Digital Electronics

Instead of allowing voltages to take on any value, we allow voltage signals to be either H (often 5V) or L (usually 0V).

Simple logic devices:

inverter:

one input, one output

characterized by a "truth table"

In	Out
L	H
H	L

input = A

Output = $\bar{A}$

the "‾" indicates the logical "NOT" operation performed by the inverter.

AND

$Q = A \cdot B$

A	B	Q
L	L	L
L	H	L
H	L	L
H	H	H

OR

$Q = A + B$

A	B	Q
L	L	L
L	H	H
H	L	H
H	H	H

Also

NAND

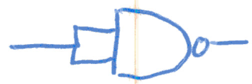
$\overline{A \cdot B}$

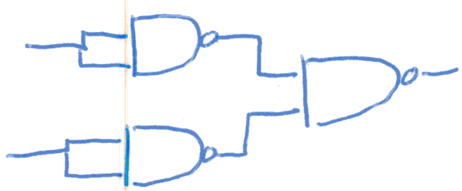
A	B	Q
L	L	H
L	H	H
H	L	H
H	H	L

NOR

A	B	Q
L	L	H
L	H	L
H	L	L
H	H	L

NAND is important because all other gates can be built from it.

es  from 

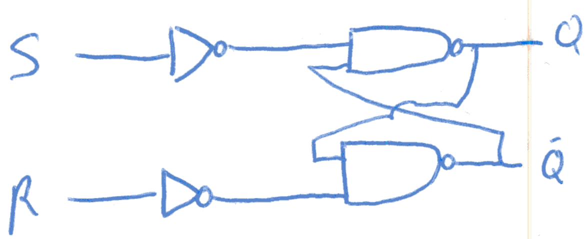
 from: 

Useful theorem: De Morgan's Theorem

$$\overline{A + B} = \bar{A} \cdot \bar{B}$$

Memory

Flip-flops

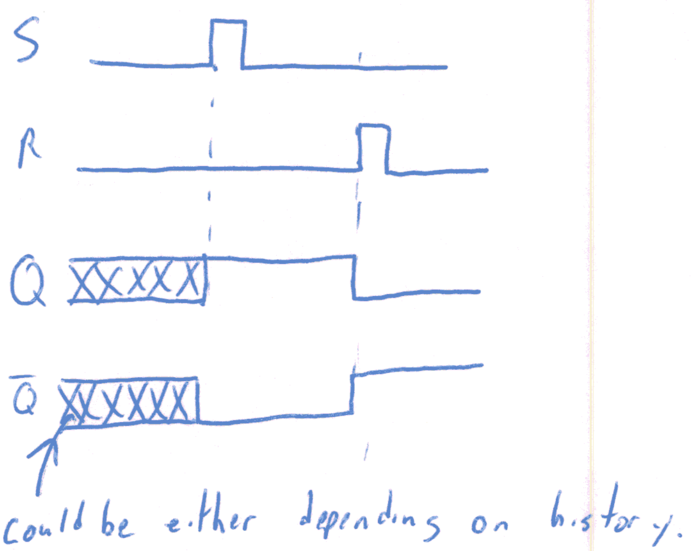


Truth Table:

S	R	Q	$\bar{Q}$
H	H	H	H
H	L	H	L
L	H	L	H
L	L	X	$\bar{X}$

X means could be either H or L. It depends on which of S or R was most recently H!

timing diagram:



This is an S-R flip-flop (set-reset).

Simple logic gates come in packages with several gates.

eg 74HC00 is a "quad 2-input NAND" meaning there are 4 nand gates on the single chip. Each has 2 inputs (you can buy nand gates with 3, 4 etc inputs).

Logic Chips aren't perfect!

→ Not infinitely fast, time delay depends on logic chip family
for 74HC ~10-20ns

→ Finite fanout: one output can drive only a limited number of inputs → though for many logic families, the fanout is ~hundreds.

→ Different families not all compatible.

Common Families

74XX (XX gives the device function
00 is quad 2-input nand).
original TTL (transistor-transistor logic).

74LSXX - faster, lower power

74F XX - much faster still.

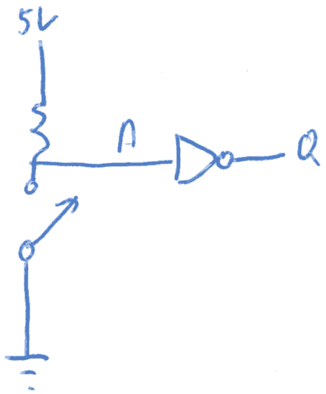
4000 CMOS - slow, but very low power.

74HC CMOS - "modern" CMOS, low power, relatively fast, good fanout, mostly compatible with 74LS TTL

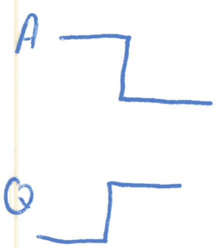
Subtleties emerge when mixing families!

Switch Bounce:

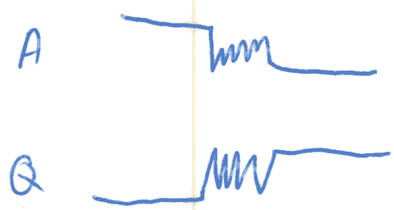
interface human input into circuit with a switch:



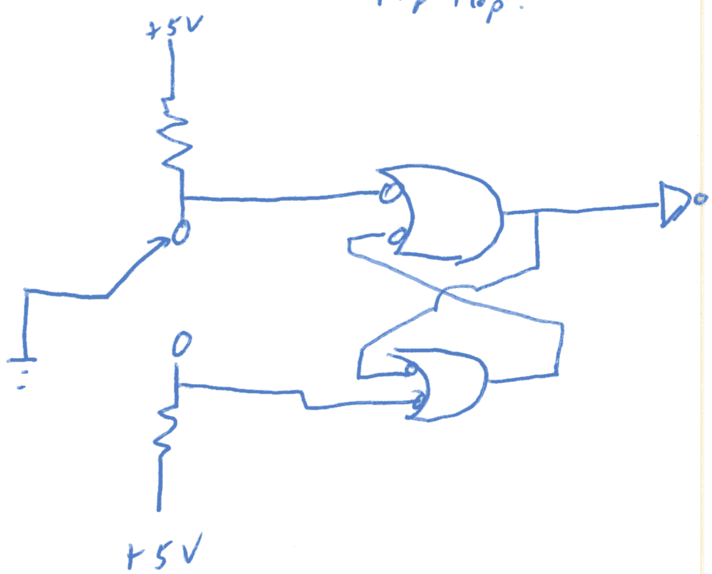
want:



but we find:



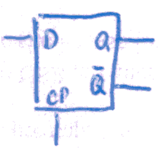
Solution, an S-R flip flop:



There are hundreds of devices in the 74HC family

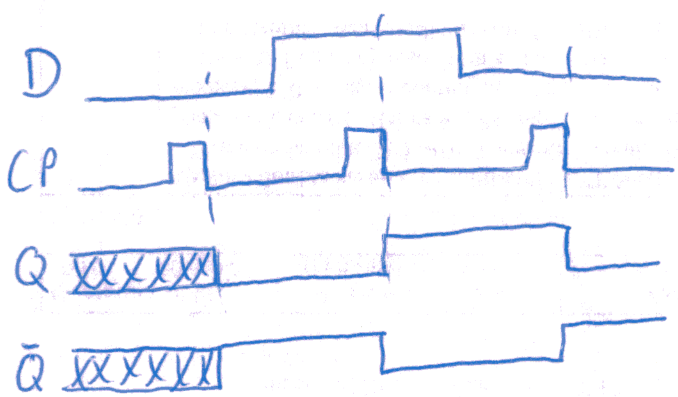
Eg 74HC390 "Dual decade ripple counter"

To understand it, first consider a device called a "D-type flip-flop"

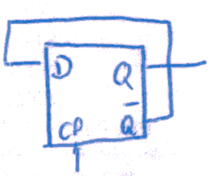


This is like our S-R flip-flop, except it has just one input (D) and a "clock" input.

The value of D is transferred to Q on the "edge" where CP goes from H → L



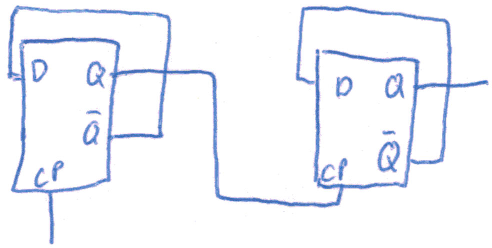
We can make a "counter" by connecting $\bar{Q}$ to D



now Q will alternate between L and H.

count (# of CP pulses)	Q
0	L
1	H
2	L
3	H

By connecting 2 of these:



now:

count	Q_1	Q_2
0	L	L
1	H	L
2	L	H
3	H	H
4	L	L

By connecting more of these this way, we can build an 8, 16, 32 or as-big-as-you like counter.

The 74HC390 has 2 ÷2 counters and 2 ÷5 counters

when one ÷2 counter drives a ÷5 counter we can count from 0-9.

Count	Q_0	Q_1	Q_2	Q_3
0	L	L	L	L
1	H	L	L	L
2	L	H	L	L
3	H	H	L	L
4	L	L	H	L
5	H	L	H	L
6	L	H	H	L
7	H	H	H	L
8	L	L	L	H
9	H	L	L	H
0	L	L	L	L

This counting scheme is known as Binary Coded Decimal, or BCD.

Some extra logic is needed to "roll over" after 9. See the data sheet for details.