

# Physics 623

## Analog and Digital Simulation

April 22, 2023

The simulations will be done using the commercial software, National Instruments *MultiSim 12.0*, which is installed on the laboratory computers. With some preparation before the lab, you should be able to do both an analog and a digital simulation. The simulations run the circuits in software and all voltages, currents, and waveforms can be examined and printed out.

The circuits are entered by schematic capture, i.e. you draw the circuit on the computer screen by placing the parts and connecting them with wires. Once the circuit is entered, the simulation is run or an analysis is performed. There are various type of analyses that can be performed, including DC operating point, Transient Analysis, and AC analysis. A large variety of instruments such as Multimeters, Function Generators, Oscilloscopes, Bode plotters, and Logic Analyzers, may be connected to various points in the circuit for obtaining information. The outputs of the instruments may be printed out by using the *Print Instruments* under *Print Options*.

### Part 1– Analog Simulation

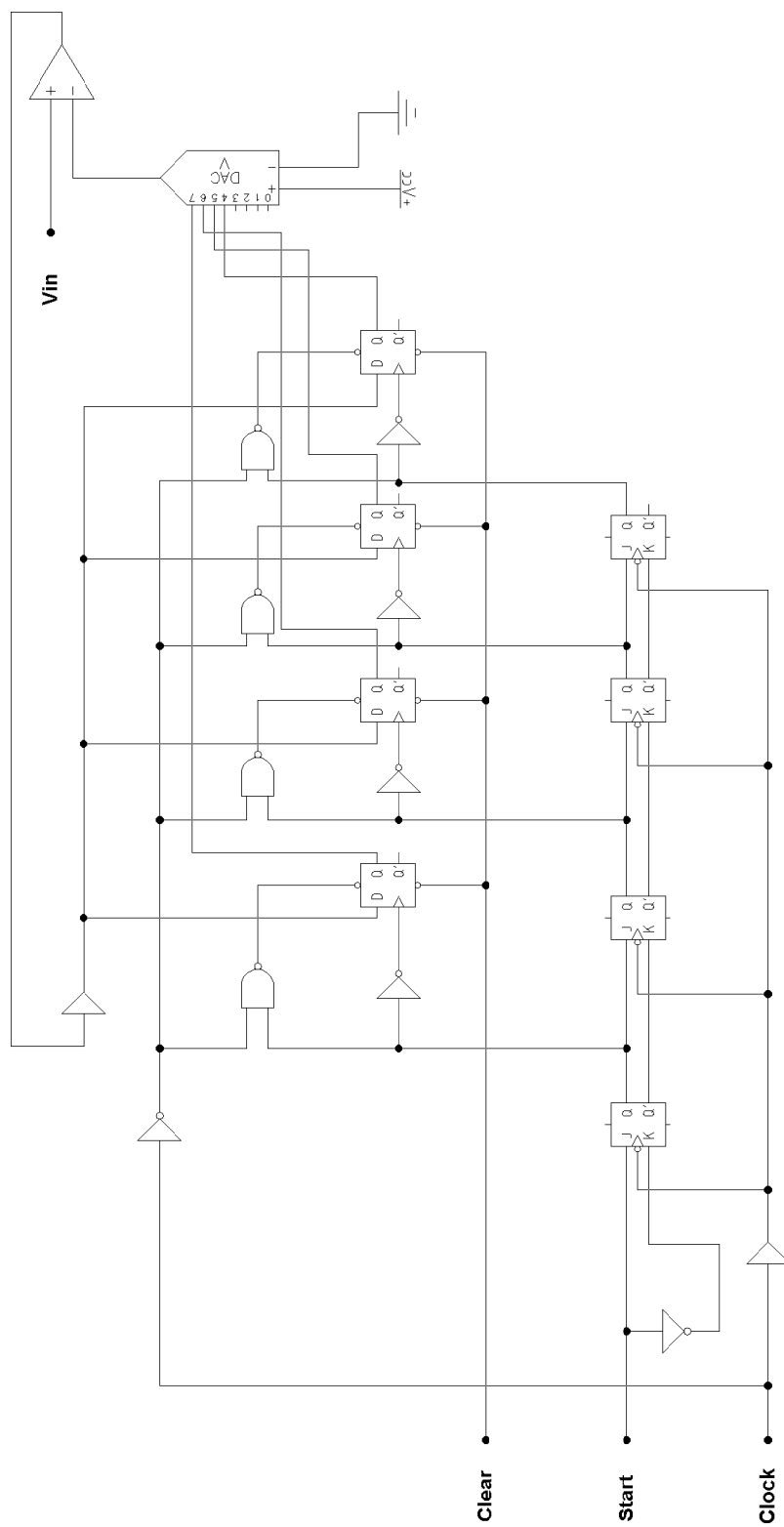
The analog simulation circuit will be the difference amplifier from the difference amplifier lab. Prepare a table with three columns for the calculated and measured values from the diff amp lab and for the simulated values from this lab. Values should include the differential and common mode gains, the DC levels at the two collectors, and the low and high corner frequencies. The simulated circuit should have the same component values used in the lab circuit.

1. Simulate the difference amplifier circuit using the circuit you built for the Difference Amplifier lab. The component values should be identical to those used in the lab. We use the *MultiSim 12.0* application.
2. The first step is to make a schematic diagram.
3. Find the DC operating point of the circuit. Check the results against the expected values.
4. Perform a Transient analysis for 5 cycles and compute the difference and common mode gains. Use the same frequency as you used in the lab. Use the Analysis Graphs window to print out the desired waveforms.
5. Perform an AC frequency analysis and determine the low and high rolloff frequencies. Print out the Bode plot using the *Print Instruments*.
6. Present the results as a three column table: theory, measurement, and simulation for the requested quantities. Most people did not measure the frequency dependence in lab, but you should be able to calculate the lower 3 dB point. The upper one will depend on the stray capacitances in the transistor and the source impedance of your signal source.
7. The final results will include the table, a copy of the circuit diagram, waveforms, and your explanations as to why the simulation might be giving different results from theory and measurement.

## Part 2– Digital Simulation

You will simulate a 4 bit Successive Approximation ADC made up of a DAC, comparator, D flip flops, J-K flip flops, and NAND gates. You will enter a DC input voltage, run the simulation, and read out the digital state of the circuit under the control of CLK pulses. The circuit also requires START and CLEAR inputs. All three can be generated in the proper sequence using the Word Generator.

1. Enter the circuit via schematic capture. Consult the Multisim Hints sheet for details. You can ask the instructor for a file with the completed schematic if you're running out of time.
2. The initial conditions for the various lines are entered using the Word Generator tool, which allows you to enter the CLK, START and CLEAR pulses and run them as a sequence either step by step or as an automatic sequence at a given frequency.
3. Use the Logic Analyzer tool to display the circuit output. This allows you to display the waveform on up to 16 channels simultaneously. The analog output can be viewed on the Oscilloscope instrument. The DAC output is  $V_{out} = V_{ref} \times D/256$  where  $V_{ref} = 5$  V. The binary outputs can also be viewed with LEDs which light up on a logical "1".
4. Make a plot of the DAC output as a function of successive clock pulses. You should see the DAC output converge to the analog input voltage with an accuracy consistent with the 4 bits of the circuit, i.e. one part in fifteen. The digital result resides in the four D flip flops. Try several different DC input voltages.



**Successive Approximation ADC**