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EET 1131 Lab #11
Counters

Objectives:
1) Simulate asynchronous counters constructed from flip-flops.
2) Simulate, build, and test circuits using a counter chip.
3) Display counter outputs on LEDs, on a seven-segment display, and on the oscilloscope.
4) Cascade two counter chips to form a high-modulus counter.

Equipment Required:
- Safety glasses
- Multisim simulation software
- Quartus II software and Altera DE2-115 board
- Digital Storage Oscilloscope with print capability

Part 1. MOD-16 Flip-Flop Counter
- Figure 12-12(a) in the textbook (reproduced below) shows a 4-bit asynchronous counter constructed from flip-flops. Using this diagram as a guide, **and with the following additional instructions**, draw the circuit in Multisim.
  - Use 74LS76 flip-flops.
  - Connect the first flip-flop's clock input (labeled $\bar{C}_{p0}$ in the drawing) to a Clock Voltage Source whose frequency is set to 2 Hz.
  - Connect the four output bits (Q_3, Q_2, Q_1, and Q_0) to four red digital probes, and arrange the probes horizontally so that the most significant bit is on the left and the least significant bit is on the right.
  - Connect the circuit's $\bar{R}_D$ input to an SPDT switch that is wired to V_{CC} and ground.
- Simulate the circuit. It should count in binary from 0000_2 to 1111_2, and then recycle.
- When your Multisim circuit works correctly, ask me to check it. _____
- On your Multisim drawing, add an EET1131 title block showing:
  - Your name
  - Today's date
  - The title "MOD-16 Flip-Flop Counter"
- Get a printout of your circuit and **turn it in with this lab**.
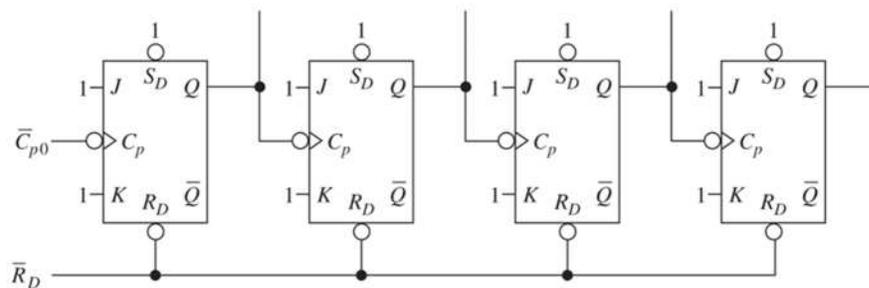
Part 2. 7493 Asynchronous Counter Chip
- Still in Multisim, let's see how you can make your life much easier by using a counter IC instead of building counters out of flip-flops. The 7493 chip contains flip-flops internally connected together to form a counter.
- The *incomplete* diagram below shows how to use a 7493 as a MOD-16 counter, which counts from 0000_2 to 1111_2 and then recycles.
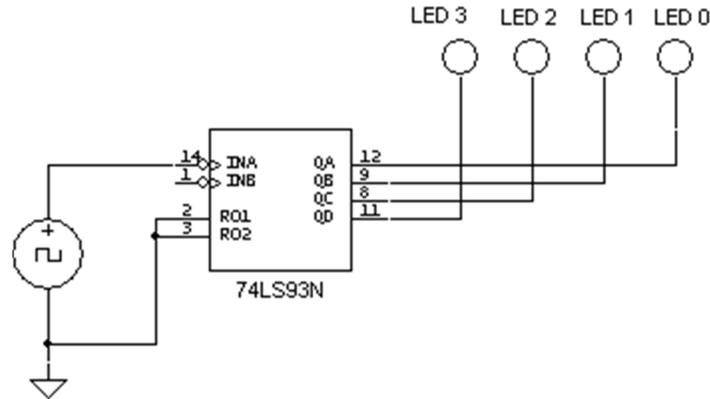
- Build this circuit in Multisim. *To get this circuit to work, you'll need to provide one more connection that is not shown in the diagram but which we discussed in class.*
- Simulate the completed circuit. It should count in binary from 0000_2 to 1111_2, and then recycle.
- When your Multisim circuit works correctly, ask me to check it. _____
- Get a printout of your circuit (with title "MOD-16 7493 Counter" in the title block) and **turn it in with this lab**.

Part 3. The Same Circuit in Quartus II
- Create a Quartus II project named **Lab11MOD16** and a bdf file with the same name.
- In the bdf file, build the same 7493 circuit from above. Your circuit will have one Quartus input pin in place of Multisim's Clock Voltage Source, and four Quartus output pins (assigned to LEDs on the Altera board) in place of Multisim's LEDs.
- Perform analysis and synthesis, and then simulate to verify correct operation. (In your .vwf file, configure the input to behave like a clock.) When you run the simulation, the four output bits should count in binary from 0000_2 to 1111_2, and then recycle.

- When your simulation results are correct, ask me to check them. _____

- Recall that one of the Altera chip's input pins is connected to a 50 MHz clock signal. In previous labs you've used a chain of frequency dividers to reduce the frequency from 50 MHz to a much lower frequency (about 3 Hz in Lab #4, and about 6 kHz in Lab #6, and about 12 Hz in Lab #8). Use that same technique here to generate a clock signal of 3 Hz or less for the 7493's clock input.
- Assign pin numbers, compile, and download your design to the Altera chip.
- When your circuit works correctly, ask me to check it.

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Part 4. Displaying the Count on an Oscilloscope
- Create a Quartus II project named **Lab11MOD16Oscope** and a bdf file with the same name. Copy and paste the circuit from Lab11MOD16.bdf into this new bdf file.
- Let's display the counter's output on the oscilloscope. In Quartus, assign the following pin numbers to your 7493's four output bits: pins J10, J14, H13, and H14. As shown in Table 4-13 of the DE2-115 user manual, these pins are connected to four pins of the DE2-115 board's 14-pin general-purpose I/O connector. Then display the outputs on the oscilloscope's four channels, in the following order:
    - Output bit Q_A on oscilloscope Channel 1.
    - Output bit Q_B on oscilloscope Channel 2.
    - Output bit Q_C on oscilloscope Channel 3.
    - Output bit Q_D on oscilloscope Channel 4.
- Modify your chain of frequency dividers to increase the clock frequency from about 3 Hz to about 750 Hz.
- Compile your design and download it to the Altera chip.
- Arrange the four traces in order on the oscilloscope screen, with Channel 1 at the top of the screen and Channel 4 at the bottom. Make sure that at least one cycle of each waveform is displayed.
- Also be sure to set your trigger appropriately to get a stable display without using the **STOP** button.
- Use the oscilloscope's **MEASURE** button to simultaneously display the frequencies of all four waveforms, with Channel 1's frequency displayed first and Channel 4's displayed last.
- When you're satisfied with your display, ask me to check it. _____
- Get a printout of the oscilloscope screen (including the four frequency measurements), and turn it in with this lab. Label it as **MOD-16 Counter Waveforms**.

Part 5. Changing the Modulus (Still Using the Oscilloscope)
- Create a Quartus II project named **Lab11MOD12Oscope** and a bdf file with the same name. Copy and paste your previous circuit into this new bdf file.
- Notice that in this circuit the two reset pins (named **R01** and **R02**) are grounded, which disables them. These reset pins are the key to modifying the counter so that it has a **truncated sequence**, which means it recycles before it counts all the way up to 1111_2. Using these pins (and without using any additional gates or chips), change your Quartus II design so that it's a MOD-12 counter that counts from 0000_2 to 1011_2 and then recycles.
- Compile and download your design to the chip. Displays its outputs on the oscilloscope. When your circuit works correctly, ask me to check it. _____

- Create a Quartus II project named **Lab11MOD10Oscope** and a bdf file with the same name. Copy and paste your previous circuit into this new bdf file.
- Modify the circuit so that it's a MOD-10 counter that counts from 0000_2 to 1001_2 and then recycles.
- Compile and download your design to the chip. Display its outputs on the oscilloscope. When your circuit works correctly, ask me to check it.

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- You're finished with the oscilloscope, so you can disconnect it and turn it off.

Part 6. An Up-Down Counter (74190)
- Create a Quartus II project named **Lab11UpDownCounter** and a bdf file with the same name. Copy and paste your 3-Hz chain of frequency dividers from Lab11MOD16 into this new bdf file. But don't copy the 7493 counter, because for this circuit we'll use a 74190 up-down counter.
- Place a 74190, and connect its clock input to the output from your chain of frequency dividers.
- Connect each of the 74190's inputs to a Quartus input pin. Refer to the DE2-115 board's user manual to find the pin numbers for the push-button and slide switches listed in the table below. Record these pin numbers in the table, and assign these same numbers to your Quartus input pins.

74190 Input	Slide Switch or Push-Button	Pin Number
LDN	KEY0	
A	SW0	
B	SW1	
C	SW2	
D	SW3	
GN	SW16	
DNUP	SW17	

- Connect the 74190's four Q outputs to four Quartus output pins, and assign them the pin numbers of four LEDs on the DE2-115 board. (Put them in proper order, with the most significant bit on the left.) Leave the 74190's other two outputs unconnected.
- Compile your design and download it to the Altera chip. Using the board's switches and push-button, test the counter's various functions: counting up, counting down, loading, and disabling. When your circuit works correctly, ask me to check it.

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Part 7. Displaying the Count on a Seven-Segment Display
- Create a Quartus II project named **Lab11SevenSegment** and a bdf file with the same name. Copy and paste your previous circuit into this new bdf file.
- Let's display the counter's count on a seven-segment display. To do this, you'll use a 7447 BCD-to-seven-segment decoder chip. In Quartus II, place a 7447, and connect its A, B, C, D inputs to your counter's similarly named outputs.
- Make the 7447's other inputs inactive. (To do this, you must decide whether to tie them low or high.)
- Connect the 7447's outputs to Quartus output pins.
- Note that the Altera DE2-115 board has eight built-in seven-segment displays. These displays are permanently connected (through current-limiting resistors) to certain pins on the Altera chip. To figure out which of the Altera's pins are permanently connected to which segments on the seven-segment displays, refer to Table 4-4 in the DE2-115 board's user manual. Connect the 7447's outputs to Quartus II output pins,

and then assign pin numbers so that your count will be displayed on the board's rightmost seven-segment display.

- Compile your design and download it to the Altera chip. When your circuit works correctly, ask me to check it.

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Part 8. Cascading Two MOD-10 Counters to make a MOD-100 Counter

- Create a Quartus II project named **Lab11MOD100** and a bdf file with the same name. Copy and paste the circuit from Lab11SevenSegment.bdf into this new bdf file.
- Add another 74190 counter and another 7447 to your Quartus II design. Connect the two counters so that they form a MOD-100 counter. Connect the two 7447s to the two rightmost seven-segment displays on the DE2-115 board so that the count increases from 0 to 99, and then repeats.
- Compile your design and download it to the Altera chip. When your circuit works, ask me to check it.

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