

Physics 623

Analog and Digital Simulation

Nov. 14, 2006

The simulations will be done using the commercial software, “Electronics Workbench”, 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, an analysis is run. There are several kinds of analyses including DC conditions, small signal transfer functions, and digital logic states for the case of digital circuits.

Part 1– Analog Simulation

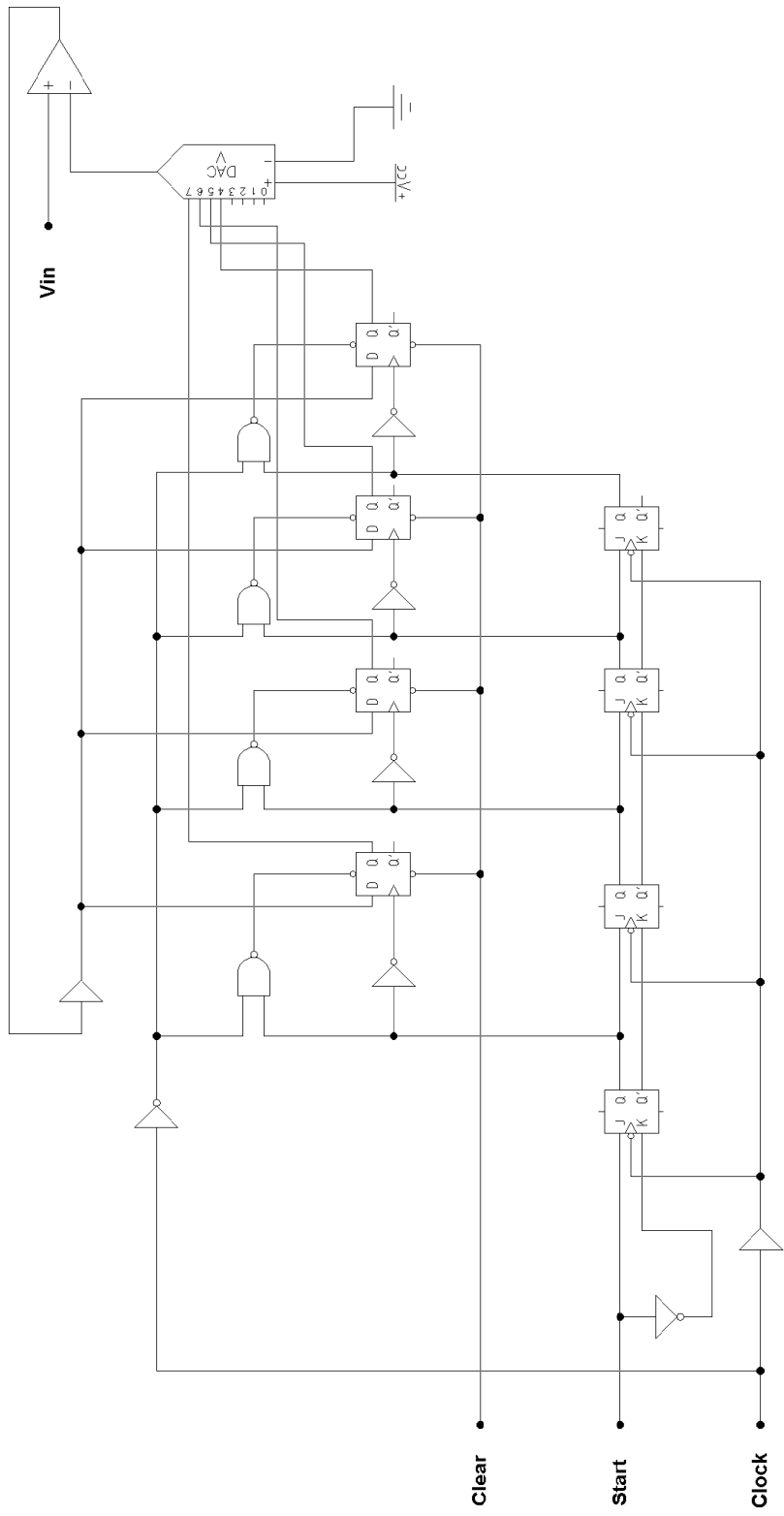
The analog simulation circuit will be the difference amplifier from the difference amplifier lab. Before the lab prepare a table of of the measured and calculated DC node voltages, the sum and difference gains, CMRR, and the amplifier high and low roll-off frequencies. You should have almost all this information in your laboratory notebook. The simulated circuit should have the same component values used in the lab circuit. The results of the simulation should then be entered as a separate column in your table.

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 Electronics Workbench application.
2. The first step is to make a schematic diagram.
3. Perform a DC analysis. 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 a frequency analysis and determine the low and high rolloff frequencies. Print out the Bode plot using the Analysis Graphs window.
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 roll-off frequencies.
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 includes START and CLEAR lines.

1. Enter the circuit via schematic capture.
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

Chapter 5

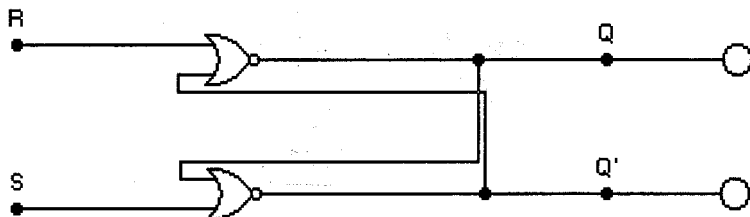
Trying Out the Digital Instruments

Open the Circuit

In the previous two chapters, you learned how to build and test a simple analog circuit. In this chapter you will work with the flip-flop circuit provided with Electronics Workbench, testing it using the word generator to supply input and then the logic analyzer to display the signal.

- Open the Rs_ff.ewb file from the Tutorial directory or folder.

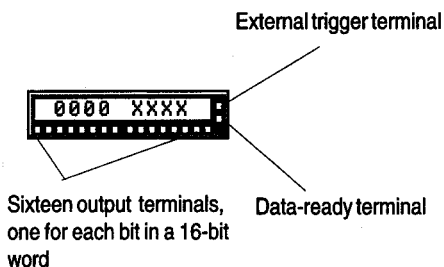
The flip-flop circuit should look like this:



- Save the file with a new name.

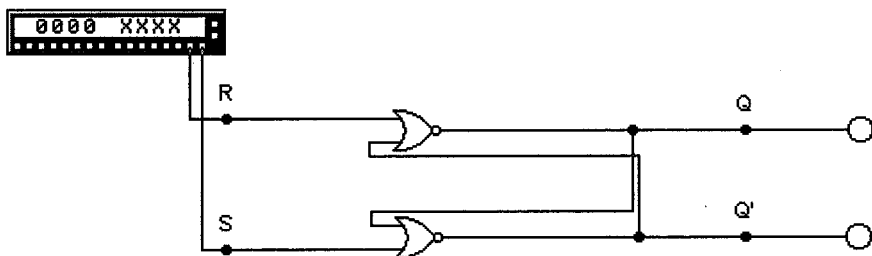
Try Out the Word Generator

The word generator can drive a digital circuit by producing streams of 16-bit words. Use it to send digital words or patterns of bits into circuits to test them. The word generator icon looks like this:



Step 1. Attach a Word Generator to the Circuit

- First, attach a word generator to the circuit.
- Connect the word generator's terminals as shown below.



1. Select the terminal on the far right of the icon and drag a wire to connector S.
2. Connect the next terminal to R.

Step 2. Enter Words in the Word Generator

- Open the word generator's controls by double-clicking on its icon.

On the word generator's controls, you should see a number of buttons, a hex field, a binary field and an ASCII field. You can use any one of the fields to enter words in the generator.

In this exercise, you will use the binary field to input 16-bit words. Since the RS flip-flop circuit you are building has two inputs, you only need to create a bit pattern in the word generator's first five rows.

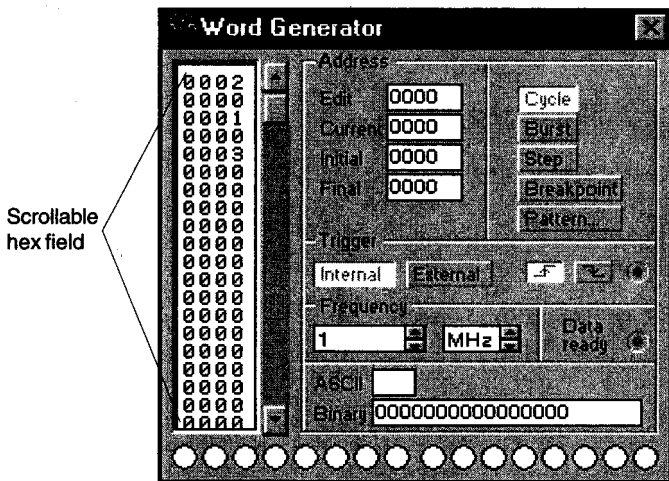
- Enter the inputs S and R for the predicted outputs Q and Q', as shown in the table following.

Inputs		Outputs		
S	R	Q	Q'	
1	0	1	0	
0	0	1	0	(no change from previous state)
0	1	0	1	
0	0	0	1	(no change from previous state)
1	1	X	X	(undefined)

1. Make sure you are in address 0000. Place your cursor in the first word in the scrolling hex field (the Edit field should read 0000).
2. The first condition in the truth table is $S = 1$ and $R = 0$. In the Binary field, highlight the second 0 from the right and type 1. The first word in the hex field should change to 0002.
3. In the third condition, $S = 0$ and $R = 1$, so place your cursor on the third word down in the hex field. The Edit field should read 0002, as the first word address is 0000. In the Binary field, change the least significant bit (the bit furthest to the right) to 1.
4. The fifth condition in the truth table is $S = 1$ and $R = 1$. Change word five (address 0004) to show binary 000000000000011. The hex field for the fifth word should read 0003.

The second and fourth conditions are zeros, so you do not have to change the word generator. The last condition is prohibited, since the outputs cannot be predicted.

The word generator controls should now look like this:



Tip To test a circuit, use a bit pattern that gives you a predictable output, as indicated by a truth table. Once you have clicked a hex word in the word generator, you can press the arrow keys to move the insertion point to other words.

Step 3. Activate the Circuit

- Change the final address to 000A (this will only cycle from 0000 to 000A).
- Change the frequency to 1 Hz (this will slow down the cycle).
- While watching the probes, send the bits into the circuit by clicking the Step button on the word generator three times.

When the state changes, the alternate probe lights up.

Electronics Concepts Demonstrated

When $Q = 1$ and $Q' = 0$, the flip-flop is in the set state (or 1-state) and the probe attached to Q lights up. When $Q = 0$ and $Q' = 1$, the flip-flop is in the reset or clear state, and the probe attached to Q' lights up.

The Step, Burst or Cycle setting on the word generator determines whether the input is one word, a series of words or a continuous cycle.

Breakpoint allows you to input a previously determined pause at any number of words during Burst or Cycle setting.

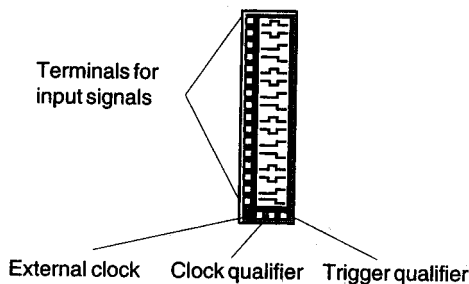
Options to Explore

Try activating the circuit using the Burst and Cycle buttons. Clicking Burst sends a series of words; clicking Cycle sends a continuous stream of words. To stop the simulation, turn off the power switch.

You can determine the length of a series of words by using the initial and final fields. Just insert the hex word in the field.

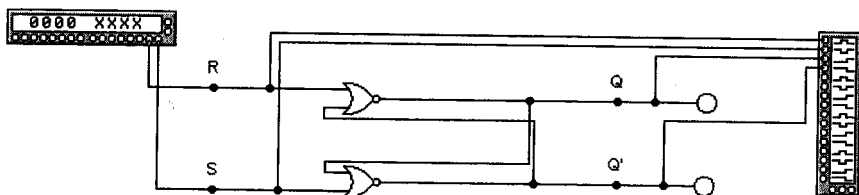
Try Out the Logic Analyzer

Now that you have the input to the circuit ready, the next step is to set up the logic analyzer so you can see the output. The sixteen-channel logic analyzer displays a circuit's output as a waveform diagram showing voltage level and timing, similar to what you might observe on an oscilloscope attached to an analog circuit. The logic analyzer icon looks like this:



Step 1. Attach a Logic Analyzer to the Circuit

- Attach a logic analyzer to the flip-flop circuit as shown below by connecting the first terminal to connector R, the second terminal to S, the third terminal to Q and the fourth terminal to Q'.

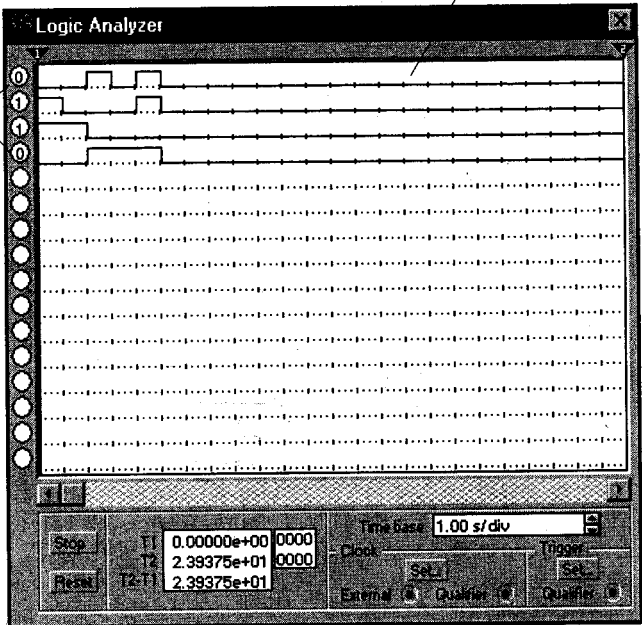


- Set instrument settings and activate the circuit.
 1. Set the frequency of the word generator to 1 Hz.
 2. Set the logic analyzer to time base 1.00 s/div.
 3. Make sure the current address on the word generator is at 0000.
 4. Click the Cycle button on the word generator.

You should see input and output signals similar to those shown below. (The signal starts with the current word as indicated in the word generator.)

As the input signals change state, the output signals respond according to the truth table.

At this point in the word generator's cycle, the input for R and S is 0. The output for Q and 1 is Q'.



Help If you don't see similar signals, check the word patterns in the word generator, the settings on the word generator and logic analyzer, and the circuit wiring.

Step 2. Change the Color of the Wires

If you have a color display, try making the wires going to each of the logic analyzer's terminals a different color. When the circuit is activated again, each signal will be the same color as its wire, so you can easily correlate input or output with the resulting waveform.

- Double-click a wire. On the Display tab that appears, click the Color button and choose the color you want.
- Save your work.