, measures the voltage drop across it and then uses Ohm's Law to determine the current. Calculate the currents the DMM measures. Note that they differ from part (a) since because of the additional resistor added by the DMM.
   c) Calculate the measurement error in percent (difference divided by the ideal value, i.e. the calculated result).
   d) Briefly comment if this difference is relevant in practice and in what conditions the series resistance of the ammeter (which ideally should be zero) maters.

4. Circuit analysis provides an unlimited reservoir for homework and exam problems, but the ultimate objective is of course to use it to create new designs.

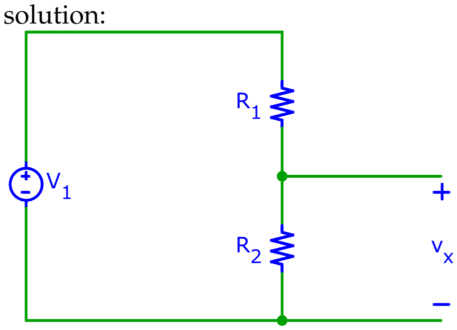
   Practical design starts with a well defined problem followed by a succession of solution attempts, each improving on the previous idea.

In this assignement you design an IoT device that keeps cranes from toppling over. Unfortunately this is a rather frequent occurance as a web search for "images cranes falling over" vividly demonstrates. While there are many reasons, a common problem is that the weight to be lifted is too great.

We are going to develop an electronic device that measures the weight of the item lifted so that corrective action can be taken hopefully before a disaster occurs.

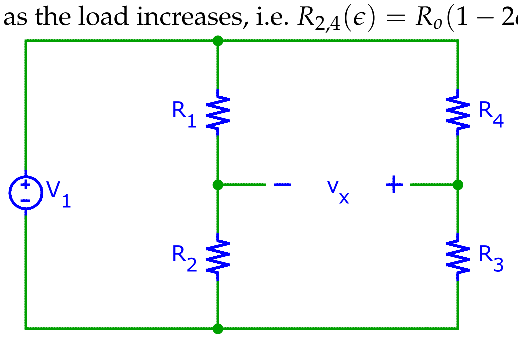
a) When a crane lifts a heavy weight its arm bends a little. From measuring the bending that occurs it is possible to estimate the weight lifted. We will use this effect to take action when the lifted weight is too great, hopefully before an accident happens!
The elongation due to beam bending can be expressed as strain ϵ, expressed as the ratio of the elongation divided by the unloaded length. For example, the strain in a section of a beam that is nominally 1 m long and extends by 1 mm under load is $\epsilon = 0.1\,\%$.
From statics calculations you determine that the strain in the crane you are working with is $\epsilon = 10^{-5}/\text{ton}$ or 50×10^{-5} at the crane's rated capacity of 50 tons. Note: for good engineering practice, we overdesign the circuit (at little added cost, in this case) to work up to 100 tons.
You decide to use a strain gauge to measure this strain. The resistance of the gauge is $R(\epsilon) = R_o(1 + 2\epsilon)$ with $R_o = 1\,\text{k}\Omega$.
Calculate $R(\epsilon)$ for 0, 10, 50, and 100 tons.
Your job is therefore to measure this resistance with an MCU (and transmit the result to the operator and crane control circuits).

b) Unfortunatly MCUs cannot directly measure resistance. However, they are good for measuring voltage, e.g. using it's built-in ADC or a device like the INA219). Therefore, you need a circuit that converts resistance into voltage.
Scratching your head (or whatever it takes for being creative), you come up with the following solution:



In this circuit, R_2 represents the strain gauge and R_1 is an auxilliary resistor with value R_o. Use $V_1 = 3.3\,\text{V}$ unless otherwise indicated.
Calculate v_x for for 0, 10, 50, and 100 tons.
This looks promising! But the output is not zero for 0 tons lifted. Let's fix this!

c) Shown below is an improved circuit. All four resistors are strain gauges. R_1 and R_3 are placed in the crane's arm at a location where strain increases with load. For R_2 and R_4 the strain decreases as the load increases, i.e. $R_{2,4}(\epsilon) = R_o(1 - 2\epsilon)$.



Calculate v_x for for 0, 10, 50, and 100 tons.
We are getting there!

d) Even for maximum load (50 tons), v_x is pretty small, too small for the ADC to provide an accurate measurement. To address this issue, we connect an amplifier to v_x with output v_y. What voltage gain v_y/v_x is required such that $v_y = 3\,\text{V}$ with 100 tons load?

e) Now we are ready to connect our circuit to the MCU's ADC. The ADC output is a digital number $D_o = 4096 \times v_y/V_{ref}$, rounded to the nearest integer. We can either use the ADC's built-in

precision reference for V_{ref}, or the supply voltage, V_1. Both voltages are nominally 3.3 V.
Calculate D_o for a 50 ton load, first using the built-in reference and then using V_1 for V_{ref} (hint: the results are the same, as they should be!).
In practice, the value of V_1 will often vary due for a number of reasons including decreasing supply voltage in battery operated systems or temperature variations.
Calculate D_o again for a 50 ton load, but this time assuming that V_1 decreased from its nominal value of 3.3 V to 3 V. Note: the value of v_y changes!
Which solution is preferable, using the built-in reference or using V_1 for V_{ref}? Explain!

Next step is to prototype this circuit and evaluate it in the lab. Once the basic functionality is verified, addtional features can be added, e.g. sending the results to the crane operator or motor controller.

5. Redo practice problem 5.3 in Alexander and Sadiku, 5h Edition. Replace the 3 kΩ resistor with 5 kΩ.
6. Redo practice problem 5.5 in Alexander and Sadiku, 5h Edition. Replace the 8 kΩ resistor with 12 kΩ.
7. Redo practice problem 5.8 in Alexander and Sadiku, 5h Edition. Replace the 40 kΩ resistors with 55 kΩ.
8. (5-1) Calculate the ratio v_2/v_1. First assume that the operational amplifier is ideal, then redo the problem assuming the opamp gain is $a_v = 10^5$. Use $R_1 = 6.9\,\text{k}\Omega$, $R_2 = 2.7\,\text{k}\Omega$.

Ideal opamp $v_2/v_1 =$

Finite gain $v_2/v_1 =$