Lab Assignment #2

Number Representation Systems

1. Objective
- Generation and observation of the single digit number sequence in binary coded decimal (BCD) number representation,
- an application specific exercise in using the laboratory environment: protoboard, oscilloscope, and integrated circuit components,
- learning how to use a simple schematic capture CAD tool,
- developing skills in analyzing the behavior of sequential logic circuits.

2. Prelab Assignment

2.1 positional number representation

Study the positional number representation in base two, base eight, base sixteen, and the BCD representations. Prepare a table T2.1-1, whose five columns will contain the representation of numbers zero through twenty-two in base ten, base two, base eight, base sixteen, and BCD representation, in this same sequence. For base two use eight bit representation.

2.2 Binary representation of non-negative integers

2.2.1 Use the graphics capabilities of your preferred text editor, or the PSPICE tool, to prepare your own copy of the logic circuit diagram shown in Figure A.4-1 of this assignment and show it as Figure 2.2-1(a) in the Prelab part of the Lab Report.

2.2.2 Design a physical layout of the logic circuit shown in Figure A.4-1; show a computer generated drawing of the layout as Figure 2.2-1(b). Include IC package pinouts on both drawings of Figure 2.2-1.

2.3 BCD representation of numbers

2.3.1 Use the graphics capabilities of your preferred text editor, or the PSPICE tool, to prepare your own copy of the logic circuit diagram shown in Figure A.4-2 of this assignment and show it as Figure 2.3-1(a) in the Prelab part of the Lab Report.

2.3.2 Design a physical layout of the logic circuit shown in Figure A.4-2; show a computer generated drawing of the layout as Figure 2.3-1(b). Include IC package pinouts on both drawings of Figure 2.3-1.
3. Lab equipment and circuit components

3.1 Equipment

Equipment to be used includes:
- protoboard ETS-7000,
- Mixed-Signal oscilloscope HP54645D,
- Dell GxaEM computer system.

3.2 Logic circuit components
- integrated circuit 7493, 4-bit ripple counter

4. Lab Experiment

4.1 Binary representation of non negative integer numbers

4.1.1 Insert the IC 7493 into the protoboard. Using the physical layout prepared in Figure 2.3-1(b) of the Prelab assignment, establish the connections shown in Figure A.4-1. The created circuit counts the number of pulses (precisely, the negative edges of pulses) applied to pin number 14, which is designated as input A of the IC 7493. The count is shown in binary representation at the outputs designated as $Q_A$, $Q_B$, $Q_C$, and $Q_D$, where $Q_A$ is the LSB and $Q_D$ is the MSB. Make sure that +5V power supply is properly connected to the protoboard. Turn the power supply on.

Predict the range of count numbers which can be captured by this counter circuit.

State the number of outputs that would need to be added to the circuit if we wanted to design a new counter, one capable of capturing counts of pulses in the range 0 to 1,000.

4.1.2 On the front panel of the function generator:
- have the output signal connection cable attached to the signal outlet/jack marked TTL,
- select the square waveform,
- adjust the frequency of the signal to 1MHz,
- after the TA has checked the settings, turn the power on.

And by the way, what is the length of the period of the signal at the output of the function generator?

4.1.3 Connect the digital channels D0 through D4 of the Mixed signal oscilloscope HP 54645D to the circuit shown in Figure A-4.1:
- digital channel D0: to the input A of the IC 7493,
- digital channel D1: to the output QA of the IC 7493,
- digital channel D2: to the output QB of the IC 7493,
- digital channel D3: to the output QC of the IC 7493,
- digital channel D4: to the output QD of the IC 7493.

Make the connection to ground. Turn on digital channels D0 through D4, and rename the channels D0 through D4 as: A, QA, QB, QC, QD respectively.

4.1.4 Set the triggering mode of the HP 54645D to the combination 0000 on channels D1 through D4. Hit the key Single. Adjust the display of the waveforms so that the first appearance of the combination of signal values 0000 on channels D1 through D4 is positioned at the left end of the screen, and that the whole screen shows ten percent more than just two periods of the signal at QD.

4.1.5 Using the instructions from the BenchLink tutorial posted at the course webpage, transfer the Screen Image of the waveforms of the channels D0 through D4 into a file named s11l2_415.tif on the Dell GxaEM computer system.

4.1.6 Make the following observations, and provide answers to questions:
   a) How many periods (equivalent to the number of positive pulses) of the function generator’s square wave signal had to be applied to input A of 7493 to observe all sixteen states of the outputs QA, QB, QC, QD?
   b) What happens when one more pulse (period of the signal) is applied to the input A?
   c) Record the sequence of numbers represented by the outputs QA, QB, QC, QD, starting from the output state 00012 and terminating after fourteen pulses have been applied to input A.
   d) Observe the output QA. Could you tell the frequency of the periodic signal at the output QA?

4.1.7 Adjust the frequency of the function generator so that the frequency of the output signal QA becomes 400 kHz (if you can not guess directly, make a few trials). Hit the key Single. Adjust the display so that the first appearance of the combination of signal values 0000 on channels D1 through D4 is positioned at the left end of the screen, and that the whole screen shows ten percent more than just two periods of the signal at QD. Answer the following questions,
   e) What is the frequency of the square wave signal when the output QA is at 400 kHz?
   f) What is the ratio of the frequency of the signal at input A to the frequency of the signal
at output $Q_A$ of the 7493?

**g)** Does that frequency ratio depend on the signal frequency? To find the answer, compare the ratio calculated under **f)** with the one which results from the waveforms saved in Section 4.1.5.

**h)** Calculate and record the ratios of the signal frequency at input $A$ to the frequencies of the output signals at $Q_B$, $Q_C$, and $Q_D$.

4.1.8 Using the instructions from the BenchLink tutorial posted at the course webpage, transfer the Screen Image of the waveforms of the channels D0 through D4 to a file named s11l2_416.tif on the Dell GxaEM computer system.

### 4.2 Binary Coded Decimal (BCD) number representation

**4.2.1** Using as a reference the physical layout prepared in Figure 2.4-1(b) of the Prelab assignment, change the connections on the protoboard so that the circuit shown in Figure A.4-2 is established. The new circuit counts the number of pulses applied to the pin number 14, and shows the count at the outputs $Q_A$, $Q_B$, $Q_C$, and $Q_D$ in BCD number representation.

**4.2.2** Keep the settings and the connections of signal probes of the Mixed-Signal oscilloscope as they were in section 4.1. Adjust the frequency of the function generator to 1MHz. Hit the key Single. Adjust the display of the waveforms so that the first appearance of the combination of signal values 0000 on channels D1 through D4 is positioned at the left end of the screen, and that the whole screen shows ten percent more than just the two periods of the signal at $Q_D$.

**4.2.3** Using the instructions from the BenchLink tutorial posted at the course webpage, transfer the Screen Image of the waveforms of the channels D0 through D4 to a file named s11l2_423.tif on the Dell GxaEM computer system.

**4.2.4** Make the following observations, and provide answers to questions:

a) How many pulses need to be applied to input $A$ of 7493 to observe all ten states of the 
outputs $Q_A, Q_B, Q_C, Q_D$?

b) What happens when one more pulse is applied to the input $A$?

c) Record the sequence of numbers represented by the outputs, starting from the output state 0001\textsubscript{2} and terminating after eleven pulses have been applied to the input $A$.

d) Could you tell what is the frequency of the periodic signal at the output $Q_A$?

e) Which of the output signals at $Q_B, Q_C$, and $Q_D$ have their waveforms different from those observed in the circuit of Figure A.4-1, and which ones have the same waveforms?

4.2.5 Adjust the frequency of the function generator signal so that the frequency of the signal at output $Q_A$ becomes 500 kHz.

f) What is the frequency of the function generator’s square wave signal now, when the signal at the output $Q_A$ is at 500 kHz?

g) What is the ratio of the function generator’s square wave frequency to the frequency of the output signal at the output $Q_A$?

h) Does this ratio differ from that one determined in Section 4.1.

4.3 Other representation sequences.

Now is the time for an adventure! You do not know the internal circuit connections of the IC 7493, so you do not know which external connections to the inputs R1 and R2 (but those shown in figures A.4-1 and A.4-2) will select which base (radix) representation will be shown at the outputs QA, QB, QC, and QD. Using the experimental techniques that you have exercised in Sections 4.1 and 4.2, find out the connections which will function as described in Sections 4.3.1 and 4.3.2, and record their connections and waveforms.

**Hint#3:** The only difference between the circuits shown in figures A.4-1 and A.4-2 is in the connections applied to the pins R1 and R2 of the 7493. Obviously, those connections affect the base (radix) in which the output signals represent the count of pulses applied to input $A$; the connections of the circuit in Figure A.4-1 produce the output in base two, and the connections of Figure A.4-2 produce the output in binary coded decimal form.

4.3.1 Establish experimentally which connections to inputs R1 and R2 will cause the counting circuit to show the count of pulses to input $A$ in binary coded base five. Then record the circuit connections in Figure 4.3-1(a), and save the Screen Image of the waveforms of the channels D0 through D4 to a file named s1112_431.tif on the Dell GxaEM computer system.

4.3.2 Establish experimentally which connections to inputs R1 and R2 will cause the counting circuit to show the count of pulses to input $A$ in binary coded base six. Then record the circuit connections in Figure 4.3-2(a), and use the instructions from the BenchLink tutorial posted at the course webpage, to transfer the Screen Image of the waveforms of the channels D0 through D4 to a file named s1112_432.tif on the Dell GxaEM computer system.

4.4 Transfer of captured waveforms.

Upload the files s1112_*.tif from the Lab computer Dell GxaEM to the:\H-drive of your account in the UTAD file system using the instructions from the tutorial named uploading_to_H_drive.pdf that is posted at the course webpage.
5. **LAB REPORT**

To be considered complete the lab report must contain the following,

1. Cover sheet - Lab style, filled out,
2. The number representation table T2.1-1 prepared under 2.1.
3. The logic circuit and physical layout diagrams prepared under 2.2 and 2.2.
4. The logic circuit diagrams recorded under 4.3.
5. The waveforms obtained in experiments 4.1 through 4.3.
6. Answers to all questions asked in conjunction with experiments 4.1 through 4.3.
7. A report on items not included under 1. and 2. above, but listed in the Guidelines for Preparing Lab Reports document that is posted at the course web page and asks for:
   - a discussion of the insights gained through the conducted experiments,
   - textual description and graphical/ tabular illustration of the design procedure(s),
   - description of implemented testing procedures,
   - comments and suggestions that might lead to easier and/or deeper understanding of the topics covered by the assignment.