Number Representation

By: Dr. A. D. Johnson   **Lab Assignment #2**
  EECS: 1100 Digital Logic Design
  The University of Toledo

1. Objectives

- learning how to use a simple schematic capture CAD tool,
- generation and observation of the single digit number sequence in the binary coded decimal **(BCD)** number representation,
- an application specific exercise in using the laboratory environment: protoboard, oscilloscope, and integrated circuit components,
- 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 number representation. Prepare a table T2.1-1, whose five columns will contain the representation of numbers zero through twenty-two in base ten representation, base two representation, base eight representation, base sixteen representation, and BCD representation, in the given sequence. For base two use eight bit representation.

2.2 INTRODUCTION TO ALTERA'S SCHEMATIC CAPTURE TOOL

Use a web browser to access the Altera's web site at the URL:

> http://www.altera.com/html/literature/lsig.html

You should see the following text there:

On-Line Literature: MAX+PLUS II Documentation

  • MAX+PLUS II Programmable Logic Development System & Software Data Sheet, ver. 8

  • For information on using the MAX+PLUS® II software with other EDA tools, go to the

  • MAX+PLUS II ACCESSSM Key Guidelines on this web site. These guidelines replace the software interface guides that were available for MAX+PLUS II version 8.1 an earlier.

  • MAX+PLUS II Getting Started version 8.1 (5.4 MB)

  • This manual is also available in 4 parts:

    - Preface & Section 1: MAX+PLUS II Installation

    - Section 2: MAX+PLUS II - A Perspective

    - Section 3: MAX+PLUS II Tutorial

Select the link:

- Section 3: MAX+PLUS II Tutorial

The first page number in the opened document will be 155. From the document, print the pages 155 to 184.

Hint#1: The document is in .pdf format, so Acrobat Reader will open the document for you. In Acrobat Reader's *Print* window you might need to request pages 1 to 29 because Acrobat Reader does not see the shown page numbering, but sees instead the actual pages present in the document.

With the printed tutorial in your hands, invoke the Altera's CAD software suite available from the College of Engineering server in NE-1002 and NE-1047 Computer Labs. Follow the downloaded Tutorial for the Schematic capture tool. The effort invested in learning how to use the tool will pay off not only in this Lab, but also in other contemporary digital electronic design courses.

2.3 BINARY REPRESENTATION OF NON-NEGATIVE INTEGERS

2.3.1 Use the Altera's schematic capture 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 2.3-1(a).

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

2.4 BCD REPRESENTATION OF NUMBERS

2.4.1 Use the Altera's schematic capture 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 2.4-1(a).

2.4.2 Design a physical layout of the logic circuit shown in Figure A.4-2; show a computer generated drawing of the layout as Figure 2.4-1(b). Include IC package pinouts on both drawings of Figure 2.4-1.

3. Lab Equipment and Circuit Components

3.1 EQUIPMENT

- Proto board Global PB-104,
- Agilent E3631A DC power supply,
- Function generator Agilent 33120A,
- Mixed-Signal oscilloscope Agilent 54645D,
- Dell GxaEM computer system.

3.2 LOGIC CIRCUIT COMPONENTS

- integrated circuit 7493, 4-bit ripple counter (1)

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.
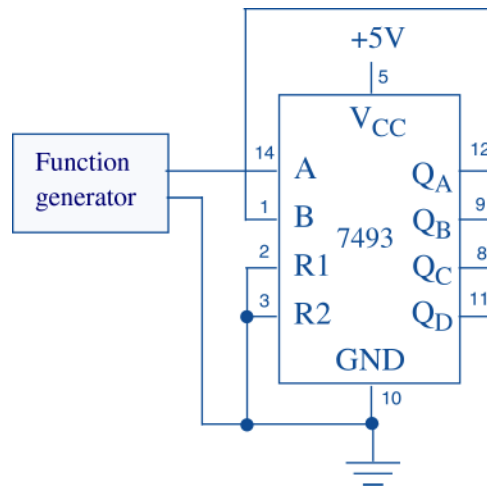

Figure A.4-1 Logic circuit to be used for generating the electrical signals which represent number sequence 0000_2 through 1111_2.

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 output is 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 count numbers in the range 0 to 1,000.

4.1.2 On front panel of the function generator, Agilent 33120A:
- have the output signal connection cable attached to the signal outlet/jack marked **TTL/CMOS**,
- select the square waveform,
- adjust the frequency of the signal to 1MHz,
- select the TTL level by making sure that the **CMOS LEVEL** switch is in the **OFF** position,
- after the TA has checked the settings, turn on the power.

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

Hint#2: Consult the Function Generator Tutorial that you have studied in the Lab Assignment #1, if you do not remember the relation between the frequency and the period of a periodic signal.

4.1.3 Connect the digital channels D0 through D4 of the Mixed signal oscilloscope Agilent 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 Q_A of the IC 7493,

- digital channel D2: to the output Q_B of the IC 7493,

- digital channel D3: to the output Q_C of the IC 7493,

- digital channel D4: to the output Q_D of the IC 7493.

Establish a ground connection. Turn on digital channels D0 through D4, and rename the channels D0 through D4 as: A, Q_A, Q_B, Q_C, Q_D respectively.

4.1.4 Set the triggering mode of the Agilent 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 the two periods of the signal at Q_D.

4.1.5 Save the Screen Image of the waveforms of the channels D0 through D4 to a file named L2_415.tif on the Dell GxaEM computer system. (Alternatively, use the Screen Capture tool.)

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 needed to be applied to input A of 7493 to observe all sixteen states of the outputs Q_A, Q_B, Q_C, Q_D?

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 Q_A, Q_B, Q_C, Q_D starting from the output state 0001_2 and terminating after fourteen pulses have been applied to input A.

d) Observe the output Q_A. Could you tell the frequency of the periodic signal at the output Q_A ?

4.1.6 Adjust the frequency of the function generator so that the frequency of the output signal Q_A 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 the two periods of the signal at Q_D. Save the Screen Image of the waveforms of the channels D0 through D4 to a file named L2_416.tif on the Dell GxaEM computer system. (Alternatively, use the Screen Capture tool.)

e) What is the frequency of the square wave signal when the output Q_A 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.

4.2 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.
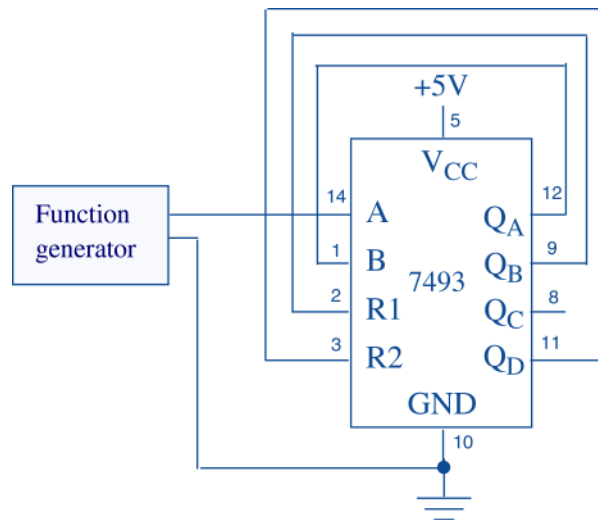

Figure A.4-2 Logic circuit to be used for generating the electrical signals which represent number sequence 0000$_2$ through 1111$_2$.

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 Save the Screen Image of the waveforms of the channels D0 through D4 to a file named L2_423.tif on the Dell GxaEM computer system. (Alternatively, use the Screen Capture tool.)

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 2 and terminating after eleven pulses have been applied to the input A.

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

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

Hint#3: The only difference between the pulse counting 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.

Now is the time for an adventure! You do not know the internal circuit connections within 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 cause which base (radix) representation to be shown at the outputs Q_A, Q_B, Q_C, and Q_D. Using the experimental techniques that you have exercised in Sections 4.1 and 4.2, find out the circuits which will function as described in Sections 4.3.1 and 4.3.2, and record their connections and waveforms.

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 L2_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 save the Screen Image of the waveforms of the channels D0 through D4 to a file named L2_432.tif on the Dell GxaEM computer system. (Alternatively, use the Screen Capture tool.)

4.4 TRANSFER OF CAPTURED WAVEFORMS.

Transfer (ftp) the files L2_*.tif from the Dell GxaEM computer system to your personal College of Engineering computer account.

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 2.3 and 2.4.

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 already included under 1. through 6. above, which includes:

   - 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,

   - conclusions reached as a result of performing the lab experiment,

   - comments and suggestions that might lead to easier and/or deeper understanding of the topics covered by the assignment.