EGR 270
Fundamentals of Computer Engineering
File: N270L6

Lab # 6
Synchronous Counters

Lab Format
- This is a **Individual Lab** so each student must design and test their own circuits.
- Each student must complete the Preliminary Work Section **before** lab begins. Preliminary Work will be checked in lab and will be part of the lab report grade.
- Each student must submit his or her own lab report.
- Lab reports will not be accepted until all required circuits have been demonstrated to the instructor.

A.   Objective
The objective of this laboratory is to introduce the student to synchronous sequential counter circuits designed with JK flip-flops using the excitation table method and to introduce the student to the 74191 synchronous UP/DOWN counter as an example of a commercially available counter.

B.   Materials
Breadboard	74LS47
5V Power Supply	7-Segment display (common anode)
74LS76 Dual JK flip-flops	555 Timer IC
74LS191 Synchronous UP/DOWN Counter	Assorted resistors and capacitors

C.   Introduction
No new material is introduced in this lab, however, the student may want to review the design of sequential circuits by the "excitation table method" covered in the lecture part of the course. A data sheet for the 74191 is available on the instructor's web page.

D.   Preliminary Work
1. Design a clock generator using a 555 timer with a frequency of about 1 Hz (any duty cycle is OK). Use resistor values between 1kΩ and 1MΩ and use capacitor values available in lab (see table in "Pinouts.doc available on course Bb site). Show your calculations for R_A, R_B, and C.

2. Select the nearest **standard 5% resistor values** to the values for R_A and R_B shown above. Include a printout of a table of standard 5% resistor values and circle the ones selected. The table is available in "Pinouts.doc" or can be easily found online.

3. Recalculate f using these standard values chosen. Also calculate the values of T, T_H, T_L, and D. Show all calculations and the results.

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4. Design a modified sequence counter that will count out the following sequence: The first four unique digits in your StudentID (not including the digit 9) followed by the digit 9 and then repeat. If you do not have 4 unique digits, then add in as many of the follow digits as you need: 7, 2, 6, 8. Several examples are shown below.

StudentID	Counting Sequence
2869834	2, 8, 6, 3, 9, and repeat
2662518	2, 6, 5, 1, 9, and repeat
2552525	2, 5, 7, 6, 9, and repeat

Use the excitation table method for your design. Treat unused states as "don't cares". Note that this is the same design used in PSPICE Assignment #2.
Include a switch to initialize the counter to the first count in your sequence.
Your design should include the following:
- a state diagram (include only the valid states)
- a circuit excitation table used to determine JK flip-flop input connections
- the K-maps used to generate minimal expressions for JK inputs

3. Generate a detailed schematic using PSPICE for the counter designed above, including the 555 timer circuit designed above, the initialization switch, and the connection of the outputs of the flip-flops to the 74LS47 and 7-segment display. A basic block diagram for the circuit to be built and tested is shown below.
Extra Credit: Simulate the counter using PSPICE to verify that it works correctly. Note that this simulation is a required part of PSPICE Assignment #2. If you are simulating the circuit, you do not need to include the 74LS47 and 7-segment display, even though they will be used in lab.

4. Generate a detailed schematic using PSPICE for the connection of a 74191 synchronous UP/DOWN counter, including the clock input, a switch to control the count direction, and the connection of the the 7447 and 7-segment display. Check the data sheet for the 74191 for proper operations of the device (looking at the timing waveforms on the data sheet is particularly useful). Note that the 74LS191 is not in the EVAL library in PSPICE, but it is available in the Counter library (but cannot be analyzed).

E. **Laboratory Work**
1. Measure and record the resistor and capacitor values to be used for the 1 Hz clock generator. Recalculate the frequency using the measured values and compare it to the designed frequency.

|	R_A (kΩ)	R_B (kΩ)	C (μF)	f (Hz)
Value from Preliminary Work				
Value measured in lab (or recalculated)				

2. Construct the 1 Hz clock generator. Connect an LED and current-limiting resistor to the output to insure that it is working properly (it should blink once per second). Use a stopwatch and count the number of blinks that occur in 60 seconds. Record the results. Calculate the frequency from this result f = (number of blinks in 60 s)/60. Compare this frequency to the recalculated value from step 1 and record the results in a table with % error.

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3. Construct the modified sequence counter. Use the 1 Hz clock generator built in the previous step to clock the counter. Connect the output of the counter to the 7-segment display device. A basic block diagram is shown below. Also add the initialization switch to the circuit. Be sure to connect all unused Presets and Clears to HIGH or the circuit may not operate correctly. Demonstrate proper operation of the circuit to your instructor. Record the results (including the sequence displayed and the operation of the initialization switch).

| 555 Timer (1 Hz Clock) | — | Modified Sequence Counter | ═══ | 7447 and 7-segment display circuit board |
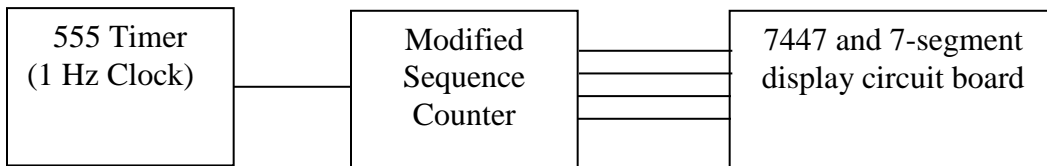
4. Connect the 74191 synchronous UP/DOWN counter. Use the constructed 1 Hz clock generator to clock the counter. Connect the output of the counter to the 7-segment display device. A basic block diagram is shown below. Demonstrate proper operation of the circuit to your instructor (counting 0 up to 15 and 15 down to 0).

| 555 Timer (1 Hz Clock) | — | 74191 Synchronous UP/DOWN Counter | ═══ | 7447 and 7-segment display circuit board |
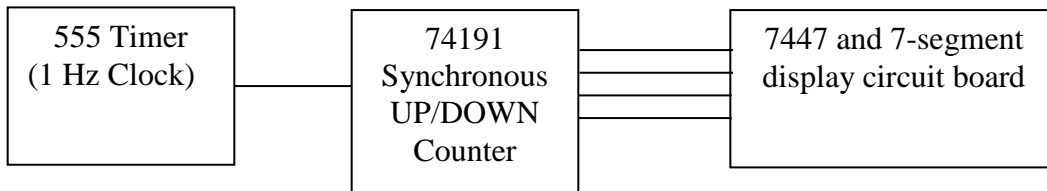
F. Report

Remember that each lab report should have the following four sections. Also see additional notes below.

Title Page

Preliminary Work

- Include instructions

Lab Results

- Include all measured or demonstrated results.
- Include step numbers and titles or headings that make it clear what is being shown.

Discussion/Conclusion

- Discuss each circuit tested in lab.
- Discuss the usefulness of the 555 timer.
- Compare your designed frequency for the 555 timer to the frequency measured in lab. Discuss reasons for any differences. Were the differences important in this lab? Why or why not?
- Explain why the duty cycle of the 555 clock generator wasn't important in this lab.
- Compare the design of a custom counter using JK flip-flops to the use of a commercially-available counter (such as the 74191).
- What have you proven or demonstrated by completing the experiment?