Hacettepe University Computer Engineering Department

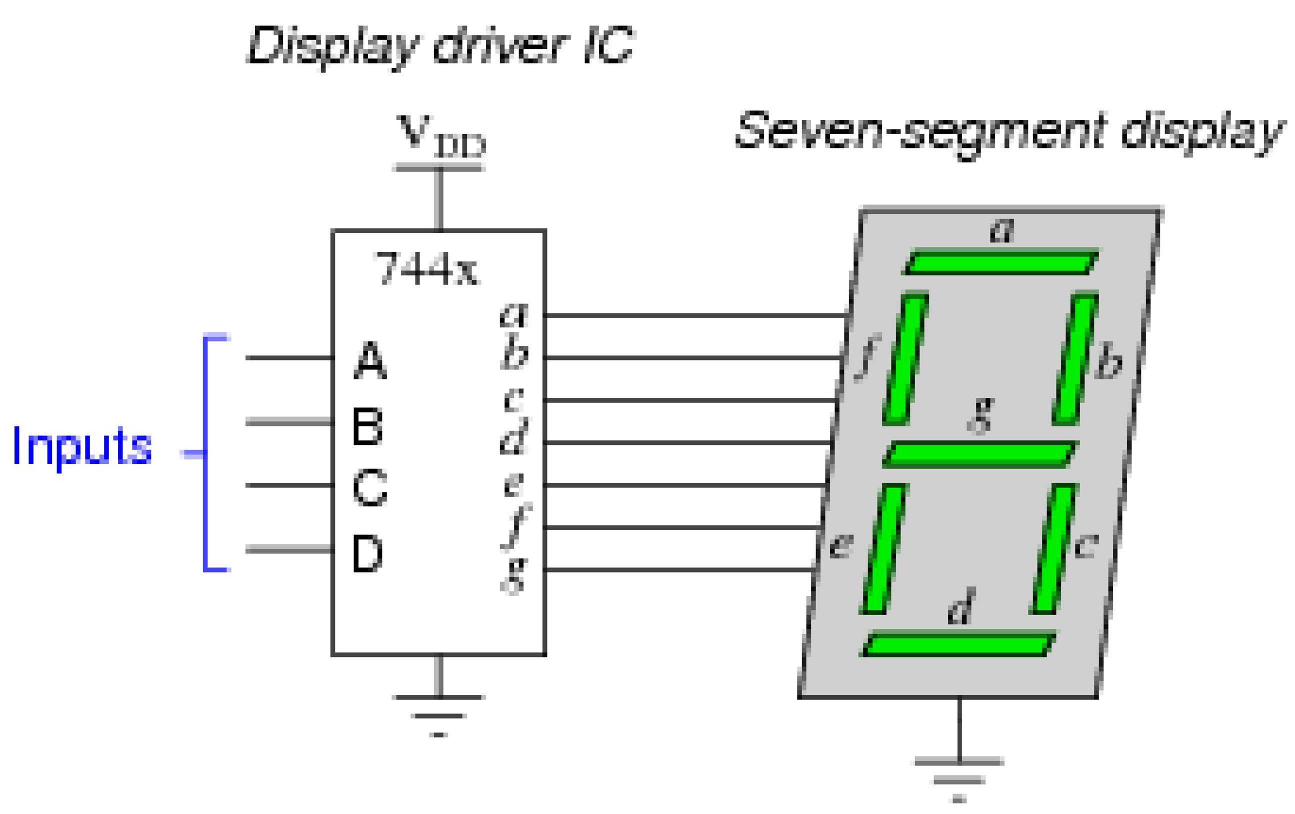
Experiment 2 - Universal Logic Gates, Experiment 3 - BCD-to-7 Segment Display Decoders

Due date for report and circuit: Week 7 (05/11/2024) - Report until 13:40 ALL SECTIONS!

BBM233 Digital Design Lab - 2024 Fall

AIMS

1. Show that NAND and NOR gates are universal gates.
2. Design and build a BCD-to-7 segment display decoder.

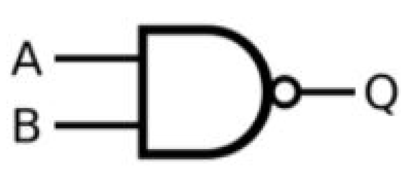


UNIVERSAL GATES

A universal gate is a gate which can implement any Boolean function without need to use any other gate type.

NAND Gate

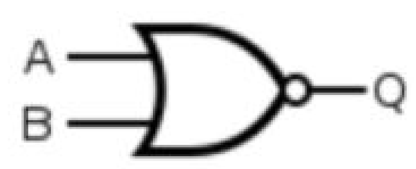
- A NAND gate (NOT-AND) is a logic gate which produces an output which is false only if all its inputs are true; thus, its output is complement to that of an AND gate.
- The small circle (or bubble) represents the operation of inversion.



INPUT		OUTPUT
A	B	A NAND B
0	0	1
0	1	1
1	0	1
1	1	0

NOR Gate

- A NOR gate (NOT-OR) is a logic gate which produces an output which is true only if all its inputs are false; thus, its output is complement to that of an OR gate.
- The small circle (or bubble) represents the operation of inversion.

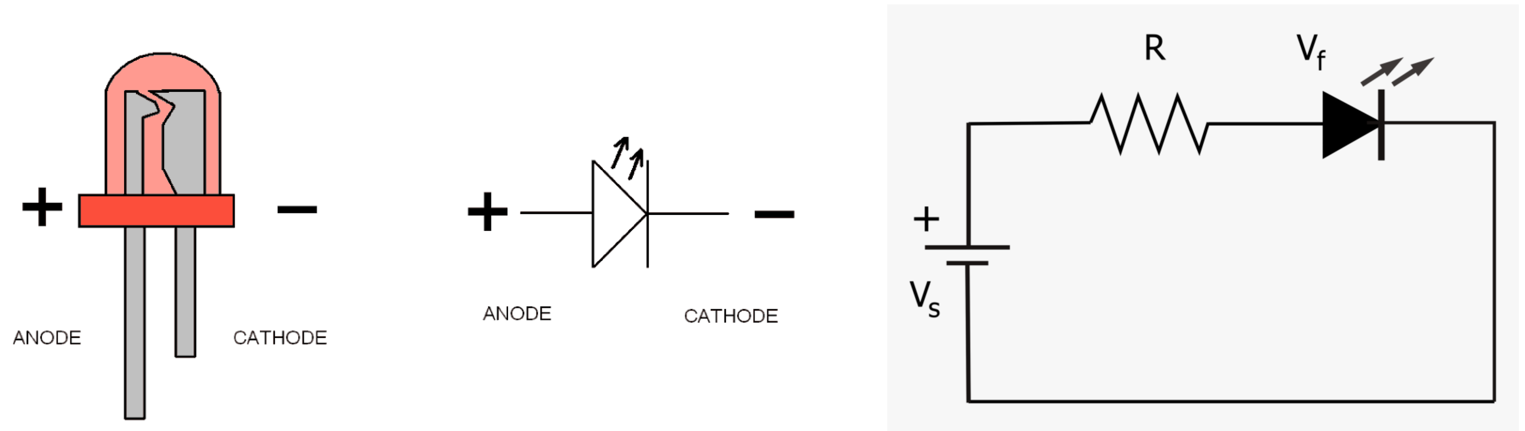


INPUT		OUTPUT
A	B	A NOR B
0	0	1
0	1	0
1	0	0
1	1	0

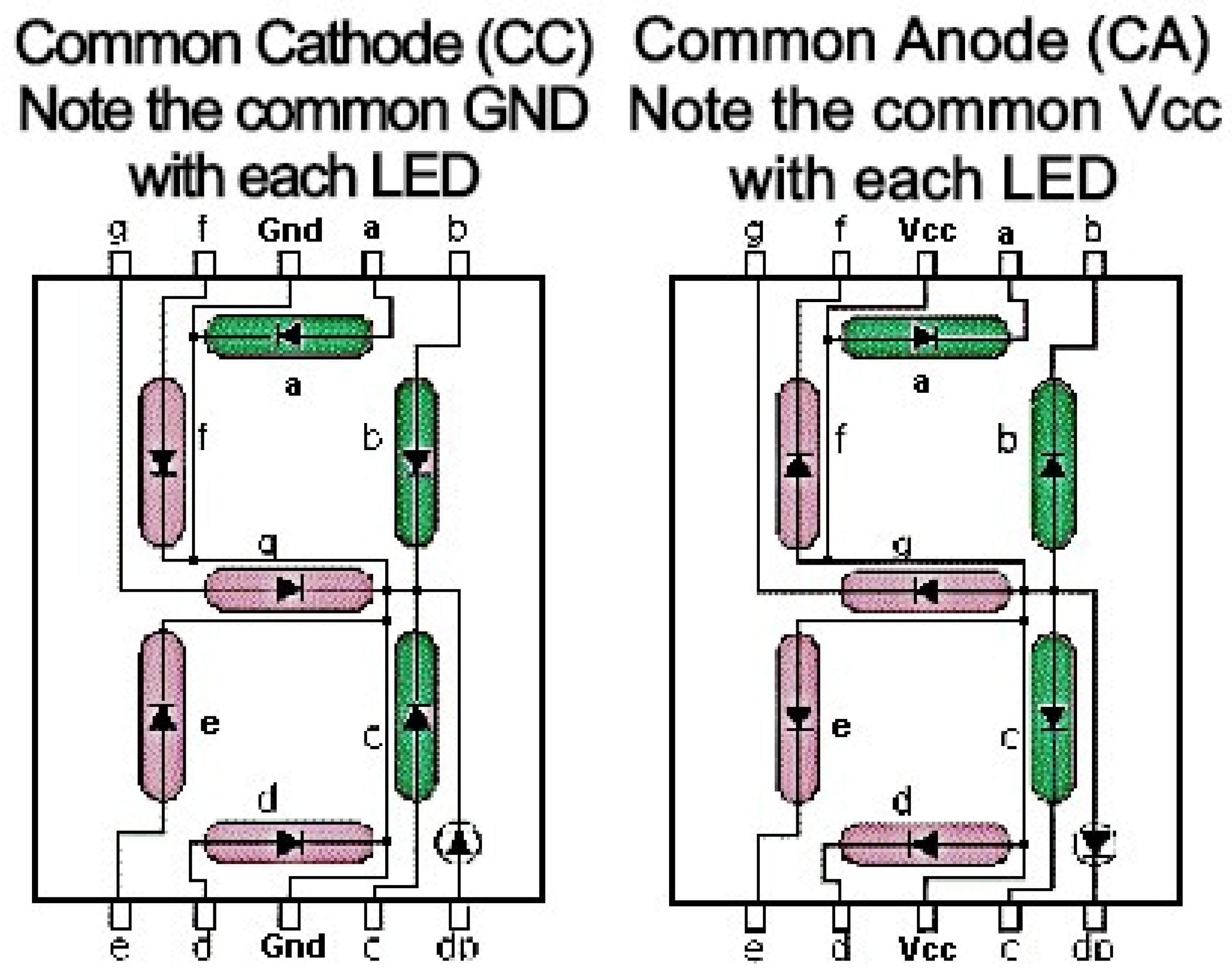
7-SEGMENT LED DISPLAY

The conversion from one code to another is common in digital systems. Sometimes the output of a system is used as the input to another system. A conversion circuit (decoder) is necessary between two systems if each system uses different codes for the same information.

A light emitting Diode (LED) is a specialized form of a PN junction. When a diode is forward biased, a current flows through the junction and the light is emitted.



A seven segment LED display contains 7 LEDs. Each LED is called a segment and they are identified as **a, b, c, d, e, f, g** segments. When illuminated, a segment forms part of a numerical digit to be displayed.



A display's common pin is generally used to identify which type of 7-segment display it is. As each LED has two connecting pins, one called the "Anode" and the other called the "Cathode", there are therefore two types of LED 7-segment display called: **Common Cathode (CC)** and **Common Anode (CA)**.

In the CC display, all the cathode connections of the LED segments are joined together to logic "0" or ground. The individual segments are illuminated by application of a "HIGH", or logic "1" signal via a current limiting resistor to forward bias the individual Anode terminals (a-g).

In the CA display, all the anode connections of the LED segments are joined together to logic "1". The individual segments are illuminated by applying a ground, logic "0" or "LOW" signal via a suitable current limiting resistor to the Cathode of the particular segment (a-g).

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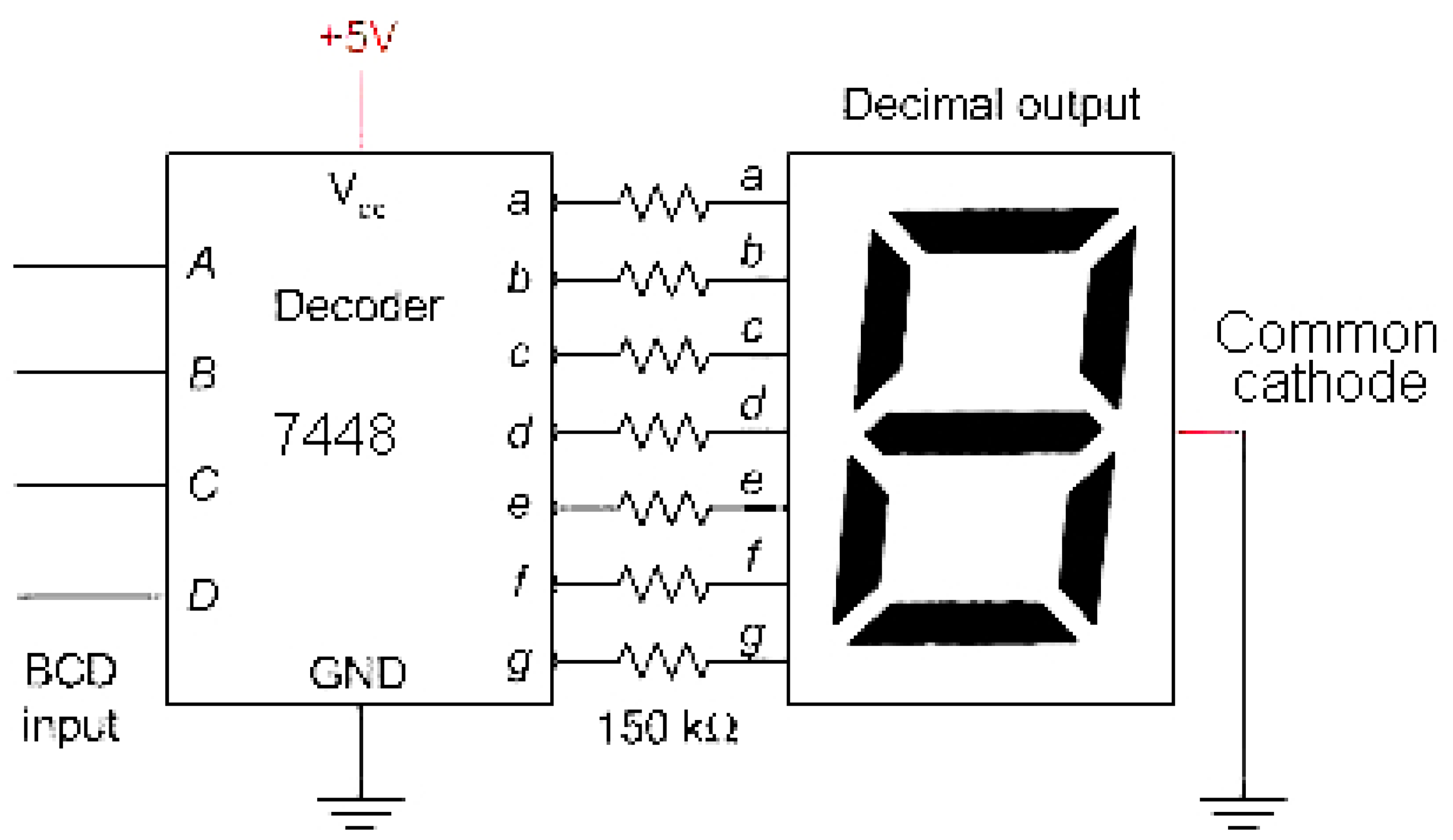
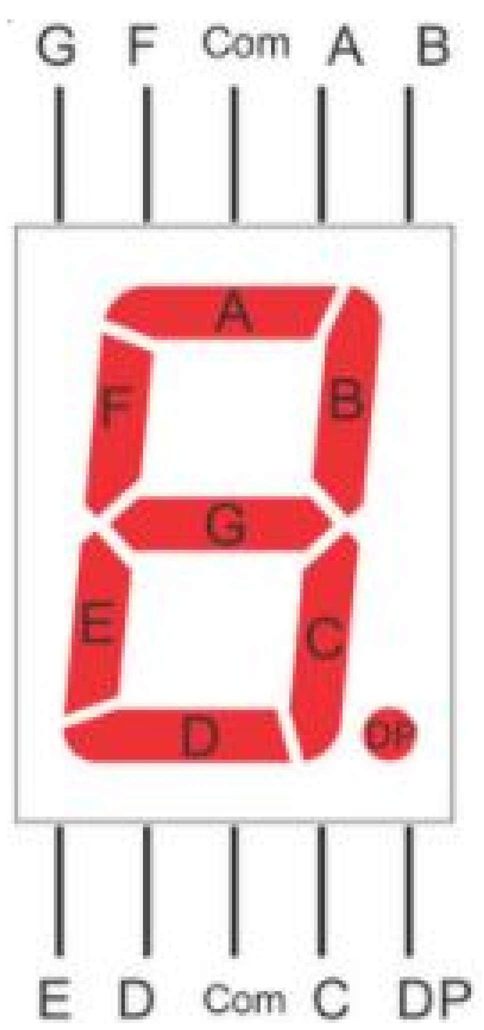
BCD-TO-7 SEGMENT DECODERS

Decoders 7447 (for common anode) and 7448 (for common cathode) from 7400-series of integrated circuits accept a 1-2-4-8 positive-logic Binary Coded Decimal (BCD) input and convert it to the proper pattern necessary to illuminate a 7-segment display. Think of it as converting a 4-bit binary representation to the corresponding decimal digit (e.g. 0001 will be displayed as 1, 0111 as 7, etc.).





For pin diagrams, you may consult the specification data-sheets for decoder and 7-segment display units. We will disregard the decimal point (DP) segment in this experiment

In this lab experiment, you will design and implement a 7448 BCD-to-7 segment display decoder for common cathode displays. Then, you will use the ready 7447 decoder and 7 segment common anode display to build the circuit in the lab.

Grading

For each experiment:

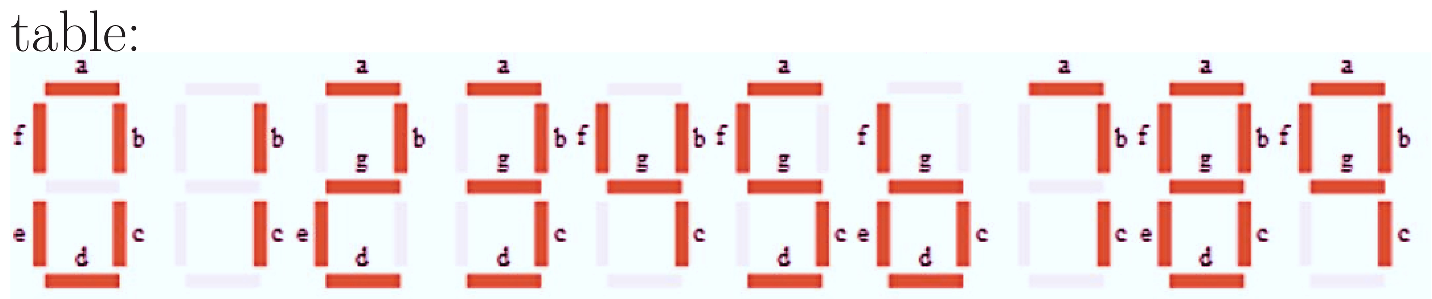
1. Report: 20%
2. Circuit implementations in the lab: 80%

EXPERIMENT PART 1 STEPS

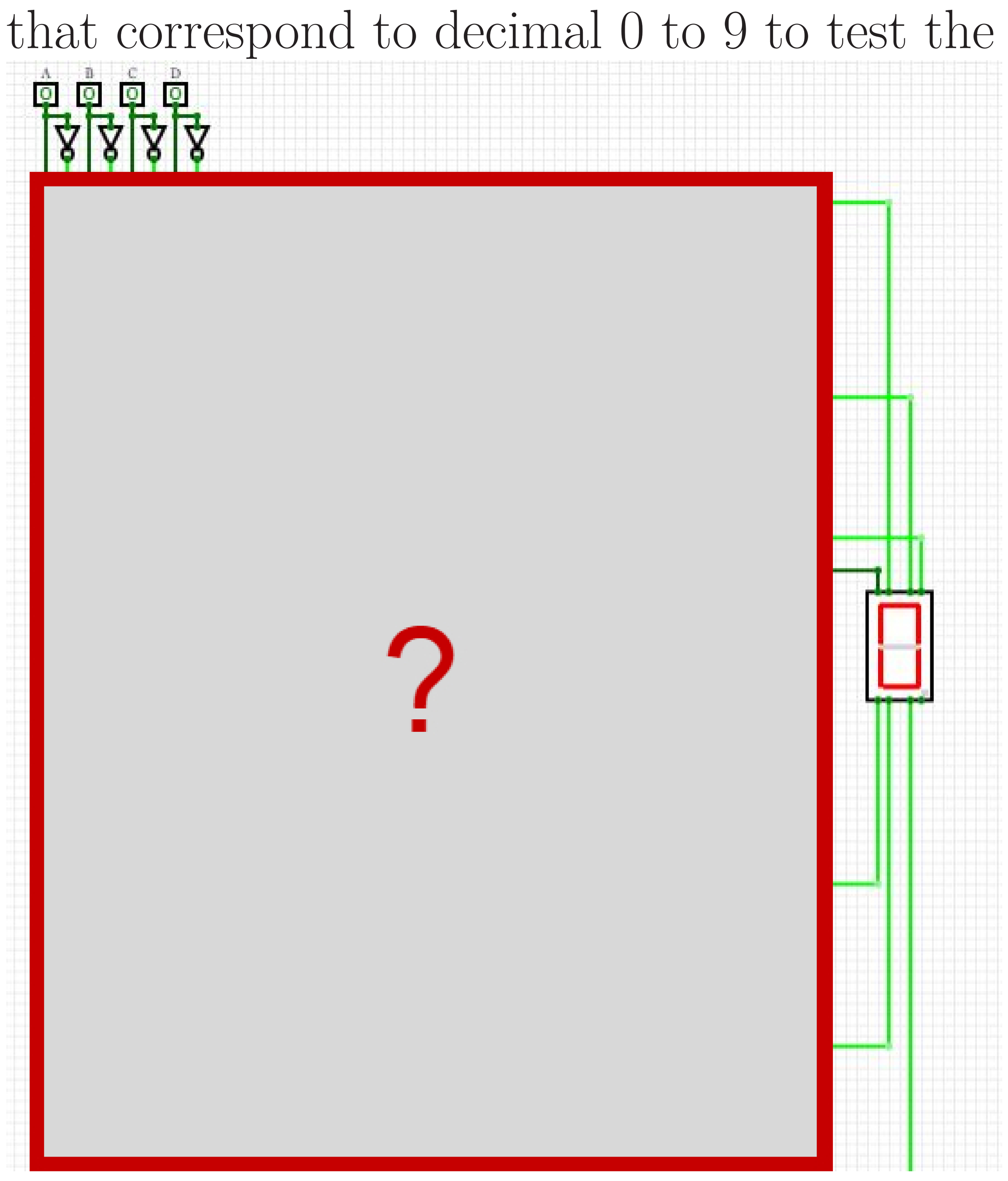
1. First, you will design a combinational circuit that will simulate the 7448 decoder function. Fill in the truth table with four 1-bit inputs and seven 1-bit outputs for digits corresponding to 0-9 in decimal as shown below. **For the remaining combinations (10 to 15), use don't cares (X).**

Decimal Digit	Input lines				Output lines							Display pattern
	A	B	C	D	a	b	c	d	e	f	g	
0	0	0	0	0	1	1	1	1	1	1	0	
1	0	0	0	1								
2	0	0	1	0								
3	0	0	1	1								
4	0	1	0	0								
5	0	1	0	1								
6	0	1	1	0	0	0	1	1	1	1	1	
7	0	1	1	1								
8	1	0	0	0								
9	1	0	0	1								

You may refer to these display patterns to fill in the truth table:



2. For each output (a-f) obtain a minimum logic function using Karnaugh maps (7 K-maps will be drawn in total to obtain 7 Boolean functions for each segment).
3. Construct (implement) the circuit (e.g., in CircuitVerse). Connect the outputs to a 7-segment display and apply inputs that correspond to decimal 0 to 9 to test the circuit.



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WHAT TO INCLUDE IN THE REPORT 20%

This week you are expected to write a bit more detailed report. **One report for both experiments will be accepted**. Note that the deadline for submission of the reports is before the lab session.

You are encouraged to use this Experiment Report LaTeX Template (click for a PDF preview) and create your reports in LaTeX. We suggest using Overleaf platform for this. This is not mandatory, and you can submit a handwritten report as well.

Your report needs to include the following for full credit:

STEPS FOR EXPERIMENT 3:

1. Include your name, surname, ID, and experiment name.
2. Answer these questions:
   - What is a 7-segment display and how it works (in short).
   - How many types of 7-segment display are there and what differentiates them from one another?
   - Why do we need a decoder to use 7-segment displays?
   - If this assignment were about designing a common anode instead of common cathode, would there be any change in truth table and if yes what kind of change?
   - What happens if you apply inputs for which you used don't cares (X), i.e., inputs 10-15?
3. Include the completely filled out truth table.
4. For each output (**a-g**) simplify the function using a Karnaugh Map to obtain a minimized Boolean function in sum-of-products form (for each output include the corresponding K-map and the obtained function in your report - **7 K-maps and 7 Boolean functions**),
5. Draw or include the screenshot of the final circuit,

STEPS FOR EXPERIMENT 2:

6. Answer these questions: What does a universal gate mean? Which logic gates are universal gates?
7. Show how to implement other logic gates using universal gates (show the equivalent circuits).
8. For each Boolean function you obtained in the previous step using K-Maps (all 7 functions), **express them using only NAND gates**. You may find using De Morgan's Laws useful,
9. **Do the same but this time using only NOR gates** (all 7 functions).

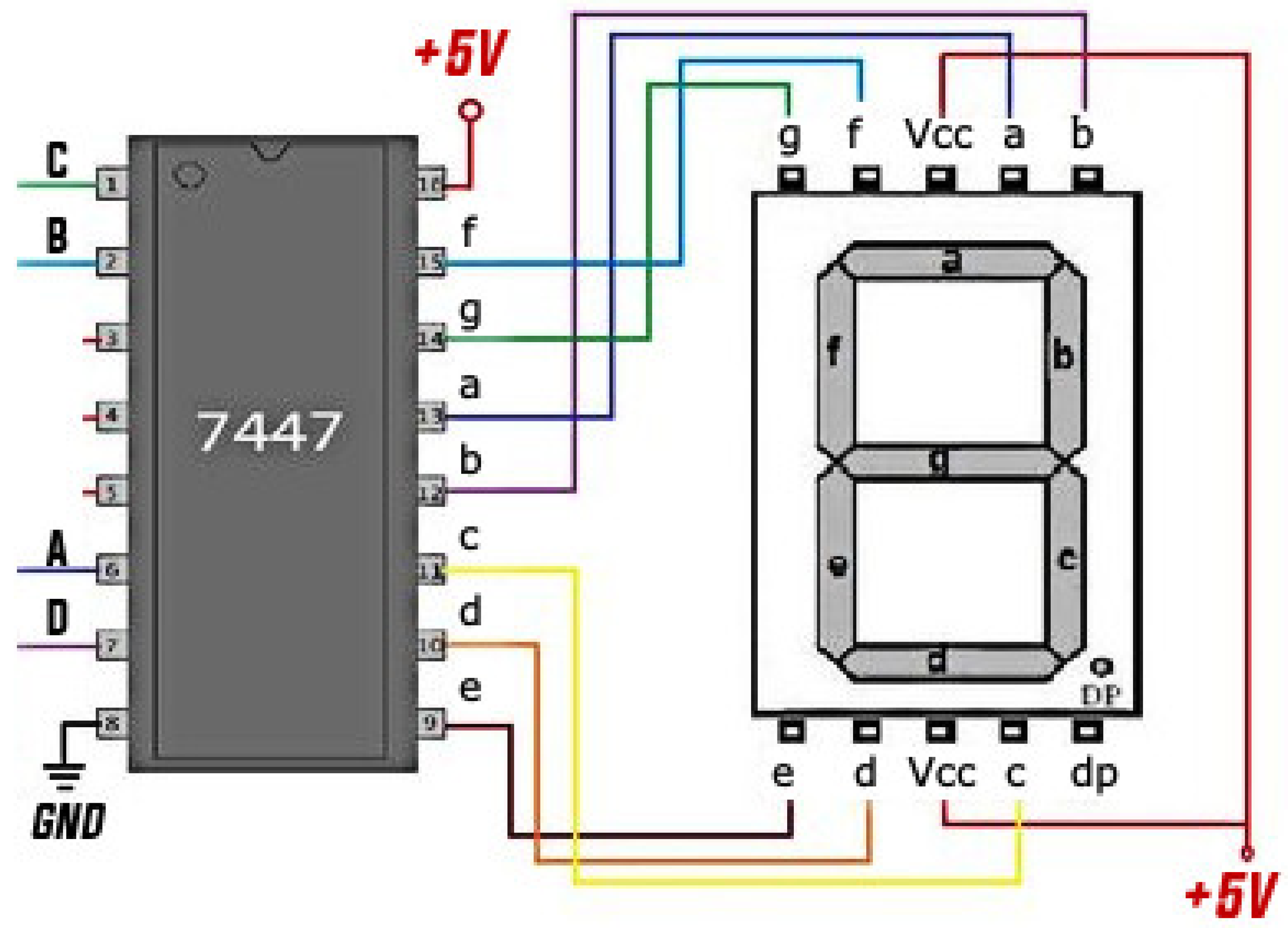
Submit the report in PDF format through https://submit.cs.hacettepe.edu.tr/

Submission format only zip archives are supported:
- b<StudentID>.zip
  - name_surname.pdf

You must have either a hard copy of your report or be able to show the electronic version at the beginning of the lab. EACH STUDENT MUST SUBMIT THEIR INDIVIDUAL REPORT!

EXPERIMENT PART 2: Implementation 80%

For Experiment 2, you will implement one of the Boolean functions from your report using only **NAND** or only **NOR** gates. TAs will tell you which function to implement during the lab session. For Experiment 3, you will construct the circuit of connecting 7447 decoder to the 7-segment display on the breadboard as shown in the figure below.



Important experiment steps:

1. Make sure that the power supply to the board is turned off.
2. Place the ICs on the breadboard, and connect the GND (0V) and Vcc (5V) to their corresponding pins on each IC. Use the IC schematics as a reference to check the pin numbers and what they correspond to.
3. Select switches on the board that will correspond to the function inputs, and an LED to represent the function output for Experiment 2. Make sure to select switches in order left to right such that the leftmost switch will represent the most significant bit.
4. Implement the given Boolean function for Experiment 2.
5. Implement the correct circuit of connecting 7447 decoder with the 7-segment display to show the digits 0-9.
6. When you are certain that everything is connected correctly, power on the board and try your implementation for all input cases to verify its correctness.
7. For Experiment 3, apply binary-coded decimal inputs 0 to 9 using four switches. Also apply other input combinations and note the output patterns for each combination from 10 to 15.

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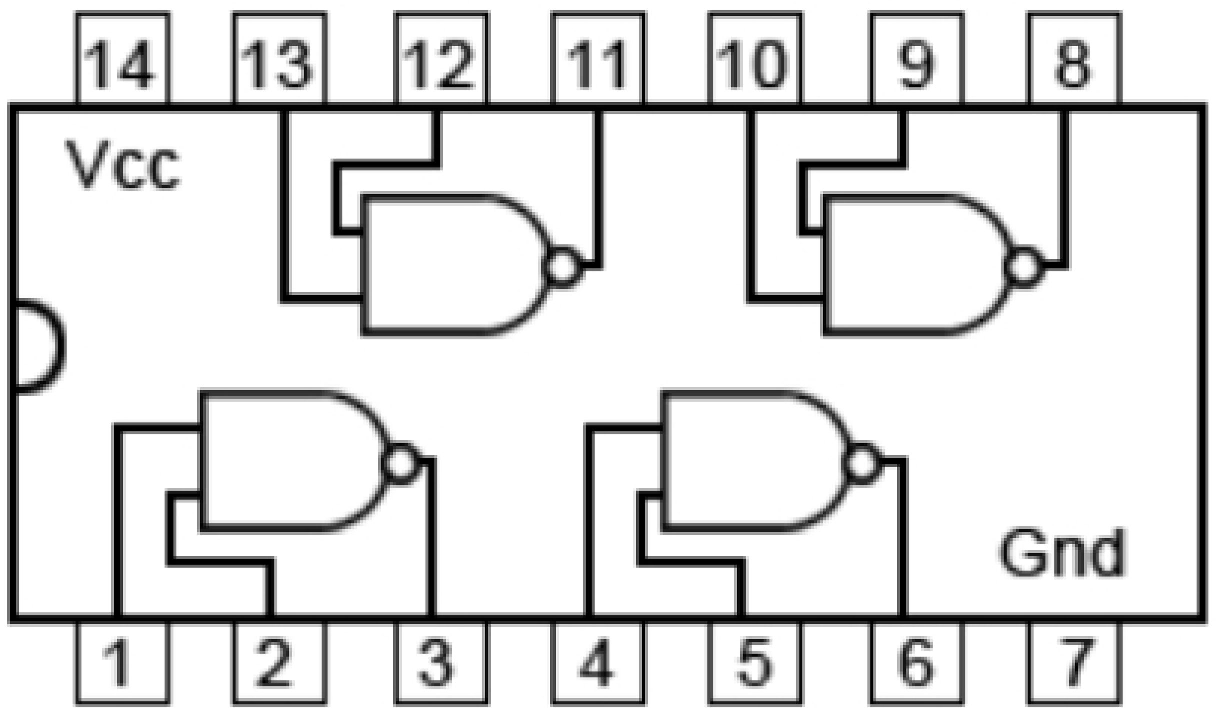
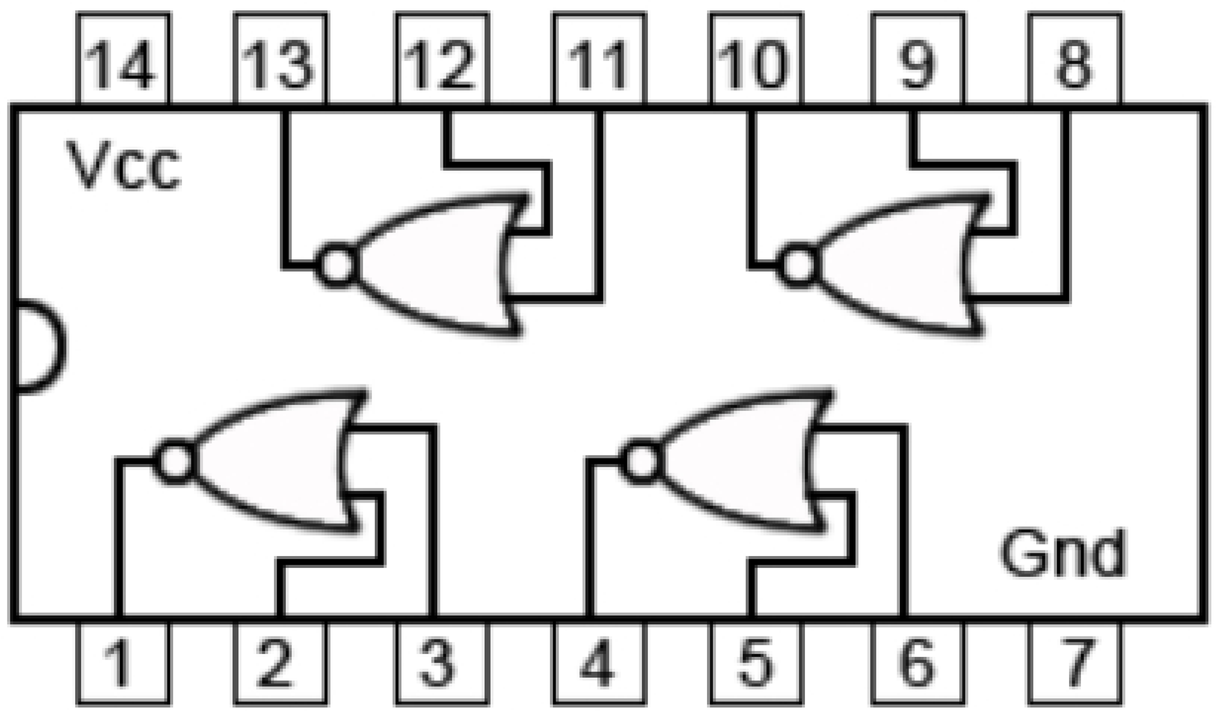
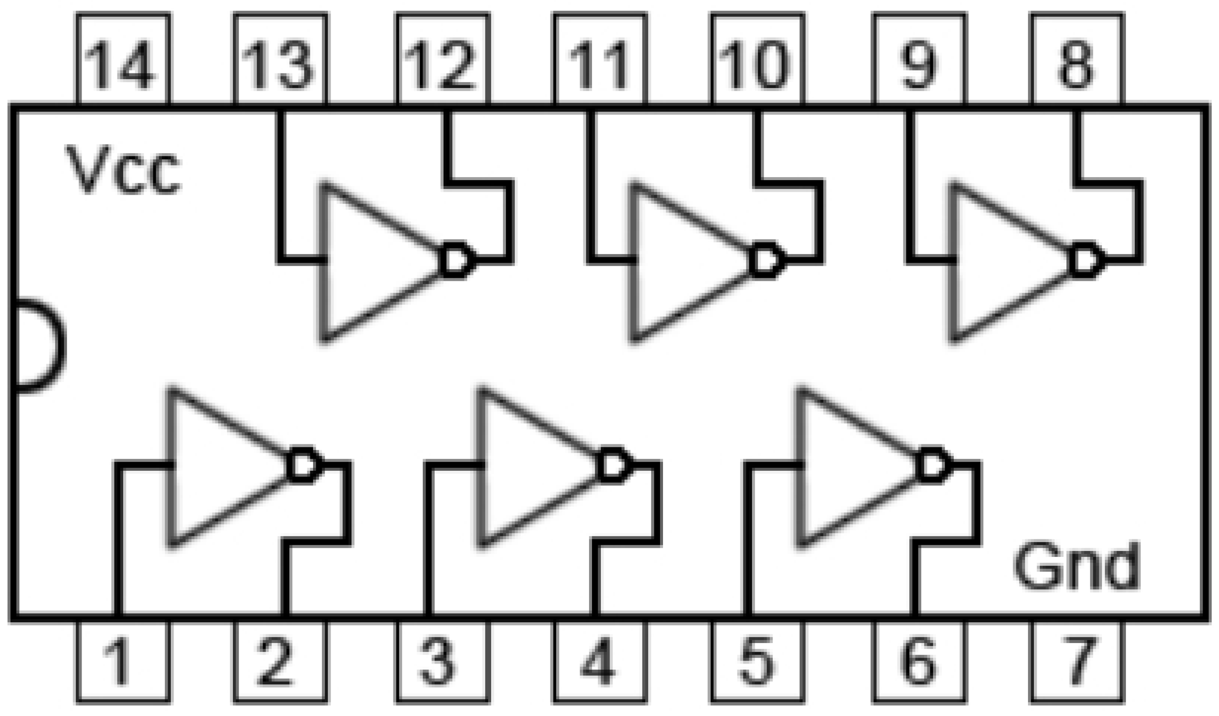
Circuit Diagrams of the Integrated Circuits



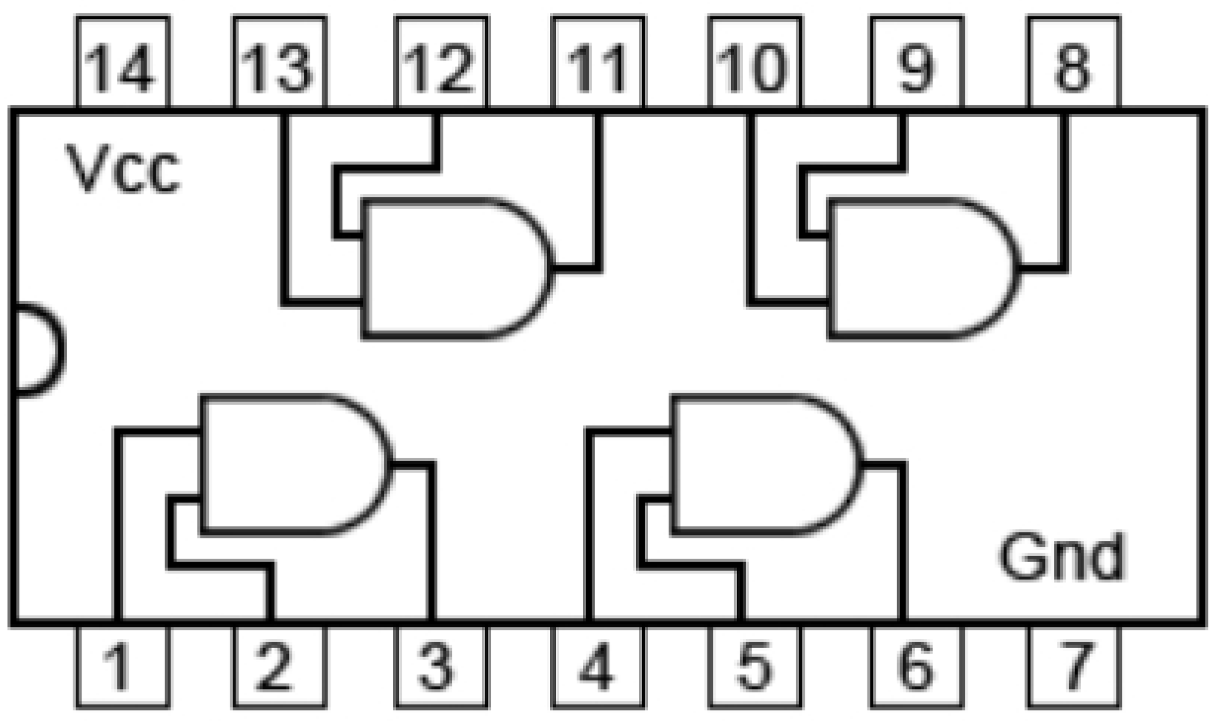
7400 Quad 2 input
NAND Gates



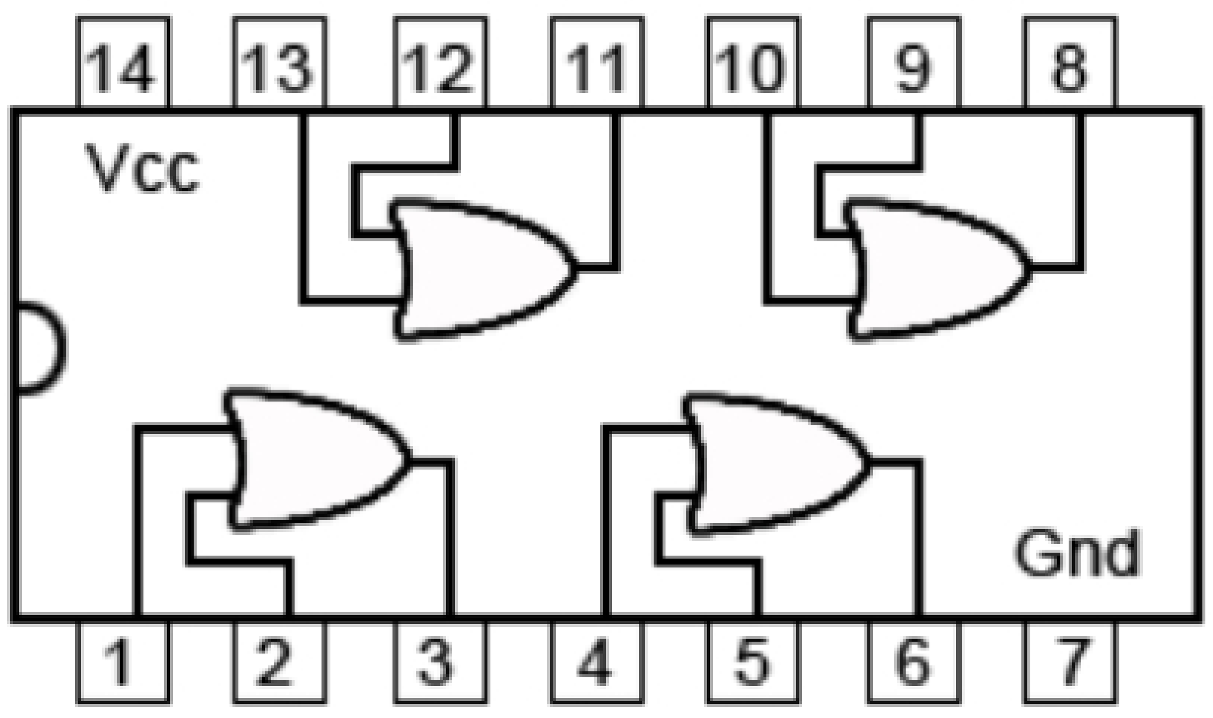
7402 Quad 2 input
NOR Gates



7404 Hex NOT Gates
(Inverters)



7408 Quad 2 input
AND Gates



7432 Quad 2 input
OR Gates