ENGINEERING GATORTRAX MATH EXCELLENCE PROJECT
ENGINEER-FOR-A-DAY LABORATORY MODULES

ELECTRICAL ENGINEERING
INTRODUCTORY GRADE LEVEL
BUILDING A BINARY MACHINE

Introduction

Electrical engineering is concerned with the uses of electrical energy. This energy is used in the various appliances, equipment, and instruments with which we come into contact on a daily basis. The key component of these appliances equipment and instruments is the electrical circuit. Using this circuit electrical engineers are able to design

- Communications systems
- Computers
- Electronic components for computers, stereos systems and TVs
- Robots
- Aircraft and spacecraft controls
- Utility and industrial power systems
- Biological/medical systems

Electrical circuits general contains

- Switches
- Resistors
- Connecting wires

Objective

The objective of this lab is to demonstrate the use of exponential in current technology.

Goal

Link the use of classroom mathematics to the real world.

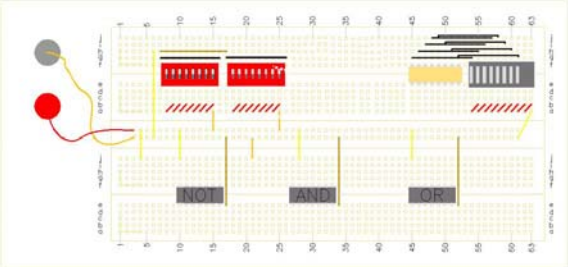
Activity Description/Problem Statement

Today we are electrical engineers who are responsible for working with binary numbers. The purpose of this lab is to build a Binary Machine from scratch. This machine is constructed with switches, and red lights. Follow the instructions step by step and answer all the questions.

Copyright © 2003, GATORTRAX. Created, Designed and Edited by Sandra C. Gonzalez and Afsheen Akbar

Materials for each Team
First, go through the material inside the box and make sure you have the following:

1. Designed board



2. Power supply

3. Multimeter

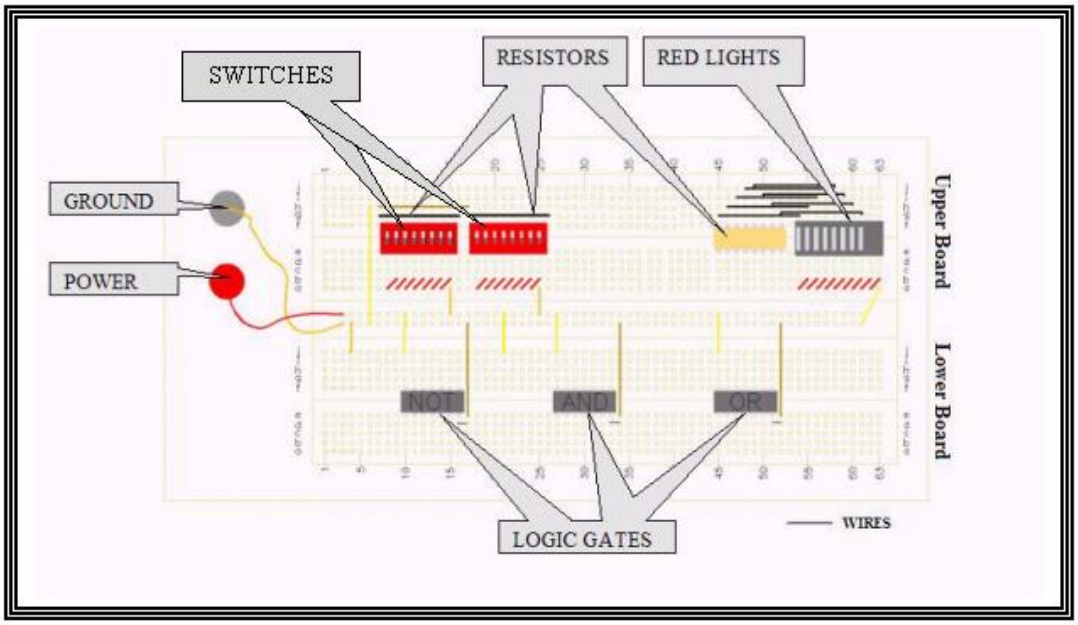
4. 3 1k Resistors (black and red)

5. 3 2.2k Resistors (red and red)

6. Wires

Copyright © 2003, GATORTRAX. Created, Designed and Edited by Sandra C. Gonzalez and Afsheen Akbar

Second, check that your board is complete by comparing it to the picture and checking with the check list below:



CHECK LIST	
	3 Resistors
	8 Red Lights (off)
	3 Logic Gates
	Power
	Ground
	Wires
	2 Set of Switches

- For the **CONNECTIONS SECTION** in each step you would be asked to place a wire from one point to another, this will be given in coordinates composed of one letter and a number. Also make the distinction between the upper and the bottom board. The **BOARD SCHEMATIC** will show the wire you are connecting at the given step but may not show all the wire that are connected at the moment, this is for simplicity reasons. To check all the connections that are supposed to take place at the moment refer to the CONNECTIONS section.

Copyright © 2003, GATORTRAX. Created, Designed and Edited by Sandra C. Gonzalez and Afsheen Akbar

GENERAL LAB PROCEDURES

For every single level step do the following:

CONNECTIONS:

1. Make the connections as listed in the **CONNECTIONS SECTION.** Use the **BOARD SCHEMATIC** to have a better view of where the connections take place. For an enlarge view of the **BOARD SCHEMATIC,** turn to the back of the page.

EXPERIMENT : OBSERVATION

2. After all the connections are made, use the circuit to find as many on/off combinations of the given switches. Use a pen or pencil to move the switches easily.

3. With a red pen or marker, record all the on/off combination found in the previous step by coloring the red light picture with the different results of light combination shown by the red lights, on the left column of the **EXPERIMENT LOG TABLE.**

BINARY NUMBERS :

4. After coloring all the possible on/off combinations of lights (HINT: As many combinations as rows available on the **EXPERIMENT LOG TABLE**), fill the middle part of the table by replacing a red light with 1 and no light with 0.
NOTE: The numbers have to be on the same order, from left to right, as displayed on the left column.

DECIMAL NUMBERS :

5. Rewrite each number, written in the white box of the BINARY NUMBER section of the table, in the shaded bottom portion of the box next to the exponential.

6. After filling out the bottom shaded part for each number, perform each of the calculation.

7. After the multiplications are done, add all the numbers of the same line and write the result on the DECIMAL NUMBER column.

Copyright © 2003, GATORTRAX. Created, Designed and Edited by Sandra C. Gonzalez and Afsheen Akbar

ACTIVITY LEVEL 1

BINARY PLACE: UNITS

CONNECTIONS:

1. Make the connections as listed in the **CONNECTIONS SECTION, Table 1.1.** Use the **BOARD SCHEMATIC** to have a better view of where the connections take place. For an enlarge view of the **BOARD SCHEMATIC, Figure 1,** turn to the back of the page.

	CONNECTIONS SECTION	
1	Uh25=>Ud52	
U= upper board	B= bottom board	

Table 1.1

EXPERIMENT : OBSERVATION

2. After all the connections are made, use the circuit to find as many on/off combinations of the given switch 8. Use a pen or pencil to move the switches easily.

3. With a red pen or marker, record in each row of **Table 1.2**, all the on/off combination found when using switch 8, by coloring the red light picture with the different results of light combination shown by the board's red lights, on the left column "Red Lights", of the **EXPERIMENT LOG TABLE, Table 1.2.**

EXPERIMENT LOG TABLE

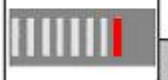
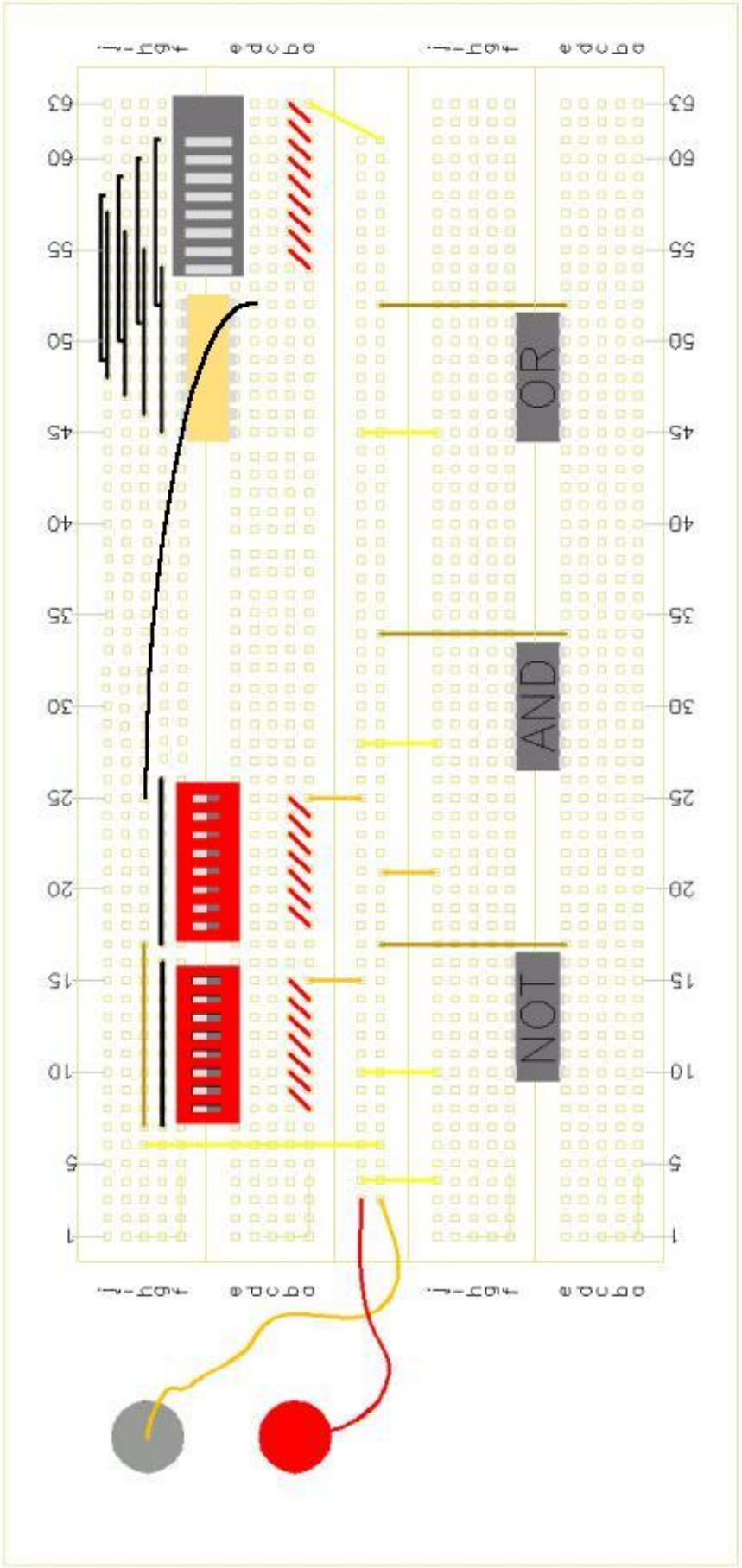
Red Lights	Binary Numbers	Decimal Numbers
	units	
	0 0×2^0 0 =	0
	1 1×2^0 1 =	1

Table 1.2

Copyright © 2003, GATORTRAX. Created, Designed and Edited by Sandra C. Gonzalez and Afsheen Akbar



Copyright ©

bar

BINARY NUMBERS :

4. After coloring all the possible on/off combinations of lights (HINT: As many combinations as rows available on the **EXPERIMENT LOG TABLE, Table 1.2**), fill the middle part of the table "Binary Number" by replacing a red light with 1 and no light with 0.
   NOTE: The numbers have to be on the same order, from left to right, as displayed on the left column.

DECIMAL NUMBERS :

5. Rewrite each number, written in the white box of the BINARY NUMBER section of the table, n the shaded bottom portion of the box next to the exponential.

6. After filling out the bottom part for each number, perform each of the calculation.

7. After the multiplications are done, add all the numbers of the same line and write the result on the DECIMAL NUMBER column.

Copyright © 2003, GATORTRAX. Created, Designed and Edited by Sandra C. Gonzalez and Afsheen Akbar

ACTIVITY LEVEL 2

BINARY PLACE: TWOS

CONNECTIONS:

1. Make the connections as listed in the **CONNECTIONS SECTION, Table 2.1.** Use the **BOARD SCHEMATIC** to have a better view of where the connections take place. For an enlarge view of the **BOARD SCHEMATIC, Figure 2,** turn to the back of the page.

	CONNECTIONS SECTION	
1	Uh25=>Ud52	✔
2	Uh24=>Ud51	
U= upper board	B= bottom board	

Table 2.1

EXPERIMENT : OBSERVATION

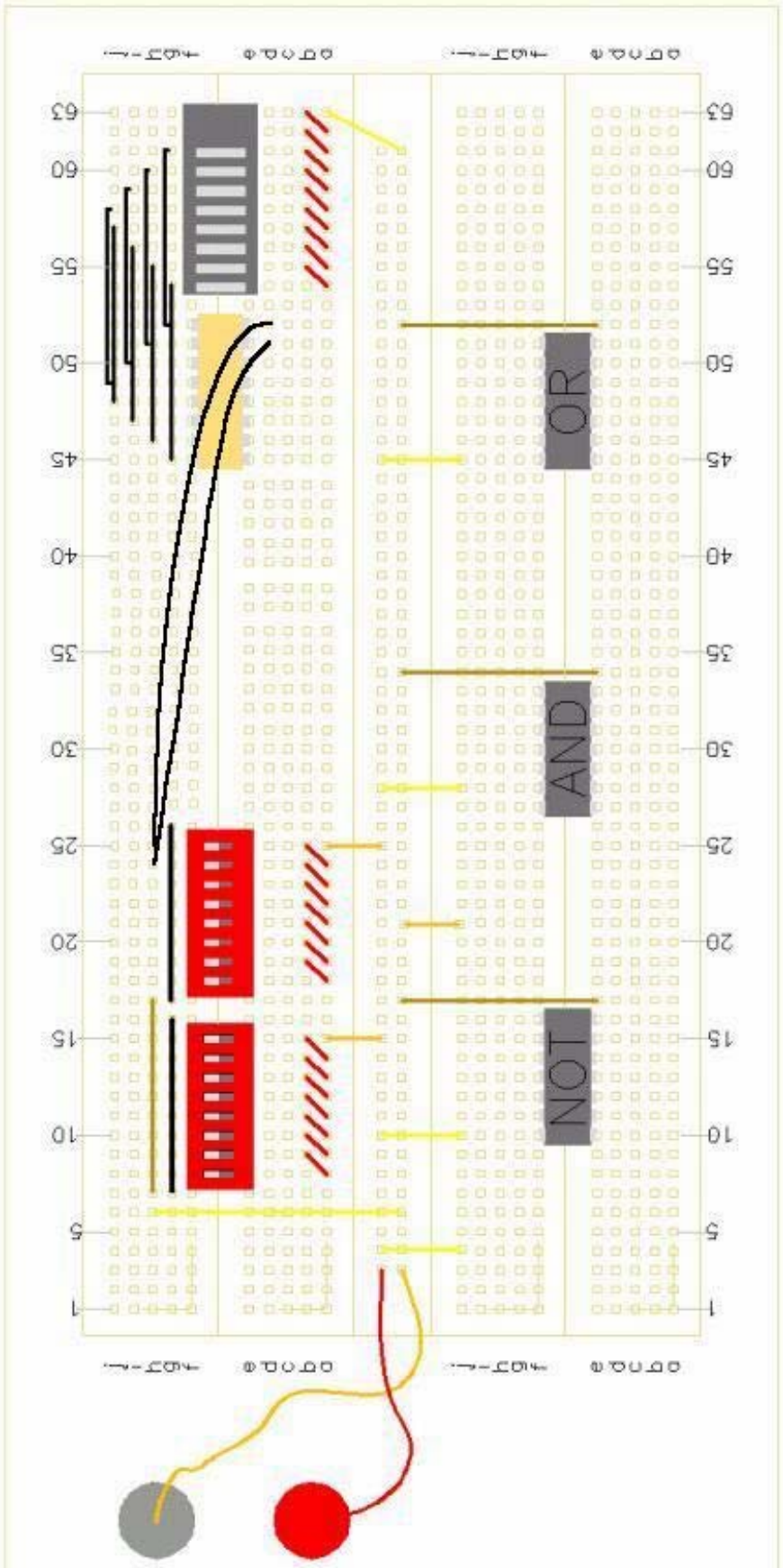
2. After all the connections are made, use the circuit to find as many on/off combinations of the switches 8 and 7. Use a pen or pencil to move the switches easily.

3. With a red pen or marker, record in each row of **Table 2.2**, all the on/off combination found when using switch 8 and 7, by coloring the red light picture with the different results of light combination shown by the board's red lights, on the left column "Red Lights", of the **EXPERIMENT LOG TABLE, Table 2.2.**

BINARY NUMBERS :

4. After coloring all the possible on/off combinations of lights (HINT: As many combinations as rows available on the **EXPERIMENT LOG TABLE, Table 2.2, below**), fill the middle part of the table "Binary Number", by replacing a red light with 1 and no light with 0.
NOTE: The numbers have to be on the same order, from left to right, as displayed on the left column.

Copyright © 2003, GATORTRAX. Created, Designed and Edited by Sandra C. Gonzalez and Afsheen Akbar



Copyright ©

EXPERIMENT LOG TABLE

Red Lights	Binary Numbers								Decimal Numbers
							twos	units	
							0	0	0
							0×2^1 +	0×2^0	
							0 +	0 =	
							0	1	1
							0×2^1 +	1×2^0	
							0 +	1 =	
							1	0	2
							1×2^1 +	0×2^0	
							2 +	0 =	
							1	1	3
							1×2^1 +	1×2^0	
							2 +	1 =	

Table 2.2

DECIMAL NUMBERS :

5. Rewrite each number, written in the white box of the BINARY NUMBER section of the table, n the shaded bottom portion of the box next to the exponential.

6. After filling out the bottom part for each number, perform each of the calculation.

7. After the multiplications are done, add all the numbers of the same line and write the result on the DECIMAL NUMBER column.

Copyright © 2003, GATORTRAX. Created, Designed and Edited by Sandra C. Gonzalez and Afsheen Akbar

ACTIVITY LEVEL 3

BINARY PLACE: FOURS

CONNECTIONS:

1. Make the connections as listed in the **CONNECTIONS SECTION, Table 3.1.** Use the **BOARD SCHEMATIC** to have a better view of where the connections take place. For an enlarge view of the **BOARD SCHEMATIC, Figure 3,** turn to the back of the page.

	CONNECTIONS SECTION	
1	Uh25=>Ud52	✔
2	Uh24=>Ud51	✔
3	Uh23=>Ud50	
U= upper board	B= bottom board	

Table 3.1

EXPERIMENT : OBSERVATION

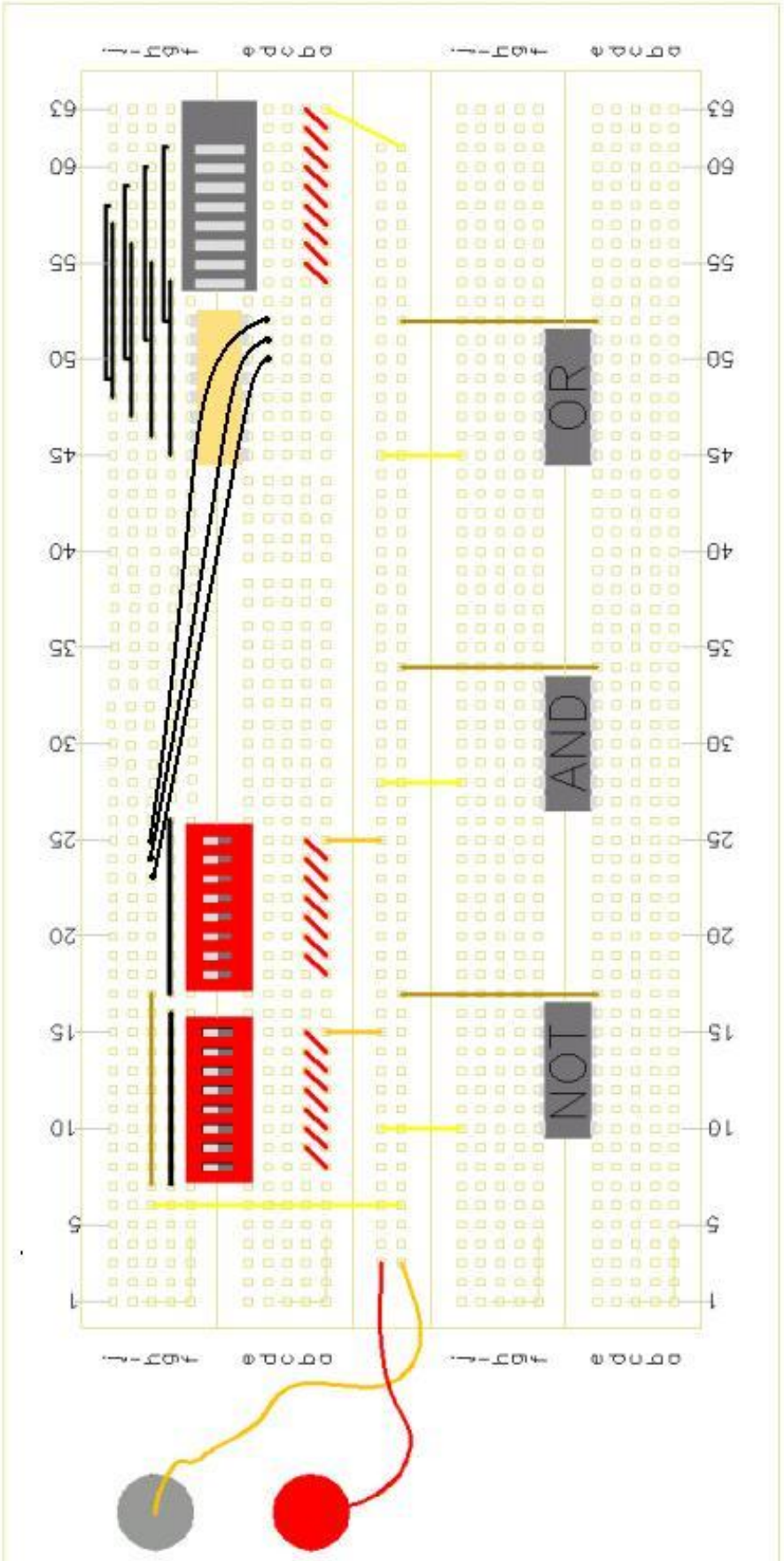
2. After all the connections are made, use the circuit to find as many on/off combinations of the given switches 8, 7 and 6. Use a pen or pencil to move the switches easily.

3. With a red pen or marker, record in each row of **Table 3.2**, all the on/off combination found when using switch 8,7 and 6, by coloring the red light picture with the different results of light combination shown by the board's red lights, on the left column "Red Lights", of the **EXPERIMENT LOG TABLE, Table 3.2.**

BINARY NUMBERS :

4. After coloring all the possible on/off combinations of lights (HINT: As many combinations as rows available on the **EXPERIMENT LOG TABLE, Table3.2, below**), fill the middle part of the table "Binary Number", by replacing a red light with 1 and no light with 0.
NOTE: The numbers have to be on the same order, from left to right, as displayed on the left column.

Copyright © 2003, GATORTRAX. Created, Designed and Edited by Sandra C. Gonzalez and Afsheen Akbar


OR
AND
NOT

Write the binary equivalent.

EXPERIMENT LOG TABLE

Red Lights	Binary Numbers (fours)	(twos)	(units)	Decimal Numbers
	0	0	0	0
	$0 \times 2^2 + 0 \times 2^1 + 0 \times 2^0$			
	0 + 0 + 0 =			
	0	0	1	1
	$0 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$			
	0 + 0 + 1 =			
	0	1	0	2
	$0 \times 2^2 + 1 \times 2^1 + 0 \times 2^0$			
	0 + 2 + 0 =			
	0	1	1	3
	$0 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$			
	0 + 2 + 1 =			
	1	0	0	4
	$1 \times 2^2 + 0 \times 2^1 + 0 \times 2^0$			
	4 + 0 + 0 =			
	1	0	1	5
	$1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0$			
	4 + 0 + 1 =			
	1	1	0	6
	$1 \times 2^2 + 1 \times 2^1 + 0 \times 2^0$			
	4 + 2 + 0 =			
	1	1	1	7
	$1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0$			
	4 + 2 + 1 =			

Table 3.2

Copyright © 2003, GATORTRAX. Created, Designed and Edited by Sandra C. Gonzalez and Afsheen Akbar

DECIMAL NUMBERS :

5. Rewrite each number, written in the white box of the BINARY NUMBER section of the table, n the shaded bottom portion of the box next to the exponential.

6. After filling out the bottom part for each number, perform each of the calculation.

7. After the multiplications are done, add all the numbers of the same line and write the result on the DECIMAL NUMBER column.

Copyright © 2003, GATORTRAX. Created, Designed and Edited by Sandra C. Gonzalez and Afsheen Akbar

FINAL STEP

Now organize all the decimal numbers in ascending order from 0 to 7 and write the binary equivalent on the Binary Number column.

Red Lights	Binary Numbers								Decimal Numbers
						fours	twos	units	
						0	0	0	0
						0×2^2 +	0×2^1 +	0×2^0	
						0 +	0 +	0 =	
						0	0	1	1
						0×2^2 +	0×2^1 +	1×2^0	
						0 +	0 +	1 =	
						0	1	0	2
						0×2^2 +	1×2^1 +	0×2^0	
						0 +	2 +	0 =	
						0	1	1	3
						0×2^2 +	1×2^1 +	1×2^0	
						0 +	2 +	1 =	
						1	0	0	4
						1×2^2 +	0×2^1 +	0×2^0	
						4 +	0 +	0 =	
						1	0	1	5
						1×2^2 +	0×2^1 +	1×2^0	
						4 +	0 +	1 =	
						1	1	0	6
						1×2^2 +	1×2^1 +	0×2^0	
						4 +	2 +	0 =	
						1	1	1	7
						1×2^2 +	1×2^1 +	1×2^0	
						4 +	2 +	1 =	

Table 4.1

Copyright © 2003, GATORTRAX. Created, Designed and Edited by Sandra C. Gonzalez and Afsheen Akbar

EXTRA CREDIT ACTIVITY

BINARY PLACE: EIGHTS

1. Analyze the final step table, **Table 4.1**.
2. Try to find a pattern in binary number by filling out the **Table 5.1** and estimating the unknown values from 0-15. (HINT: Look how numbers are repeated for each defined column)

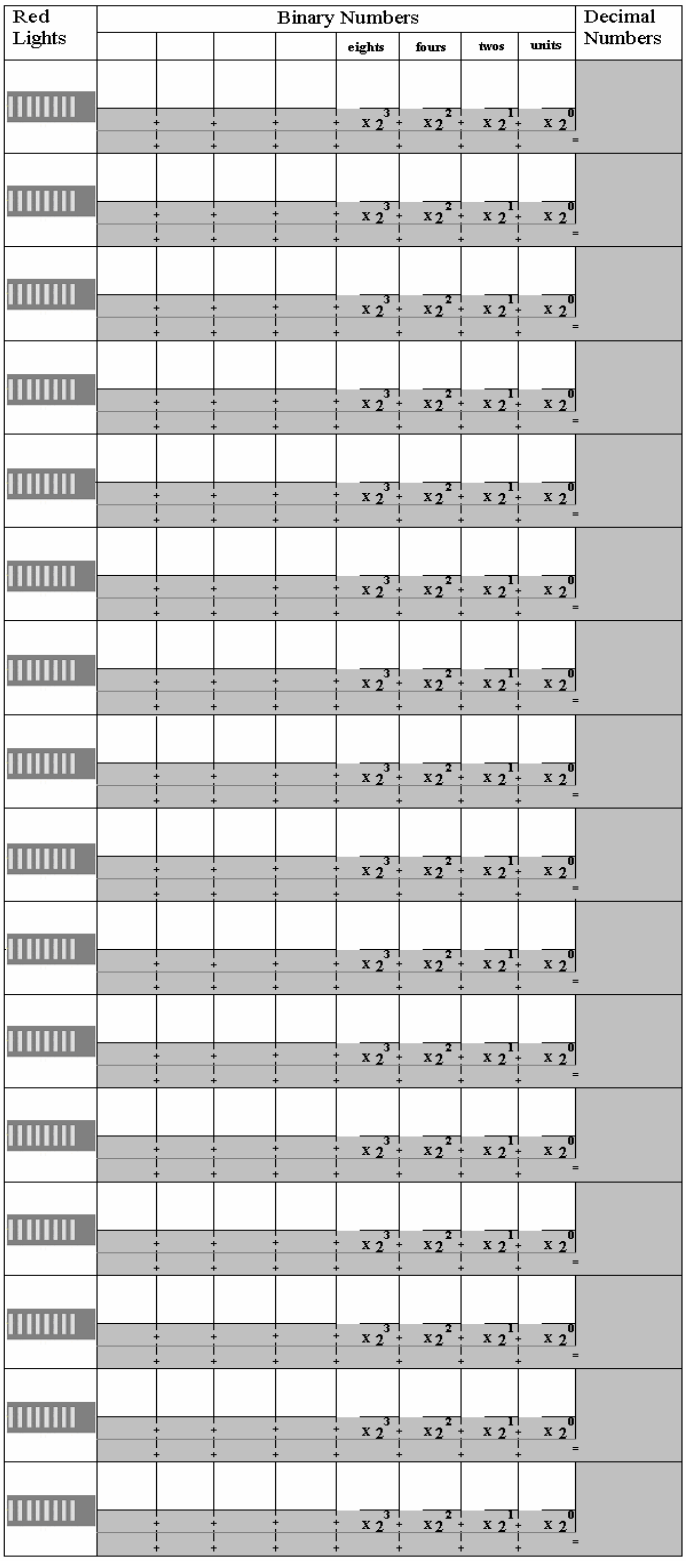


Table 5.1

3. Check you answer for **Table 5.1** by using the circuit and the connections given below.

CONNECTIONS:

1. Make the connections as listed in the **CONNECTIONS SECTION, Table 5.2.** Use the **BOARD SCHEMATIC** to have a better view of where the connections take place. For an enlarge view of the **BOARD SCHEMATIC, Figure 1,** turn to the back of the page.

	CONNECTIONS SECTION	
1	Uh25=>Ud52	✔
2	Uh24=>Ud51	✔
3	Uh23=>Ud50	✔
4	Uh22=>Ud49	
U= upper board	B= bottom board	

Table 5.2

EXPERIMENT : OBSERVATION

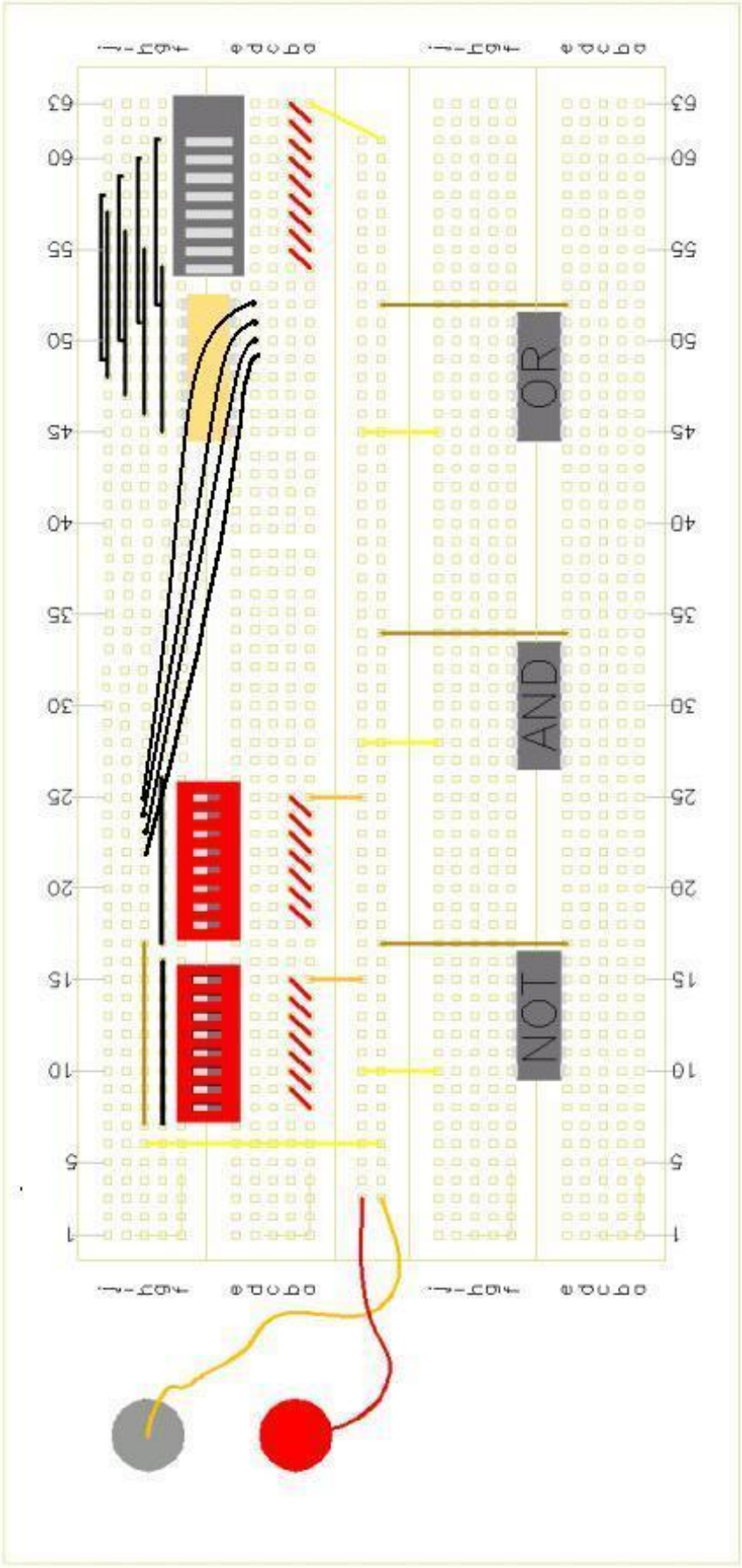
2. After all the connections are made, use the circuit to find as many on/off combinations of the given switches 8, 7,6 and 5. Use a pen or pencil to move the switches easily.

3. With a red pen or marker, record in each row of Table 5.2, all the on/off combination found when using switch 8,7,6 and 5, by coloring the red light picture with the different results of light combination shown by the board's red lights, on the left column "Red Lights", of the **EXPERIMENT LOG TABLE, Table 5.2.**

BINARY NUMBERS :

4. After coloring all the possible on/off combinations of lights (HINT: As many combinations as rows available on the **EXPERIMENT LOG TABLE, Table 5.2, below**), fill the middle part of the table "Binary Number", by replacing a red light with 1 and no light with 0.
NOTE: The numbers have to be on the same order, from left to right, as displayed on the left column.

Copyright © 2003, GATORTRAX. Created, Designed and Edited by Sandra C. Gonzalez and Afsheen Akbar


OR
AND
NOT

DECIMAL NUMBERS :

5. Rewrite each number, written in the white box of the BINARY NUMBER section of the table, n the shaded bottom portion of the box next to the exponential.

6. After filling out the bottom part for each number, perform each of the calculation.

7. After the multiplications are done, add all the numbers of the same line and write the result on the DECIMAL NUMBER column.

Copyright © 2003, GATORTRAX. Created, Designed and Edited by Sandra C. Gonzalez and Afsheen Akbar

EXPERIMENT LOG TABLE (Check your estimated binary numbers values with the circuit.)

Red Lights	Binary Numbers								Decimal Numbers
					eights	fours	twos	units	
	+	+	+	+	$x\,2^3$ +	$x\,2^2$ +	$x\,2^1$ +	$x\,2^0$ =	
	+	+	+	+	$x\,2^3$ +	$x\,2^2$ +	$x\,2^1$ +	$x\,2^0$ =	
	+	+	+	+	$x\,2^3$ +	$x\,2^2$ +	$x\,2^1$ +	$x\,2^0$ =	
	+	+	+	+	$x\,2^3$ +	$x\,2^2$ +	$x\,2^1$ +	$x\,2^0$ =	
	+	+	+	+	$x\,2^3$ +	$x\,2^2$ +	$x\,2^1$ +	$x\,2^0$ =	
	+	+	+	+	$x\,2^3$ +	$x\,2^2$ +	$x\,2^1$ +	$x\,2^0$ =	
	+	+	+	+	$x\,2^3$ +	$x\,2^2$ +	$x\,2^1$ +	$x\,2^0$ =	
	+	+	+	+	$x\,2^3$ +	$x\,2^2$ +	$x\,2^1$ +	$x\,2^0$ =	
	+	+	+	+	$x\,2^3$ +	$x\,2^2$ +	$x\,2^1$ +	$x\,2^0$ =	
	+	+	+	+	$x\,2^3$ +	$x\,2^2$ +	$x\,2^1$ +	$x\,2^0$ =	
	+	+	+	+	$x\,2^3$ +	$x\,2^2$ +	$x\,2^1$ +	$x\,2^0$ =	
	+	+	+	+	$x\,2^3$ +	$x\,2^2$ +	$x\,2^1$ +	$x\,2^0$ =	
	+	+	+	+	$x\,2^3$ +	$x\,2^2$ +	$x\,2^1$ +	$x\,2^0$ =	
	+	+	+	+	$x\,2^3$ +	$x\,2^2$ +	$x\,2^1$ +	$x\,2^0$ =	
	+	+	+	+	$x\,2^3$ +	$x\,2^2$ +	$x\,2^1$ +	$x\,2^0$ =	
	+	+	+	+	$x\,2^3$ +	$x\,2^2$ +	$x\,2^1$ +	$x\,2^0$ =	

Table 5.3

Copyright © 2(...) heen A(...)