Introduction to Logic Circuits

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Assignment C: Working with a SME

CIMT 720, Fall 2013

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Introduction

The topic for our Assignment C is Introduction to Logical Circuit. This topic is the first module for the course - ECT403 Practical Digital Logic Design. ECT 403 is a required course for the undergraduate degree of Electronics & Computer Technology in the Department of Electronics & Computer Engineering Technology (ECET) at Indiana State University. The subject-matter expert (SME) is the current instructor, who has strong background in mathematics and computer engineering. We chose to work on the first module of ECT403 to create an instructional example for the other modules of the course.

Learning Context Analysis

Needs for training

ECT 403 – Practical Digital Logic Design is provided ECET. ECT 403 is to “Introduce the Hardware Description Language (HDL) for developing, verifying, and synthesizing designs of digital circuits. CAE tools are used to design circuits for Application Specific Integrated Circuits (ASICs) and/or Field Programmable Gate Array (FPGA) implementation” (Indiana State University, 2013a, “Description”, para. 1). The prerequisites of ECT 403 is ECT 232, which is about “sequential logic circuit systems and application of integrated circuits to logic controls, counters, data storage, converters, circuit synthesis, and analysis” (Indiana State University, 2013b, “Description”, para. 1). Students in Electronics & Computer Technology and Engineering Technology with concentration on Computer Engineering Technology are required to take ECT403.

Learning environment

ECET provides two rooms for this course. One room is a traditional classroom with a computer and a projector for lecture, the other is a laboratory with twelve PC computers. There is no projector in the laboratory, so the instructor has to do the lecture and labs in different places. The designed number of students for this course is 20, but it has 22 this semester. The lab has eight sets of Spartan-3 FPGA board and Xilinx ISE Verilog program software. Because of the lab does not have enough devices for students, the instructor has to divide students into small groups in the lab.

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The primary instructional methods are lectures plus experiments. The lectures are based on PowerPoint. There is a course site in Blackboard for delivering course materials and collecting experiment reports and assignments. There is no quiz and test in this course. Students have to finish 10 labs, 5 mini projects, 1 midterm project, and 1 final project. All the labs and projects are hands-on works. The class time is from 12:30pm-15:15pm, every Thursday.

Textbook and Existing Instructional Resources

The current textbook for ECT403 is Fundamentals of Digital Logic with VHDL Design (Brown & Vranesic, 2009). This textbook is well designed. It covers basic aspects of logic circuits, VHDL, CAD tools, and a number of practical issues in the design of real systems. This textbook uses Verilog as the VHDL, which is the same with the environment of the lab. However, the software is different from the one provided in the lab. The authors do provide PowerPoint files, but these slides just repeat the content in the textbook rather than present the content visually or interactively. The PowerPoint for instruction and learning could be redesign to be more interactive for both instructors and students with advanced techniques.

Instructor's characteristics

This semester is the first semester for the instructor. He is very familiar with the subject content of this course. He is also familiar with the instructional environment, because he took several courses at ISU in the same classroom and the same laboratory. However, the instructor does not have any experience in teaching and training. He has a BS degree in Electronic and Computer Technology, but never been trained as an instructor or instructional designer.

Implications

The implications of learning context analysis are threefold. First of all, the learning materials need to be redesigned. The existing PowerPoint files are not sophisticated designed. They only reproduce the content on the textbook. More visualized and interactive elements could be integrated. Second, more instructional guidelines need for the instructor. The instructor is a subject matter expert, but he is lack of instructional experience. The new instructional design should provide detailed guidelines for the instructor. Last, group problem-based learning strategies could be applied in labs and projects. Because of the shortage of devices, we need to make sure that every student in a group learns from these group labs and projects.

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Learner Analysis

The target learners are the senior students in the College of Technology at Indiana State University. In this class, 22 senior students are involved in the observation, and these students range from more than 20 years old to 30 years old. Among these students, 4.5 percent students are Asian students, 9.1 percent students are from Saudi Arabia. The followings are the characteristics of target learners:

Cognitive Characteristics

As for the target learners of this class, they are senior students who have completed most of their undergraduate credits, so they have the basic knowledge of mathematics, physics, and science. They have conducted lots of experiments in some of their required classes, which enable them have the design abilities, logical thinking skills, and manipulative abilities. All of these abilities and skills will be evaluated in the learning process of the target contents of digital logic. According to the assignments that have been submitted in the blackboard, most of the students have the positive attitude in studying the target materials.

According to the ages of the target learners, they are the millennials, so these target learners have the common characteristics of the millennials. For these students, they grow up in the age of technology, have understanding and knowledge of technology and keep up well with the changes. Moreover, they can take advantage of the changes of the technologies. For the millennials, they are used to adapting and being comfort in various situations. The generation of millennials is usually learning-oriented, which an imperative clue for teachers to adopt instructional strategies (Santos, 2006).

As for the language level of the target learners, the Asian students and Saudi Arabia students have passed their language level test during their studies in the language center at Indiana State University (ISU). Moreover, they are the senior students and have alread completed lots of required courses and optional courses at ISU, so the language is not a big problem for their studies of the target contents. For the students of native speakers, and the communicative ability is not a problem for them.

All of the students grow up in the age of technology, so they have the preference of visual learning and their learning environments have provided suitable and appropriate visual learning tools. Moreover, lots of them are multi-taskers, so the visual learning could help them attract with their learning materials and arouse their learning interests.

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Physiological Characteristics

For the target learners in our project, they have the normal sense of listening, eyesight, speaking and cognitive abilities. All of them are with good health and the normal learning abilities.

Affective Characteristics

From the observation of the target class, most of them show great interest in the learning of digital logic. According to the communication with the target learners, they are preferable to learn digital logic because the learning contents are related with the future work. Moreover, most of their assignments are hands-on homework, which enables them to practice their operational abilities. Most of the target learners are technology enthusiast, which one of the motivations for them to learning the technology principles. The target learners have the positive attitudes towards their learning contents, which could be an imperative motivation in the learning.

Social Characteristic

All of the target learners in our project are sophisticated adults, so they have the high abilities to keep good relationships with their partners and classes. For the millennials, they treasure every opportunity to show off their skills and receiving recognition from their tasks, in terms of which they prefer to share their ideas and opinions with their classmates, which will create a good learning environment for the whole class. As for the results of communication with target learners, most of them prefer to the collaborative learning, which could get more creative ideas in the brainstorm. For the target learners, all of them have the normal communicative abilities with each other, which makes the learning style more flexible.

Specific Prior Learning

Mayer (2008) states that advanced organizer could foster the process of integrating, and points out that “advance organizer activates or provides organized prior knowledge that can be used to assimilate the incoming information” (p. 378). He also indicates that advance organizers can help learners connect the presented material with what they already know. Therefore, instructors should know of the level of the prior knowledge of the target learners at the beginning of the class.

The followings are the specific prior learning for the target learners:

Table 1 Prior Learning

Number System	Identify and discriminate the decimal the decimal and binary

	number system.
Algebra 1	Comprehend the basic algebraic knowledge of function and variable, and the relationship between them.
Algebra 2	Identify the basic arithmetic principle in mathematics, including commutative, associative, distributive principles.
Algebra 3	Comprehend the basic concepts of set, and know the function and usage of the set.
Algebra 4	Calculate the basic arithmetic problems.
Physics 1	Identify the function of electronic resistance.
Physics 2	Identify the difference the series circuit and parallel circuit, and the functions of these two circuits.

Implications for Instruction

According to the result of learner analysis, it shows that the target learners have the abilities to complete the incoming knowledge. For the teaching style, the learners are flexible with the learning environments, so teachers could employ some interesting and collaborative activities in the instructional process. Most of the target learners are visual learners, so the visual instruments can be involved in the instructional and learning process. The problem-solving based learning could be used in the teaching process in that the target learners care about whether their learning knowledge are relative with their future jobs and the function of their learning materials. Moreover, the experiment plays an important role in learning the contents of digital learning, so hand-on activities and experiments would be the best choices for instructors. For the instructional process, the recalling method could be used, which could enable students to connect their prior knowledge with incoming information, and the process of connection makes meaningful learning easier to happen. For the evaluation of this project, the paper-based test is not the only way to evaluate the learning outcomes of the target learners, and the learning performance in the activities and experiments is a significant factor that affects the learning outcomes.

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Learning Task Analysis

Instructional Goal

In this instructional project, the target learners are required to apply the basic concepts and functions to the authentic logic circuit. Therefore, the instructional goal of our project is that the target learners will be able to design the simplest logic circuit that implements a given function with particular gates.

Learning Domain

According to Gagne's types of learning outcomes (Gagne, 1970), this learning belongs to the type of problem solving. In the process of problem solving, the target learners also should learn some basic concepts, principles, and rules. To accomplish this learning goal, the learners should be able to apply the axioms, theorems, and principles to analyze and synthesize logic networks.

Information Processing Analysis

The information processing analysis for designing the simplest logic circuit that implements a given function with particular gates includes the following major procedural steps:

Step 1: Analyze the functions of designed circuit.

Step 2: Analyze the given variables and function included in the project.

Step 3: Identify the logic expression in terms of the function of the given logic circuit.

Step 4: Simplify logic expression to be simplest possible logic expression.

Step 5: Verify the equivalence between the simplest logic expression and original logic expression.

Step 6: If the simplest possible logic expression equals with the original one, go to next step. If not, go back to the step 4.

Step 7: Convert the simplest possible logic expression to NAND or NOR form.

Step 8: Draw the digital circuit.

Step 9: Simulate the digital circuit in lab or by using relative software.

Step 10: Check whether the design is correct. If the design is correct, do prototype implementation, which is the end of this learning unit. If not, go back to the first step.

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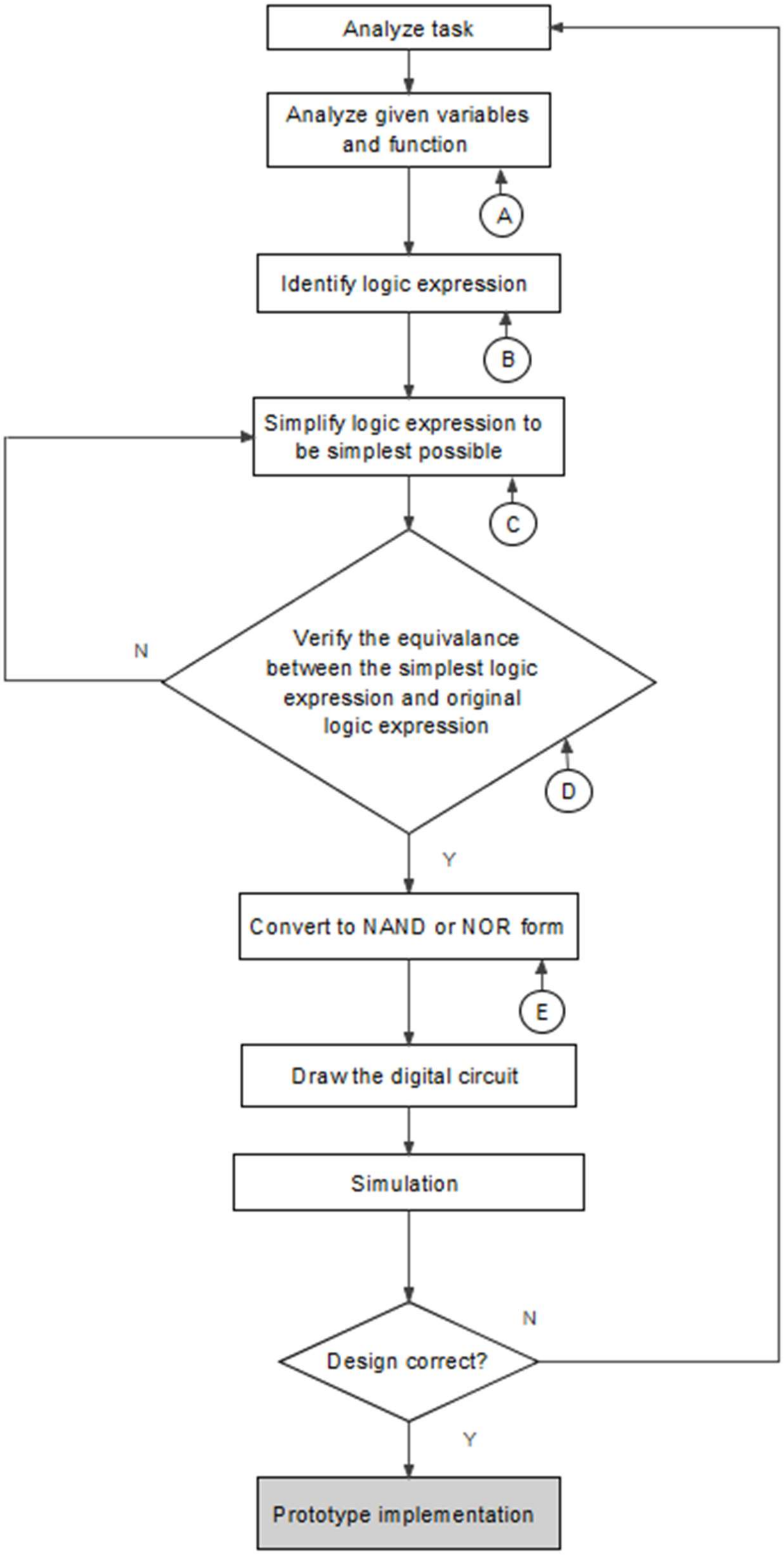

Figure 1 Main steps

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Prerequisite Analysis

According to the information-processing of the learning of this project, the students are required to design a logic circuit in terms of given function, they must do the followings:

1. Analyze the given function that will be designed.
    a. Analyze all of the conditions in the given problem.
    b. Identify task in this problem.
2. Analyze given variables and function.
    a. Recall the definition of variable in algebra.
    b. Define variable in logic circuit.
    c. Recognize the variables in given problem.
    d. Recall function in algebra.
    e. Define function in logic circuit.
    f. Recognize the function in given problem.
    g. Recall the relationship between variable and function in algebra.
    h. Recognize the relationship between variables and function in given problem.

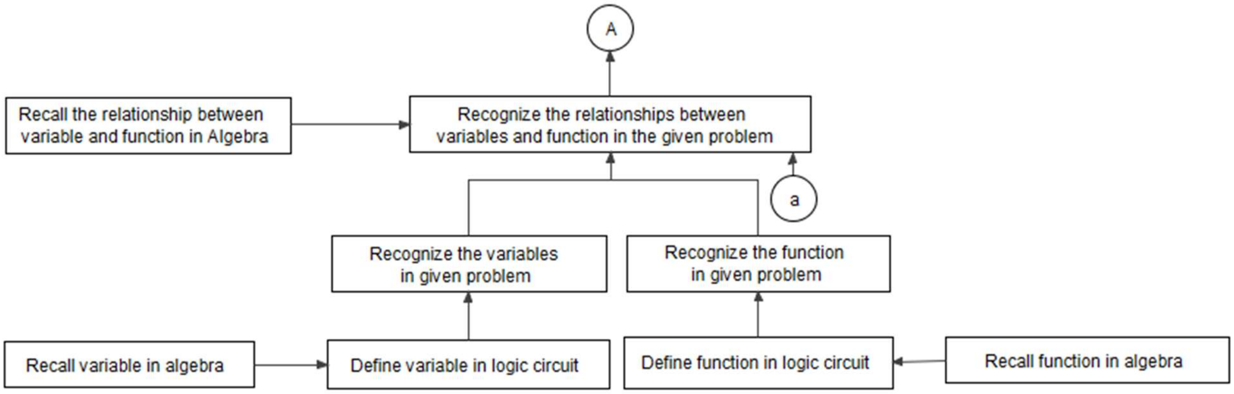

Figure 2 Prerequisites of analyzing variables and function

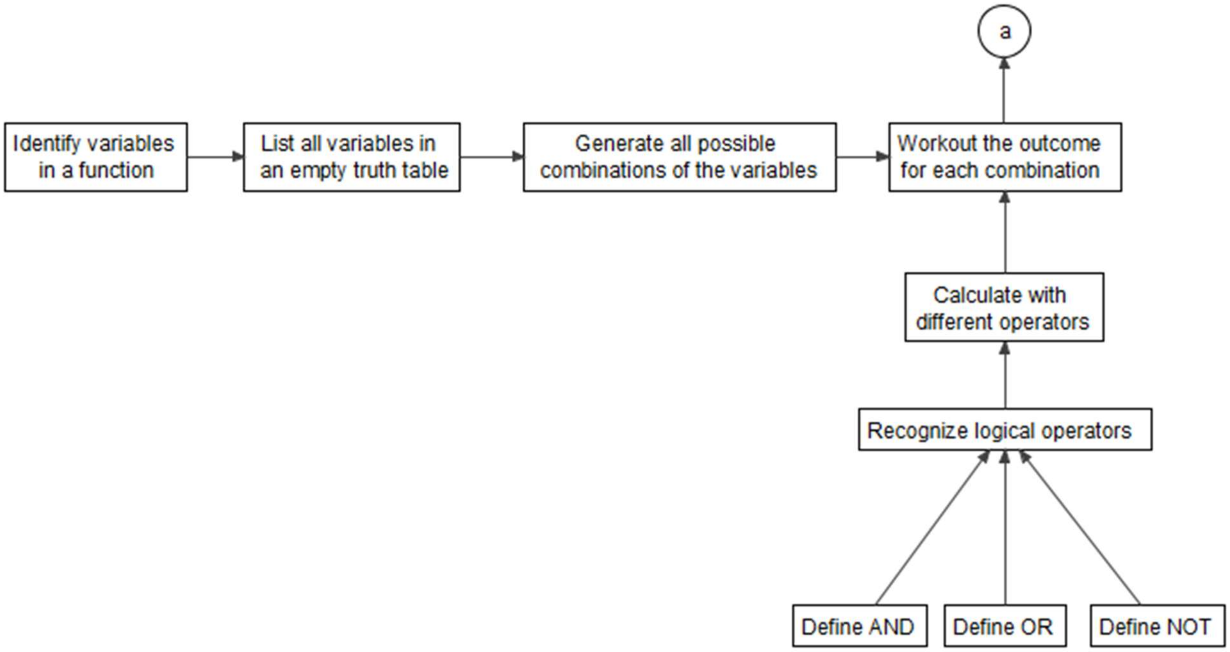

Figure 3 Prerequisites of recognize relationship between variables and functions

3. Identify the logic expression.
    a. Select a method to identify the logic expression.
    b. Use Sum-of-Products (SOP) form to represent logic expression, or use Product-of-Sums (POS) form to represent logic expression.
    c. Know what SOP form and POS form are.
    d. Know the definition of Minterm and the relationship between Midterm and SOP form.
    e. Know the definition of Maxterm and the relationship between Maxterm and POS form.
    f. Identify all of Minterms in given problem.
    g. Identify all of Maxterms in given problem.

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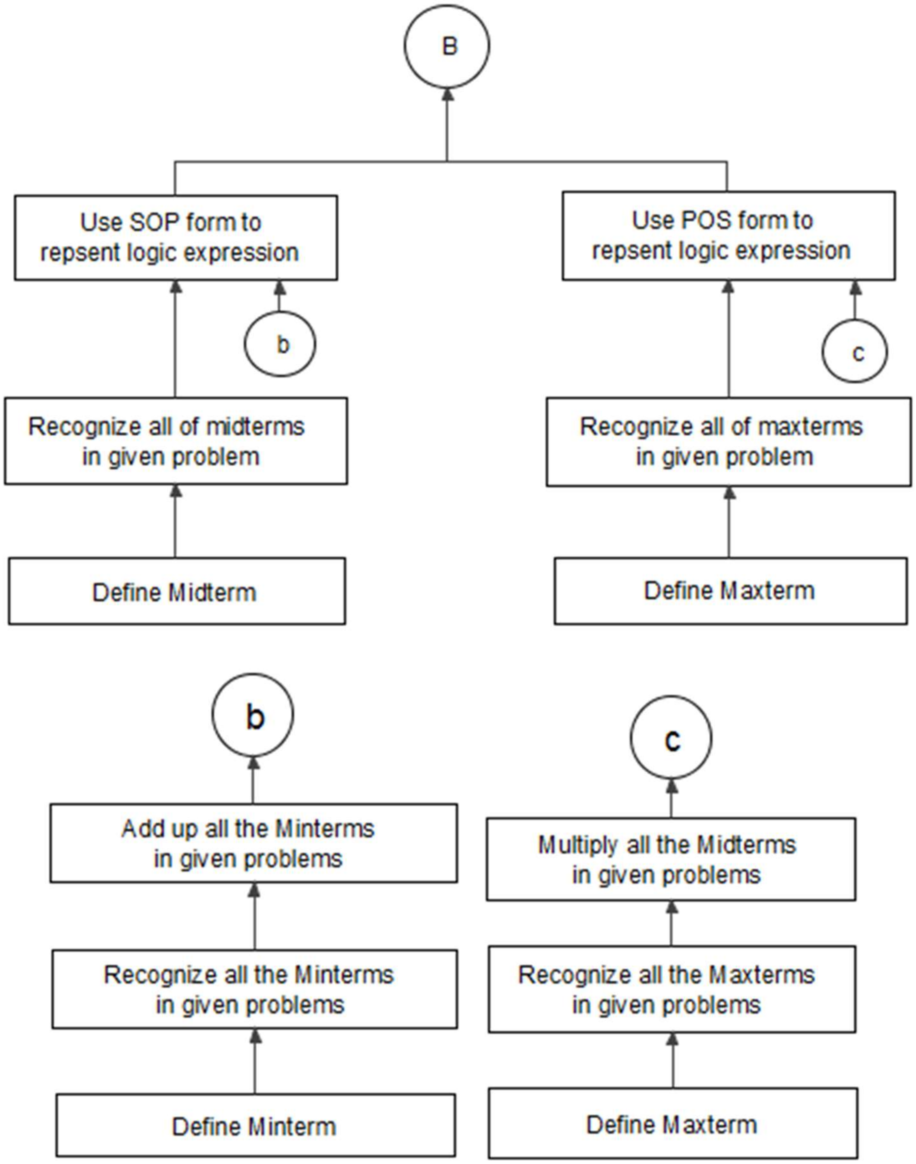

Figure 4 Prerequisites of identifying the logic expression

4. Simplify logic expression to be simplest possible logic expression.
    a. Know the basic algebraic manipulation.
    b. Perform algebraic manipulation.
    c. Know notation and terminology in logic circuit.
    d. Know precedence of operations.
    e. Find out available Axioms and Theorems.
    f. Recall Axioms and Theorems.

g. Know Axioms of Boolean Algebra.

h. Know Single-Variable Theorems.

i. Know Two- and Three- Variable Properties.

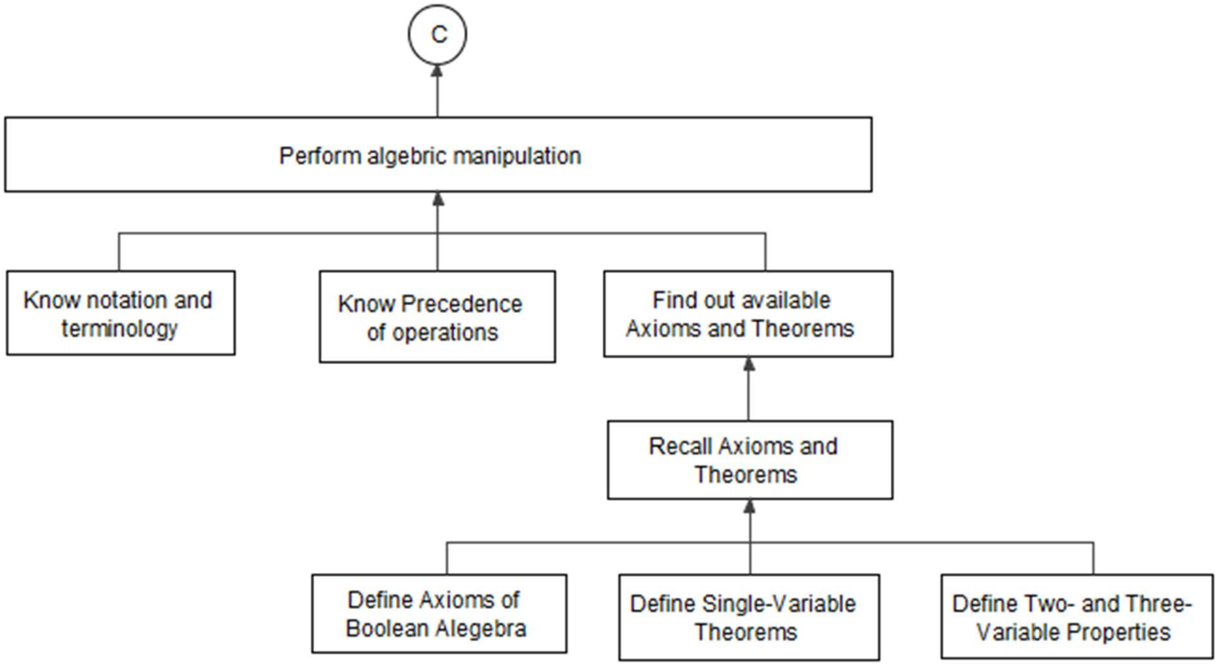

Figure 5 Prerequisites of simplify the expression

5. Verify the validity of the simplest possible logic expression.
    a. Select the method do verify the equivalence between the simplest possible logic expression and the original logic expression.
    b. Know what Venn Diagram and the purpose of this tool.
    c. Recall the definition of set in algebra.
    d. Recall the tool of Truth Table.
    e. Know what Timing Diagram is and the function of this tool.

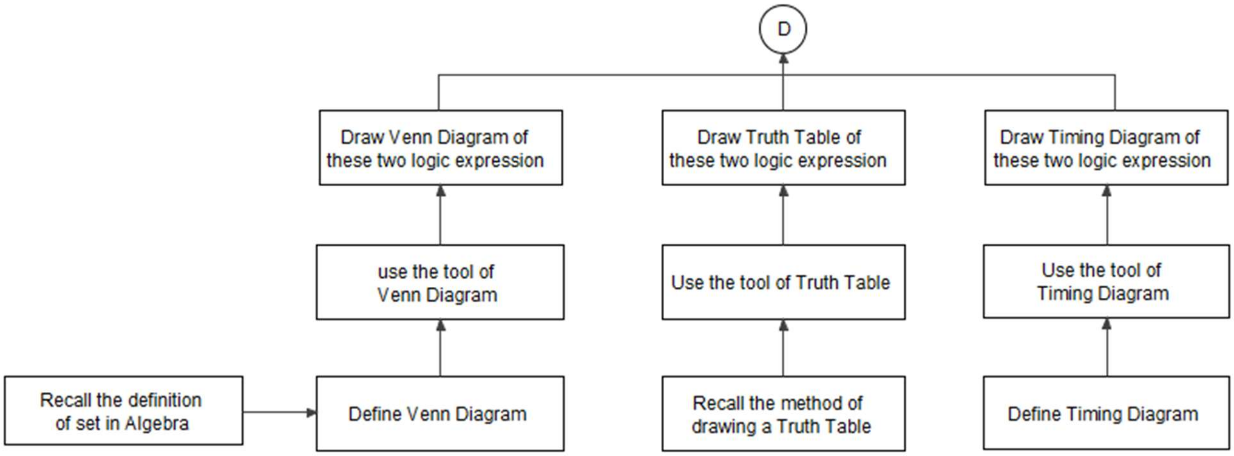

Figure 6 Prerequisites of validate the simplest expression

6. Convert the simplest possible logic expression to NAND and NOR form.
    a. Identify the form of simplest possible logic expression. If it is AND-OR form, convert it to NAND form. If it is OR-AND form, convert it to NOR form.
    b. Know the purpose of conversion.
    c. Know what is NAND form.
    d. Know what is NOR form.
    e. Know AND-OR form and OR-AND form.

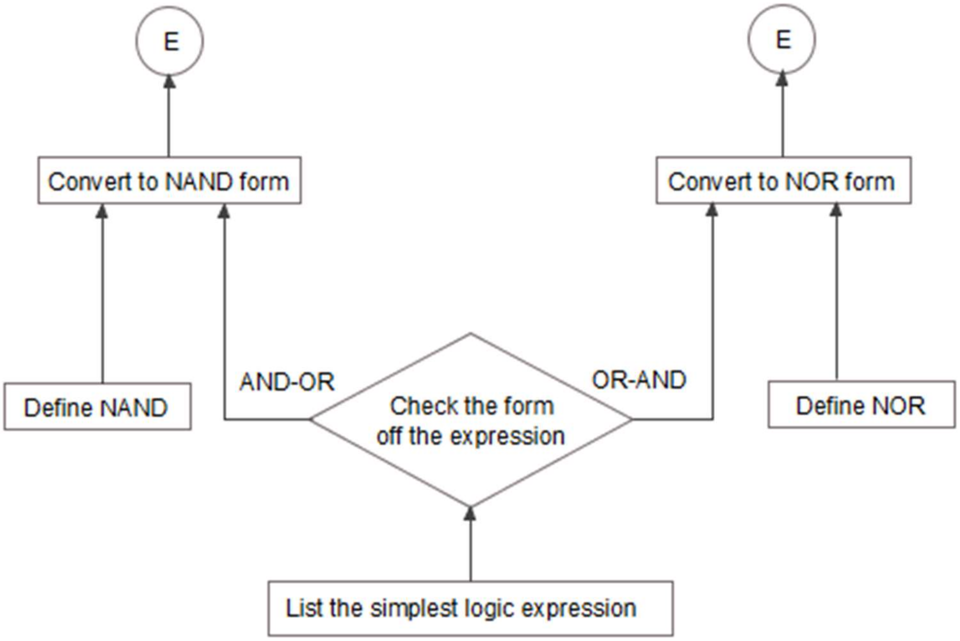

Figure 7 Prerequisites of converting NAND or NOR form

Learning Objectives

After the step of information-processing and prerequisite analysis, the terminal learning objectives and subordinate objectives of the whole instructional project are as following:

1. **Given a design problem, learners can synthesize a logic expression through analyzing the design functions of logic circuit.**
    - 1.1. Identify variables and function in a given problem.
    - 1.2. Identify the logic relationship between variables and function with a truth table.
        - 1.2.1. Identify Boolean logic operators: AND, OR, and NOT.
        - 1.2.2. Calculate the result of a Boolean logic expression.
    - 1.3. Conduct a logic expression using Sum-of-Products (SOP) form or Product-of-Sums (POS) form.
        - 1.3.1. Identify SOP form and POS form.
        - 1.3.2. Explain the concept of minterm(m) and the relationship between m and SOP.
        - 1.3.3. Explain the concept of maxterm(M) and the relationship between M and POS.
        - 1.3.4. Identify all m or M in a given problem.
2. **Given a logic expression, learners can simplify the logic expression to be simplest possible.**
    - 2.1. Perform Boolean algebraic manipulation
        - 2.1.1. Apply Axioms of Boolean algebra in manipulation.
        - 2.1.2. Apply Single-Variable Theorems in manipulation.
        - 2.1.3. Apply Two- and Three- Variables properties in manipulation.
    - 2.2. Convert a logic expression to NAND or NOR form.
        - 2.2.1. Explain the concepts of NAND and NOR and the purpose of conversion.
        - 2.2.2. Identify the form of expression, AND-OR (SOP) or OR-AND (POS).
3. **Given two logic expression, learners can verify the equivalence of two logic expressions.**
    - 3.1. Apply Venn diagram to prove the equivalence of two logic expression.
    - 3.2. Apply Truth Table to prove the equivalence of two logic expression.
    - 3.3. Apply Timing Diagram to prove the equivalence of two logic expression.

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4. **Given a logic expression, learners can draw the digital circuit in terms of logic expression.**
    4.1. Identify the symbol of logic gates for AND, OR, NOT, NAND, and NOR.
    4.2. Apply the rules of drawing a digital circuit with logic gates.
5. **Given a situation or a function, learners can design a logic circuit to implement the given function.**

Assessment

Assessment Specifications

ECT403 is an advanced course in electronics & computer technology. It has prerequisite courses, ECT232 and ECT 231. Therefore, the entry skill assessment is not necessary. Students have to complete the prerequisite courses to enroll this course.

The following table is assignments and assessments plan

Table 2 Assignments and assessment plan

	Quizzes	Unit test
Time	Periodically during instruction	End of unit
Learning targets	Learning targets of each section	Unit learning targets
Assessment type	Formative	Summative

The following table of specifications is for both pre-assessment and post-assessment.

Table 3 Assessment specifications

	Knows[1]	Understand[2]	Application[3]	Total percentage of points
Boolean algebra	4	6	6	16
Logical gates	4	6	6	16
Logic functions	6	8	10	24

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Synthesize expression	4	8	10	22
Design circuit	4	8	10	22
Total Percentage of points	22	36	42	100

Note:

[1] For discrimination and concept

[2] For rules (principles and procedures)

[3] For problem solving

Assessment Item Specifications

To help instructors design assessment instruments, the assessment item specifications were defined. The structure of assessment item specifications was adapted from Smith & Ragan (2005). The adapted structure has objective statement, types of learning outcome, sample item, question characteristics (and form), response characteristics, number of items and mastery criteria, and notes (for any other information).

The types of learning outcome are based on Gagné’s types of learning outcomes. This instructional unit focus mainly on intellectual skills, including discrimination, concepts, rules (principles and procedures), and problem solving (Smith & Ragan, 2005).

The forms of assessment items include Short answer, True-False, Matching, Multiple-Choice, Interpretive exercise, Essay questions, Performance-based questions (restricted/extended), and Portfolios (Miller, Linn, & Gronlund, 2009).

Following tables are list of assessment item specifications. Sample questions were adapted from Brown & Vranesic (2009).

Table 4 Objective 1

Objective 1: Synthesize a logic expression through analyzing the design functions
Objective statement
Given a design problem, learners can synthesize a logic expression through analyzing the design functions of logic circuit.
Type of learning outcome

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Problem solving
Sample item
Directions: Read the task statement and answer the questions. Assume that a large room has three doors and that a switch near each door controls a light in the room. It has to be possible to turn the light on or off by changing the state of any one of the switches. Conduct a logic expression in SOP or POS form Sample response: $\boldsymbol{f(x1,x2,x3) = \overline{x1}\cdot\overline{x2}\cdot x3 + \overline{x1}\cdot x2\cdot\overline{x3} + x1\cdot\overline{x2}\cdot\overline{x3} + x1\cdot x2\cdot x3}$ (SOP form) Or $\boldsymbol{f(x1,x2,x3) = (x1+x2+x3)(x1+\overline{x2}+\overline{x3})(\overline{x1}+x2+\overline{x3})(\overline{x1}+\overline{x2}+x3)}$ (POS form)
Question form
Performance task
Question characteristics
The question statement should have enough information for identify possible variables (inputs).
Response characteristics
Correct answers should be in SOP or POS form.
Number of items and mastery criteria
Please refer to assessment specifications. Mastery is 100% of the items correct.
Notes

Table 5 Objective 1.1

Objective 1.1: Identify variables and function in a given problem
Objective statement
Given a problem, learners can identify all variables and function in the problem.
Type of learning outcome
Concept, Rules
Sample item
Directions: Read the task statement and answer the questions.

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Assume that a large room has three doors and that a switch near each door controls a light in the room. It has to be possible to turn the light on or off by changing the state of any one of the switches. How many variables in this situation? Please list all the possible variables and the function. Sample response: There are three variables in the situation: x1=the switch near the first door, x2=the switch near the second door, x3=the switch near the third door. The function is $\boldsymbol{f(x1, x2, x3)}$.
Question form
Restricted performance task
Question characteristics
The question statement should have enough information for identify possible variables (inputs).
Response characteristics
Correct answers will be determined by the task statement.
Number of items and mastery criteria
This objective does not have to be assessed by standalone questions. It could be embedded into an item for objective 1 or objective 4. It is required to perform objectives 1 and 4. Mastery is 100% of the items correct.
Notes

Table 6 ***Objective 1.2***

Objective 1.2: Identify the logic relationship between variables and function with a truth table
Objective statement
Given a problem, learners can identify the logic relationship between variables and function with a truth table.
Type of learning outcome
Rules
Sample item

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Directions: Read the task statement and answer the questions.

Assume that a large room has three doors and that a switch near each door controls a light in the room. It has to be possible to turn the light on or off by changing the state of any one of the switches.

Conduct a truth table for the task.

Sample response:

$x1$	$x2$	$x3$	f
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

Question form

Restricted performance task

Question characteristics

The question statement should have enough information for identify possible variables (inputs) and the relationship between the variables and function.

Response characteristics

Correct answers will be determined by the task statement. The form of a response should be a truth table containing all the possible combinations of Boolean value and the output (the value of the function).

Number of items and mastery criteria

This objective does not have to be assessed by standalone questions. It could be embedded into an item for objective 1 or objective 4. It is required to perform objectives 1 and 4. Mastery is 100% of the items correct.

Notes

Table 7 Objective 1.2.1

Objective 1.2.1: Identify Boolean logic operators: AND, OR, and NOT
Objective statement
Given a function, learners can identify Boolean logic operators.
Type of learning outcome
Discrimination
Sample item
Directions: Choose the correct answer. Sample 1: Which Boolean operator does the symbol "+" represent? A. AND B. OR C. NOT Sample response: B Sample 2: Which Boolean operator is used in the expression: $\boldsymbol{x1x2}$? A. AND B. OR C. NOT Sample response: A
Question form
Multiple-choice
Question characteristics
Only one symbol will be presented in a question.
Response characteristics
Correct answer will be randomly assigned to A, B, or C.
Number of items and mastery criteria
Please refer to assessment specifications. Mastery is 100% of the items correct.
Notes

Table 8 Objective 1.2.2

Objective 1.2.2: Calculate the result of a Boolean logic expression
Objective statement
Given values of the variables in an expression, learners can calculate the result of the expression
Type of learning outcome
Concept, Rules
Sample item
Direction: Please fill in the blank with your answer. Example 1: For $\boldsymbol{f(x1, x2) = x1 \cdot x2}$, if $\boldsymbol{x1 = 1}$ and $\boldsymbol{x2 = 0}$, then $\boldsymbol{f(x1, x2) =}$ __________ Sample response: 0 Example 2: For $\boldsymbol{f(x1, x2) = x1 \cdot x2 + \overline{x1}}$, if $\boldsymbol{x1 = 1}$ and $\boldsymbol{x2 = 0}$, then $\boldsymbol{f(x1, x2) =}$ __________ Sample response: 0
Question form
Short answer
Question characteristics
Operators AND, OR, and NOT will be shown in the expression. The number of variables could be more than two and typically less than 5 for this objective. All variables must have a Boolean value.
Response characteristics
The response would be either 1 or 0.
Number of items and mastery criteria
Please refer to assessment specifications. Mastery is 100% of the items correct.
Notes

Table 9 Objective 1.3

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Objective 1.3: Conduct a logic expression using SOP form or POS form

Objective statement

Given a truth table, learners can conduct a logic expression using SOP form or POS form

Type of learning outcome

Rules

Sample item

Direction: Look at the truth table and answer question.

Truth table:

$x1$	$x2$	$x3$	f
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

Write a function using SOP form.

Sample response:

$\boldsymbol{f(x1, x2, x3) = \overline{x1} \cdot \overline{x2} \cdot x3 + \overline{} \cdot x2 \cdot \overline{x3} + x1 \cdot \overline{x2} \cdot \overline{x3} + x1 \cdot x2 \cdot x3}$ (SOP form)

Question form

Restricted performance task

Question characteristics

A truth table will be presented. The number of variables should be more than three and typically less than 5. Questions can ask for functions in either SOP form or POS form or both forms.

Response characteristics

The response would be a function in SOP or POS form.

Number of items and mastery criteria

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Please refer to assessment specifications. Mastery is 100% of the items correct.
Notes

Table 10 Objective 1.3.1

Objective 1.3.1: Identify SOP and POS forms
Objective statement
Given an expression, learners can identify the forms (SOP or POS)
Type of learning outcome
Concept
Sample item
Directions: Choose the correct answer. Which form is used in the expression: $\boldsymbol{x1\overline{x2} + \overline{x1}x2}$ A. Sum-of-Products B. Product-of-Sums C. Product-of-Products D. Sum-of-Sums Sample response: A
Question form
Multiple-choice
Question characteristics
Questions should use simplest form of an expression in SOP or POS form.
Response characteristics
Correct answer will be randomly assigned to A, B, C, or D.
Number of items and mastery criteria
Please refer to assessment specifications. Mastery is 100% of the items correct.
Notes

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Table 11 Objective 1.3.2

Objective 1.3.2: Explain the concept of minterm (m)
Objective statement
Learners can explain the concept of minterm(m) and the relationship between m and Sum-of-Products
Type of learning outcome
Concept
Sample item
Directions: Please answer the following question using no more than 150 words. What is minterm? Please give an example Sample answer: For a function of n variables, a product term in which each of the n variables appears once is called a minterm. For example, for function $\boldsymbol{f(x1, x2, x3)}$, $\boldsymbol{x1x2x3}$ is a minterm.
Question form
Essay question
Question characteristics
Questions should have words limitation.
Response characteristics
Response may vary.
Number of items and mastery criteria
Please refer to assessment specifications. Mastery is 100% of the items correct.
Notes

Table 12 Objective 1.3.3

Objective 1.3.3: Explain the concept of maxterm (M)
Objective statement
Learners can explain the concept of maxterm(M) and the relationship between M and Product-

of-Sums
Type of learning outcome
Concept
Sample item
Directions: Please answer the following question using no more than 150 words. What is maxterm? Please give an example Sample answer: For a function of n variables, a sum term in which each of the n variables appears once is called a maxterm. For example, for function $\boldsymbol{f(x1, x2, x3)}$, $\boldsymbol{x1 + x2 + x3}$ is a maxterm.
Question form
Essay question
Question characteristics
Questions should have words limitation.
Response characteristics
Response may vary.
Number of items and mastery criteria
Please refer to assessment specifications. Mastery is 100% of the items correct.
Notes

Table 13 Objective 1.3.4

Objective 1.3.4: Identify all m or M in a given problem
Objective statement
Given a truth table, learners can identify all m(s) or M(s).
Type of learning outcome
Concept, Rules
Sample item
Direction: Look at the truth table and answer question.

ASSIGNMENT C

Truth table:

$x1$	$x2$	$x3$	f
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

Write down all minterms that are needed to be included in the function.

Sample answer:

$\boldsymbol{m1 = \overline{x1} \cdot \overline{x2} \cdot x3}$

$\boldsymbol{m2 = \overline{x1} \cdot x2 \cdot \overline{x3}}$

$\boldsymbol{m4 = x1 \cdot \overline{x2} \cdot \overline{x3}}$

$\boldsymbol{m7 = x1 \cdot x2 \cdot x3}$

Question form

Restricted performance task

Question characteristics

A truth table or a problem statement, which can be used to generate a truth table, will be presented. Questions can ask for minterms, maxterms, or both.

Response characteristics

Response may vary.

Number of items and mastery criteria

Please refer to assessment specifications. Mastery is 100% of the items correct.

Notes

ASSIGNMENT C

Table 14 Objective 2

Objective 2: Simplify the logic expression to be simplest possible
Objective statement
Given a logic expression, learners can simplify the logic expression to be simplest possible
Type of learning outcome
Problem solving
Sample item
Direction: Design the simplest sum-of-products expression for the function $\boldsymbol{f(x_1, x_2, x_3) = \overline{x_1}\, x_2x_3 + x_1\overline{x_2}\,\overline{x_3} + x_1x_2\overline{x_3} + x_1x_2x_3}$ Sample response: $\boldsymbol{f(x_1, x_2, x_3) = \overline{x_1}\, x_2x_3 + x_1\overline{x_2}\,\overline{x_3} + x_1x_2\overline{x_3} + x_1x_2x_3}$ $\boldsymbol{= (\overline{x_1} + x_1)x_2x_3 + x_1(\overline{x_2} + x_2)\overline{x_3}}$ $\boldsymbol{= x_2x_3 + x_1\overline{x_3}}$
Question form
Restricted performance task
Question characteristics
The function should have more than 3 variables and typically no more than 5 variables.
Response characteristics
There could be different possibility for the same function
Number of items and mastery criteria
Please refer to assessment specifications. Mastery is 90% of the items correct.
Notes

Table 15 Objective 2.1

Objective 2.1: Perform Boolean algebraic manipulation
Objective statement

ASSIGNMENT C

Learners can perform Boolean algebraic manipulation.
Type of learning outcome
Rules
Sample item
Direction: Use algebraic manipulation to prove the equation(s): $x + yz = (x + y)(x + z)$ Sample response: $(x + y)(x + z) = xx + xz + xy + yz$ $= x + xz + xy + yz$ $= x(1 + z + y) + yz$ $= x \cdot 1 + yz$ $= x + yz$
Question form
Restricted performance task
Question characteristics
Questions should be a valid equation.
Response characteristics
There could be more than one possibility for the same function
Number of items and mastery criteria
Please refer to assessment specifications. Mastery is 90% of the items correct.
Notes

Table 16 Objective 2.1.1

Objective 2.1.1: Apply Axioms of Boolean algebra in manipulation
Objective statement
Learners can apply Axioms of Boolean algebra in manipulation.
Type of learning outcome

Rules
Sample item
Direction: Read each of the following equations. If the equation is true, circle the T. If the equation is false, circle the F. T F $\mathbf{0 \cdot 0 = 0}$ T F $\mathbf{0 \cdot 1 = 0}$ T F $\mathbf{1 + 0 = 0}$ Sample response (T) F $\mathbf{0 \cdot 0 = 0}$ (T) F $\mathbf{0 \cdot 1 = 0}$ T (F) $\mathbf{1 + 0 = 0}$
Question form
True-False
Question characteristics
Questions should be an equation.
Response characteristics
Only True or False.
Number of items and mastery criteria
Please refer to assessment specifications. Mastery is 100% of the items correct.
Notes

Table 17 Objective 2.1.2

Objective 2.1.2: Apply Single-Variable Theorems in manipulation
Objective statement
Learners can apply Single-Variable Theorems in manipulation.
Type of learning outcome
Rules

ASSIGNMENT C

Sample item
Direction: Read each of the following equations. If the equation is true, circle the T. If the equation is false, circle the F. T F $\boldsymbol{x \cdot 0 = 0}$ T F $\boldsymbol{x + 1 = 1}$ T F $\boldsymbol{x + x = 1}$ Sample response (T) F $\boldsymbol{x \cdot 0 = 0}$ (T) F $\boldsymbol{x + 1 = 1}$ T (F) $\boldsymbol{x + x = 1}$
Question form
True-False
Question characteristics
Questions should be an equation.
Response characteristics
Only True or False.
Number of items and mastery criteria
Please refer to assessment specifications. Mastery is 100% of the items correct.
Notes

Table 18 Objective 2.1.3

Objective 2.1.3: Apply Two- and Three- Variables properties in manipulation
Objective statement
Learners can apply Two- and Three- Variables properties in manipulation.
Type of learning outcome
Rules
Sample item

ASSIGNMENT C

Direction: Read each of the following equations. If the equation is true, circle the T. If the equation is false, circle the F.

T F $\boldsymbol{x \cdot y = y \cdot x}$

T F $\boldsymbol{x + y = y + x}$

T F $\boldsymbol{x + x \cdot y = y}$

Sample response

(T) F $\boldsymbol{x \cdot y = y \cdot x}$

(T) F $\boldsymbol{x + y = y + x}$

T (F) $\boldsymbol{x + x \cdot y = y}$

Question form

True-False

Question characteristics

Questions should be an equation.

Response characteristics

Only True or False.

Number of items and mastery criteria

Please refer to assessment specifications. Mastery is 100% of the items correct.

Notes

Table 19 Objective 4

Objective 4: Draw the digital circuit in terms of logic expression

Objective statement

Given a logic expression, learners can draw the digital circuit in terms of logic expression.

Type of learning outcome

Rules

Sample item

Direction: Draw a logical circuit using NOR gate for the function:

ASSIGNMENT C

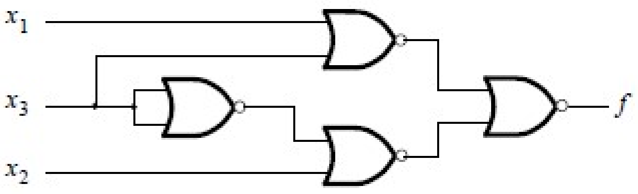
$\boldsymbol{f(x_1, x_2, x_3) = (x_1 + x_3)(x_2 + \overline{x_3})}$. Sample response: 
Question form
Restricted performance task
Question characteristics
Questions should be in a simplest expression.
Response characteristics
Response may vary in different implementation.
Number of items and mastery criteria
Please refer to assessment specifications. Mastery is 90% of the items correct.
Notes
Objective 4.2 is included in this Item

Table 20 Objective 4.1

Objective 4.1: Identify the symbol of logic gates for AND, OR, NOT, NAND, and NOR
Objective statement
Given a function, learners can identify the symbol of logic gates for AND, OR, NOT, NAND, and NOR.
Type of learning outcome
Discrimination
Sample item
Directions: Choose the correct answer.

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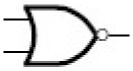
Sample 1: Which logic gate does the symbol  represent? A. AND B. OR C. NOT D. NAND E. NOR Sample response: D
Question form
Multiple-choice
Question characteristics
Only one symbol will be presented in a question.
Response characteristics
Correct answer will be randomly assigned to A, B, C, D, or E.
Number of items and mastery criteria
Please refer to assessment specifications. Mastery is 100% of the items correct.
Notes

Table 21 Objective 5

Objective 5: Design a logic circuit to implement the given function
Objective statement
Given a situation or a function, learners can design a logic circuit to implement the given function.
Type of learning outcome
Problem solving
Sample item

ASSIGNMENT C

Directions: Read the task statement and answer the questions. Assume that a large room has three doors and that a switch near each door controls a light in the room. It has to be possible to turn the light on or off by changing the state of any one of the switches. Design a logic circuit to implement the three-way light control problem at lowest cost possible.
Question form
Performance task
Question characteristics
The question statement should have enough information for identify possible variables (inputs).
Response characteristics
Responses could be vary. This item should be finished in simulation software.
Number of items and mastery criteria
Please refer to assessment specifications. Mastery is 100% of the items correct.
Notes

Sample assessment

This sample assessment follows the assessment specifications and assessment items specifications. It can be used as pre-assessment or post-assessment. Instructors also can design their own assessment based on the specifications.

	Section I	Section II	Section III	Section IV	Total
Possible Score	10	10	20	60	
Score					

Section I: True/False (10 points, 1 point for each question)

Direction: Read each of the following equations. If the equation is true, circle the T. If the equation is false, circle the F.

ASSIGNMENT C

T F $0 \cdot 0 = 0$

T F $0 \cdot 1 = 0$

T F $1 + 0 = 0$

T F $x \cdot 0 = 0$

T F $x + 1 = 1$

T F $x + x = 1$

T F $x + \bar{x} = 0$

T F $x \cdot y = y \cdot x$

T F $x + y = y + x$

T F $\boldsymbol{x + x \cdot y = y}$

Section II: Multiple Choice (10 points, 2 points for each question)

Directions: Circle the correct answer.

1. Which Boolean operator does the symbol “+” represent?

A. AND

B. OR

C. NOT

2. Which Boolean operator is used in the expression: x1x2?

A. AND

B. OR

C. NOT

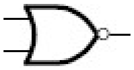
3. Which form is used in the expression: $x1\overline{x2} + \overline{x1}x2$

A. Sum-of-Products

B. Product-of-Sums

C. Product-of-Products

D. Sum-of-Sums

4. Which logic gate does the symbol  represent?

A. AND

B. OR

C. NOT

D. NAND

E. NOR

5. Which form is used in the expression? $x1\overline{x2} + \overline{x1}x2$

A. Sum-of-Products

B. Product-of-Sums

C. Product-of-Products

D. Sum-of-Sums

Section III: Essay questions (20 points, 10 points for each question)

Directions: Answer the following question using no more than 150 words.

1. What is minterm? Please give an example.
2. What is maxterm? Please give an example.

Section IV: Performance tasks (60 points, 10 points for question 1 to 4, 20 points for question 5)

Directions: Read the task statement and answer the questions.

1. Look at the truth table and answer question.

Truth table:

$x1$	$x2$	$x3$	f
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

Write down all minterms that are needed to be included in the function.

2. Design the simplest sum-of-products expression for the function

$\boldsymbol{f}(x_1, x_2, x_3) = \overline{x_1}\, x_2x_3 + x_1\overline{x_2}\,\overline{x_3} + x_1x_2\overline{x_3} + x_1x_2x_3$

ASSIGNMENT C

3. Use algebraic manipulation to prove the equation(s):

$$\boldsymbol{x + yz = (x + y)(x + z)}$$

4. Draw a logical circuit using NOR gate for the function:

$$\boldsymbol{f}(x_1, x_2, x_3) = (x_1 + x_3)(x_2 + \overline{x_3})$$

5. Assume that a large room has three doors and that a switch near each door controls a light in the room. It has to be possible to turn the light on or off by changing the state of any one of the switches. Design a logic circuit to implement the three-way light control problem at lowest cost possible and implement it in simulation software.

Instructional Strategy

This is a problem-solving based instructional design project, and various learning contents are involved in this project, which refers to the learning domain of discrimination, concept, rule, and domain-specific problem-solving. According to the specific learning objectives and learning domain, the designed strategies for this project are as follows:

Sequencing and Grouping of Objectives

The following table shows the sequence of learning objectives and the chucks of learning contents.

Sequence Number	Objectives Group
1	O.1.1, O.1.2.1, O.1.2.2, O.1.2, O.1.3.2, O.1.3.3, O.1.3.4, O.1.3.1, O.1.3, O.1
2	O.2.1.1, O.2.1.2, O.2.1.3, O.2.1, O.2.2.1, O.2.2.2, O.2.2, O.2
3	O.3.1.1, O.3.1.2, O.3.1, O.3.3.1, O.3.3.2, O.3.3, O.3.2, O.3, O.4.1, O.4.2, O.4, O.5

Organization and Management

After figure out the teaching chunks, the instructor will deliver the teaching content in terms of learning objectives. According to the learning objectives, the whole lesson will be separated into three chunks. The following is the specifications of instructional strategy in this project.

ASSIGNMENT C

Introduction

Active Attention

At the beginning of the class, the teachers can show some integrated block to attract students' attention, and ask some focus questions, such as what the working principle of cellphone is, what is the core part of cellphone, what enables the cellphone work, and so on. Learners can also share some experiences and knowledge about digital information. Moreover, instructors can show a movie clip of digital information or the usage of digital information.

Establish Purpose

The instructor can let the students describe the events in the movie clip and the functions of integrated blocks. Then, the instructor introduces the learning goals of this learning module. The main purpose of this project is to teach how to design a logic circuit to realize the given functions.

Arouse Interest and Motivation

Show a functional integrated block. Let students explain what they observe in the performance. The instructor can employ an integrated block to control the conditions of light. When the light is turned off, instructor can ask student what happens to the integrated block. Instructor can state that this interesting function you also can design a integrate circuit to realize this function. That should be the purpose of this class.

Preview Learning Activity

Ask the students to design a logic circuit to control three-control light. Assume that a large room has three doors and that a switch near each door controls a light in the room. It has to be possible to turn the light on or off by changing the state of any one of the switches.

Before learning basic rules and principles, the teachers should help students to analyze the given problem and identify the task problem.

Body

Objective 1.1 Identify variables and function in a given problem

Recall relevant prior knowledge

Recall the definitions of variable, function, and the relationship between variable and function in algebra.

Process information and examples

ASSIGNMENT C

Provide an example of variable and function in algebra. In contrast, Apply the concepts of variable and function in algebra to the real physics problem. According to this prior knowledge, identify the variable and function in the given problem. The follow is an example of variable and function in algebra:

In algebra, variable refer to a logic set of attributes, and function refers to the actions of the inputs. The functional expression, $F(x) = x^2$, indicates the relationship between x and f, which is an algebraic expression.

Focus Attention

According to the explanation of variable and function in algebra, instructor can present the question that what the variables and function in this given problem. (In the prior knowledge of algebra, students are required to apply the concept of variables and function to analyze a real problem.) The instructor can use questions or algebra problems to focus students' attention.

Employ Learning Strategies

- Questions: $F(x1, x2) = (x1 + x2)/3$. What are the variables and function in this algebraic problem?
- Group discussion: Analyze the given problem and identify the variables and function in this given problem.

Practice

Practice is not needed for this part because all of these contents have been delivered in the prerequisite courses, in which students have mastered the variables in algebra. In this part, the instructor just needs to recall the learned knowledge of variables and function, and let students to analyze this problem.

Evaluate Feedback

In this given problem, it covers three variables and one function, which can be noted as $f(x^1, x^2, x^3)$

Objective 1.2.1 Identify Boolean logic operators: AND, OR, and NOT.

Recall Relevant Prior Knowledge

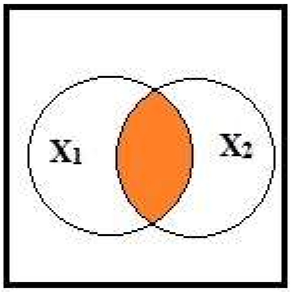
Recall the manipulation of Boolean algebra, and the relationship between variables and function.

Process Information and Examples

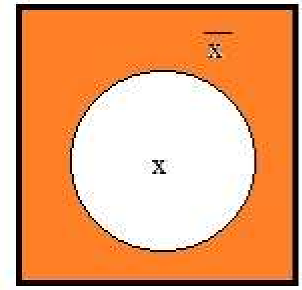
ASSIGNMENT C

In algebra, we use AND, OR, and NOT to indicate the relationship among set. In algebra, the following diagram can explain the definition of AND, OR, and NOT.

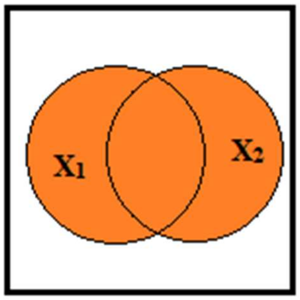
Example #1: Use the shapes to indicate the manipulation of AND, OR, and NOT.



The red area on the left side shows the result of the AND manipulation of the variable x_1 and x_2.



The red area on the left side shows the result of the NOT manipulation of the variable x.



The red area on the left side shows the result of the OR manipulation of the variable x_1 and x_2.

According to the contrast with these three manipulations in algebra, students can transfer their prior knowledge to recognize the operations of AND, OR, and NOT in digital logic.

Example #2: Use the circuit diagram to make the operations more concrete.

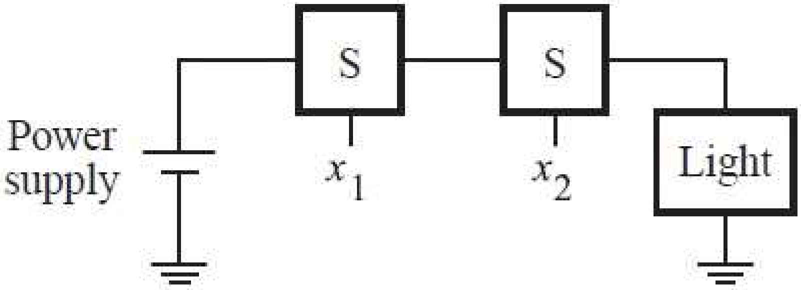


Figure 8 The circuit diagram above simulates the working principle of series connection circuit.

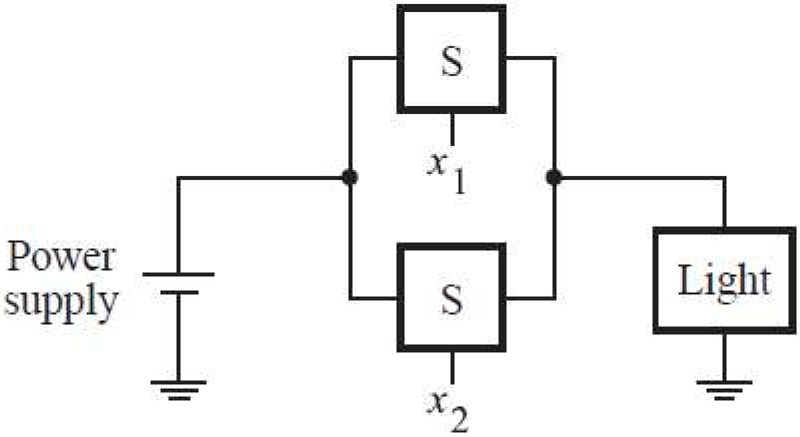


Figure 9 The circuit diagram above simulates the working principle of parallel connection circuit.

In this part, the instructor can help student to recall the working principle, and then let student contrast the pertinence between Boolean logic manipulation and working principle of series connection circuit and parallel connection parallel.

Focus Attention

In this part, the teacher can use animation to attract students' attention. For the series connection circuit, if one light switch is closed, the light will be off. In contrast of the animation, if one switch is closed, the state of light should be off. When two switches are closed, the light will be on.

Employ Learning Strategies

ASSIGNMENT C

- Use analogy method to induct Boolean algebra.
- Use relative physics principle to deduct the operations of Boolean algebra.

Group discussion and identify analog connection in the given problem. In this part, it can evaluate students' learning performance in analog circuit, which also enables the function of the designed circuit more concrete, which is also useful for the follow-up learning of the Truth Table.

Practice

The practice for this part is group discussion to draw the analog circuit in terms of the given function of designed circuit. The practice for the operations will be conducted after identifying the logic expression of given problem.

Evaluate Feedback

The analogy circuit is as follow:

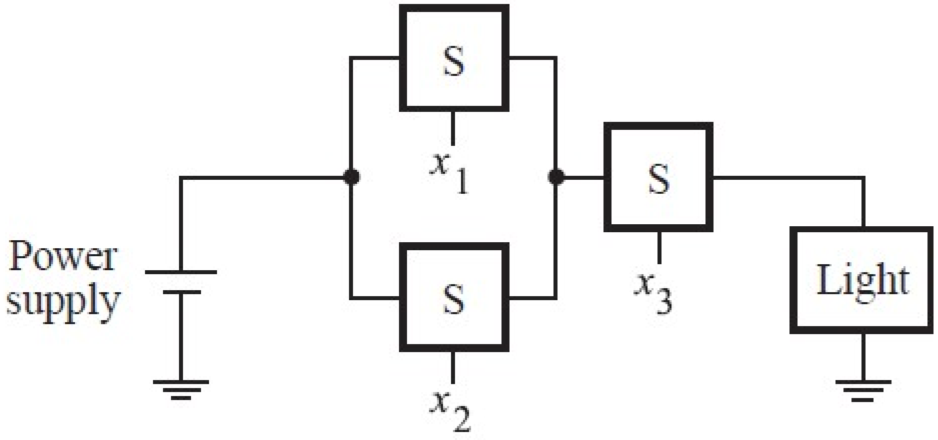


Figure 10 This is a series-parallel connection, which shows the functions of three switches controlling one light.

Objective 1.2 Identify the logic relationship between variables and function in given problem with a Truth Table

Recall relevant prior knowledge

Recall the relationship between variables and function in algebra.

Process information and examples

In algebra, variable refer to a logic set of attributes, and function refers to the actions of the inputs. The functional expression, $F(x) = x^2$, indicates the relationship between x and f, which is an algebraic expression. Using above explanation can help learners recall the prior knowledge.

ASSIGNMENT C

According to prior knowledge of the relationship between variables and function, learners can use x1, x2, and x3 as three switches in the given problem. List all of the conditions in the given problem. To express all of the logic results between switches and light, learners can use Truth table to record all of logic results. For this part, the instructor can insert the new knowledge of Truth Table.

Use a simple example to explain what Truth table is and how to conduct a Truth Table. In Boolean algebra, there are two logic results, which should 1 and 0. Use Boolean algebra in logic circuit, and it can be used as two states of the light in the given problem. The following is a Truth Table of one variable, which show logic results of $f(x) = x^2$.

Table 22 Truth table

X	X^2
0	0
1	1

The above example shows all of the logic results of the function of x^2. On the left side, it shows all of the conditions of the variable, x. On the right side, it shows all of the results of this function. This is the function or purpose of Truth Table, which is to record all of the logic results of one function.

Focus Attention

Use questions to attract learners' attention. The questions should be interesting. An animation showing an analogy circuit of series connection circuit. By using this animation, students are required to conduct a Truth Table for their observation.

Employ Learning Strategies

- Using an analogy diagram to show the entire situations in given problem. The instructor can use bring a real electronic circuit to show the equivalent function with the following analogy diagram. The following analogy diagram can represent the entire function in the given problem.

ASSIGNMENT C

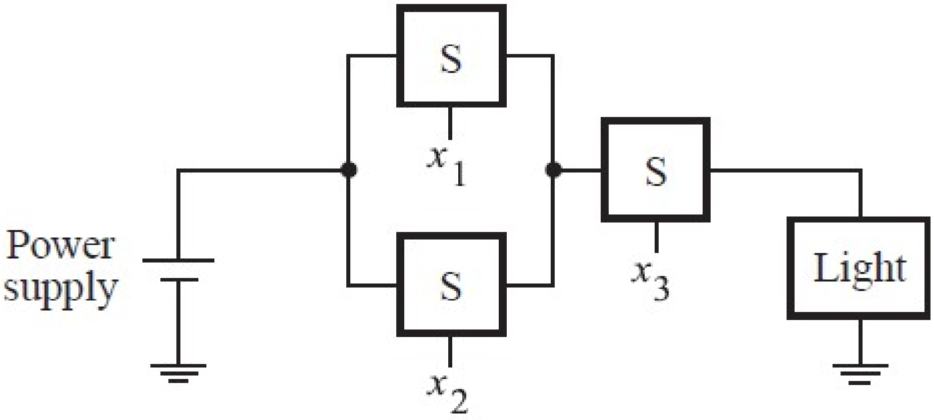


Figure 11 Sample circuit

- Group discussion: Analyze the given problem and identify the relationship between variables and function in given problem.
- According to the analysis results, learners are required to conduct the Truth Table to express the relationship between variables and function in given problem.

After discussion, each group should present their results to verify their comprehension.

Practice

Turn word statement into a formal specification using a Truth Table.

Evaluate feedback

The Truth Table for the given problem is as follows:

Let x1, x2, and x3 be the input variables that denote the state of each switch. Assume that the light is off if all switches are open. Closing any one of the switches will turn the light on. Then turning on a second switch will have to turn off the light. Thus the light will be on if exactly one switch is closed, and it will be off if two switches are closed. If the light is off when two switches are closed, then it must be possible to turn it on by closing the third switch. It denotes that the switch is open, if x=1. It denotes that the switch is closed, if x=0.

The following Truth Table shows all of the situations of given problem.

$x1$	$x2$	$x3$	f

ASSIGNMENT C

Objective O.1.3.2 Explain the concepts of minterm(m) and the relationship between m and SOP

Recall relevant prior knowledge

Recall the operations of Boolean Algebra and the axioms of Boolean algebra.

Process information and examples

In the objective 1.2, the Truth Table of the given problem has been identified, which is shown as follows:

$x1$	$x2$	$x3$	f

In the analysis, we assume that if switch is closed, x=0. If switch is open, x=1. According to learned knowledge of Boolean operation of NOT, if x=0, then $\overline{x} = 1$.

Introduce the definition of Minterm, it states that “For a function of n variables, a product term in which each of the n variables appears once is called a minterm. For a given row of the truth table, the minterm is formed by including x_i if $x_i = 1$ and by including $\overline{x_1}$ if $x_i = 0$.”

According to the definition of Minterms, the following table show the Mindterms in the given problem:

Table 23 Truth table

ASSIGNMENT C

Row number	$x1$ $x2$ $x3$	f	Minterm
0	0 0 0	0	$m_0 = \overline{x_1}\,\overline{x_2}\,\overline{x_3}$
1	0 0 1	1	$m_1 = \overline{x_1}\,\overline{x_2}\,x_3$
2	0 1 0	1	$m_2 = \overline{x_1}\,x_2\,\overline{x_3}$
3	0 1 1	0	$m_3 = \overline{x_1}\,x_2x_3$
4	1 0 0	1	$m_4 = x_1\,\overline{x_2}\,\overline{x_3}$
5	1 0 1	0	$m_5 = x_1\,\overline{x_2}\,x_3$
6	1 1 0	0	$m_6 = x_1x_2\,\overline{x_3}$
7	1 1 1	1	$m_7 = x_1x_2x_3$

According to the truth table, learners are required to indentify the Minterms.

The form of SOP is the sum of all the Minterms in one logic problem. In the above example, the SOP should be $m_0 + m_1 + m_2 + m_3 + m_4 + m_5 + m_6 + m_7$. The SOP stands for sum of product. In this part, learners can connect the product in math with the AND operation in Boolean algebra. This is the reason plus all of the Minterms together is sum of product.

Focus Attention

Use Questions to Focus students' attention.

Employ Learning Strategies

- Deductive reasoning method to learning what Minterm is.
- Use truth table to get all the Minterms in one logic problem.

Practice

Describe all the Minterms in given problem.

Evaluate Feedback

$$m_0 = \overline{x_1}\,\overline{x_2}\,\overline{x_3}$$

$$m_1 = \overline{x_1}\,\overline{x_2}\,x_3$$

$$m_2 = \overline{x_1}\,x_2\,\overline{x_3}$$

$$m_3 = \overline{x_1}\, x_2 x_3$$

$$m_4 = x_1 \overline{x_2}\, \overline{x_3}$$

$$m_5 = x_1 \overline{x_2}\, x_3$$

$$m_6 = x_1 x_2 \overline{x_3}$$

$$m_7 = x_1 x_2 x_3$$

Objective O.1.3.3 Objective 1.3.2 Exlain the concepts of minterm(m) and the relationship between m and SOP

Recall relevant prior knowledge

Recall the operations of Boolean Algebra and the axioms of Boolean algebra.

Process information and examples

In the objective 1.2, the Truth Table of the given problem has been identified, which is shown as follows:

$x1$	$x2$	$x3$	f

In the analysis, we assume that if switch is closed, x=0. If switch is open, x=1. According to learned knowledge of Boolean operation of NOT, if x=0, then $\overline{x}$ = 1.

Introduce the definition of Maxterm, which indicates that “the alternative approach uses the complements of minterms, which are called maxterms.”

According to the definition of Maxterms, the following table shows the Maxterms in the given problem:

Table 24 Minterm and maxterm

ASSIGNMENT C

Row number			$x1$	$x2$	$x3$	f	Maxterm
0			0	0	0	0	$m_1 = x_1 + x_2 + x_3$
1			0	0	1	1	$m_2 = x_1 + x_2 + \overline{x_3}$
2			0	1	0	1	$m_3 = x_1 + \overline{x_2} + x_3$
3			0	1	1	0	$m_4 = x_1 + \overline{x_2} + \overline{x_3}$
4			1	0	0	1	$m_5 = \overline{x_1} + x_2 + x_3$
5			1	0	1	0	$m_6 = \overline{x_1} + x_2 + \overline{x_3}$
6			1	1	0	0	$m_7 = \overline{x_1} + \overline{x_2} + x_3$
7			1	1	1	1	$m_8 = \overline{x_1} + \overline{x_2} + \overline{x_3}$

The form of SOP is the sum of all the Minterms in one logic problem. In the above example, the SOP should be $m_0 + m_1 + m_2 + m_3 + m_4 + m_5 + m_6 + m_7$. The SOP stands for sum of product. In this part, learners can connect the product in math with the AND operation in Boolean algebra. This is the reason plus all of the Minterms together is sum of product.

Focus Attention

Use questions to focus students' attention.

Employ Learning Strategies

- **Deductive reasoning method to learning what Maxterm is.**
- **Use truth table to get all the Maxterms in one logic problem.**

Practice

Describe all the Maxterms in the given problem.

Evaluate Feedback

$m_1 = x_1 + x_2 + x_3$

$m_2 = x_1 + x_2 + \overline{x_3}$

$m_3 = x_1 + \overline{x_2} + x_3$

$m_4 = x_1 + \overline{x_2} + \overline{x_3}$

ASSIGNMENT C

$m_5 = \overline{x_1} + x_2 + x_3$

$m_6 = \overline{x_1} + x_2 + \overline{x_3}$

$m_7 = \overline{x_1} + \overline{x_2} + x_3$

$m_8 = \overline{x_1} + \overline{x_2} + \overline{x_3}$

Objective O.1.3.4, Objective O.1.3.1, Objective O.1.3

In the practice of learning O.1.3.2, O.1.3.3, the learners have identify all m and M in a given problem, and then students can do the OR operation for all the Minterms, and do the AND operation for all the Maxterms. Then, SOP and POS form in the given problem will be conducted.

Objective 2.1.1 Apply Axiom of Boolean algebra in manipulation.

Recall relevant prior knowledge

Recall the operation of Boolean logic, including AND, OR, and NOT.

Process information and examples

For the Boolean operation, the students are required to the axioms of Boolean Algebra. The following axioms are the basic axioms of Boolean algebra:

1a. $0 \cdot 0 = 0$

1b. $1 + 1 = 1$

2a. $1 \cdot 1 = 1$

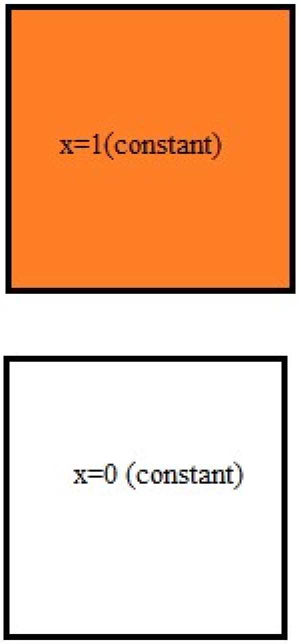
2b. $0 \cdot 1 = 1 \cdot 0 = 0$

3a. If $x = 0$, then $\overline{x} = 1$

3b. If x = 1, then $\bar{x} = 0$

Use the definition of set, and use shapes to express prove the validity of these equations. For example, the following shapes show the axiom that $0 \cdot 1 = 1 \cdot 0 = 0$.

ASSIGNMENT C



The first set indicates that the variable equals 1, which should a constant. The second set indicates that the variable equals 0, which should be a constant and there is nothing in this set. Thus, there will be no connections for these two sets forever. These two diagram can approve the validity of the axiom that $\mathbf{0 \cdot 1 = 1 \cdot 0 = 0}$

Figure 12 Diagram of value

Focus Attention

Use focus questions to focus attention. Let student find out a way to approve the validity of axioms. Students also could share their comprehension of these axioms.

Employ Learning Strategies

- Contrast the definition of set in algebra with the operations of Boolean algebra.
- Prove the validity of axioms to enhance students' comprehension and memory.

Practice

Practice1: For $f(x1, x2) = x1 + x2$, if $x1 = 1$ and $x2 = 1$, then $f(x1, x2) =$ __________

Practice 2: For $f(x1, x2) = x1 \cdot x2 + \overline{x1}$, if $x1 = 1$ and $x2 = 0$, then $f(x1, x2) =$ __________

Evaluate feedback

Answer for Practice 1: 1

Answer for Practice 2: 0

Objective 2.1.1 Apply Single-Variable Theorems in manipulation.

Recall relevant prior knowledge

ASSIGNMENT C

Recall the operation of Boolean logic, including AND, OR, and NOT, and the axioms of Boolean algebra.

Process information and examples

For the Boolean operation, the students are required to know the single-value theorems of Boolean Algebra. The following table is a list of the single-value theorems of Boolean algebra:

Table 25 Single-value theorems

5a	$x \cdot 0 = 0$
5b	$x + 1 = 1$
6a	$x \cdot 1 = x$
6b	$x + 0 = x$
7a	$x \cdot x = x$
7b	$x + x = 1$
8a	$x \cdot \bar{x} = 0$
8b	$x + \bar{x} = 1$
9	$\bar{\bar{x}} = x$

Then prove the validity of these theorems through set in algebra, which is similar to approve the validity of the axiom that is $1 \cdot 0 = 0$.

Focus Attention

Use focus questions and animation to focus students' attention. Let students to approve the validity of some of the Single-Variable theorems.

Employ learning Strategies

- Contrast the definition of set in algebra with the operations of Boolean algebra.
- Let them use set diagram to express the operations of Boolean algebra.
- Group work to use their own way to approve the validity of Single-Variable Theorems.

Practice

Direction: Read each of the following equations. If the equation is true, circle the T. If the equation is false, circle the F.

T F $x \cdot 0 = 0$

T F $x + 1 = 1$

T F $x + x = 1$

Evaluate Feedback

(T) F $x \cdot 0 = 0$

(T) F $x + 1 = 1$

T (F) $x + x = 1$

Objective 2.1.1 Apply Two- and Three- variables properties in manipulation.

Recall relevant prior knowledge

Recall the operation of Boolean logic, including AND, OR, and NOT. Recall the principles of the axioms of Boolean algebra, and Single-Variables in manipulation.

Process information and examples

For the Boolean operation, the students are required to know the two- and three- variables properties of Boolean Algebra. The following table is a list of the two- and three- variables properties of Boolean algebra:

Table 26 Two- and Three- variables properties

10a	$x \cdot y = y \cdot x$
10b	$x + y = y + x$
11a	$x \cdot (y \cdot z) = (x \cdot y) \cdot z$
11b	$x \cdot (y + z) = (x + y) \cdot z$
12a	$x \cdot (y + z) = x \cdot y + x \cdot z$
12b	$x + y \cdot z = (x + y) \cdot (x + z)$
13a	$x \cdot \bar{x} = 0$
13b	$x + \bar{x} = 1$
14a	$x \cdot y + x \cdot \bar{y} = x$
14b	$(x + y) \cdot (x + \bar{y}) = x$
15a	$\overline{x \cdot y} = \bar{x} + \bar{y}$
15b	$\overline{x + y} = \bar{x} \cdot \bar{y}$
16a	$x + \bar{x} \cdot y = x + y$
16b	$x \cdot (\bar{x} + y) = x \cdot y$

ASSIGNMENT C

17a	$x\cdot y + y\cdot z + \bar{x}\cdot z = x\cdot y + \bar{x}\cdot z$
17b	$(x+y)\cdot(y+z)\cdot(\bar{x}+z) = (x+y)\cdot(\bar{x}+z)$

Then prove the validity of these theorems through set in algebra, which is similar to approve the validity of the axiom that is $1\cdot 0 = 0$.

The other way is to contrast these principles with the commutative rule, associative rule, and so on in algebra. For examples, the manipulation allocation rate is similar to the property of 12a and 12b. These comparisons can help students memorize the Two- and Three-Variables properties.

Focus Attention

Use focus questions and animation to focus students' attention. Let students to recall the similar rules in algebra. Students also can use set can approach the validity of these theorems.

Employ Learning Strategies

- Use the basic rules in algebra to induce the Two- and Three-Variable properties. Some of them have the same
- Let them use set diagram to express the operations of Boolean algebra.
- Group work to use their own way to approve the validity of Single-Variable Theorems.

Practice

Direction: Read each of the following equations. If the equation is true, circle the T. If the equation is false, circle the F.

T F $x\cdot y = y\cdot x$
T F $x + y = y + x$
T F $x + x\cdot y = y$

Evaluate feedback

(T) F $x\cdot y = y\cdot x$
(T) F $x + y = y + x$
T (F) $x + x\cdot y = y$

Objective 2.1 Perform Boolean algebraic manipulation.

ASSIGNMENT C

Recall relevant prior knowledge

Recall the operation of Boolean logic, including AND, OR, and NOT. Recall the principles of the axioms of Boolean algebra, Single-Variables in manipulation, and Two- and Three- Variables Properties.

Process information and examples

In the given problem, the SOP form and POS form of logic expression have been conducted. At this time, use the learned principles to simplify the logic expression to be simplest possible.

In the given problem, SOP expression for f:

$f\,(x1, x2, x3) = \overline{x1}\,\overline{x2}\,x3 + x1\,\overline{x2\,x3} + x1\,\overline{x2}\,x3 + x1\,x2\,\overline{x3}$

The expression can be manipulated as follows:

$f = (\overline{x1} + x1)\overline{x2}\,x3 + x1\,(\overline{x2} + x2)\,\overline{x3}$

$= 1 \cdot \overline{x2}\,x3 + x1 \cdot 1 \cdot \overline{x3}$

$= \overline{x2}\,x3 + x1\,\overline{x3}$

In the given problem, POS expression for f:

$f = M0\ \cdot\ M1\ \ \cdot\ M5$

$= (x1 + x2 + x3)\,(x1 + x2 + \overline{x3})\,(\overline{x1} + x2 + \overline{x3})$

A simplified POS expression can be derived as

$$f = \big((x1 + x2) + x3\big)\big((x1 + x2) + \overline{x3}\big)\big(x1 + (x2 + \overline{x3})\big)(\overline{x1} + (x2 + \overline{x3}))$$

$$= ((x1 + x2) + x3\,\overline{x3})\,(x1\,\overline{x1} + (x2 + \overline{x3}))$$

$$= (x1 + x2)(x2 + \overline{x3})$$

Note that by using the distributive property 12b, this expression leads to

$$f = x2 + x1\,\overline{x3}$$

Focus Attention

Use focus question to attract students' attention. Let students simplify the given logic expression.

Employ Learning Strategies

- Use problem-solving methods to give them more experiences in simplifying the logic expression.

Practice

ASSIGNMENT C

Consider the function f (x1, x2, x3) = $\sum m\ (2, 3, 4, 6{,}7)$. What is the simplest possible expression for this function?

Evaluate Feedback

The canonical SOP expression for the function is derived using minterms

$$f = m2 + m3 + m4 + m6 + m7$$

$$= \overline{x1}\, x2\, \overline{x3} + \overline{x1}\, x2\, x3 + x1\, \overline{x2}\, \overline{x3} + x1\, x2\, \overline{x3} + x1\, x2\, x3$$

The expression can be simplified as follows:

$$f = \overline{x1}\, x2\, (x3 + \overline{x3}\,) + x1\, (\overline{x2} + x2)\overline{x3} + x1\, x2\, (\overline{x3} + x3)$$

$$= \overline{x1}\, x2 + x1\, \overline{x3} + x1\, x2$$

$$= (\overline{x1} + x1)\ \mathrm{x2} + \mathrm{x1}\ \overline{x3}$$

$$= \mathrm{x2} + \mathrm{x1}\ \overline{x3}$$

Objective 2.1 Identify the form of expression, AND-OR (SOP) or OR-AND (POS).

Recall relevant prior knowledge

Recall the operation of Boolean logic, including AND, OR, and NOT.

Process information and examples

Example:

F (x1, x2, x3) = x1·x2 + x2·x3

This is the form of AND-OR expression.

F(x1, x2, x3) = (x1+x3)(x2+x1)

This is the form of OR-AND expression.

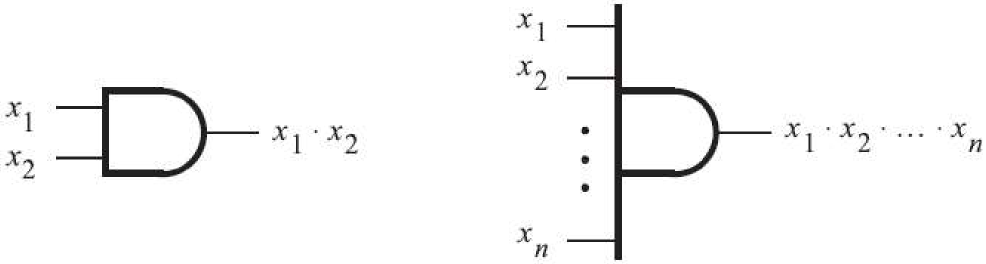
The learners can identify the form through check the operation in the middle of the manipulation.

This part could be enhanced by the next step.

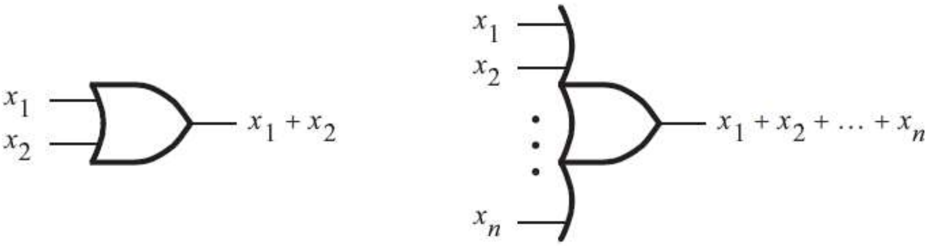
Objective 4.1 Identify the symbol of logic gates for AND, OR, NOT, NAND, and NOR.

Information process and Examples:

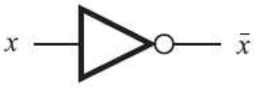
The learners are required to discriminate the shapes of AND, OR, NOT, NAND, and NOR.



(a) AND gates



(b) OR gates



(c) NOT gate

Figure 13 Logical gates

Objective 2.2.1 Explain the concepts of NAND and NOR and the purpose of conversion.

Recall relevant prior knowledge

Recall symbol of logic gates for AND, OR, and NOT.

Process information and examples

NAND gate is used to simplify SOP form. The following is an example to use NAND gates to implement a SOP form:

ASSIGNMENT C

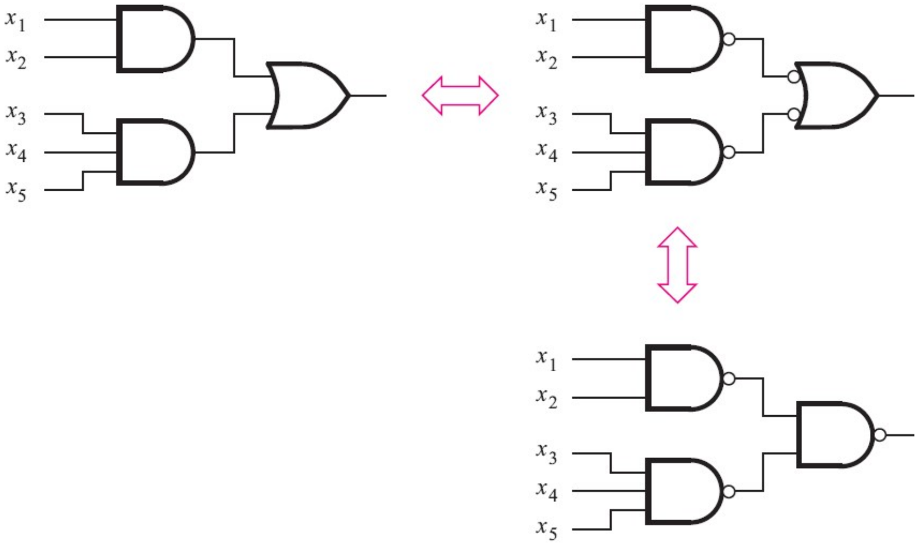


Figure 14 SOP to NAND gates

The following is a diagram to use NOR gates to simplify POS form:

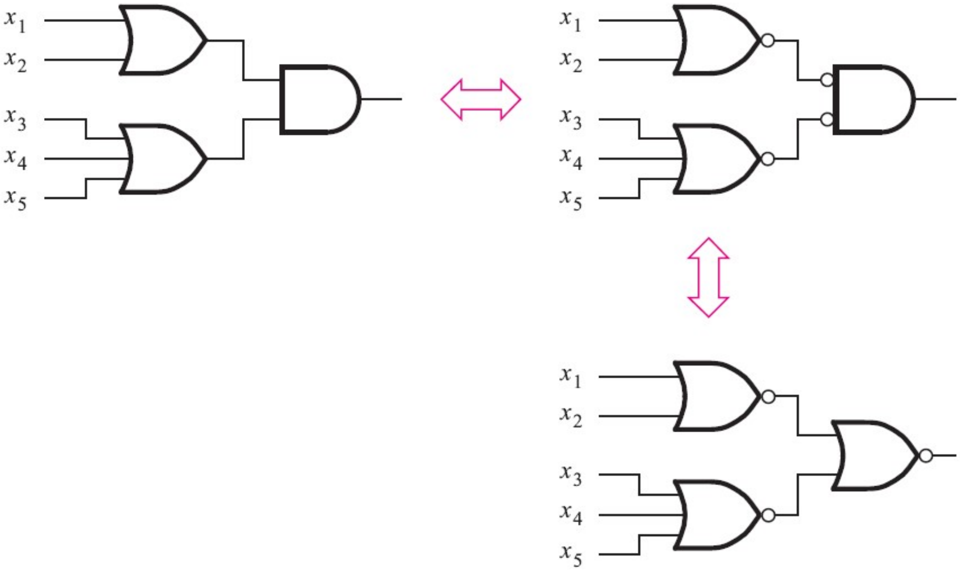


Figure 15 POS to NOR gate

According to the above method, a logic expression can be converted to NAND or NOR form.

Focus Attention

Use practice to focus students' attention.

Employ Learning Strategies

- Use concrete diagram to explain abstract concept.

ASSIGNMENT C

Practice

In the given problem, convert the conducted simplest possible expression to NAND or NOR expression. After the practice, the Objective 2 can be realized.

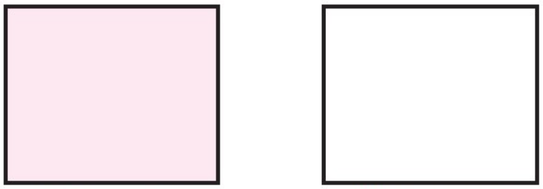
Objective 3.1 Apply Venn Diagram to prove the equivalence of two logic expression.

Recall relevant prior knowledge

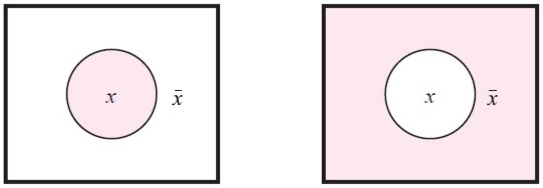
Recall the definition of set.

Process information and examples

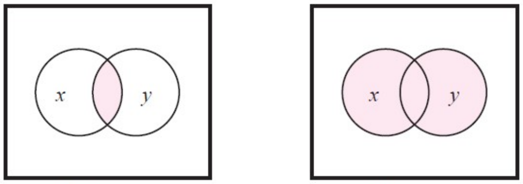
Give the learners the expression of Venn Diagram directly. Then, contrast the pertinence with set. The following is the Venn diagram representation:



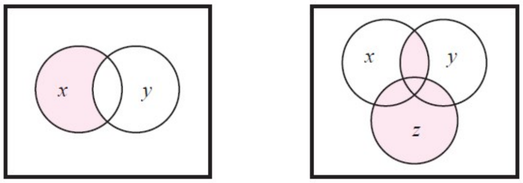
(a) Constant 1 (b) Constant 0



(c) Variable x (d) $\bar{x}$



(e) $x \cdot y$ (f) $x + y$



(g) $x \cdot \bar{y}$ (h) $x \cdot y + z$

Figure 16 Venn Diagrams

The Venn Diagram has the similar expression with set in algebra, and the same function. The learners can use Venn Diagram to prove the equivalence of two logic expression.

Focus Attention

ASSIGNMENT C

Use practice to focus students’ attention.

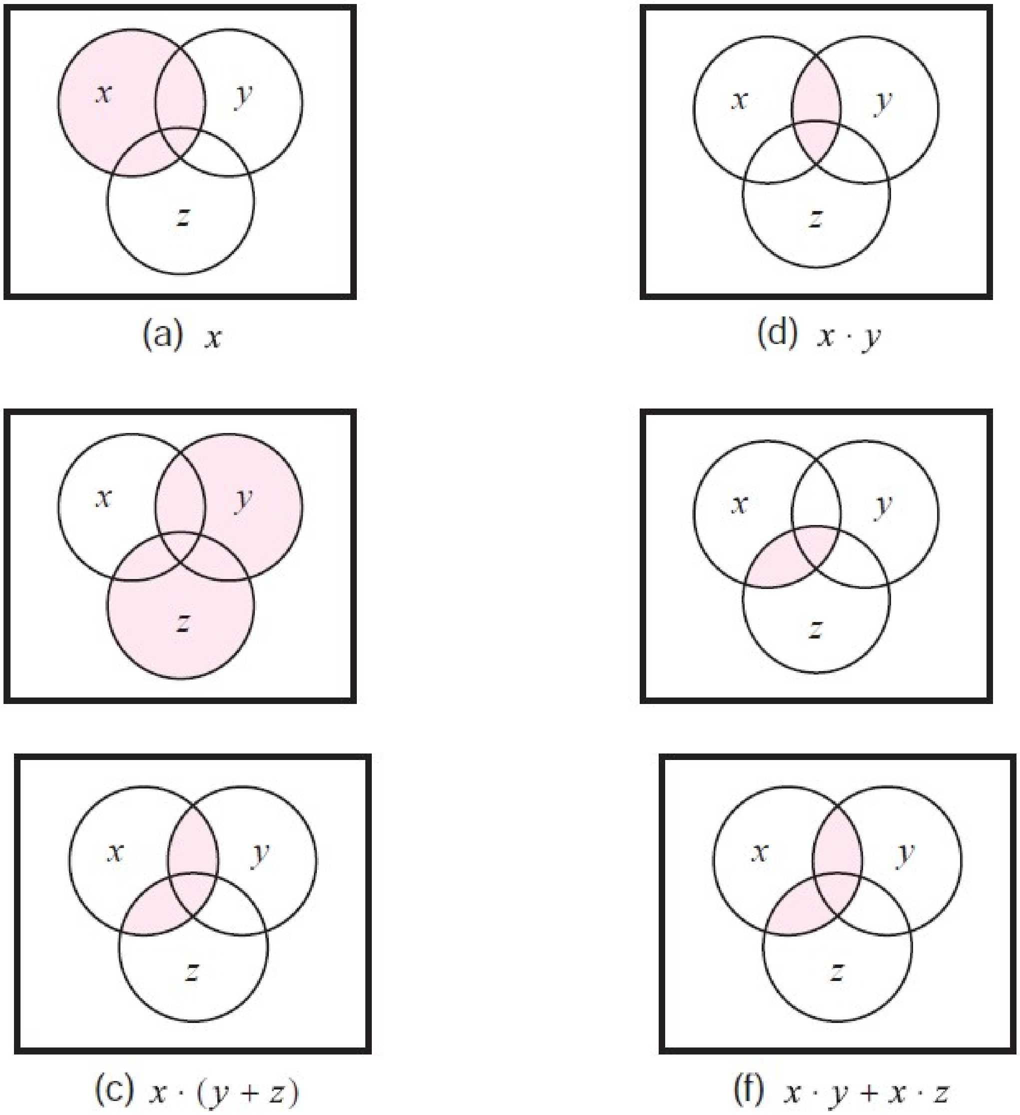
Employ Learning Strategies

- **Use concrete diagram to explain abstract concept.**

Practice

Verify the distributive property: $x \cdot (y + z) = x \cdot y + x \cdot z$

Evaluate feedback



(a) x

(d) $x \cdot y$

(c) $x \cdot (y + z)$

(f) $x \cdot y + x \cdot z$

Figure 17Venn Diagrams

Objective 3.2 Apply Truth Table to prove the equivalence of two logic expression.

ASSIGNMENT C

Recall relevant prior knowledge

Recall the function of Truth Table and what it is.

Use Truth Table to express the logic expression of design function.

Objective 3.3 Apply Timing to prove the equivalence of two logic expression.

Recall relevant prior knowledge

There is no relevant prior knowledge.

Process information and examples

Example: The following is one timing diagram:

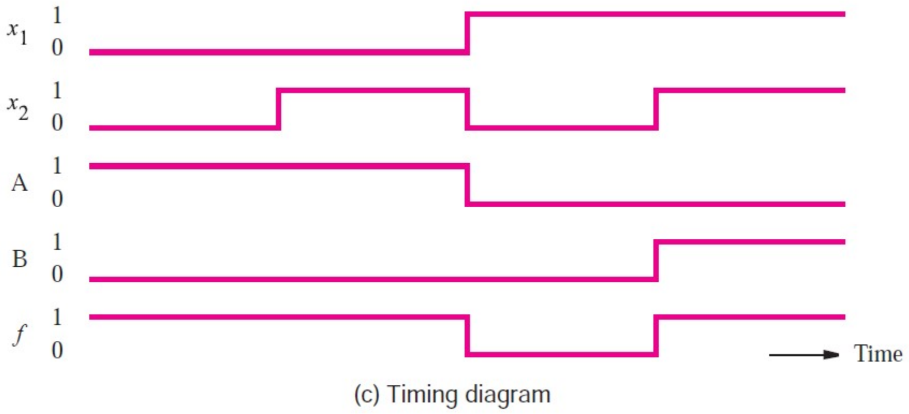


Figure 18 Timing diagram

The learners can select one of these three tools to prove the equivalence of two logic expressions.

In the end, the learners can draw the digital circuit with logic gates and also can design a logic circuit with given function.

Conclusion

Summarize and Review/Employ Learning Strategies

At this stage, the module one has been finished. In this part, the instructor can use the assessment sample to design a quiz for learners to help them enhance their comprehension and focus their attention before next module is started.

Transfer Learning

After learning the contents of this project, learners are required to design a logic circuit with given function. For example, they are required to design a logic circuit, in which three switches can control a light in a big classroom.

Remotivate and Close

The instructor can create a logic circuit that can resolve some function at first. At the end of the instruction, the instructor can show his designed logic circuit to his students.

Plan of Formative Evaluation

In the stage of formative evaluation, it will include design reviews, expert reviews, learners evaluation, and field trials.

Design Reviews

As for design reviews, these reviews have been conducted in the process of project design. For each phrase of the project design, one instructional designer worked as a leading designer, the other worked as a reviser. We considered the following considerations (Smith & Ragan, 2005, p. 328):

- Does the instructional goal reflect a satisfactory response to the problems identified in the needs assessment?
- Do the environments and learner analysis accurately portray these entities?
- Does the task analysis include all of the prerequisite skills and knowledge needed to perform the learning goal, and is the prerequisite nature of these skills and knowledge accurately represented?
- Do the test items and resultant test blueprints reflect reliable and valid measures of the instructional objects?
- Do the assessment instruments and their related mastery criteria reliably distinguish between competent and incompetent learners?

Expert Reviews

As for the expert reviews, we had SME evaluations after task analysis and assessment analysis. Suggested revisions have been made. We will ask the SME to help us to review the content of learning materials.

Learners Evaluation

For this part, we will find three student in the department of engineering to go through the designed materials. Then, we should do the observations when they learn the designed materials to record the corresponding data.

ASSIGNMENT C

The following tables will be used in one-to-one evaluation to collect data.

Table 27 Query guidelines for each learner

Section No.	General Questions	Responses	Learner's Questions
0	Do you have any unfamiliar words in the text? Can you follow the steps? Do you need more explanation on the diagram? Were all objective covered?		
1			
2			
3			
4			
5			
6			

Table 28 Attitude questionnaire (Adapted from *Smith & Ragan, 2005, p. 331)*

Directions: Please place a check mark by the phrase below that match your opinion of the unit. Write down any comments you have about any of the questions. Please be candid in your comments. Help us to get the "bugs" out of this lesson.

1. How difficult was this unit?

☐ ☺ ☐ 😐 ☐ ☹ Comments:

2. How was the vocabulary in the unit?

☐ ☺ ☐ 😐 ☐ ☹ Comments:

3. How was the length of the unit?

☐ ☺ ☐ 😐 ☐ ☹ Comments:

4. How were the practice exercises?

   ☐ ☺ ☐ 😐 ☐ ☹ Comments:

5. How difficult were the test questions?

   ☐ ☺ ☐ 😐 ☐ ☹ Comments:

6. Did the test question match the things taught in the unit?

   ☐ ☺ ☐ 😐 ☐ ☹ Comments:

7. How were the directions on the practice items and tests?

   ☐ ☺ ☐ 😐 ☐ ☹ Comments:

8. What did you think about the examples given?

   ☐ ☺ ☐ 😐 ☐ ☹ Comments:

9. How did you like the pictures in the unit?

   ☐ ☺ ☐ 😐 ☐ ☹ Comments:

10. Would you like to receive instruction in this form again?

    ☐ ☺ ☐ 😐 ☐ ☹ Comments:

Field Trials

As for field trials, the SME (also the instructor) will try to use the instructional materials in his class.

The following questionnaire will be used to collect field trial data.

Table 29 Instructor Questionnaire (Adapted from Smith & Ragan, 2005, p. 339, figure 19.6

Direction: Please indicate with a circle the degree to which you agree with the following statements. Additional comments will be very helpful.				
	Strongly Agree	Agree	Disagree	Strongly Disagree

ASSIGNMENT C

1. All of the materials and equipment that I needed to teach the unit were available me.	4	3	2	1
2. The facilities that I needed to teach the unit were available to me.	4	3	2	1
3. The intention and perspective of the instruction were clear to the learners	4	3	2	1
4. The intention and perspective of the instruction were clear to me.	4	3	2	1
5. The time estimates provided in the guide were accurate form my class.	4	3	2	1
6. My class(es) is(are) very similar to the target audience for the instruction that is describe in the guide.	4	3	2	1
7. The instruction required adaptation to fit my class(es) and this context	4	3	2	1
8. I found the unit easy to teach	4	3	2	1
9. I found the unit interesting to teach	4	3	2	1
10. I feel that the students learned from the unit	4	3	2	1
11. I would like to teach other units with designs similar to this one	4	3	2	1
12. Additional comments:				

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ASSIGNMENT C

Appendix A: Project timeline

	Tasks	Week 1 (9/9-9/13)		Week 2 (9/6-9/20)		Week 3 (9/23-9/27)		Week 4 (9/30-10/4)		Week 5 (10/7-10/11)		Week 6 (10/14-10/18)		Week 7 (10/21-10/25)		Week 8 (10/28-10/29)
☑	Identify SME	■	■	■	■											
☑	Needs Assessment				■	■										
☑	Learner Analysis					■	■	■	■							
☑	Task Analysis					■	■	■	■							
☑	SME Evaluation								■	■						
☑	Assessment Specifications									■	■					
☑	SME Evaluation									■	■					
☑	Instructional Strategies Design										■	■	■			
☑	Instructional/Learning Materials Development												■	■	■	
☑	Formative Evaluation Plan														■	■

Appendix B: SME discussion outline

1. How do you arrange the class time?
2. What is the instructional goal of the part of logic circuit?
3. What are the characteristics of the students in this class? Can you describe this part from the facts of the students' prior knowledge, prerequisite classes, grade, and the population?
4. What is your teaching style for this class?
5. Are there quiz, test, or pre-assessment involved in the part of logic circuit?
6. How about the assignments for this part?
7. How about the learners' homework performance?
8. How about the learning context for this class? (Learning context includes the place, basic instructional instrument, experimental conditions/equipment, software)
9. What are the interests and preferences of the teacher for this class? How do you see your roles in the classroom?
10. How do you in the learning environments feel about having instruction delivered via media or other nontraditional methods?
11. What is the level of your experience with the content, learners, and teaching in general?
12. What hardware is commonly available in the potential learning environments? Are computer workstations available? What software and other materials are available?
13. What are the characteristics of the classes and facilities that will use the new instruction?

Appendix C: Topic concept map