Discrete Maths - Digital Logic
Laboratory 1: Protoboard and Logic Gates

2007 September 14 edition

Assessment Criteria

Assessment in these labs based on these performance measures:

1. Mastery of Boolean Logic;
2. Adherence to Design Principles;
3. Circuit construction;
4. Record of Results;
5. Tidying up after yourself.

1 Equipment List

1. 5V power supply
2. Protoboard
3. I/O board
4. 74LS04 (Inverter) integrated circuit
5. 74LS08 (AND)
6. 74LS32 (OR)
7. Single strand hook-up wire
8. Cutters
9. Pliers

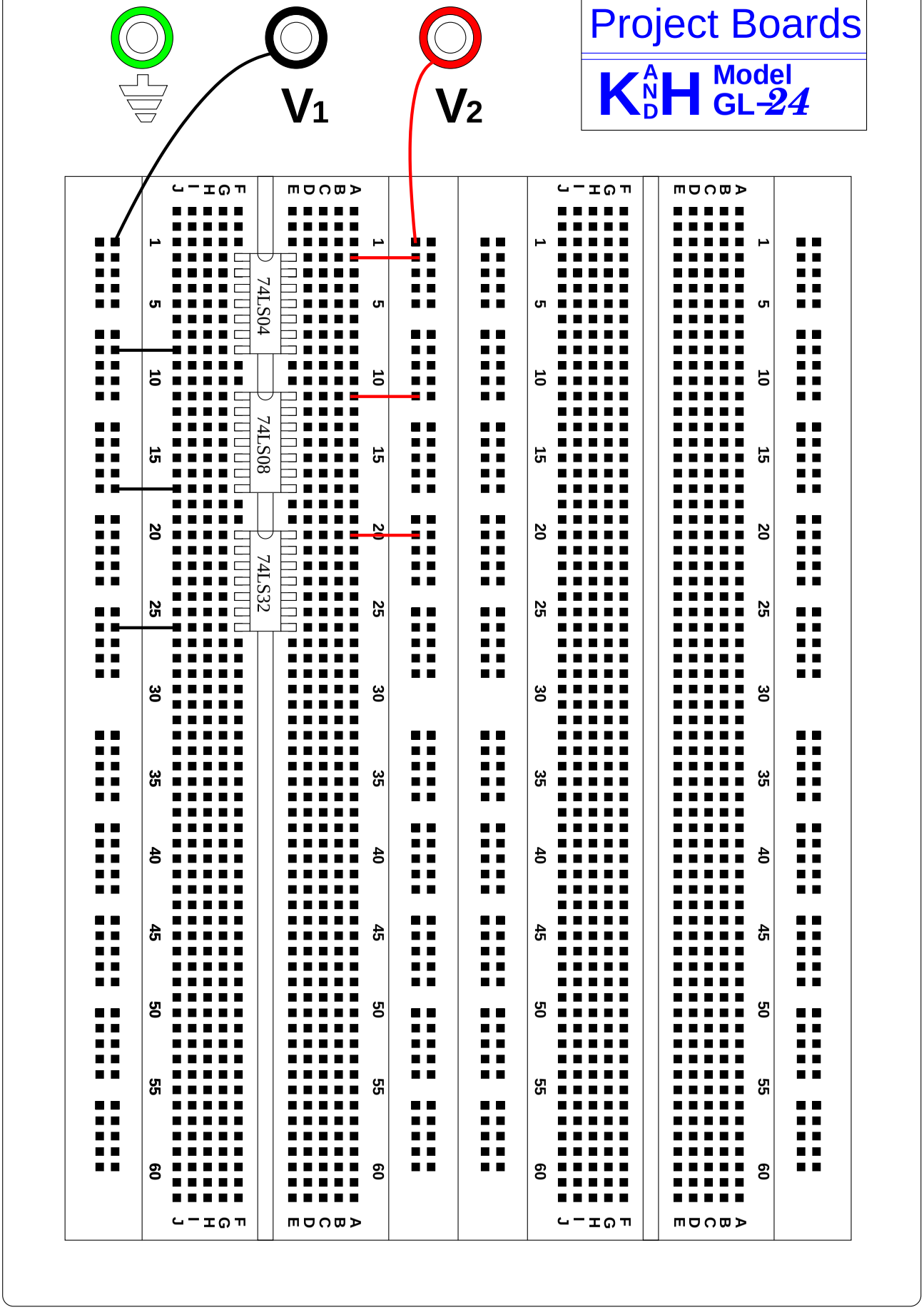
2 Use of Protoboard

Make sure that the power supply is **switched off**. Fetch a black and a red cord from the racks, plug one end of each into the +5V (red) and GND (black) sockets of the supply, and the other end into the binding post of the same color on the protoboard. *See the diagram below.* Now obtain about 20 cm each of red and black hookup wire from the container at the front of the laboratory. Cut these into several lengths of three and five cm, and remove about seven or eight mm of insulation from both ends of each wire. Use these wires to connect from the holes in the binding posts to the +5 and GND power rails on the board, exactly as shown.

Place the ICs (integrated circuits) as indicated. In these dual inline IC packages, the connection pins are arranged **anticlockwise** from the top left. Most 14 pin ICs have GND at pin 7 on the lower left corner, and Vcc (the +5 supply) at pin 14 on the upper right corner; this is true for the ICs we will be using today. The top of the IC is indicated by a notch, and sometimes there is a dot or a circular indentation near pin 1.

Make sure that each IC is right side up, and that you connect a black wire from the GND rail to the IC's GND pin, and a red wire from the +5V rail to the Vcc pin. If this is done wrongly, the IC will be destroyed. A symptom of this mistake is that the IC is too hot to touch.

When placing or removing ICs, do so gently, as the metal pins are frail and easily bend and break, making the IC useless. Static electricity on your hands or clothing can also harm ICs. Damage to ICs delays your work, and adds to your fees, so please be careful when handling them.



OVER/

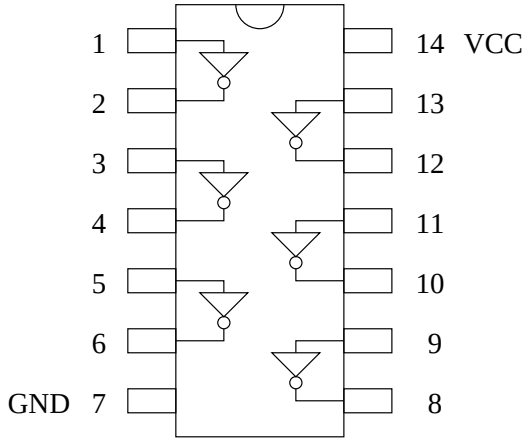
3 I/O board

Each group will be provided with a printed circuit board (PCB) containing several switches and LEDs (light emitting diodes), which you can use to set inputs and observe outputs of your circuits.

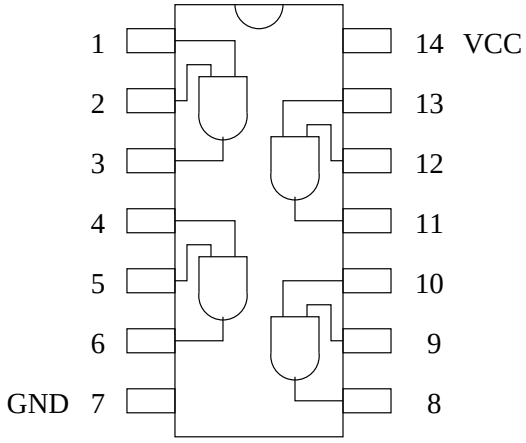
4 Basic Logic Gates

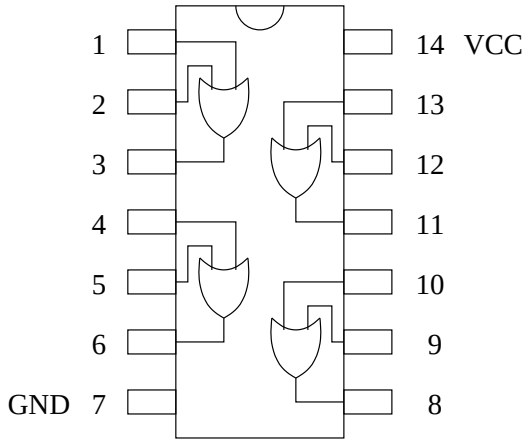
In the first experiment, we will test whether the AND, OR and NOT gates in the ICs satisfy the expected truth tables. Each IC contains several gates, which are arranged as shown in the following pinout diagrams.

74LS04 HEX NOT



74LS08 QUAD AND

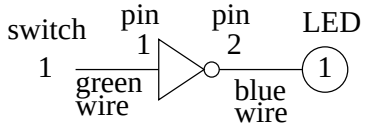




74LS32 QUAD OR

4.1 NOT gate

Obtain two lengths of hookup wire, of different colors, *but not* red or black. Use them to wire up the top left gate from the 74LS04 Inverter IC with its input (pin 1) coming from one of the switches, and its output (pin 2) going to one of the LEDs. I recommend that you follow this diagram:

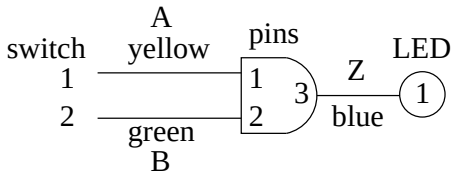


There are two possible inputs, 0 and 1 (switch OFF and switch ON, which connect to GND and +5V respectively). Observe the outputs (the LED is bright when the gate's output is 1 and dark when it's 0), and record them in the following truth table.

Input	Output
0	
1	

4.2 AND gate

The 74LS08 IC has four 2-input AND gates. Again choose the top left one (input pins 1 and 2, output pin 3), and test it as you did for the NOT gate. You will need to use two switches. It's best if you use a differently colored wire for each logic input and output, to clearly distinguish the different signals in the circuit.

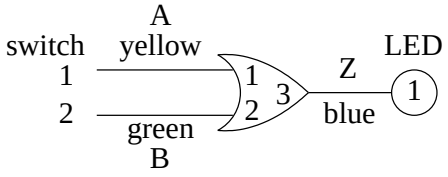


Conventionally the inputs to a combinational logic circuit are labelled A, B, C, etc, (early letters of the alphabet) and the outputs and other signals are labelled Z, Y, etc (late letters). *Hint:* You may find it quicker to test the AB input combinations in the order 00, 01, 11, then 10.

A	B	Z
0	0	
0	1	
1	0	
1	1	

4.3 OR gate

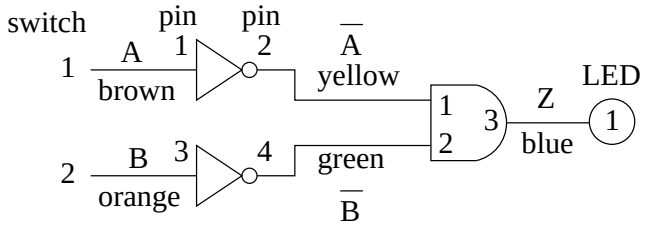
The 74LS32 quad 2-input OR gate IC ('quad' meaning four gates) is arranged in the same way as the AND gate IC of the previous section, so wire it up and test it in the same manner.



A	B	Z
0	0	
0	1	
1	0	
1	1	

5 De Morgan's Theorems

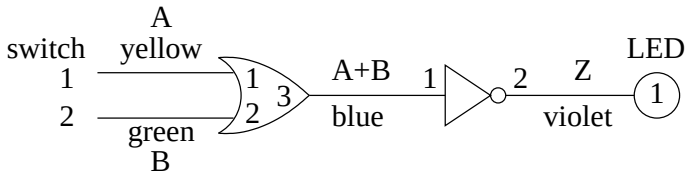
Let's demonstrate one of Augustus de Morgan's theorems relating AND, OR and NOT, by using our three ICs. Connect two switches to two NOT gates, connect their outputs to the inputs of an AND gate, connect its output to a LED.



Record the circuit's truth table.

A	B	Z
0	0	
0	1	
1	0	
1	1	

Replace that circuit with one in which the two switches are connected to the inputs of an OR gate, and connect its output to the input of a single NOT gate.



Observe its output on a LED.

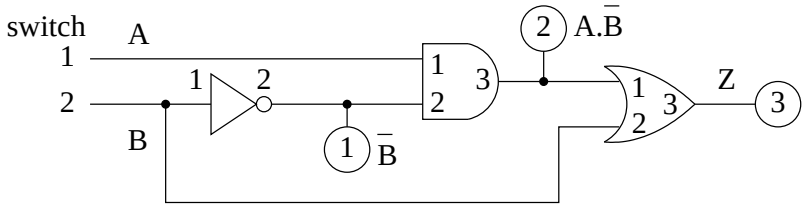
A	B	Z
0	0	
0	1	
1	0	
1	1	

We could also reverse the roles of AND and OR, to illustrate the other de Morgan theorem, but it wouldn't add anything qualitatively new, so having proven the point, let's move on.

6 More complex combinational circuits

6.1 Complex circuit 1

The following logic circuit implements the boolean formula $Z = A.\overline{B} + B$. It needs two switches and three LEDs.



Choose colors for the wires carrying each of the five (5) signals by completing this **color table**.

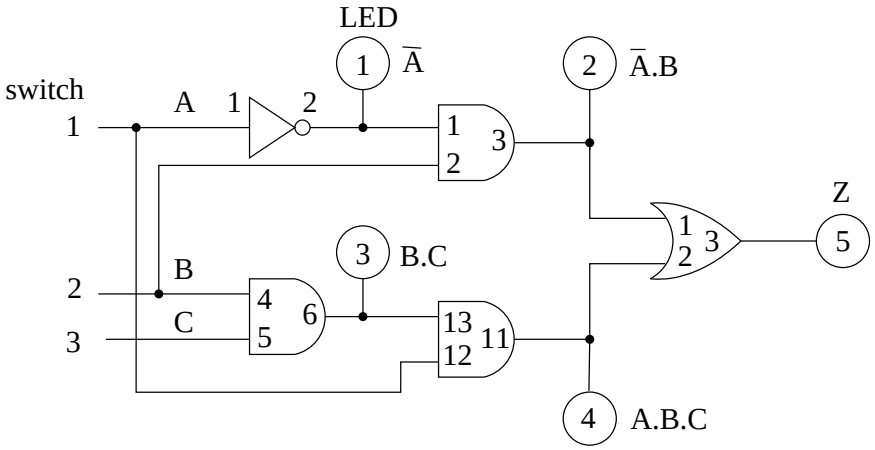
Signal	Color
A	
B	
$\overline{B}$	
$A.\overline{B}$	
Z	

Build the circuit, and record your observations in this table.

A	B	$\overline{B}$	$A.\overline{B}$	Z
0	0			
0	1			
1	0			
1	1			

6.2 Complex circuit 2

This circuit requires three switches and five LEDs. Incidentally, if you create circuits at random, there are surprisingly many that constantly give 0 or constantly give 1 at their output; we may hope that purpose-built circuits won't behave like that.



Complete the color table for this circuit.

Signal	Color
A	
B	
C	
$\overline{A}$	
$\overline{A}$.B	
B.C	
A.B.C	
Z	

Build the circuit, and record your results here.

A	B	C	$\overline{A}$	$\overline{A}$.B	B.C	A.B.C	Z
0	0	0					
0	0	1					
0	1	0					
0	1	1					
1	0	0					
1	0	1					
1	1	0					
1	1	1					

7 Cleaning Up

Tidying-up rules:

1. Do **NOT** attempt to remove any IC from the board.
2. **DO** switch off all instruments, return every cord, wire and board to its proper place, clean your bench, and pick up any debris from the carpet.

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END.