Experiment No. 15
Introduction To Digital Circuits
Logic Gates

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Objective:

(a) To introduce binary algebra.

(b) To construct simple gate circuits from diodes and resistors.

(c) To introduce truth tables for AND and OR gates.

(d) To introduce integrated circuits.

Apparatus:

2 silicon diodes, 1 LED, breadboard, 5-volt power supply, 1000 ohm and 220 ohm resistors, one AND-gate unit, one OR-gate unit.

A vacuum diode, shown schematically in Fig. 1a, is a vacuum tube consisting of 2 electrodes, a cathode C and a plate P, sealed in an evacuated envelope. The cathode C is heated by the filament F to give off electrons. The electrons are accelerated towards the plate P which is kept at a high positive potential with respect to the cathode. Thus the plate current is appreciable. On the other hand, if the plate voltage is negative, the plate current is negligible.

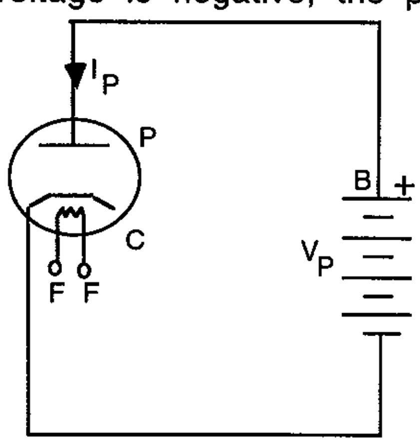


Fig. 1a.
A Vacuum Diode Circuit

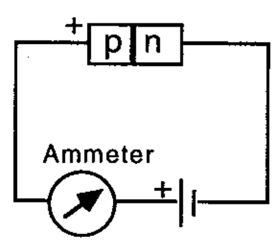


Fig. 1b
Forward-biased
pn junction

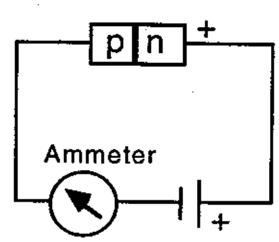
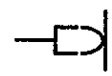


Fig. 1c
Reverse-biased
pn junction

A semiconductor diode works in a similar manner. A pn junction diode consists of p-type semiconductor and n-type semiconductor. The charge carriers in p-type semiconductors are positively charged holes while the charge carriers in n-type semiconductors are electrons. Each hole is a site where an electron is missing. A forward-biased pn junction diode, shown in Fig. 1b, allows a larger current than the reverse-biased pn junction which is shown in Fig. 1c. The resistance of a semiconductor diode in the forward direction is only about 100 ohms, though it requires about 0.6 volts to start the current. In the backward direction, it offers a large resistance (about 1 megohm) and effectively blocks the current.

We use the following symbols:

A semiconductor diode



A light-emitting diode (LED)

Background:

Binary Arithmetic:

An arithmetic that works with only two digits, 0 and 1, is called the binary arithmetic. It is ideal for use with computers which carry out complex procedures by rapid, successive operations involving two-state (on and off) logic gates.

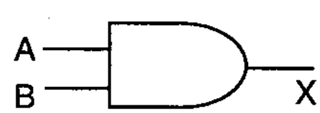
Logic Gates:

The logic gates are decision-making devices. They are the basic units of digital devices such as computers and electronic wristwatches. In this experiment, we will study AND and OR logic gates constructed with silicon diodes and resistors.

A two-input AND gate, with its output normally in the OFF [0] state, switches to ON [1] state when both input, A and B, are in the ON state. This fact is illustrated by the truth table shown in Fig. 2a. The AND gate symbol is also shown in Fig. 2a. The listing of all possible arrangements of inputs and outputs is called a truth table.

A two-input OR gate, with its output normally OFF [0], produces an ON [1] output if either of its inputs is in the ON [1] state. Fig. 2b shows the truth table for the OR gate along with the OR gate symbol.

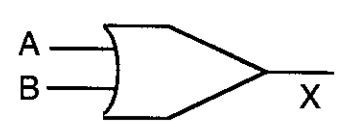
A	B	Output (A•B)
0	0	0
0	1	0
1	0	0
1	1	1



Truth Table Symbol

Fig. 2a. AND Gate

A	B	Output (A+B)
0	0	0
0	1	1
1	0	1
1	1	1



Truth Table Symbol

Fig. 2b. OR Gate

An AND logic gate can be constructed using two diodes, D_1 and D_2, and a resistor as shown in Fig. 3a. The arrows represent the forward direction (the direction in which they conduct) of the diodes. V_1 and V_2 represent the two input voltages. The operation of an AND gate is explained below.

When both input voltages, V_1 and V_2 (Fig. 3a) are zero, both diodes are conducting (have currents in them). Thus V_{out} is almost zero. Even with one of the input voltages zero, V_{out} is almost zero because the corresponding diode is conducting. When both input voltages are made positive, neither diode is conducting and V_{out} (= 5 volt) is applied to the LED circuit and it lights up.

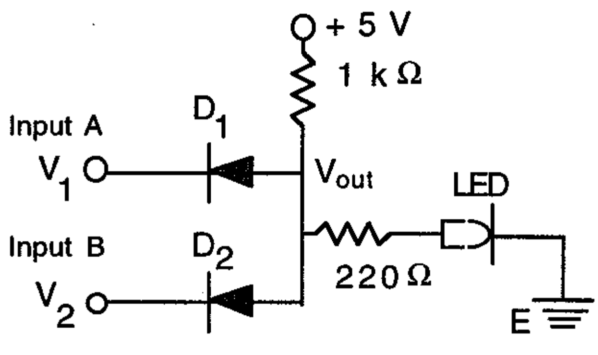


Fig. 3a
Schematic diagram of an AND gate

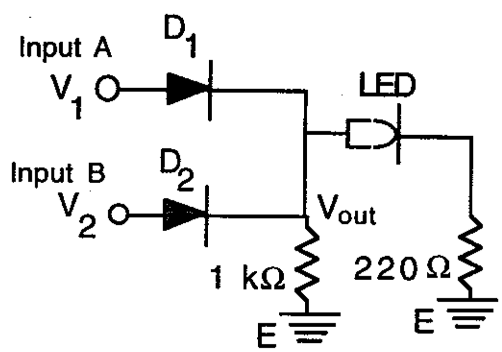


Fig. 3b
Schematic diagram of an OR gate

The schematic diagram of an OR gate is shown in Fig. 3b. In this case, if both input voltages are zero, the output voltage V_{out} is zero. When either of the input voltages are positive, one of the diodes is conducting. Consequently, V_{out} becomes positive and the LED lights up. Making the other input voltage positive does not alter the situation. This is how an OR gate operates.

In practice, miniature logic gates are fabricated on tiny silicon chips. Entire circuits can be printed on a chip so small that it is invisible to naked eye. Such a circuit is called an integrated circuit.

The breadboard to be used in this experiment is shown in Fig. 4. The lines indicate internal connections.

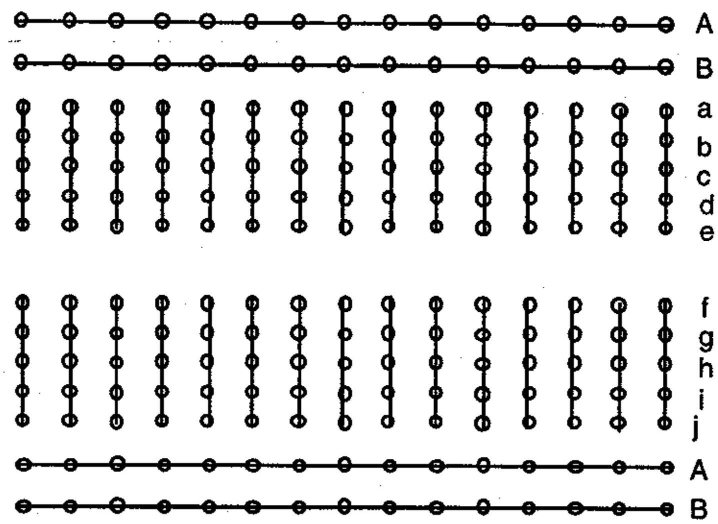


Fig. 4. Breadboard

Procedure:

Unit 1: AND Circuit:

In the following, row A and row B relate to the breadboard while input A and input B signify the inputs to the AND and OR gates. Points such as b2 and d1 indicate where the inputs A and B are applied to the gates.

(a) Make the circuit as shown in Fig. 3a using the breadboard. Connect the power supply (+ 5V) across row B at the top of the breadboard and the ground (negative of the power supply) to row A at the bottom. Remember that the silver end of the diode indicates the forward direction. Connect one diode between a2 (silver end) and a5, and the other diode between c1 (silver end) and c5. Connect the 1 KΩ resistor between row B (top) and b5. Connect the 220 Ω resistor between d5 and d7 and the LED between e7 and f7 (flat end). Connect j7 and row A (at the bottom). Input A is applied at b2 and input B, at d1.

(b) Connect both inputs, A (b2) and B (d1), to ground (A = 0 and B = 0) and fill in the output state (0 or 1) in the truth table (Data Sheet).

(c) Remove the wire connecting b2 to ground. Apply +5 V to input A (by connecting top B to b2) leaving input B grounded and write the output state in the truth table. Now apply +5 V to input B (by connecting top B to d1), connect input A (b2) to the ground and write the output state in the truth table. Finally, connect both inputs to +5 V and enter the output state in the truth table.

Unit 2: OR Circuit:

(d) Make the circuit as shown in Fig. 3b using the breadboard. Connect the power supply (+ 5V) across row B at the top of the breadboard and the ground (negative of the power supply) to row A at the bottom. Connect one diode between a2 and a5 (silver end) and the other diode between c1 and c5 (silver end). Connect the 1 KΩ resistor between e5 and f5. Connect the 220 Ω resistor between d5 and d7 and the LED between e7 and f7. Connect j7 and row A (at the bottom). Input A is applied at b2 and input B, at d1.

(e) Connect both inputs, A (b2) and B (d1), to ground (row A at the bottom). Thus input A = 0 and B = 0. Fill in the output state (0 or 1) in the truth table (Data Sheet).

(f) Apply +5 V to input A (by connecting top B to b2) leaving input B grounded and write the output state in the truth table. Now apply +5 V to input B (by connecting top B to d1), connect input A (b2) to the ground and write the output state in the truth table. Finally, connect both inputs to +5 V and enter the output state in the truth table.

Unit 3: OR To AND Circuit:

OR and AND gates can be connected to represent the following physical situation:

Consider a heavy safe that has to be carried. Two boys (Adam and Brad) together can not lift it. One man (Calvin) with the help of at least one boy can carry it. A truth table can be constructed to show all combinations of A, B and C. The states of A, B and C can be represented by 1 (working) and 0 (on a coffee break). The output column of the truth table will have 1 (if the safe can be moved) or 0 (if the safe can not be moved). This situation can be represented by a logic circuit shown in Fig. 5.

Instead of constructing the OR and AND gates using the diodes as in units 1 and 2, it is more convenient to employ commercial gates. Each commercial unit has four OR (or four AND) gates. There are fourteen pins in each unit. When the unit is mounted on the breadboard, its 7 pins are inserted in row e while the other 7 pins are inserted into row f. The recessed side should be on the left. Pin #14 (top left) receives the voltage (+5 V); pin #7 (bottom right) is connected to the ground. The inputs (A and B) and the output (x) of the first gate are pin #1, #2 and #3, respectively. The second gate is accessed by pins #4, #5 and #6, and so on and so forth.

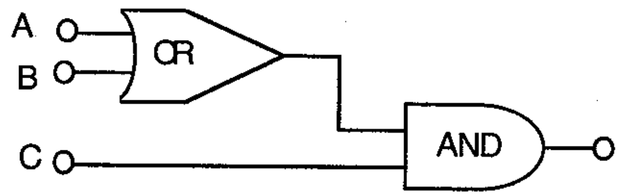


Fig. 5. OR to AND Circuit (Schematic)

(g) Make the circuit as shown in Fig. 6 using the breadboard. Connect the power supply (+ 5V) across row B at the top of the breadboard and the ground to row A at the bottom. Mount the OR-gate unit (7432) on the left side of the breadboard and the AND-gate unit (7408) on the right side. Connect pin #14 to top row B. Connect pin #7 of the OR unit to ground (bottom row A) and its pin #3 to pin #1 of the AND unit. Thus the output of the first OR gate will be fed to input A of the AND gate. The second input (B) for the AND gate will be fed to its pin #2. Connect a 220 Ω resistor and LED as shown in Fig. 6 below. Connect pins #14 of the OR-gate and the AND-gate unit to top row B of the breadboard and its pin #7 to the bottom row A (ground).

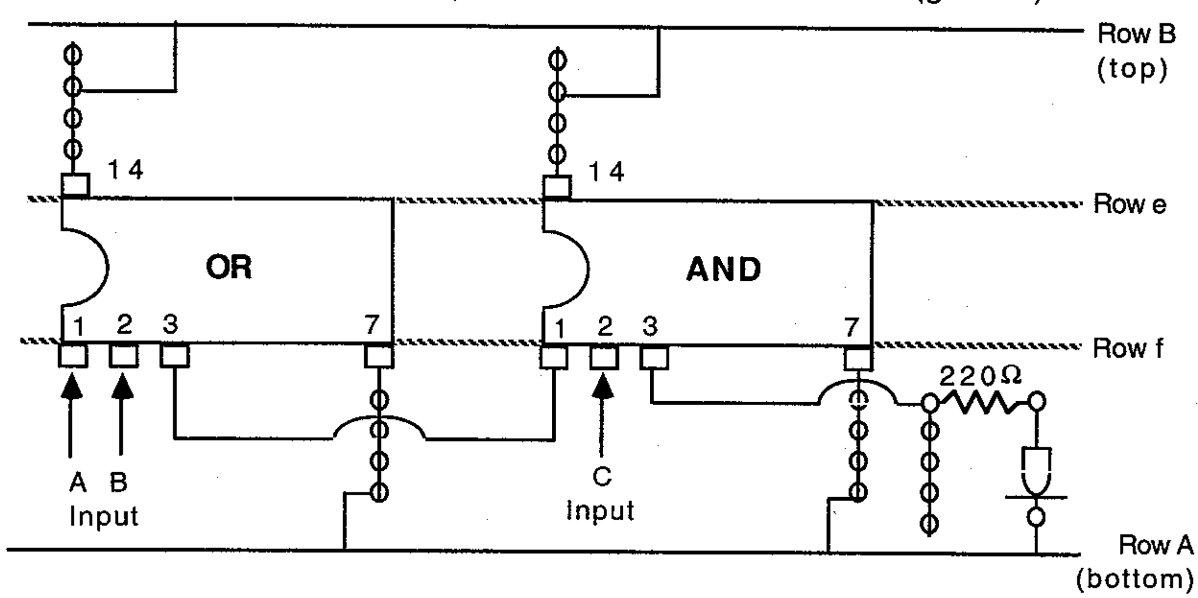


Fig. 6. OR To AND Combination Circuit.

(h) Apply different combinations of inputs to pin #1, pin #2 of the OR-gate unit and pin #2 of the AND-gate unit. Enter the output states in the truth table on the data sheet.

York College of The City University of New York

Physics II

Name:

Experiment No. 15: Pre-Lab Questionnaire

1. Why does a forward-biased pn junction diode allow a larger current than a reverse-biased pn junction?

2. When do we obtain an ON [1] output from an AND gate?

3. When do we obtain an ON [1] output from an OR gate?

4. Briefly describe an integrated circuit.

5. How are the first two gates of a four-gate commercial unit accessed?

Experiment No. 15

Name:	Marks:
Partner:	Remarks:
Section:	
Date Submitted:	

Title:

Objective:

Theory/Formulas:

Experiment 15. Introduction To Digital Circuits
DATA SHEET

Name: Partner:

Unit 1: Truth Table of AND Gate

Input states		Output state
A	B	X
0	0	
1	0	
0	1	
1	1	

Unit 2: Truth Table of OR Gate

Input states		Output state
A	B	X
0	0	
1	0	
0	1	
1	1	

Unit 3: Truth Table of OR To AND Gate

Input states			Output state
A	B	C	X
0	0	0	
1	0	0	
0	1	0	
1	1	0	
0	0	1	
1	0	1	
0	1	1	
1	1	1	