Faculty of Science, Engineering and Technology

Computer Systems

Week 3

Overview

In this laboratory session we start using Flip Flops to build useful things like registers, counters and shift registers.

Purpose:	To consolidate your knowledge of Flip Flops, and how they can be used.
Task:	
Time:	This lab is due by the start of your week 3 lab.
Assessment:	This lab is worth 1% of your assessment for this unit, and only if demonstrated to your lab demonstrator in the week it is due.
Resources:	■ Flip Flop tutorials ■ Intro to Flip Flops ■ Counters and Shift Registers: ■ Registers with D Flip Flops ■ Shift Registers with D Flip Flops ■ Ripple Counters (and HEX Display) with J-K Flip Flops

Submission Details

You must submit the following files to Canvas:

- A document containing all required work as described below.

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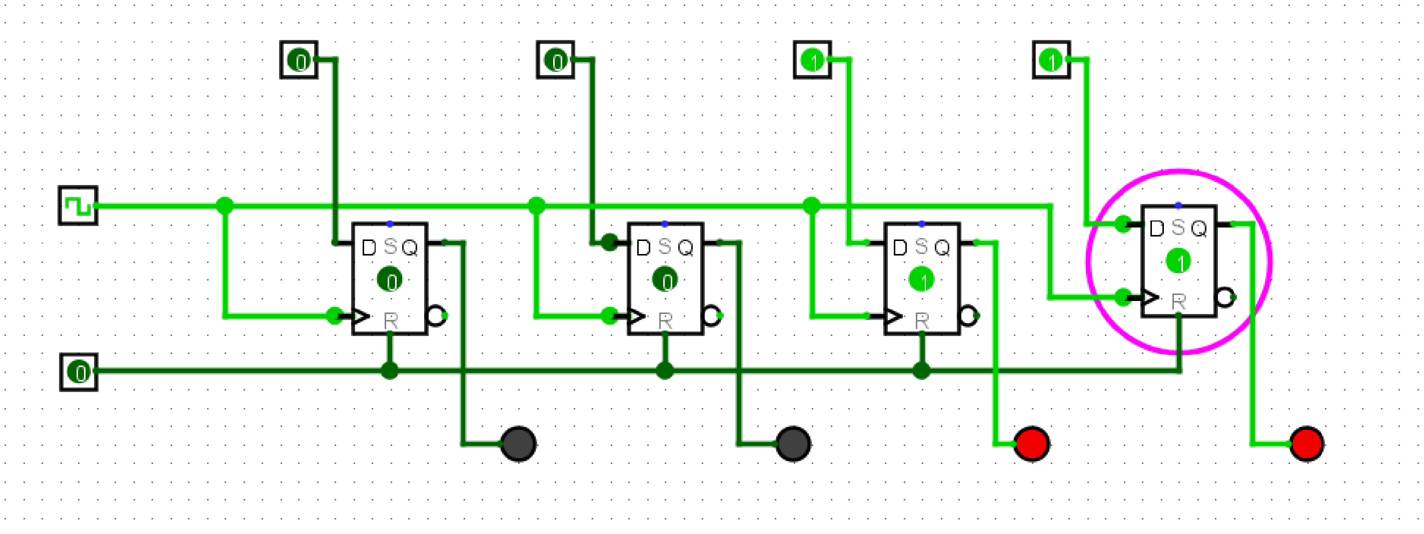
Instructions

1. Start Logisim and open a new canvas

2. Register this! Registers are just adjacent Flip-Flops that store collections of bits. You're about to wire up a register in Logisim, but first review the lecture slides, and if needed, take a look at the resources above to remind yourself how Flip Flops work. We're going to work with D Flip Flops here.
3. We're not going to wire our own Flip Flops anymore. We're going to use Logisism's. Familiarise yourself with Logisim's D Flip Flop. Bring one into your canvas, and connect up an input pin, and a clock, and connect an LED to the output "Q". Have a play and verify it works as you expect (ask your lab demonstrator for assistance if needed).
4. Now wire-up a 4-bit big-endian register with D Flip Flops in Logisim. Do this by using 4 pins for each input, and connect 4 LEDS to the output.
5. When complete, demonstrate your register to your lab demonstrator by showing them different combinations of input bits, and how this changes the output when the clock pulses.

Export your circuit as an image and include it in your submission document.



6. Use your register to fill out the following test schedule:

Ox	Input Binary	Output Binary
0	**0000**	0000
1	0001	0001
2	0010	0010
3	0011	0011
5	0101	0101

A	1010	1010
B	1011	1011
C	1100	1100
D	1101	1101
E	1110	1110
F	1111	1111

Complete this table and place a copy of it in your submission document

7. Counters are fundamental to modern computing architectures. Review the lecture slides on counters and answer the following questions:

   7.1. Name one crucial role (hardware) counters play in modern computing architectures ?

   ⇨ **It is for counting and tracking the number of times an hardware-related events occurs in the processor.**

   7.2. Describe in a few sentences how a ripple counter works. How does the “ripple” occur ?

   ⇨ **A ripple counter is an asynchronous counter works by increasing the clock-pulse of the next flip-flop in the line, the clock then linked the circuit’s flip-flop and the flip flop’s output controls the clock input for the next flip-flop.**

Provide your answers in your submission document

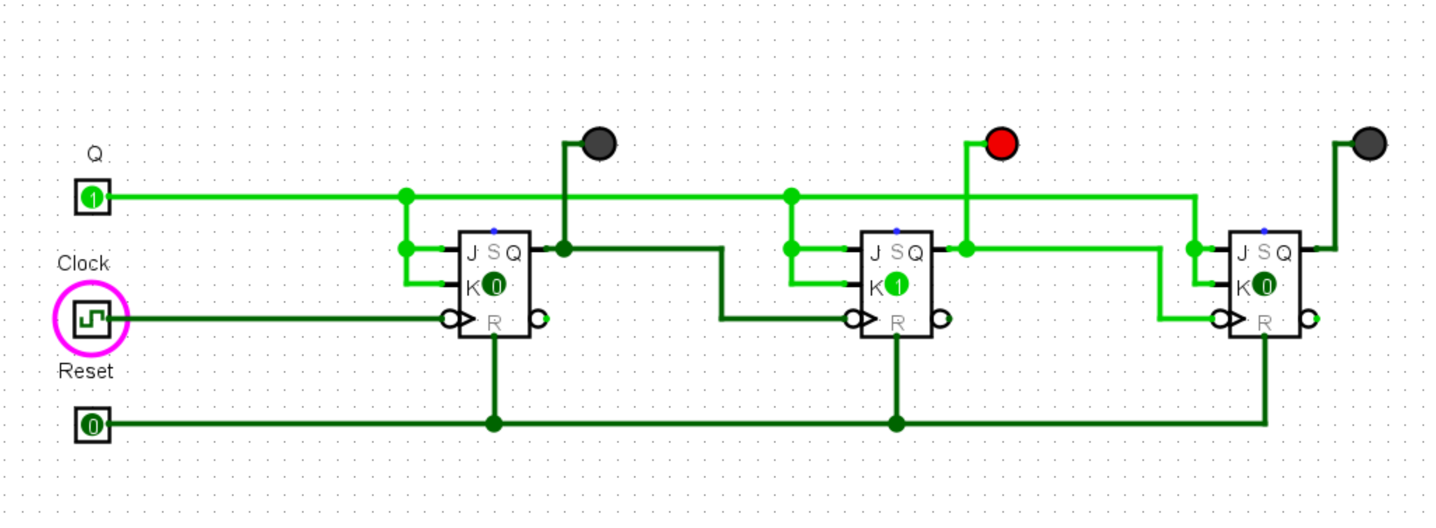
8. We are going to build a big-endian 3-bit ripple counter out of JK Flip-Flops. Yep ..I know - exciting! But first:

   - think about what big-endian means - where is the most significant bit going to be ? and what does this mean for the direction of your “ripple” ?
   - Chat with your lab demonstrator if you’re not sure.

9. When you’re comfortable, start wiring it up. Your counter should count from 000 to 111. Use LEDs to show the output “Q” from each Flip Flop. For this to work, you will also need to set your JK Flip Flops to Trigger with the clock’s Falling Edge instead of its Rising Edge (click on each FF and set this in the Attributes Pane).

10. When complete, demonstrate your counter to your lab demonstrator.

Export your circuit as an image and include it in your submission document.



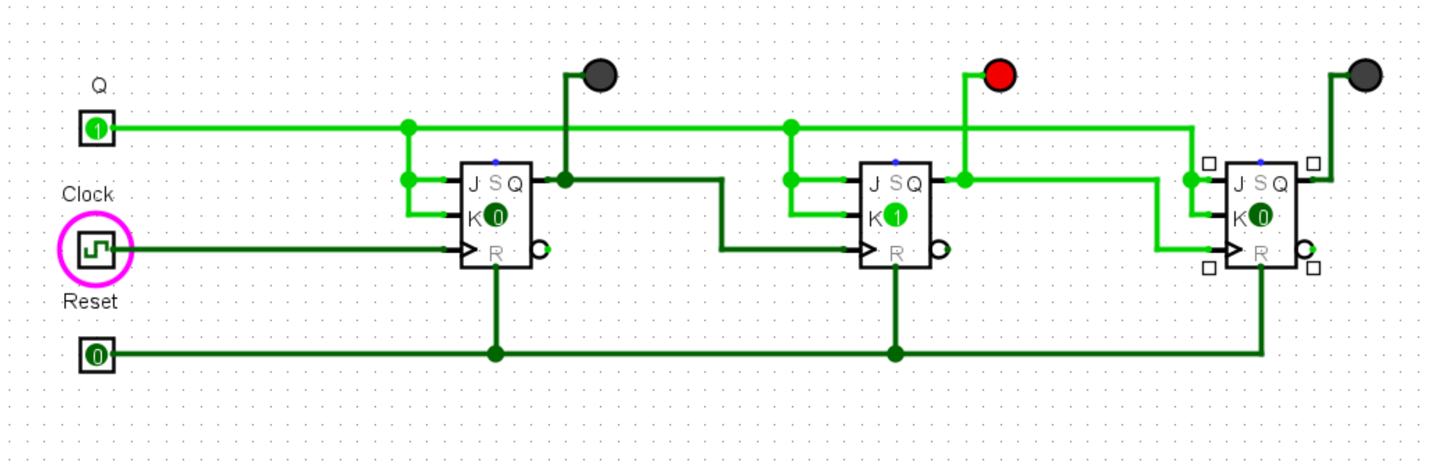
11. Save your circuit (you should always do this !).

12. Now build a big-endian 3-bit “count down” counter, that counts from 111 to 000. Review

the week 3 lecture slides to get some hints on this, and discuss your plan with your lab demonstrator if you need to.

13. When complete, demonstrate to your lab demonstrator.

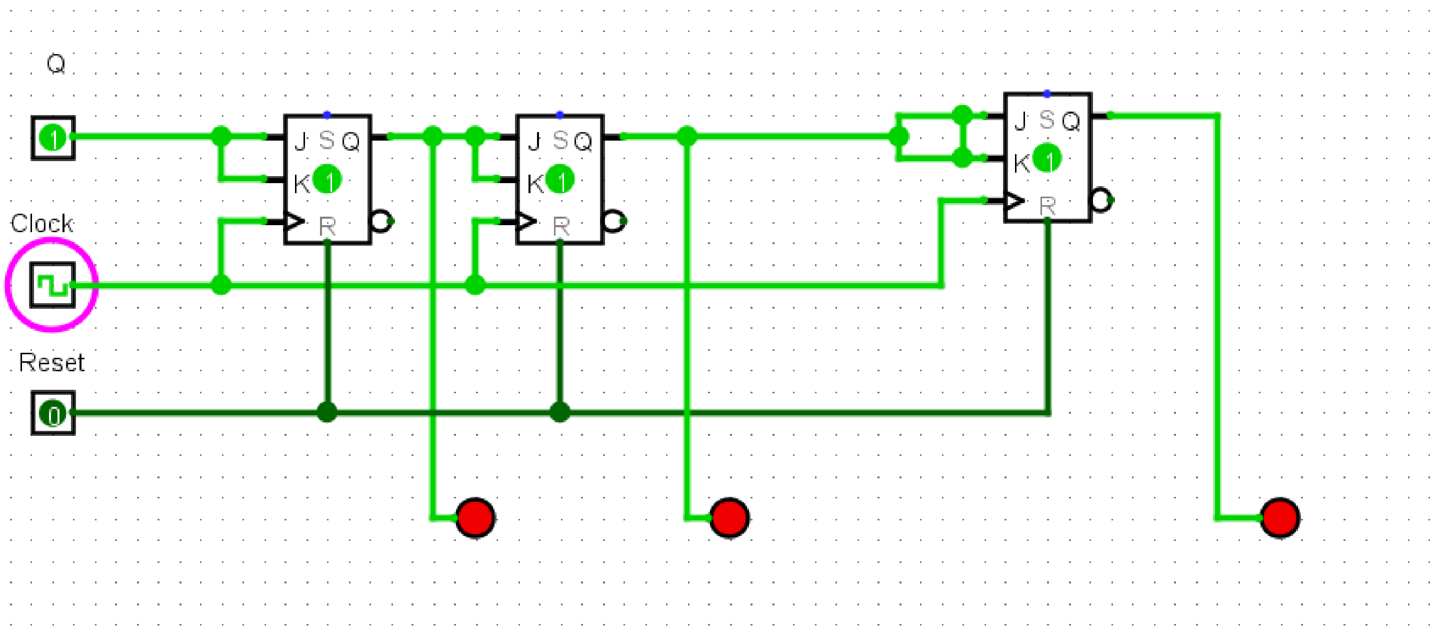
Export your circuit as an image and include it in your submission document.



14. Take your original counter from Step 9 and modify it so it now counts from 0 to 111 using a common clock. That is, each flip flop receives a clock pulse at the same time. Review the lectures if you need to.

15. When you've finished wiring it up, show your lab demonstrator.

Export your circuit as an image and include it in your submission document.



16. Now modify your clock from Step 14 so it counts from 0 to 5 (i.e, MOD 6), and then wraps around back to 0. Think about how you are going to detect the upper limit, and how you are then going to set things back to 0 when you reach 6 (110).

Hint: You will want to use an appropriate gate to detect this, with its output feeding into the re-set pins for the Flip Flops.

17. The circuit in Step 16 goes into a momentary illegal state (i.e, it displays the binary string 110 due to the delay between detection of the limit, and the eventual reset back to 0. In the lecture we discussed using D Flip Flops as a buffer, to hold the output state one extra clock pulse before showing (allowing time for any resetting to occur first).

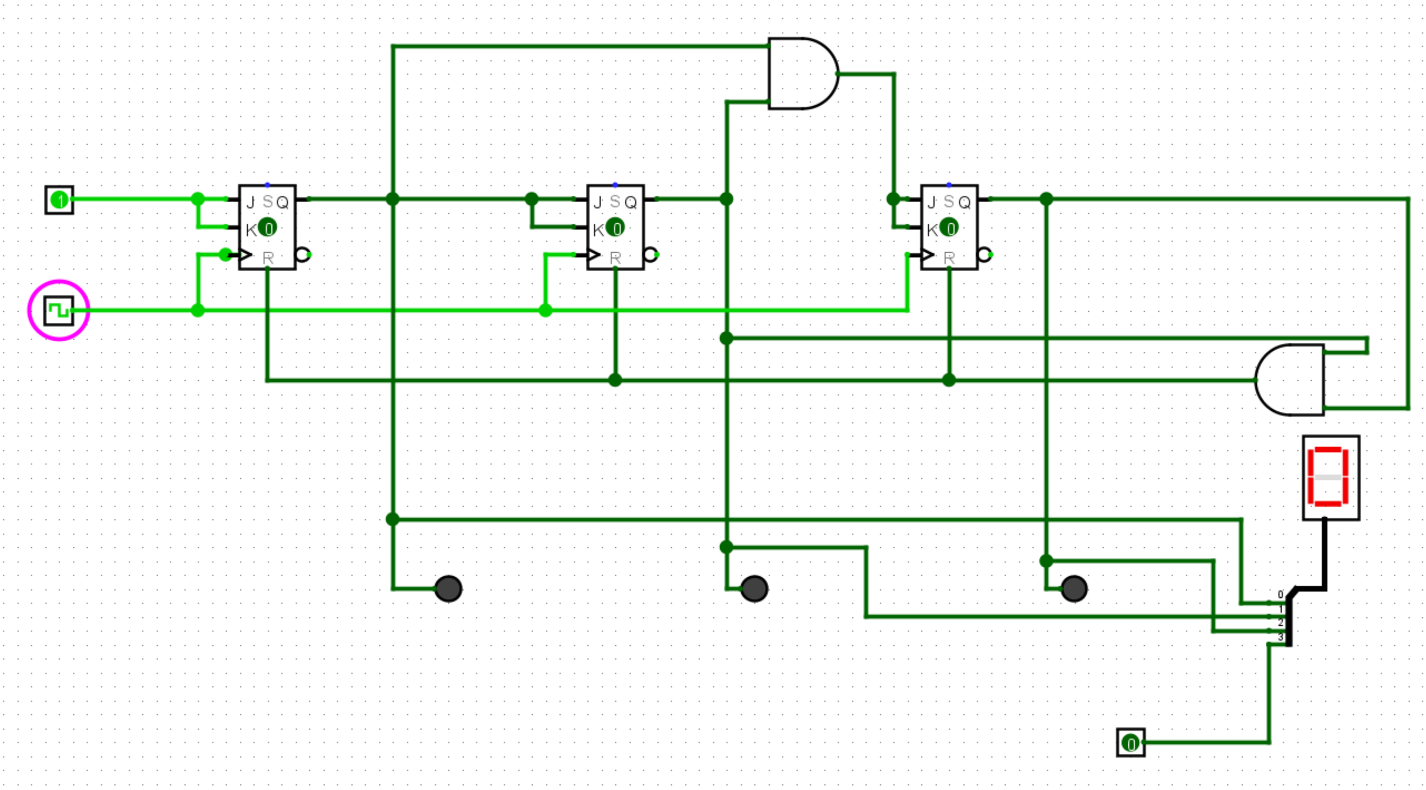
    17.1. Modify your counter so that it resets after 5 (101) back to 0 (000) without the momentary illegal state.

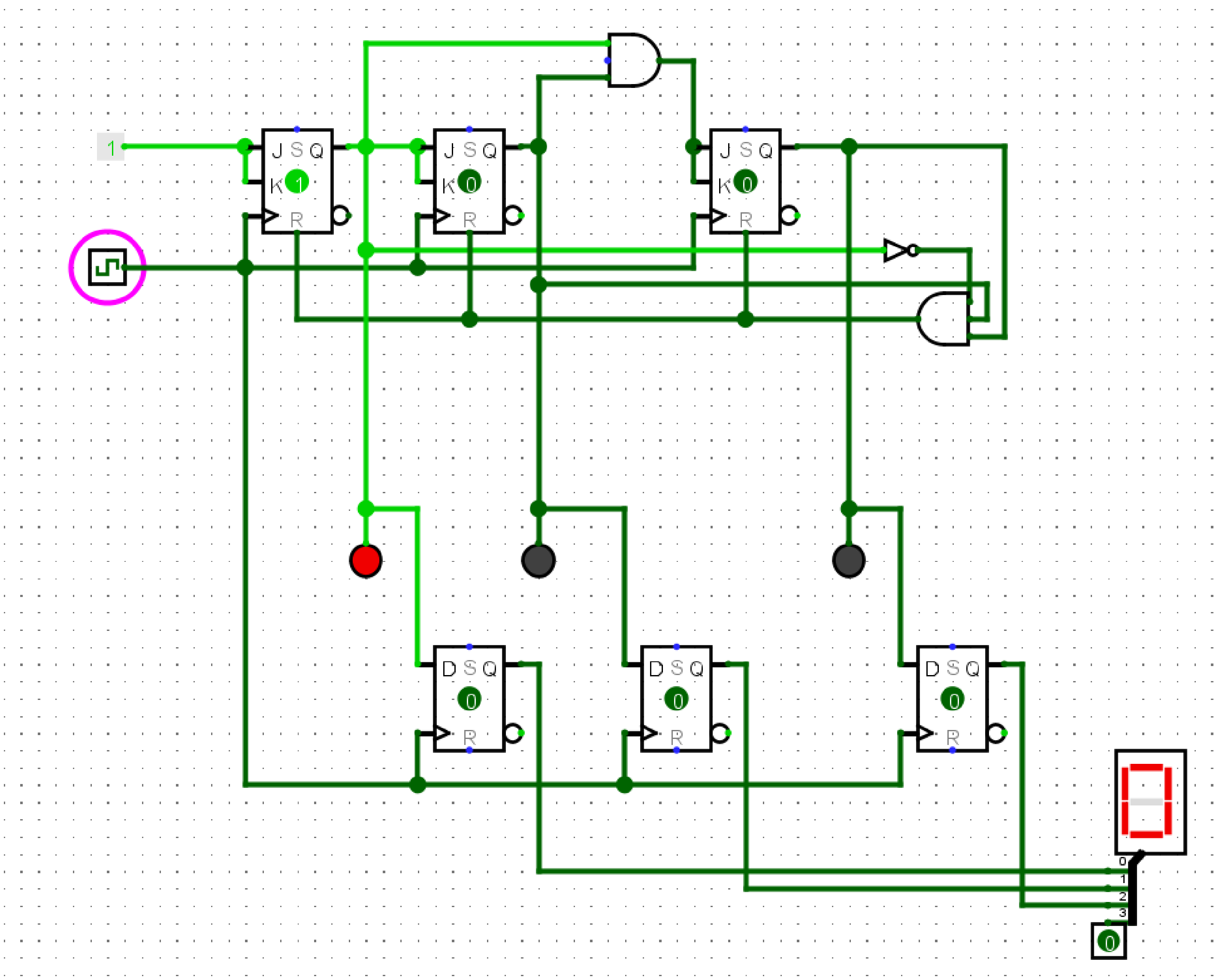
    17.2. Why is handling such things important ?

    ⇨ **This will prevent any illegal state from occurring, allow the circuit to run smoothly**

18. Display your counter output using the HEX Digit Display. Note that the Logisim HEX Display uses a single pin input with a 4 bit width. That means a 4 bit integer is expected along a single wire. Because our wires are carrying only 1 bit at a time, we will require a "Splitter" (in reverse) to combine multiple bit streams into a 4-bit "wire bundle" that is fed into the HEX display. See the video tutorial linked at the top of this lab sheet for how to use the splitter to combine single bit streams into a single wire.

Export your circuit for Step 17 and 18 as images and include it in your submission document, along with your answer to 17.2.





When complete:

- Submit your answers (screen shots, etc) in a single document using **<u>Canvas</u>**
- Show your lab demonstrator your working circuits in class (you must do this to get the 1%). Your lab demonstrator may request you to resubmit if issues exist.