EECS 3201: Digital Logic Design Lecture 2

Ihab Amer, PhD, SMIEEE, P.Eng.

Design Rules (DRs)

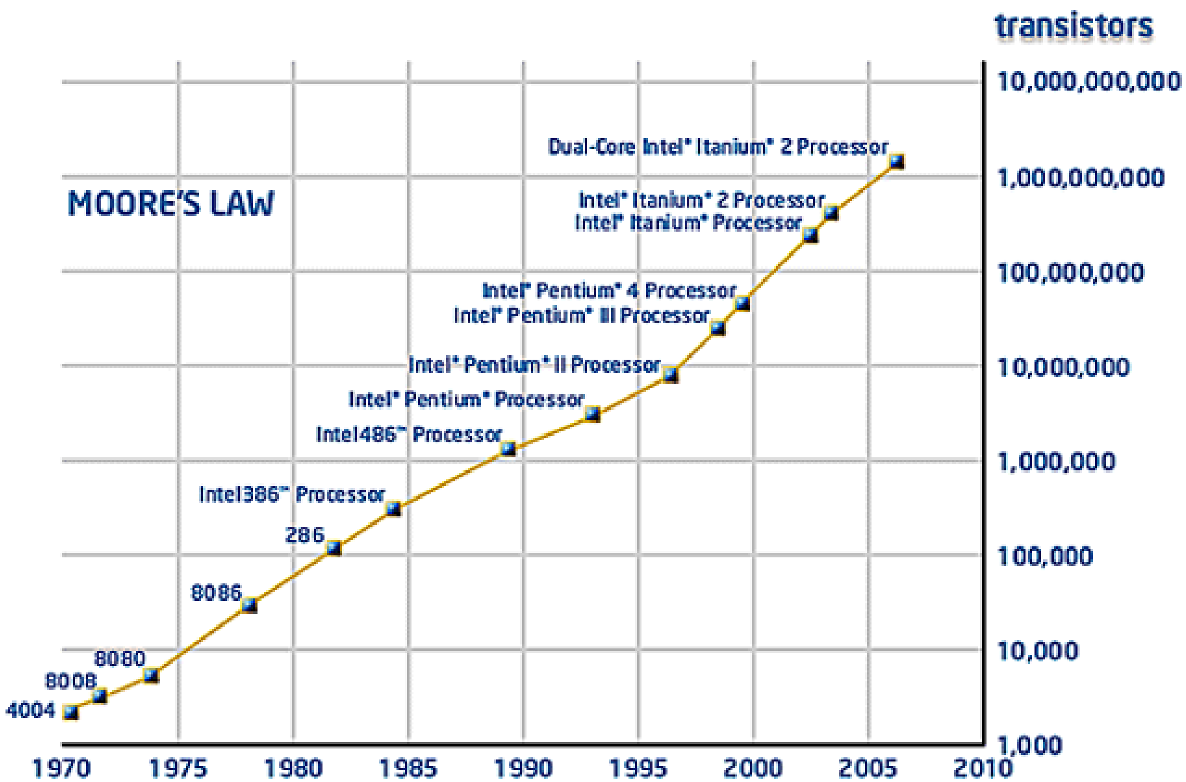
- A set of geometrical specs that dictate the design of the layout masks
- Provides numerical values for min dimensions, line spacing, & other geometrical quantities that are derived from the limits of a specific processing line
- Must be followed to insure functional correctness
- The smaller the DRs, the less delay, power, and area → ***Heard about nano-technology?***

General Notes

- Three major axes of digital design are performance, area, and power consumption
- A good designer would utilize this trade-off according to the target applications
- The speed of a gate directly affects the max clock speed of the digital system
- Gate speed is tech-dependent. E.g. 0.35 u CMOS process has faster gates than 0.8 u
- ASIC implementation is typically faster than FPGA implementation
- Smart designers can make a huge difference!

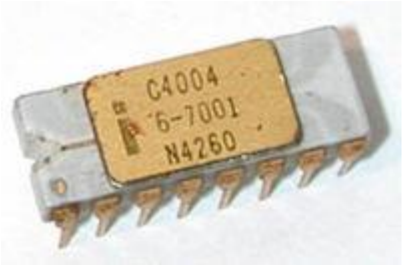
Moore's Law

It is an empirical observation made in 1965 that the number of transistors on an integrated circuit for minimum component cost doubles every 24 months. It is attributed to Gordon E. Moore (born 1929), a co-founder of Intel.



Past Vs Present

Intel 4004, 1971 **Vs** **Dual-Core Intel Itanium 2, 2006**



2300 Transistors

740 KHz

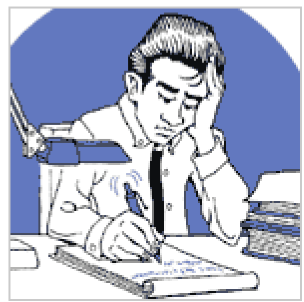
1.7 billions Transistors

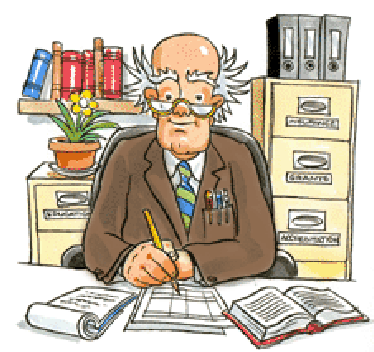
1.6 GHz

Time to Market (TTM)

- The length of time it takes from a product being conceived until its being available for sale
- Important in industries where products are outmoded quickly
- A common assumption is that TTM matters most for first-of-a kind products, but actually the leader often has the luxury of time, while the clock is clearly running for the followers

Designing a µP “by Hand”





NOT A GOOD IDEA!!

Two Design Approaches

Traditional

- Relies on mathematical models & analytical approaches
- Provides insight & understanding of the problem
- Useful for small problems
- Inadequate for large (real) problems

CAD

- SW relies on mathematical models & analytical approaches
- Transparent to user
- Many details are abstracted
- Useful (required) for real problems

Traditional Vs CAD Design

- CAD tool usage is essential
- Insight and basic understanding offered by traditional approach is still important
  - Initial conceptualization is still traditional
  - Effective use of CAD tools requires some understanding of what the tools are doing
  - Use of design options requires insight

Conclusion

This course is IMPORTANT!

Flash Back

On some Fundamentals

Please fasten your seatbelts and pay attention! We will go a little fast here. We do not want to waste so much time revising, we want to move to the good stuff ASAP!

Numbering Systems

- Decimal numbers

1000's column
100's column
10's column
1's column

$5374_{10} =$

- Binary numbers

8's column
4's column
2's column
1's column

$1101_2 =$

Powers of TWO

- $2^0 =$
- $2^1 =$
- $2^2 =$
- $2^3 =$
- $2^4 =$
- $2^5 =$
- $2^6 =$
- $2^7 =$
- $2^8 =$
- $2^9 =$
- $2^{10} =$
- $2^{11} =$
- $2^{12} =$
- $2^{13} =$
- $2^{14} =$
- $2^{15} =$

- Handy to memorize up to 2^9

Large Powers of TWO

- 2^{10} = 1 kilo ≈ 1000 (1024)
- 2^{20} = 1 mega ≈ 1 million (1,048,576)
- 2^{30} = 1 giga ≈ 1 billion (1,073,741,824)

Estimating Powers of Two

- What is the value of 2^{24}?

- How many values can a 32-bit variable represent?

Number Conversion

- Binary to decimal conversion:
  - Convert 10011_2 to decimal

- Decimal to binary conversion:
  - Convert 47_{10} to binary

Bits/Bytes/Nibbles…

- Bits

10010110

most significant bit

least significant bit

- Bytes & Nibbles

byte

10010110

nibble

- Bytes

CEBF9AD7

most significant byte

least significant byte

Binary Values and Ranges

- *N*-digit decimal number
  - How many values?
  - Range?
  - Example: 3-digit decimal number:

- *N*-bit binary number
  - How many values?
  - Range:
  - Example: 3-digit binary number:

Binary Representation

- What are the max and min representable values using 4-bit unsigned representation?
- What about 4-bit signed representation (sign-magnitude)?
- What about 4-bit signed representation (sign-2’s complement)?

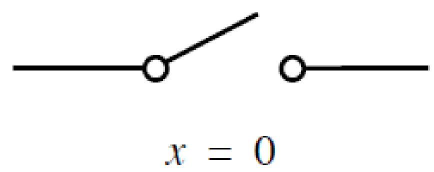
Binary Arithmetic

- Do the following assuming 4-bit (unsigned, sign-magnitude, sign-2's complement, where applicable)
  - $(2)_{10} + (3)_{10} = ?$
  - $(5)_{10} - (2)_{10} = ?$
  - $(6)_{10} + (7)_{10} = ?$
  - $(0010)_2 - (0101)_2 = ?$
  - $(-2)_{10} - (4)_{10} = ?$
  - $(-4)_{10} - (4)_{10} = ?$

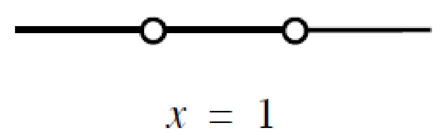
The Simplest Binary Element

- Is the switch… “has two states”

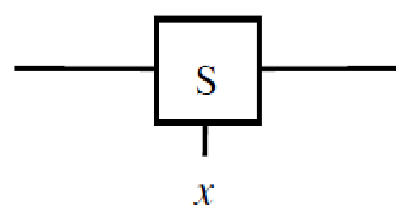
- It can be open
  - state is 0



- Or closed
  - state is 1



- x denotes a control input



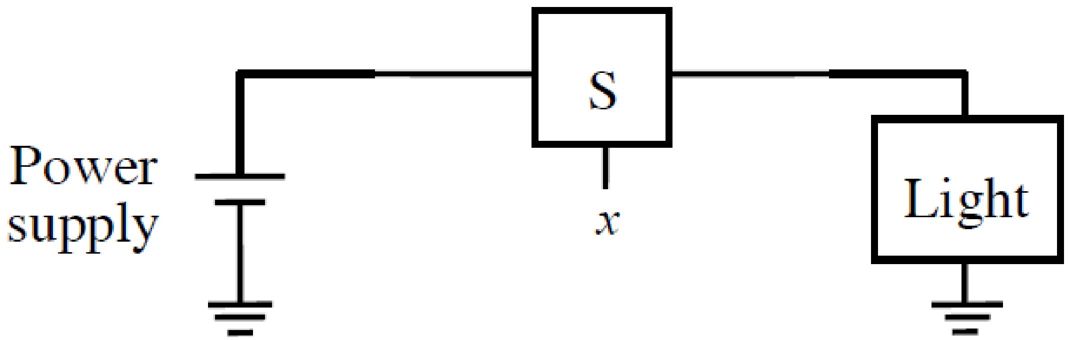
Variables and Functions

- Describe inputs & outputs and the relationship between them
- inputs: variable
- outputs: some function of the input variable

$$\text{output} = f(\text{input})$$

$$y = f(x)$$

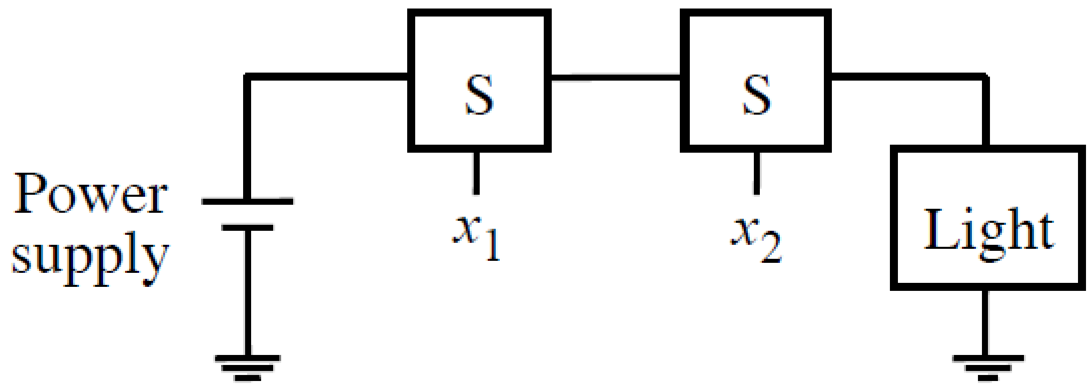
A Basic Example



- L = 1 light is on
- L = 0 light is off
- if x = 0 then L = 0
- if x = 1 then L = 1
- L(x) = x

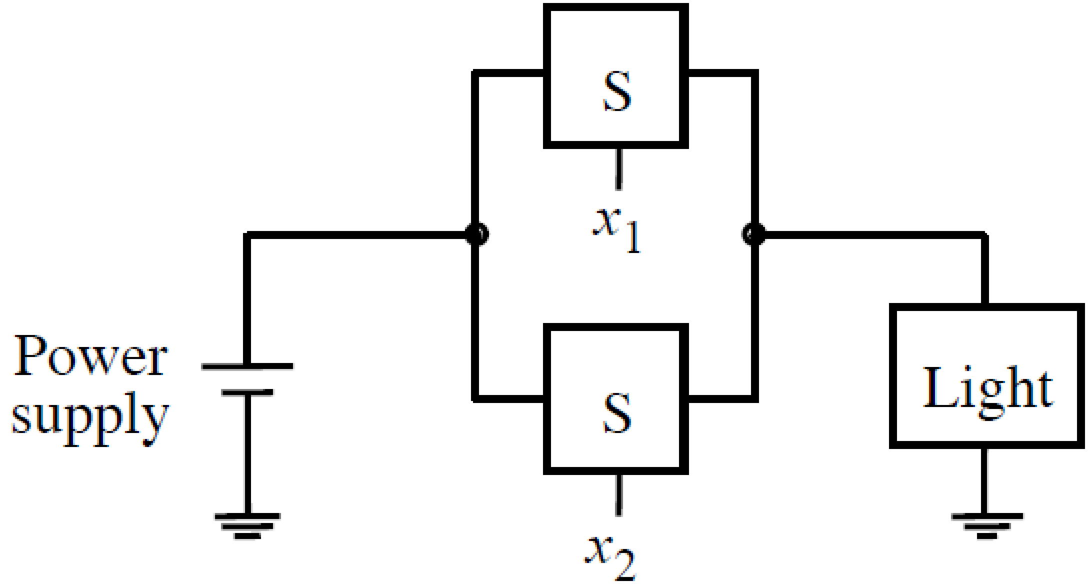
- What is the switch doing?
  - Relaying (1) power to a destination
  - Or isolating (0) power from a destination

AND: A Series Circuit



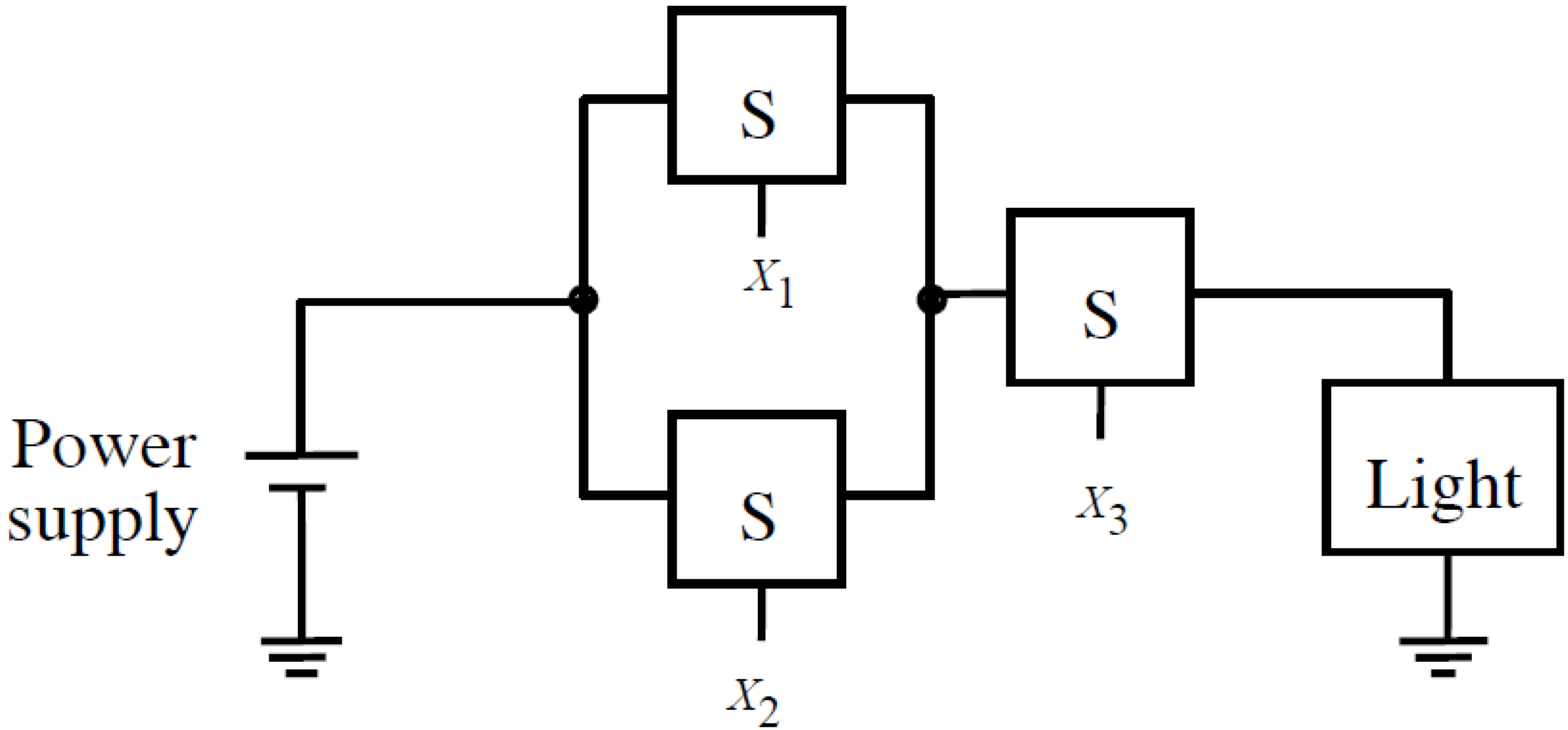
- If x_1 AND x_2 = 1 then L = 1
- Else L = 0
- This behaviour is described by the AND operator '•'
- $L(x_1, x_2) = x_1 \bullet x_2$

OR: A Parallel Circuit



- If x_1 OR x_2 = 1 then L = 1 (inclusive OR)
- Else L = 0
- This behaviour is described by the OR operator '+'
- $L(x_1, x_2) = x_1 + x_2$

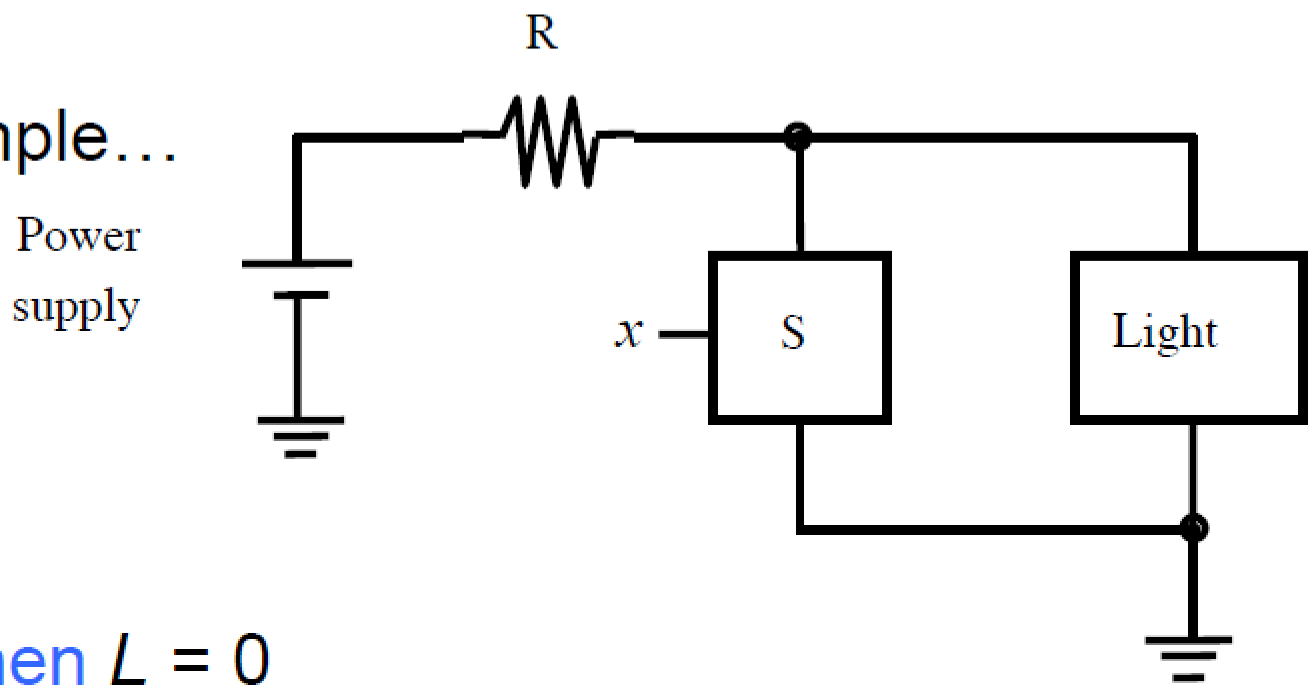
A Combination



- If x_1 OR $x_2 = 1$ AND $x_3 = 1$ then $L = 1$
- Else $L = 0$
- $L(x_1, x_2, x_3) = (x_1 + x_2) \bullet x_3$

Inversion

- Interesting things can happen when a switch is opened too
- For example…



- If $x = 1$ then $L = 0$
- Else $L = 1$
- $L(x) =$ NOT $x = \overline{x}$

Truth Table

- A handy shorthand for logic function valuations

x_1	x_2	$x_1 \cdot x_2$	$x_1 + x_2$
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	1
		AND	OR

x_1	x_2	x_3	$x_1 \cdot x_2 \cdot x_3$	$x_1 + x_2 + x_3$
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	0	1
1	0	0	0	1
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

- What happens as the number of inputs increases?

References

- Lecture Notes of Dr. Sebastian Magierowski – Fall 2013