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PHYS 219: Experiment 5 – Digital Basics

A) Verify the truth table for one of the gates available in the laboratory.

First, we will verify the truth table for the quad 2 input NAND chip (MC74HC00A)
The chip is inserted in the middle, across the ravine in the breadboard. We powered one rail to 5V and another rail is connected to ground. The chip is powered by connecting short wires from the power and ground rails to the power and ground pins on the chip (power is pin14 and ground is pin7).

We then connected a push button to the A1 pin, another button to the B1 pin. The Y1 output is connected to the BNC, which is connected to the oscilloscope. We will use the oscilloscope to measure the output voltage for all the possible inputs.

For the output:

- 0 – Voltage reading on the oscilloscope is 0.00mV
- 1 – Voltage reading on the oscilloscope is 5.04V

For the rest of this experiment, 0 represents 0V or false; 1 represents 5.04V, or true.

Truth Table for NAND chip

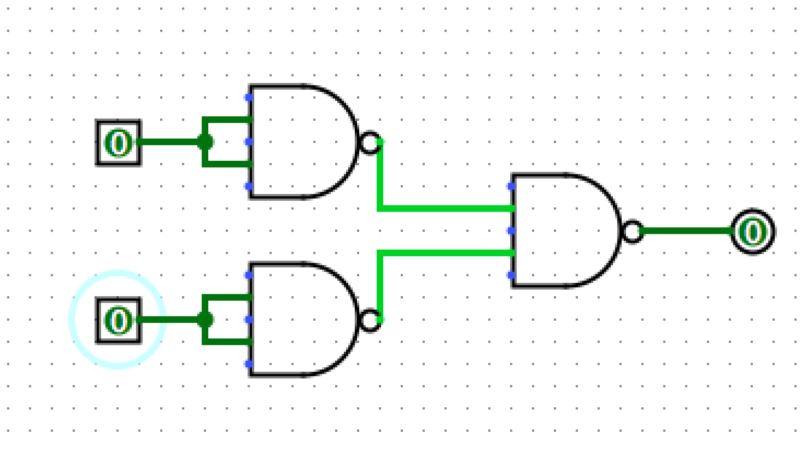
A1 (first input)	B1 (second input)	Y1 (output)
0	0	1
0	1	1
1	0	1
1	1	0

This truth table matches the truth table for NAND gates.

B) To construct the OR gate using only NAND gates we used the following logical equivalences from DeMorgan's law (applied twice). P and Q are our two inputs.

$$P \vee Q \equiv \sim(\sim P \wedge \sim Q)$$
$$\equiv \sim(\sim(P \wedge P) \wedge \sim(Q \wedge Q))$$

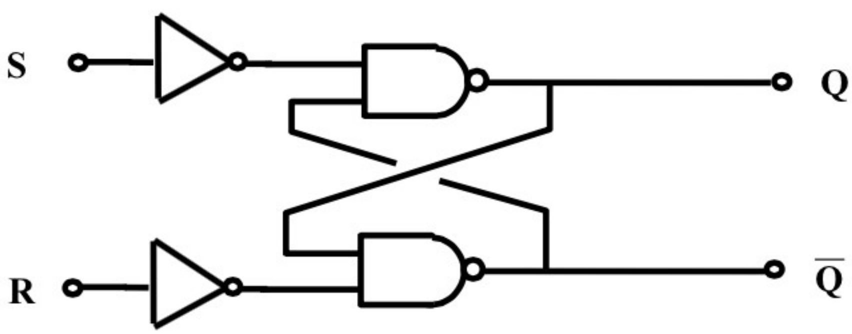
We tested this circuit in the Logisim software before building it on the breadboard.



Truth Table for the Above Circuit

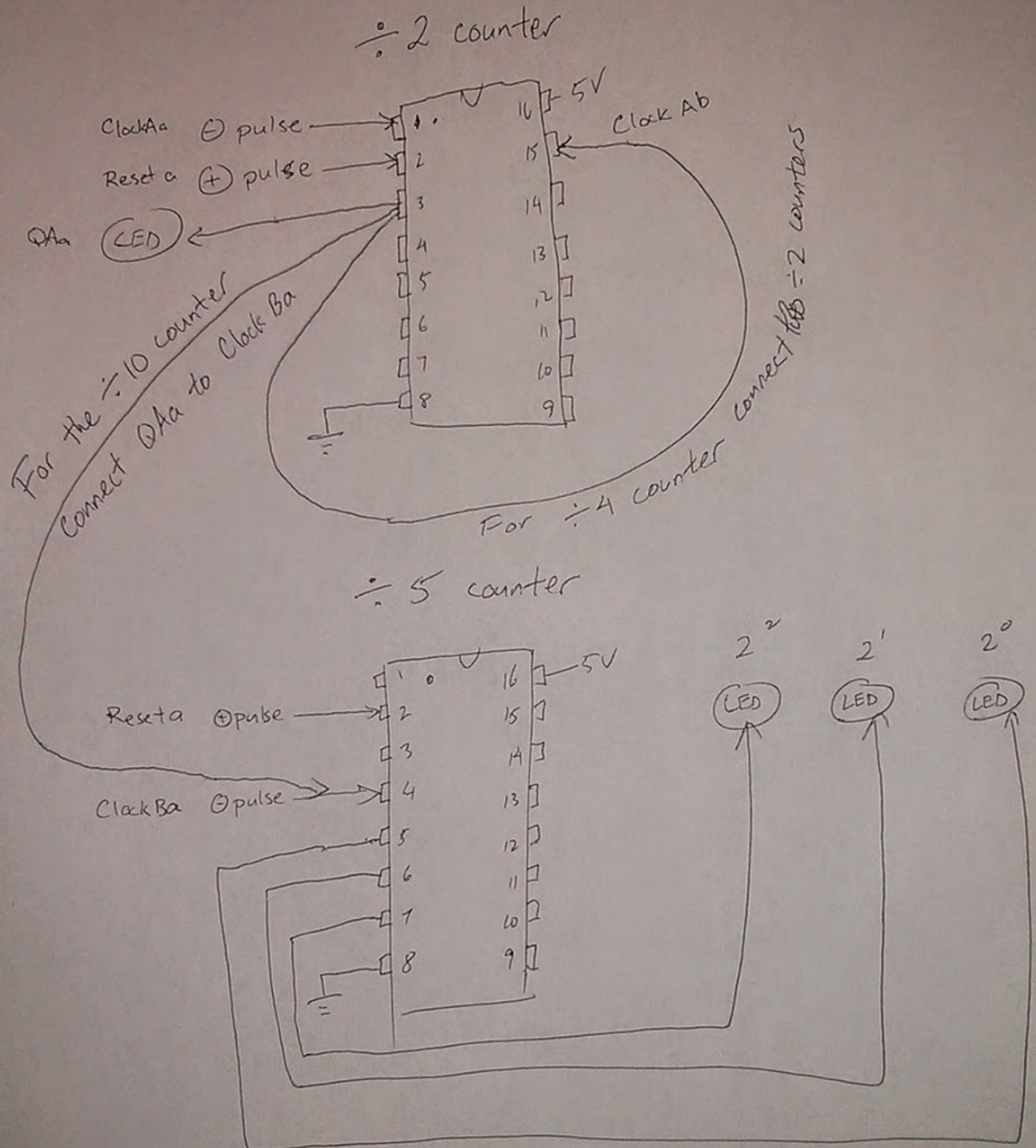
Input 1	Input2	Output
0	0	0
0	1	1
1	0	1
1	1	1

This truth table from testing the physical circuit verifies that the circuit does behave like an OR gate.



We used the 74HC14 Hex Schmitt-Trigger Inverter and the NAND chip from the previous part to construct the following circuit. Using, the oscilloscope, we verified that the outputs are always opposite the other (except for a brief moment when the buttons are pressed). There are always a line at V = 5.04V and another line at V= 0.00mV. When a button is pressed, the yellow line (channel 1) and the blue line (channel 2) switch places.

We used the Dual 4-Stage Binary Ripple Counter with ÷2 and ÷5 Sections (MC54/74HC390) the way we connected the wires for the different counters is illustrated below.



÷2 counter
5V
ClockAa ⊖ pulse
Reset a ⊕ pulse
Clock Ab
QAa
LED
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
For the ÷10 counter
Connect QAa to Clock Ba
For ÷4 counter connect ~~both~~ ÷2 counters
÷5 counter
5V
Reset a ⊕pulse
Clock Ba ⊖pulse
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
2²
2¹
2⁰
LED
LED
LED

Note the table for binary counting:

LED 4 (8)	LED 3 (4)	LED 2 (2)	LED 1 (1)	Decimal representation
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	0	0	8
1	0	0	1	9

For the ÷2 counter, we connected negative pulse push button to pin 1 (ClockAa) and the positive push button to pin 2 (Reset a). We connected the output (pin 3 Qaa) to an LED. The LED turns on and off when the Clock button is pressed. The reset button always sets the LED to off. This represents counting from 0 (LED off) to 1 (LED on) in binary.

Sequential Truth Table For ÷ 2 Counter

LED Previous	LED Out
0	1
1	0

For the ÷5 counter, we connected the positive pulse to pin 2 (reset a) and the negative pulse to pin 4 (Clock Ba). Pin 5 goes to LED 1(representing the 2^0 place), pin 6 goes to LED 2 (representing the 2^1 place), and pin 7 goes to LED 3 (representing the 2^2 place).

The LED's followed this pattern, changing to the next row each time the clock is pressed. When it reaches the last pattern, the pattern start again from the top. This is counting from 0 to 4 in binary.

LED 3 (2^2)	LED 2 (2^1)	LED 1 (2^0)	Decimal Representation
0	0	0	0
0	0	1	1
0	1	0	2
0	1	1	3
1	0	0	4

For the decade counter, we connected the output of the ÷2 counter (pin 3) to the Clock input of the ÷5 counter (pin 4). The following table shows the pattern of the LED's as the Clock for the ÷2 counter is pushed (pin 1). As before the pattern repeats when it reaches the end of the rows. This represents counting from 0 to 9 in binary.

LED 4 (8)	LED 3 (4)	LED 2 (2)	LED 1 (1)	Decimal representation
0	0	0	0	0
0	0	0	1	1
0	0	1	0	2
0	0	1	1	3
0	1	0	0	4
0	1	0	1	5
0	1	1	0	6
0	1	1	1	7
1	0	0	0	8
1	0	0	1	9

For the ÷4 counter we just connected two ÷2 counters together. This lets the circuit count from 0 to 3 in binary.

LED 2 (2^1)	LED 1 (2^0)	Decimal Representation
0	0	0
0	1	1
1	0	2
1	1	3