CS 2461: Lab 2
Using Integrated Circuits to Build Logic Circuits Using Multimeters

© 2018 Narahari, Shepherd, Preisner
© 2020 Miller, Morin

1

CS 2461 Lab 2: Digital Logic

- Recap last week
  - Ohm's Law
  - Building a simple circuit
    - Using Breadboard, LED, Resistors
- Today:
  - Intro to 7400 Series Logic chips
  - Reading a datasheet
  - Designing your first Digital Logic circuit
  - Using multimeters – Tinkercad
    - preparing wires and using wire stripper, prepping power supply

2

Pop quiz!

1. What is Ohm's law?

3

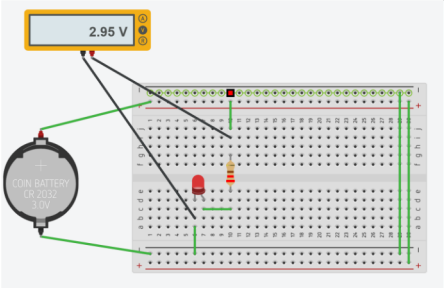
What is a Multimeter?

- Device used to measure
  - Voltage
  - Current
  - Resistance
- Has two leads/ends to connect to the points in circuit where you want to measure

4

Using a Multimeter: Voltage

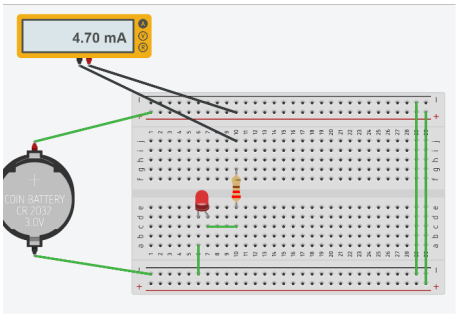
1. Set multimeter to Volts
2. Measure in parallel – touch ends to 2 points on a complete circuit and measure the voltage drop between those 2 points.
   - The positive lead should be closer to the power and the negative lead should be closer to ground. If you have them reversed you will see a negative voltage drop.



5

Using a Multimeter: Current

1. Set multimeter to Amps
2. Measure in series – the multimeter must be part of the complete circuit.
   - Again, be careful to use the positive and negative leads correctly or you will see negative Amps.

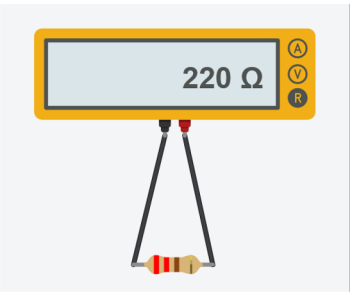


Note: without the multimeter, this circuit would be incomplete

6

Using a Multimeter: Resistance

1. Set dial to Ohms
2. Measure a component (resistor, LED, etc.) on its own.
   a. No circuit is needed, simply touch the ends of the multimeter to either side of the component



7

Multimeter Activity

1. Pull up your Tinkercad circuit from lab 1.
2. Find the multimeter in the components menu.
3. Measure the voltage drop in your circuit.
   a. Set the multimeter to voltage
   b. Connect the leads to your circuit (in parallel to your circuit)
4. Measure resistance
   a. Get a new resistor from the components menu
   b. Set the multimeter to Resistance
   c. Connect the leads to the either end of the resistor (do not connect to your circuit, just the resistor)

8

Building Digital Logic circuits

- You will be designing logic circuits in this class
  - Lectures: Cover theory of logic design, and build with discrete components (i.e., single gates) and use simulator (Cedar Logic or LogiSim or…)
  - Labs: Build and test logic circuits using integrated circuits (Chips)
    - Use TinkerCad simulator

9

Integrated Circuits

- Combinational logic gates (and devices)
  - AND, NOT, OR, ….
  - Each built using several transistors
- In practice, multiple gates are **packaged into a single chip** (Integrated Circuit – IC)
  - Example: 74HC04 is an inverter chip with multiple inverters
- An entire processor is also packaged into a single chip
- An IC is connected to circuitry outside the chip by connecting to the pins on the chip
- The gate layout and chip characteristics are specified by a **Datasheet**

10

7400 family Digital Logic Chips

- A set of digital logic chips that provide functionality like AND, OR, NOT,…
- You will use several 7400 family chips to build logic circuits
- To find these chips in Tinkercad:
  - In the components menu dropdown, select All components
  - Scroll to the logic section, these are the 7400 chips
- The gate layout and chip characteristics are specified by a **Datasheet**
  - Datasheets available on the web
  - http://www.skot9000.com/ttl/
  - http://rabbit.eng.miami.edu/info/datasheets/74LS04.pdf – for 74LS04

11

What is a Datasheet?

- Provides important information about the device
- Most useful sections: Pin Layout Diagrams and Function Table
- Reading datasheets is a necessary skill
  - Even though we are using Tinkercad, you will still need to use datasheets to understand chip layout
- See Appendix for in-depth information on reading datasheets

12

Datasheet Example

1. Go to the internet and search for "74HC04"
2. Find a link that leads to a datasheet
   a. Websites like mouser and digikey are often good
3. Determine where the power and ground connections on this chip are.
4. How many NOT gates are packaged onto this one chip?

13

Lab 2 Circuit Description

- You will build a circuit with 3 inputs (x1, x2, x3) and 3 outputs (y1, y2, y3) such that:
  - y1 = NOT x1
  - y2 = NOT x2
  - y3 = NOT x3
- Manually connect the inputs to power (for a value of 1) or ground (for a value of 0) using wires.
- Connect each of the outputs to an LED (and the necessary resistor) to visualize what your circuit is doing.

14

Lab 2 Exercise: Circuit Using Inverters

1. Get setup in Tinkercad
   a. Get necessary components ready –>
   b. Connect power source to breadboard
2. Connect the chip to the board
   a. Connect its power and ground
   b. Determine how it is oriented (use the datasheet!)
3. Wire up the 3 inputs and outputs!
   a. Identify the input/output pairs by using 3 different color wires and LEDs (for example make the wires and LEDs for x1 and y1 green)
   b. Manually connect each input to power or ground and see how it affects the output
4. When finished submit the link to your circuit on BB.

MATERIALS
- Breadboard
- Power Source
- (1) 74HC04 chip
- (3) LEDs
- (3) 220 Ohm Resistors

15

Lab Homework 1

- Use multiple chips to build a circuit that computes:
  - F = (A OR NOT B) AND (B OR NOT C)

16

Appendix

17

How to Read a Datasheet

© Scott Trocchia (BS Class of 2011)
© 2016 Narahari

18

Introduction

- The datasheet:
  - Is packed with information
  - Tells you about electrical and temperature-related characteristics about your chip
  - Gives you a physical layout of your chip (even dimensions are provided!)
- Ability to pick out relevant information about the device you are using is a valuable skill
  - You need this information so you can use this device to connect to other devices in your system

19

Breaking down the datasheet

1. Title
2. Part/Device Description
3. Packaged Diagrams – pin layout (pinout)
   - Each pin connects to an input or output or power/ground
4. Function Table
5. Logic Diagram
6. Recommended Operation Conditions

20

Example: Inverters (NOT gates)

SN5404, SN54LS04, SN54S04,
SN7404, SN74LS04, SN74S04
HEX INVERTERS

SDLS029C – DECEMBER 1983 – REVISED JANUARY 2004

description/ordering information

These devices contain six independent inverters.

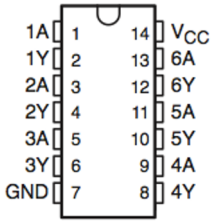
Datasheet Title

2. Datasheet Part/Device Description

21

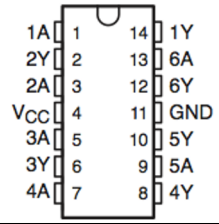
3. Datasheet Packaged Diagrams

SN5404 . . . J PACKAGE
SN54LS04, SN54S04 . . . J OR W PACKAGE
SN7404, SN74S04 . . . D, N, OR NS PACKAGE
SN74LS04 . . . D, DB, N, OR NS PACKAGE
(TOP VIEW)

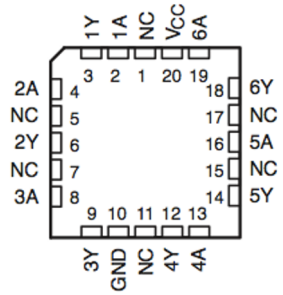


Always look for the correct part #

SN5404 . . . W PACKAGE
(TOP VIEW)



SN54LS04, SN54S04 . . . FK PACKAGE
(TOP VIEW)

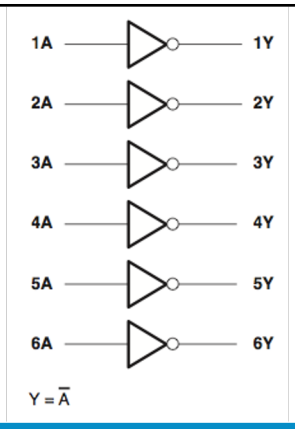


NC – No internal connection

22

FUNCTION TABLE
(each inverter)

INPUT A	OUTPUT Y
H	L
L	H



Function Table | Logic Diagram

H = high
L = low

Q: What does this say about how an inverter works?

A: Takes your signal and flips its state (0 → 1,1 → 0)

23

6. Recommended Operating Conditions

Again, find the correct part #

recommended operating conditions (see Note 3)

		SN5404			SN7404			UNIT
		MIN	NOM	MAX	MIN	NOM	MAX	
V_{CC}	Supply voltage	4.5	5	5.5	4.75	5	5.25	V
V_{IH}	High-level input voltage	2			2			V
V_{IL}	Low-level input voltage			0.8			0.8	V
I_{OH}	High-level output current			−0.4			−0.4	mA
I_{OL}	Low-level output current			16			16	mA
T_A	Operating free-air temperature	−55		125	0		70	°C

NOTE 3: All unused inputs of the device must be held at V_{CC} or GND to ensure proper device operation. Refer to the TI application report, *Implications of Slow or Floating CMOS Inputs*, literature number SCBA004.

24

6. Recommended Operating Conditions (cont'd)

electrical characteristics over recommended operating free-air temperature range (unless otherwise noted)

PARAMETER	TEST CONDITIONS‡			SN5404			SN7404			UNIT
				MIN	TYP§	MAX	MIN	TYP§	MAX	
V_{IK}	V_{CC} = MIN,	I_I = −12 mA				−1.5			−1.5	V
V_{OH}	V_{CC} = MIN,	V_{IL} = 0.8 V,	I_{OH} = −0.4 mA	2.4	3.4		2.4	3.4		V
V_{OL}	V_{CC} = MIN,	V_{IH} = 2 V,	I_{OL} = 16 mA		0.2	0.4		0.2	0.4	V

25