



## Code Conversion: BCD to Gray Code

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EECS: 1100 Digital Logic Design  
The University of Toledo

Lab Assignment #5

### 1. Objectives

- getting a hands-on insight into the structure and properties of binary codes,
- creation and observation of the four-bit Gray code number representation sequence,
- exercising the design of code conversion logic circuits,
- creating the truth table of conversion functions from BCD to Gray code of the single-digit base-ten number sequence,
- developing skills in simplification of incompletely specified logical functions,
- developing skills in designing multiple-output combinational logic circuits,
- developing skills in implementing the SOP form of logic functions as all-NAND logic.
- improving the proficiency in using sophisticated equipment.

### 2. Prelab Assignment

#### 2.1 ANALYSIS OF AN ALL-NAND LOGIC CIRCUIT

- 1) Prepare a computer generated drawing of the logic circuit shown in Figure A.2-1. Make the drawing large enough so that the space available in it can accommodate marking into the drawing the intermediate results of the circuit analysis. Show the circuit as Figure 2.1-1(a).

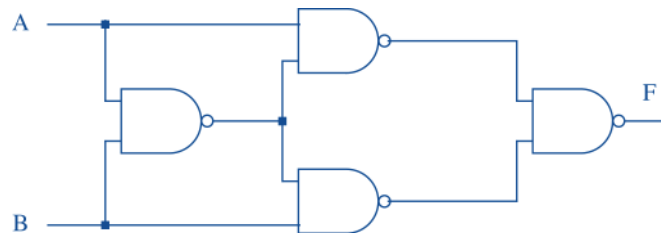


Figure A-2.1 Logic circuit whose function ought to be determined by analysis.

- 2.1.2 Perform a level by level analysis of the circuit of Figure 2.1-1(a) with the goal of obtaining the expression of the function F implemented by the circuit. Using algebraic manipulation, simplify intermediate function expressions where appropriate. Write the simplified intermediate expressions at the outputs of all gates, and write the simplified expression of the function F at the output signal terminal of the circuit.



- 2.1.3 Based on the obtained expression of the function F, try to recognize F as one of the basic logic functions of two variables. If the expression is not recognizable, check your analysis and simplification steps. State the name of the function.
- 2.1.4 Design a physical layout of the logic circuit shown in Figure 2.1-1(a). Prepare a computer generated drawing of the layout and show it as Figure 2.1-1(b). Provide the IC package pinouts on both drawings of Figure 2.1-1.
- Hint#1** Pinouts (pin numbers) are available in Figure 2.5 of the course text book, pp.107-109, and in the TTL Data Book.
- 2.1.5 Prepare a computer generated drawing of the logic circuit which implements the SOP form of the function F; show the drawing as Figure 2.1-2.

### 2.2 BCD TO GRAY CODE CONVERSION

- 2.2.1 Using the table-heading template shown in Figure A.2-1, and assuming that LSBs are  $B_0$  and  $G_0$ , prepare a truth table of the BCD to Gray code conversion functions and show it as table T2.2-1.

**Table 2.2-1 Truth table for BCD to Gray code conversion**

Decimal representation	BCD/binary code		Gray code	
	$B_3$	$B_2$	$G_3$	$G_2$
	$B_1$	$B_0$	$G_1$	$G_0$

**Figure A.2-1 Table-heading template for BCD to Gray code conversion truth table.**

- Hint#2** Do not forget to include in T2.2-1 all sixteen combinations of values of the variables  $B_3, B_2, B_1,$  and  $B_0$ .
- 2.2.2 Using the truth table T.2.2-1, prepare the Karnaugh map representations of the four conversion functions  $G_3, G_2, G_1,$  and  $G_0$  and show them as Figure 2.2-1.
- 2.2.3 Using *don't care conditions* as they best serve the goal, indicate on maps of Figure 2.2-1 the maximum size groups of minterms which can be combined to simplify the functions  $G_3, G_2, G_1,$  and  $G_0$  to their minimum number of literals SOP form.
- 2.2.4 Based on the results of the work accomplished in sections 2.2.1 through 2.2.3, derive the minimum number of literals SOP forms of logical functions  $G_3, G_2, G_1,$  and  $G_0$  and show them as equations (2.2-1) through (2.2-4) respectively.
- 2.2.5 Using only OR and XOR logic gates, prepare a computer generated drawing of the logic circuit which implements the logic functions expressed by equations (2.2-1) through (2.2-4); show the drawing as Figure 2.2-2.
- 2.2.6 Prepare a computer generated drawing of the logic circuit which implements logic functions  $G_3, G_2, G_1,$  and  $G_0$  using the collection of IC components listed in Section 3.2, and show the drawing as Figure 2.2-3(a).



**Hint#3** The list of IC components in Section 3.2 is not erroneous, an all-NAND implementation is what is intended.

2.2.7 Design a physical layout of the logic circuit shown in Figure 2.2-3(a). Prepare a computer generated drawing of the layout and show it as Figure 2.2-3(b). Provide the IC package pinouts on both drawings of Figure 2.2-3.

### 3. Lab Equipment and Circuit Components

#### 3.1 EQUIPMENT

- Proto boards: Global PB-104, or PB-105,
- Agilent E3631A DC power supply,
- Function generator: Agilent 33120A,
- Mixed-Signal oscilloscope Agilent 54645D,
- Dell GxaEM computer system.

#### 3.2 CIRCUIT COMPONENTS

- IC component 7400, quad 2-input NAND gates (3)
- IC component 7404, hex inverter (1)
- IC component 7493, ripple counter (1)

### 4. Lab Experiment

#### 4.1 BCD TO GRAY CODE CONVERTER

4.1.1 Using the physical layout diagram of Figure 2.2-3(b) as a reference, build on proto board a physical implementation of the logic circuit shown in Figure 2.2-3(a). As an auxiliary logic circuit, build additionally the binary counter which was used in Lab Assignment #1 to generate binary representations of integers 0 through 15. The same circuit is repeated in Figure A.4-1, which shows the complete circuit for experimenting with the BCD to Gray code converter.

4.1.2 Connect digital channels D0 through D7 of the Mixed-Signal oscilloscope Agilent 54645D to the circuit constructed under 4.1.1:

- digital channels D0 through D3 to inputs  $B_0$  through  $B_3$  respectively,
- digital channels D4 through D7 to outputs  $G_0$  through  $G_3$  respectively,

Establish a ground connection. Turn on digital channels D0 through D7, and rename the channels D0 through D3 as  $B_0$  through  $B_3$ , and D4 through D7 as  $G_0$  through  $G_3$  respectively.

4.1.3 Adjust the frequency of the Agilent 33120A function generator to 1MHz. Set the triggering mode of the Agilent 54645D to combination 0000 on channels D0 through D3. Hit the key Single on the Agilent 54645D. Adjust the display of waveforms so that the first appearance of the combination of signal values 0000 on channels D0



through D3 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 B<sub>3</sub>

- 4.1.4 Verify correct functioning of the circuit by comparing the obtained waveforms of the converter circuit to its truth table T2.2-1. If the waveforms do not match contents of the truth table, find and correct the error(s) causing the discrepancy.

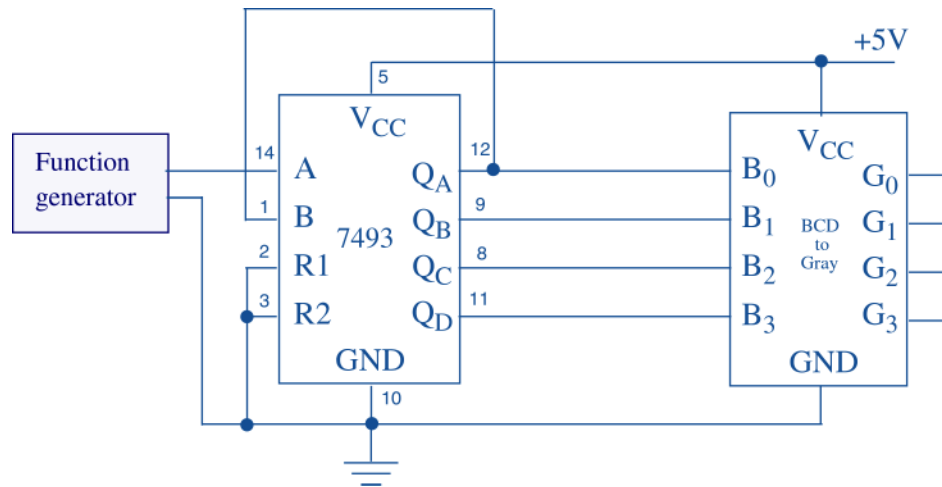


Figure A-4.1 The complete circuit for experimenting with implementation of the BCD to Gray code converter using a black-box representation of the converter.

- 4.1.5 Save the Screen Image of the correct waveforms of the channels D0 through D7 to a file named L5\_415.tif on the Dell GxaEM computer system. (Alternatively, use the Screen Capture tool.)

### 4.2 TRANSFER OF CAPTURED WAVEFORMS.

Transfer (ftp) the file L5\_\*.tif from the Dell GxaEM computer system to your personal College of Engineering computer account.

## 5. Postlab Assignment

### 5.1 DON'T CARE OUTPUT SIGNALS

- 5.1.1 Import the waveforms stored in file L5\_415.tif into your report and show them as Figure 5.1-1. Using Figure 5.1-1, determine the BCD to Gray code converter's output signal values for the don't care combinations of input signal values. Record them in table T5.1-1 using the template of Figure A.2-1.
- 5.1.2 Compare the contents of tables T2.2-1 and T5.1-1 to establish whether some of the output don't care combinations represent a valid Gray code listed in Table T2.2-1. State your finding.
- 5.1.3 Propose an alternative method of composing the don't care part of the table T5.1-1 that would have to be used if the waveforms were not available.



## 6. Lab Report

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

1. A filled out Cover sheet - Lab style.
2. The result of work under 2.1 through 2.2.
3. The result of work under 4.1 and 5.1.
4. A report on items not already included under 2. and 3. 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.