Name_____

EET 1131 Lab #10
Latches and Flip-Flops

OBJECTIVES:
1. To study the operation of a *D* latch.
2. To study the operation of a *D* flip-flop.
3. To study the operation of a *J-K* flip-flop.

EQUIPMENT REQUIRED:
- Safety glasses
- ICs: 7474, 7475, 74LS76 (**not** a standard 7476)
- Digital Circuit Trainer
- *Multisim* simulation software
- Quartus II software and Altera DE2-115 board

PART 1. 7475 Gated *D* Latches

Part 1(A). The 7475 chip contains four gated *D* latches. Shown below is the symbol for one-half of this chip (two of the latches).

Using the datasheet from www.ti.com (search for **sn7475**), find the pin numbers for the first two latches on a 7475, and **label these pin numbers** on the diagram below.

7475N
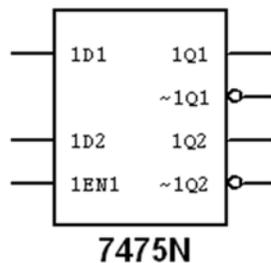
Pin number for V_{CC} = _____

Pin number for Ground = _____

Now place a 7475 on the breadboard and connect its inputs as follows:
- Connect the three input pins to three of the trainer's data switches.
- Connect the two active-high output pins to two LEDs.
- Provide the 7475 chip with power and ground.

With the Enable pin set HIGH to enable the latches, complete Table 1 by setting the data switches in the sequence shown and observing the LEDs.

Table 1

| EN	D1	D2	Q1	Q2
1	0	0		
1	0	1		
1	1	0		
1	1	1		

Revised 1/11/2018

Now set the Enable pin LOW to disable the latches. With the Enable pin set LOW, complete Table 2 by setting the data switches in the sequence shown and observing the LEDs.

Table 2

EN	D1	D2	Q1	Q2
0	1	1		
0	1	0		
0	0	1		
0	0	0		

Based on your data of Tables 1 and 2 above, *explain clearly* (and in complete sentences) how a gated *D* Latch works.

Part 1(B). In Multisim, build the circuit shown below.
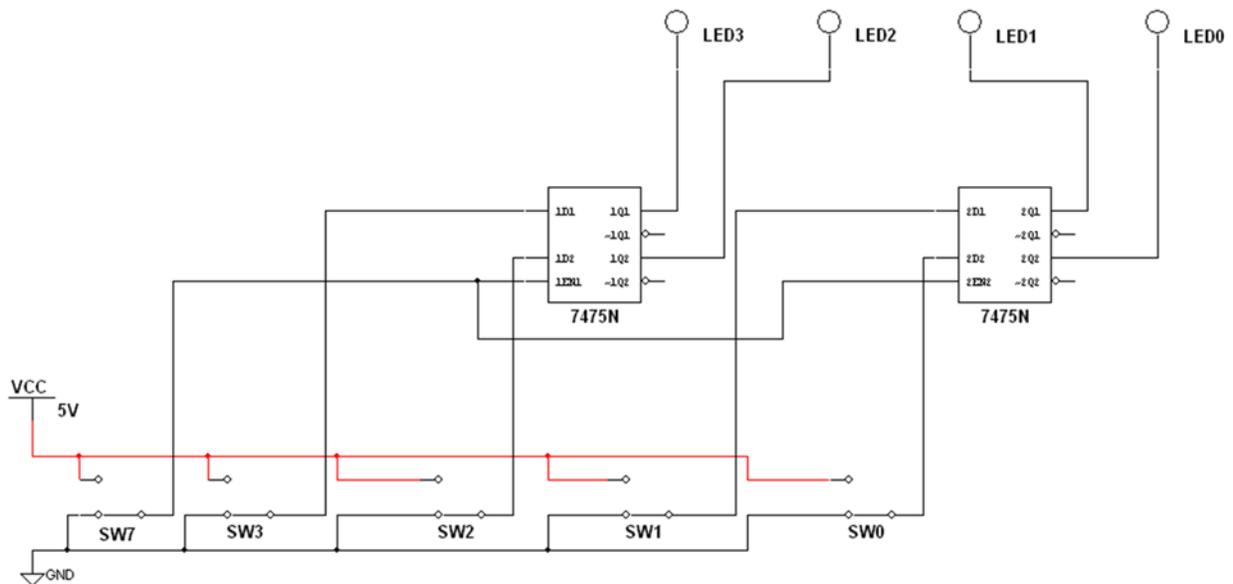
After building the circuit in Multisim, **start the simulation** and follow these steps:

(a)   We want to start with all of the LEDs dark. If your LEDs are already all dark, skip to step (b). But if any of your LEDs are lit up, do this:
- Set all five switches LOW.
- Set switch 7 HIGH. Now all of your LEDs should be dark.

(b)   Disable the latches by using the appropriate switch to set the Enable inputs to their inactive state.

(c)   Using the switches, place the binary number 1001_2 on the *D* inputs.

(d)   What binary code is displayed on the LEDs? _____

(e)   Enable the latches by switching the Enable inputs to their active state.

(f)   What binary code is displayed on the LEDs? _____

(g)   Place the binary number 0111_2 on the *D* inputs.

(h)   What binary code is displayed on the LEDs? _____

(i)   Disable the latches by setting the Enable inputs to their inactive state.

(j)   What binary code is displayed on the LEDs? _____

(k)   Place the binary number 0100_2 on the *D* inputs.

(l)   What binary code is displayed on the LEDs? _____

Add an EET 1131 title block to your drawing that shows:
- Your name
- Today's date
- The title "Lab 10 Part 1**"**

With the switches for the *D* inputs set to 0100_2 with the latches still disabled, get a printout, and **turn it in** with this lab.

What conclusions can you draw from this exercise? Explain clearly and in complete sentences.

Part 1(C). Create a Quartus II project named Lab10DLatch and a bdf file with the same name. In the bdf file, build the same circuit as above. Compile your design and download it to the Cyclone chip.

Repeat steps (a) through (l) above on your downloaded circuit. You should find it to behave the same as your Multisim circuit.

When your circuit works correctly, ask me to check your work. _____

PART 2. 7474 *D* Flip-flops

    Part 2(A). The 7474 chip contains two *D* flip-flops. Shown below is the symbol for one of these flip-flops. Judging by the symbol, is this flip-flop **positive-edge triggered** or **negative-edge triggered**?

_____

        Using a datasheet, find the pin numbers for the first flip-flop on a 7474, and **label these pin numbers** on the diagram below.

7474N
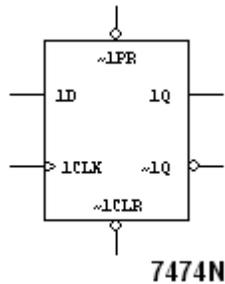
Pin number for V_{CC} = _____

Pin number for Ground = _____

Now place a 7474 on the breadboard and connect its inputs as follows:
- Connect the flip-flop's $\overline{PRE}$ input, $\overline{CLR}$ input, and *D* input to three of the trainer's data switches.
- Connect the flip-flop's *CLK* input to the trainer's pulse switch *A*. With this connection, by repeatedly pressing and releasing the pulse switch, you will apply positive clock pulses to the flip-flop's clock input.
- Connect the flip-flop's *Q* output to an LED.
- Provide the 7474 chip with power and ground.

Complete Table 3 by setting the data switches appropriately and pressing the pulse switch whenever you wish to apply a clock pulse.

Table 3

$\overline{PRE}$	$\overline{CLR}$	D	CLK	Q
1	1	1	↑	
1	1	0	↑	
0	1	1	↑	
0	1	0	↑	
1	0	1	↑	
1	0	0	↑	
1	1	1	No Pulse	
1	1	0	No Pulse	

Based on your data of Table 3 above, explain clearly (and using complete sentences):

    a. Ignoring the $\overline{\textbf{PRE}}$ and $\overline{\textbf{CLR}}$ inputs, how does a positive edge triggered *D-*Flip Flop work?

    b. How does the $\overline{\textbf{PRE}}$ input work?

    c. How does the $\overline{\textbf{CLR}}$ input work?

d. Why should the $\overline{\textbf{PRE}}$ and $\overline{\textbf{CLR}}$ inputs not be made low at the same time?

Part 2(B). 1. The glossary on pages 470-472 of your textbook defines the word **register**. Copy this definition below and make sure you understand what it means.

A **register** is

In Multisim, build the 4-bit register circuit shown below.
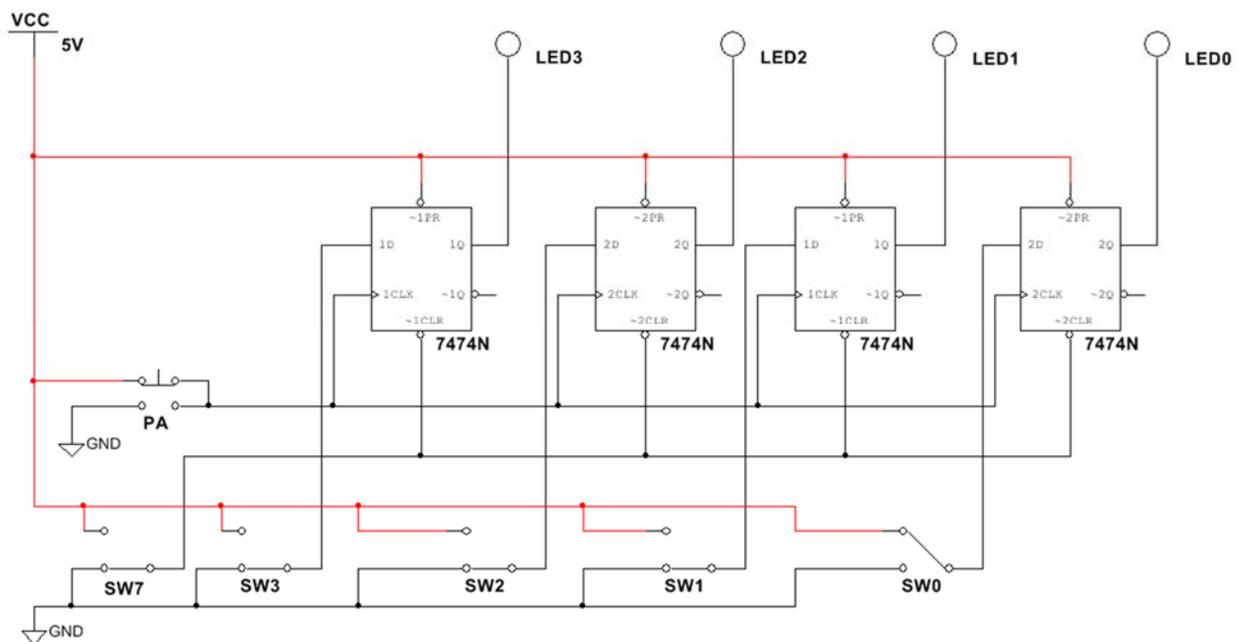
After building the circuit in Multisim, **start the simulation** and follow these steps:

(a) To clear all four flip-flops, use the appropriate switch to set the $\overline{\text{CLR}}$ inputs to their active state. Then return the $\overline{\text{CLR}}$ inputs to their inactive state.

(b) Using the switches, place the binary number 1001_2 on the *D* inputs.

(c) Before you pulse the clock input, what binary code is displayed on the LEDs? _____

(d) Pulse the clock input by pressing and then releasing the push button PA.

(e) What binary code is displayed on the LEDs? _____

(f)   Place the binary number 0111_2 on *D* inputs.
(g)   Before you pulse the clock input, what binary code is displayed on the LEDs? _____

(h)   Pulse the clock input.
(i)   What binary code is displayed on the LEDs? _____

(j)   Now set $\overline{CLR}$ low and leave it low through the following steps, which are the same as steps (b) through (i) above.
(k)   Place the binary number 1001_2 on the *D* inputs.
(l)   Before you pulse the clock input, what binary code is displayed on the LEDs? _____

(m)   Pulse the clock input.
(n)   What binary code is displayed on the LEDs? _____

(o)   Place the binary number 0111_2 on *D* inputs.
(p)   Before you pulse the clock input, what binary code is displayed on the LEDs? _____

(q)   Pulse the clock input.
(r)   What binary code is displayed on the LEDs? _____

Add an EET 1131 title block to your drawing that shows:
- Your name
- Today's date
- The title "Lab 10 Part 2"

With the switches for the *D* inputs set to 0111_2, get a printout, and **turn it in** with this lab.

What conclusions can you draw from this exercise? Explain clearly.

Part 2(C). Create a Quartus II project named Lab10DFlipFlop and a bdf file with the same name. In the bdf file, build the same circuit as above. Compile your design and download it to the Cyclone chip.

Repeat steps (a) through (r) above on your downloaded circuit. You should find it to behave the same as your Multisim circuit.

When your circuit works correctly, ask me to check your work. _____

PART 3. 74LS76 *J-K* Flip-flops

Part 3(A). The 74LS76 chip contains two *J-K* flip-flops. Shown below is the symbol for one of these flip-flops. Judging by the symbol, is this flip-flop **positive-edge triggered** or **negative-edge triggered**?

_____

Using a datasheet, find the pin numbers for the first flip-flop on a 74LS76, and **label these pin numbers** on the diagram below.
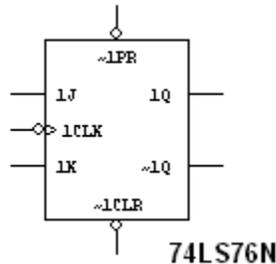
Pin number for V_{CC} = _____

Pin number for Ground = _____

Now place a 74LS76 on the breadboard and connect its inputs as follows:

- Connect the flip-flop's $\overline{PRE}$ input, $\overline{CLR}$ input, *J* input, and *K* input to four of the trainer's data switches.
- Connect the flip-flop's *CLK* input to the trainer's pulse switch *A*. With this connection, by repeatedly pressing and releasing the pulse switch, you will apply clock pulses to the flip-flop's clock input.
- Connect the flip-flop's *Q* output to an LED.
- Provide the 74LS76 chip with power and ground.

Complete Table 4, performing the steps **in the order shown**. Use the data switches to set the $\overline{PRE}$, $\overline{CLR}$, *J*, and *K* inputs to the specified values. To apply a clock pulse, press and release the pulse switch.

Table 4

$\overline{PRE}$	$\overline{CLR}$	J	K	CLK	Q
0	1	0	0	↓	
0	1	0	1	↓	
0	1	1	0	↓	
0	1	1	1	↓	
1	0	0	0	↓	
1	0	0	1	↓	
1	0	1	0	↓	
1	0	1	1	↓	
1	1	1	0	↓	
1	1	0	0	↓	
1	1	0	1	↓	
1	1	0	0	↓	
1	1	1	1	↓	
1	1	0	0	↓	
1	1	1	1	↓	

Part 3(B) **In Multisim,** place a single 74LS76 *J-K* flip-flop on the workspace.

- Connect its *J* and *K* inputs to V$_{CC}$ to make them permanently HIGH.
- Connect the $\overline{PRE}$ and $\overline{CLR}$ inputs to two SPDT switches, so that they can be switched between LOW and HIGH.
- Connect the *CLK* input to a square wave (the Multisim component called CLOCK_VOLTAGE), and set this wave's frequency to 10 kHz.

(a) Next:

- Set $\overline{PRE}$ and $\overline{CLR}$ both to HIGH.
- Display the CLK input on the oscilloscope's Channel A.
- Display output *Q* on the oscilloscope's Channel B.
- Arrange the waveforms on the oscilloscope's screen so that Channel A is located in the top half of the screen and Channel B is located in the bottom half.
- Adjust the scope's controls to show about five cycles of Channel B's waveform.
- **Press the oscilloscope's REVERSE button** so that the waveforms are displayed against a white background instead of a black background.
- Get one printout showing the circuit (titled "Lab 10 Part 3" in the title block), and another printout showing the oscilloscope face with waveforms. **Turn the printouts in** with this lab.

(b) Set $\overline{PRE}$ to LOW, and observe the waveforms on the oscilloscope. What do you see on the *Q* pin?

(c) Return $\overline{PRE}$ to HIGH, and set $\overline{CLR}$ to LOW. Observe the waveforms on the oscilloscope. What do you see on the *Q* pin?

From the Multisim oscilloscope printout that you made above, what is the mathematical relationship between the flip-flop's input frequency at its *CLK* pin and the output frequency at its *Q* pin?

Based on your data and observations in Parts 3(A) and 3(B), what conclusions can you draw about *J-K* flip-flop operation?