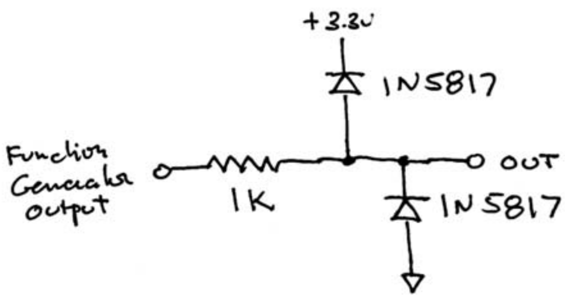
Instructions: Physics 123b/223b Day 3 Lab

Most electronic components expect inputs to not exceed the power supply voltages. For example, the FPGA we are using runs on +3.3V and ground. If the inputs go above 3.6V or below -0.5V the part may be damaged (and at $30 each we would like to avoid that).[1] If you cannot be sure that an input signal will always be within a safe range, it is a good idea to add a "clipper" circuit to its input to protect the part.

Take a look at the following circuit:



Suppose the input signal from the function generator is always between ground and +3.3V. What would you expect the output voltage to be? (You may assume that whatever is connected to the output has a resistance to ground of $\gg 1k$.)

What happens if the input signal is a 4V *peak-to-peak* sine wave centered around zero volts? Sketch the input and output waveforms then build and the circuit to test your intuition.

What happens if the input signal is an 8V *peak-to-peak* sine wave centered around zero volts? Sketch the input and output waveforms you expect, then test your intuition with the actual circuit.

What is the purpose of the $1k$ resistor?

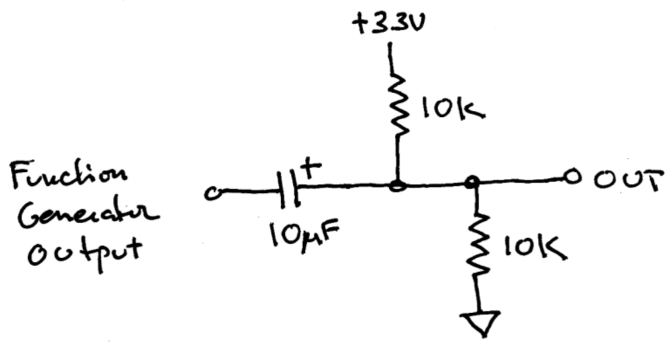
Why do you think I chose the 1N5817 Schottky diode over the 1N4148 silicon diode? (Hint: compare the data sheets.)

Ok, you should now see how to use a diode clipper to keep a voltage within safe values. However, what if we want to apply a sine wave to the input of a circuit running on zero and +3.3V? The clipper would keep the voltages within those limits, but the negative going portion of the waveform would still be clipped. To get an undistorted input, you need a sine wave with a DC offset, preferable of 1.65V so the

[1] See 4.1 Absolute Maximum Ratings on page 28 of the iCE40UltraPlus Family datasheet (available on the Canvas FPGA page).

signal would be centered in the middle of the available range. Since the breadboard function generator output is always centered around zero volts, we need a way to add a DC value to its output.[2]

Consider the following circuit:



To analyze this circuit you need to remember that the impedance of a capacitor is inversely proportional to frequency. First consider the case where the input is DC (say zero volts for example). What would you expect the output to be? Build the circuit and test your intuition by applying 0V, -3.3V and +3.3V to the input. Does it matter what the DC voltage applied to the input is? (Hint: Yes it does but it is a physical limitation not a theoretical one. What is the physical limitation?)

Next assume that a 2V peak-to-peak sine wave is applied to the input at a frequency high enough that the impedance of the capacitor is much, much less than the impedance of the resistors. What would you expect the output to be? Sketch the expected input and output waveforms. Now test the circuit (be sure to use your scope to set the function generator output **before** connecting it to the circuit). Does the result make sense? Does this circuit solve the limitation of the breadboard function generator of the output always being centered around 0V DC?

Do the following diode experiments in Chapter 3L

3L.2 Diode X–Y plots: a vivid way to display diode I–V behavior
3L.6.2 Diode clamps

Do the following MOSFET experiments in Chapter 12L

Lab 12: MOSFET Switches - 12L.1.1; 12L.1.2; 12L.1.3 (for part 12L.1.3 you can use the TTL output of the function generator for the 0 to +5V square wave signal or set up the Siglent to create the signal).

Lab 12: Test the MOSFET power transistor according to 12L.1.4. Ignore the instructions to test the MJE3055 bipolar BJT. Calculate the power loss in the MOSFET and then its efficiency $\left(\frac{\textit{Power delivered to the load}}{\textit{Power delivered to the load + Power dissapated in the MOSFET}} * 100\%\right)$.

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[2] The Siglent and Krohnhite function generators allow you to add a DC offset to an AC centered signal.