Introductory Medical Device Prototyping

Digital Circuits Part 1 – Logic Gates

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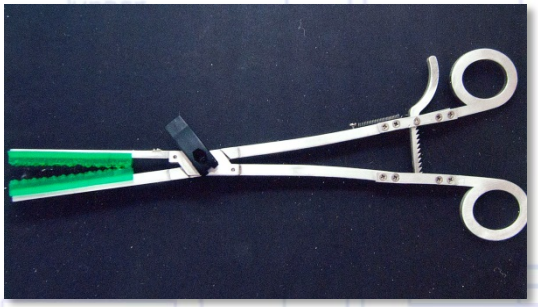
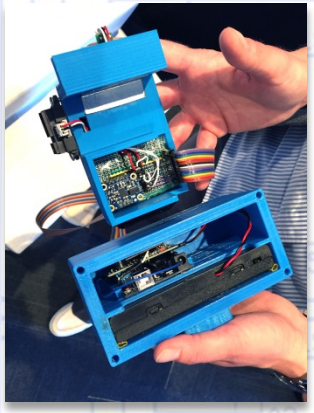
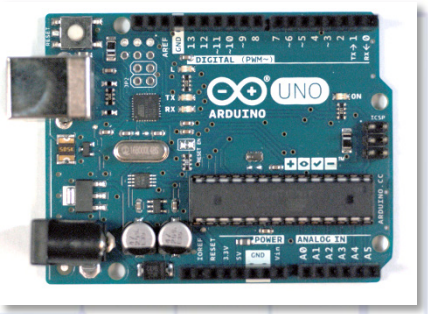
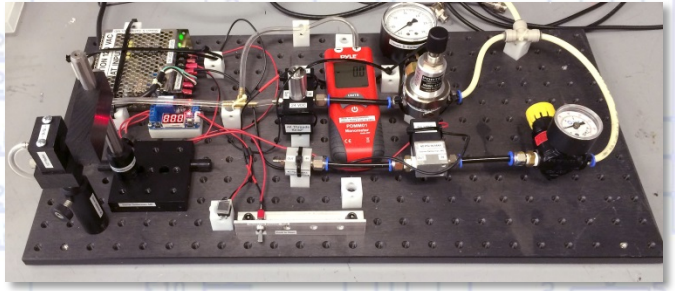
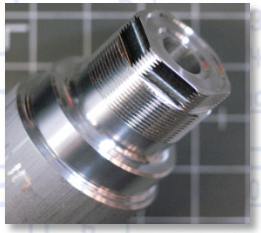






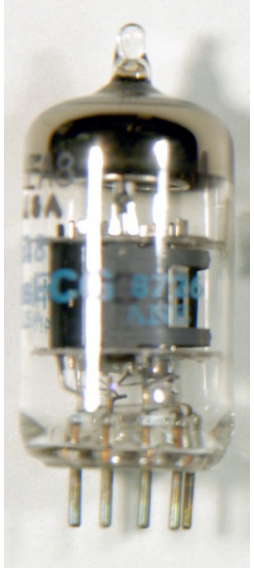




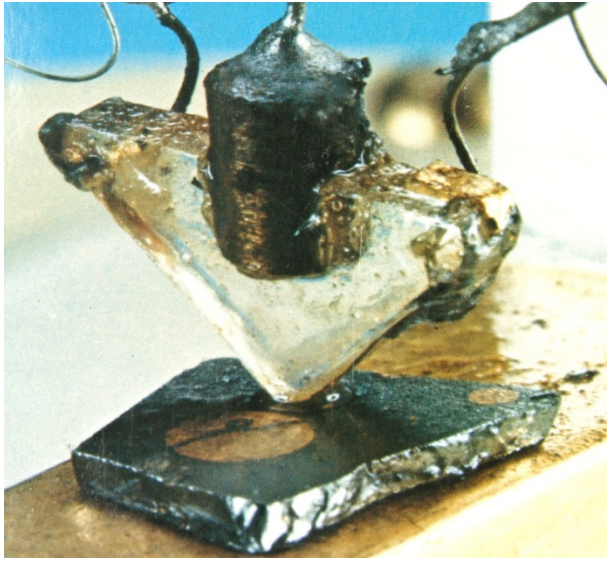
Topics

- CMOS logic.
- Designing with NI Multisim (SPICE) and Ultiboard software.
- Boolean logic.
- CMOS packaging and pinouts.
- Digital Gates: 74HC04, 74HC00, 74HC74, 4049 74HC126.
- “Bus” for addressing and data transfer.

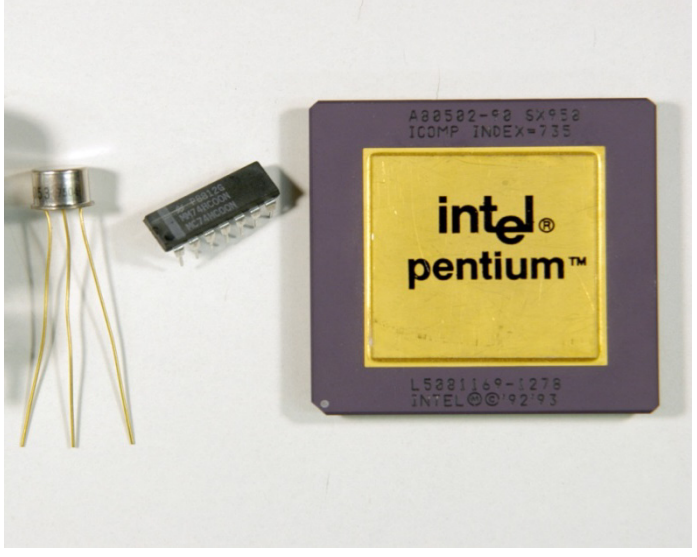
Microelectronics Revolution



Triode tube 1915
(Langmuir)

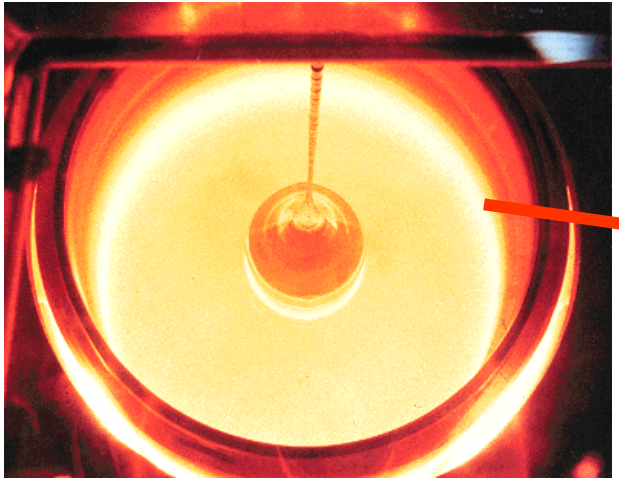


Point-contact transistor 1947,
Bell Labs (Brattain and Bardeen).



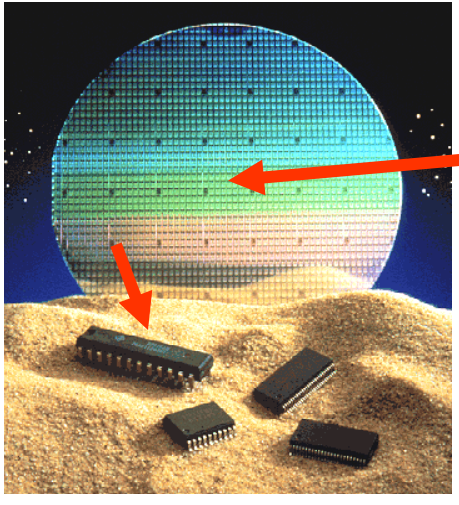
Junction transistor 1948 (Shockley),
IC 1958 (Kibly and Noyce),
& Intel Pentium Microprocessor
10^8 Transistors!

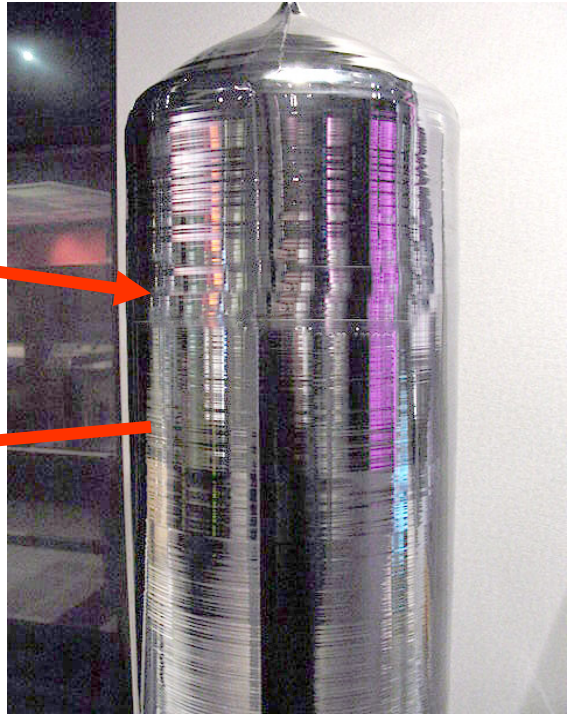
From Molten Silicon to IC Chips…



Molten silicon - Czochralski puller technique

Silicon wafer diced into integrated circuits (DIP and SMD).

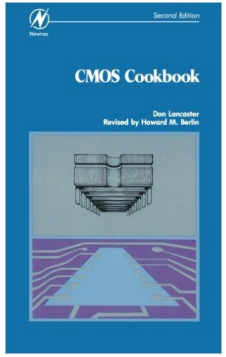




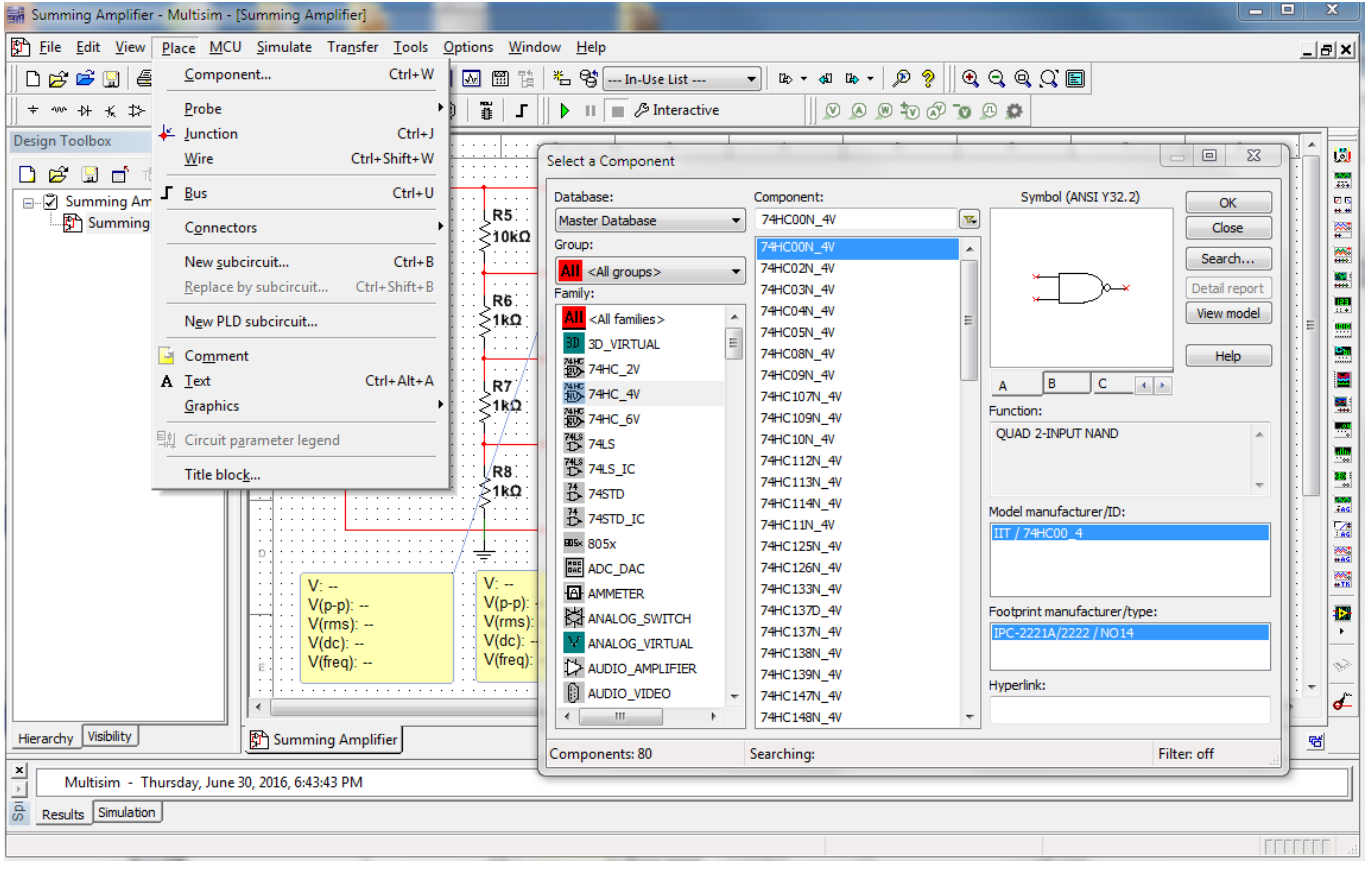
Single crystal silicon boule

CMOS Logic

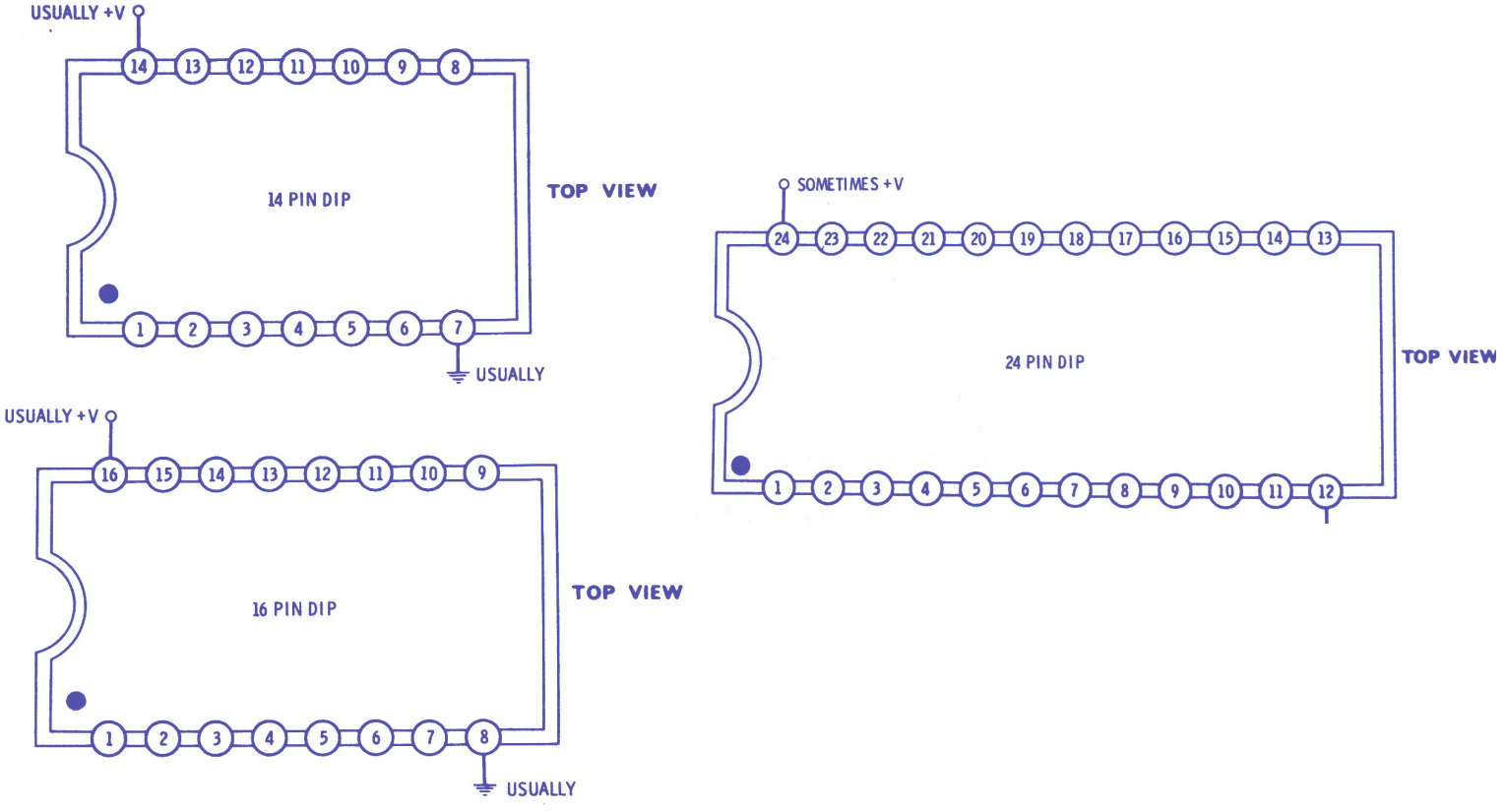
- Complementary Metal Oxide Semiconductor Logic (4000B and 74HC00 series)
- Wide range of power supply voltages, from 3 to 15 Vdc
- Logic changes half-way up the power supply voltage, giving good noise immunity.
- Almost no power supply current needed except during input logic changes.
- Inputs are open circuits and easy to drive.
- The unloaded output logic swings the full range of the power supply.
- CMOS circuits create little noise of their own.
- CMOS circuits pass along less noise.
- Low cost.



Design with NI Multisim

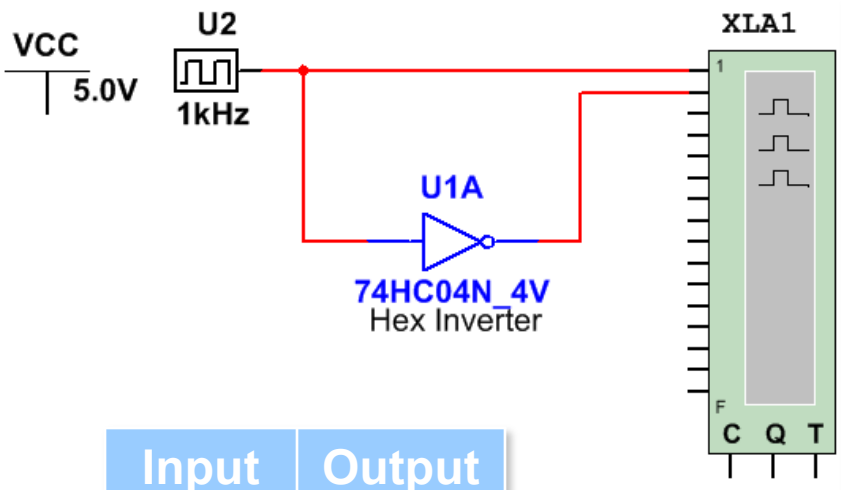


CMOS Packages & Pins

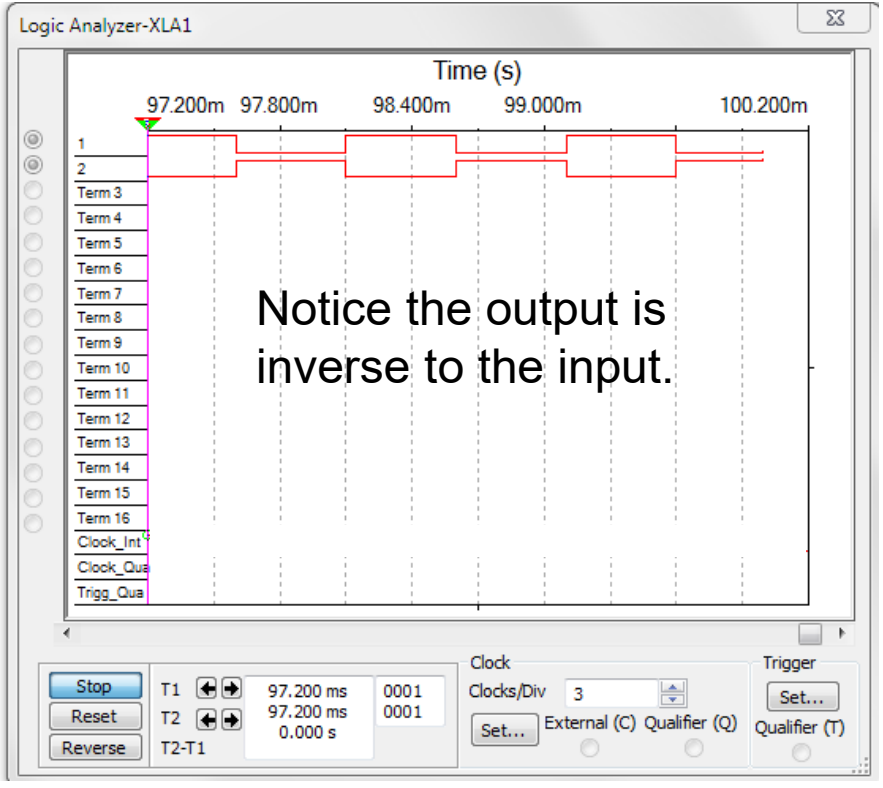


Lancaster, D. and Berlin, H.M. *CMOS Cookbook*. H.W. Sams, Indianapolis, IN (1988)

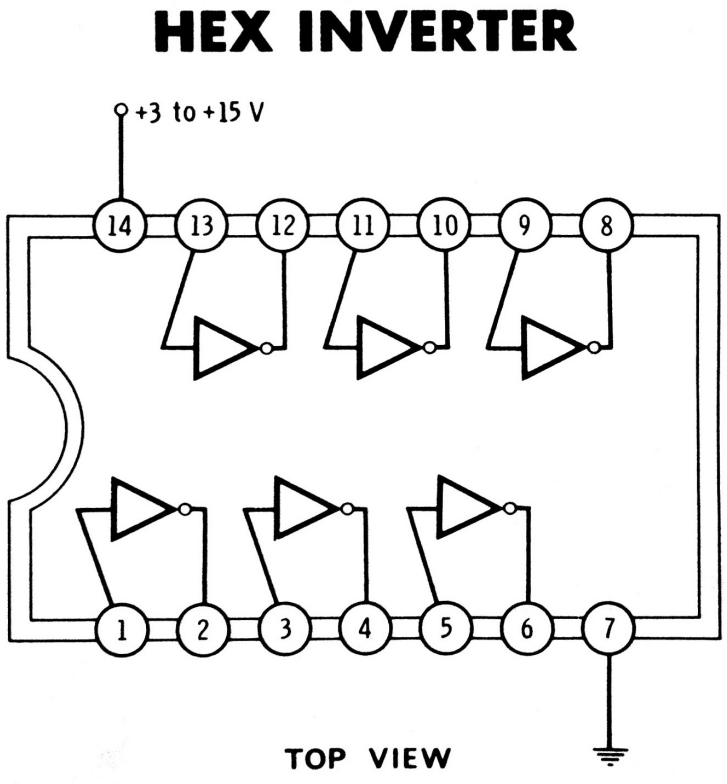
Inverter – 74HC04



Input	Output
High	Low
Low	High



Available Logic Gates in the 74HC04…



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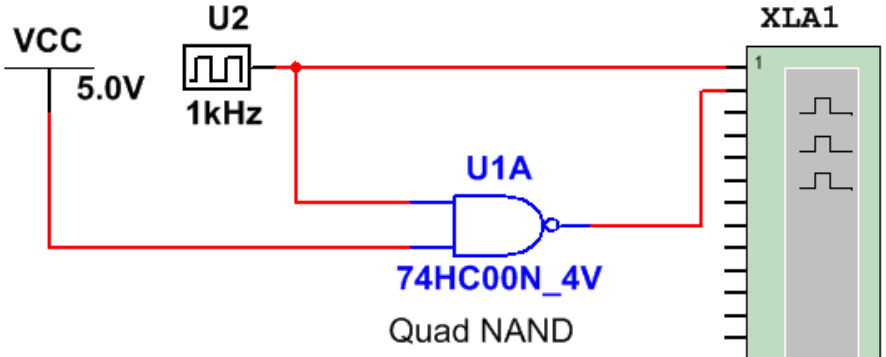
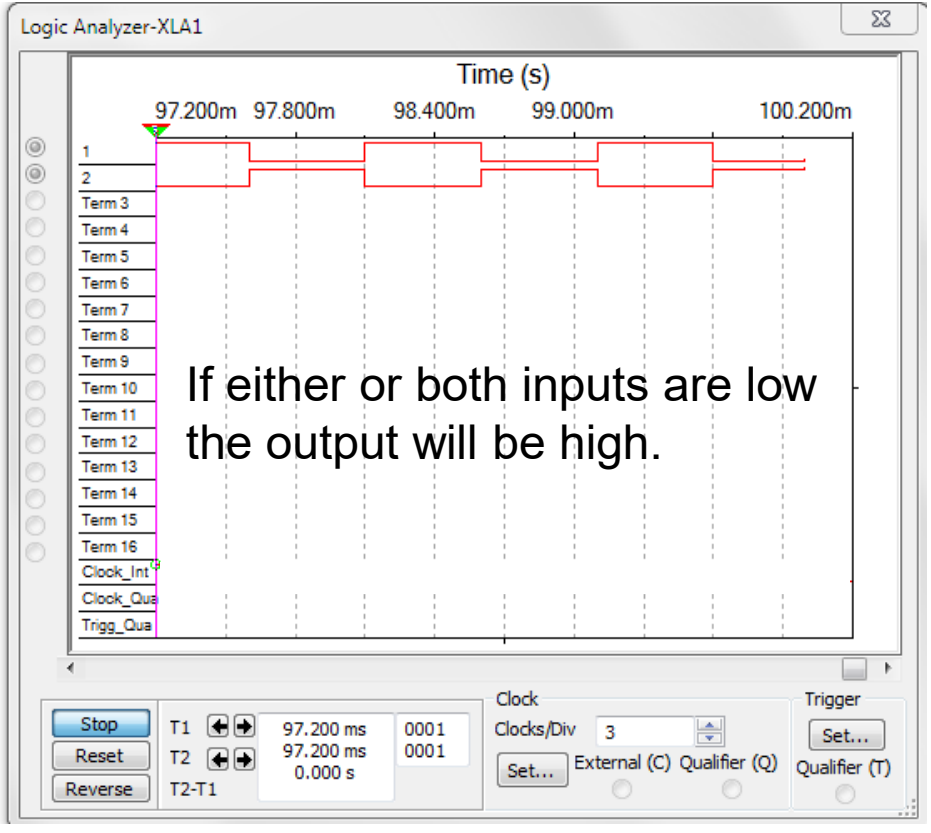
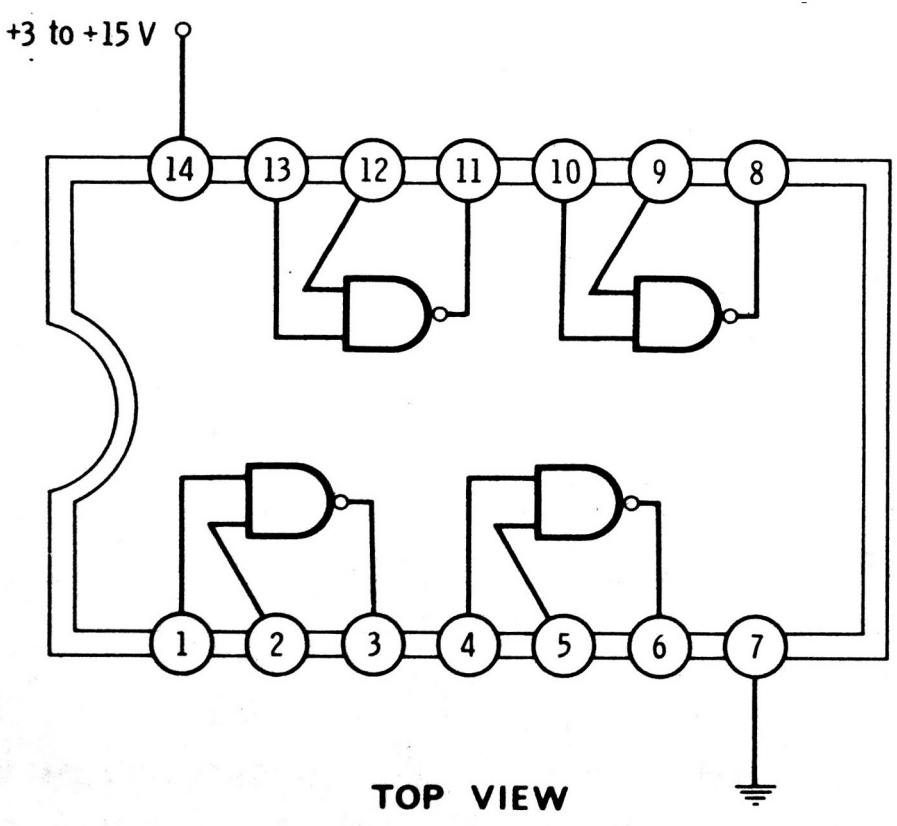
NAND – 74HC00



Input 1	Input 2	Output
0	0	1
1	0	1
0	1	1
1	1	0



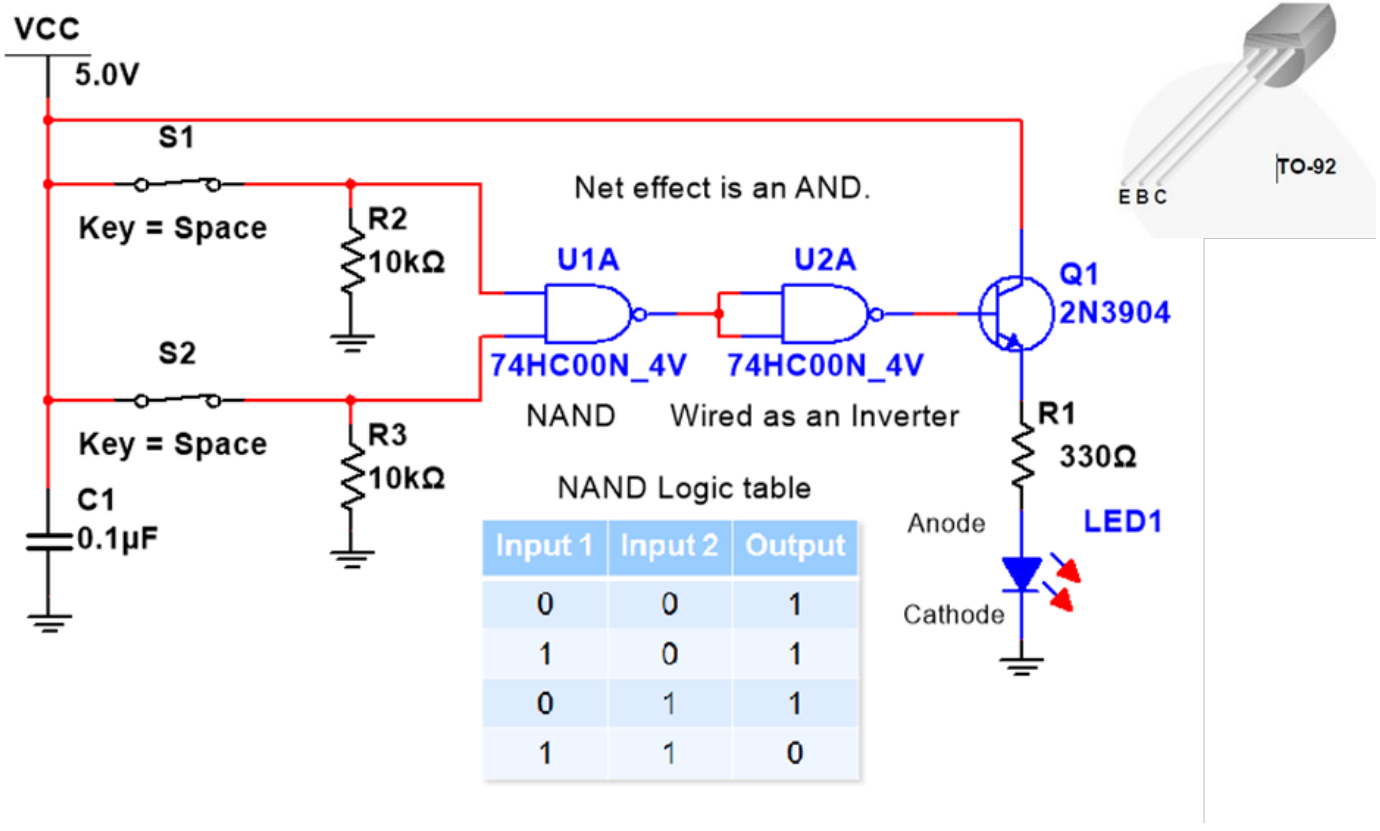
Available Logic Gates in the 74HC00…



In addition to this NAND gate, there are many different types and combinations of Boolean logic gates to select from. These include AND, OR, NOR, Exclusive OR & NOR and others.

Lancaster, D. and Berlin, H.M. *CMOS Cookbook*. H.W. Sams, Indianapolis, IN (1988)

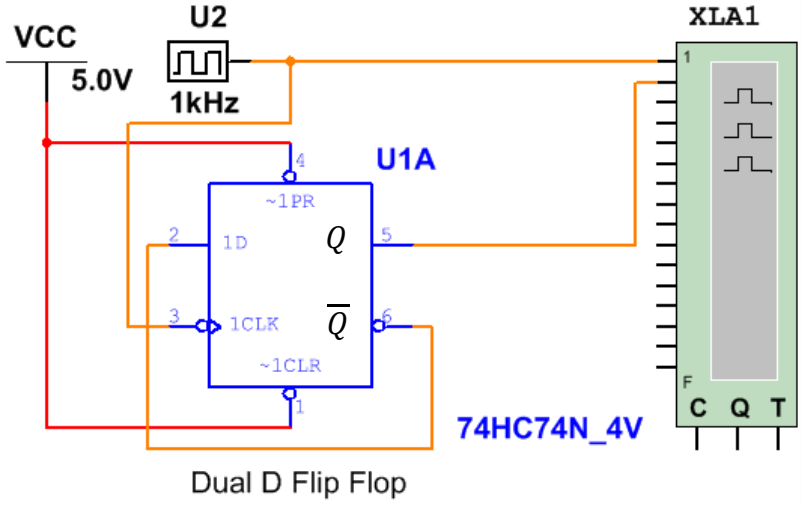
Creating an AND gate from 2 NAND

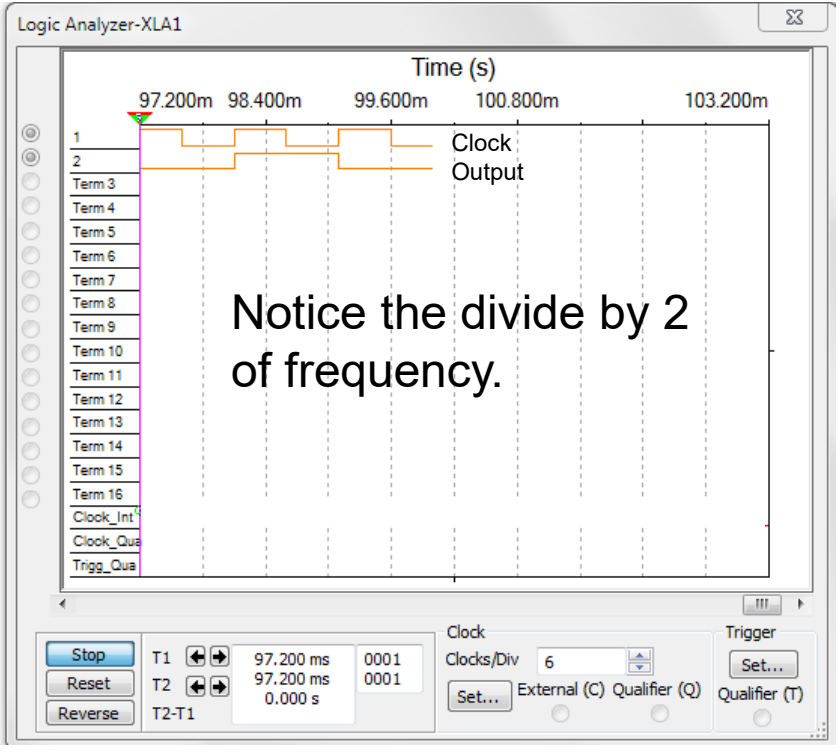


NAND Logic table

Input 1	Input 2	Output
0	0	1
1	0	1
0	1	1
1	1	0

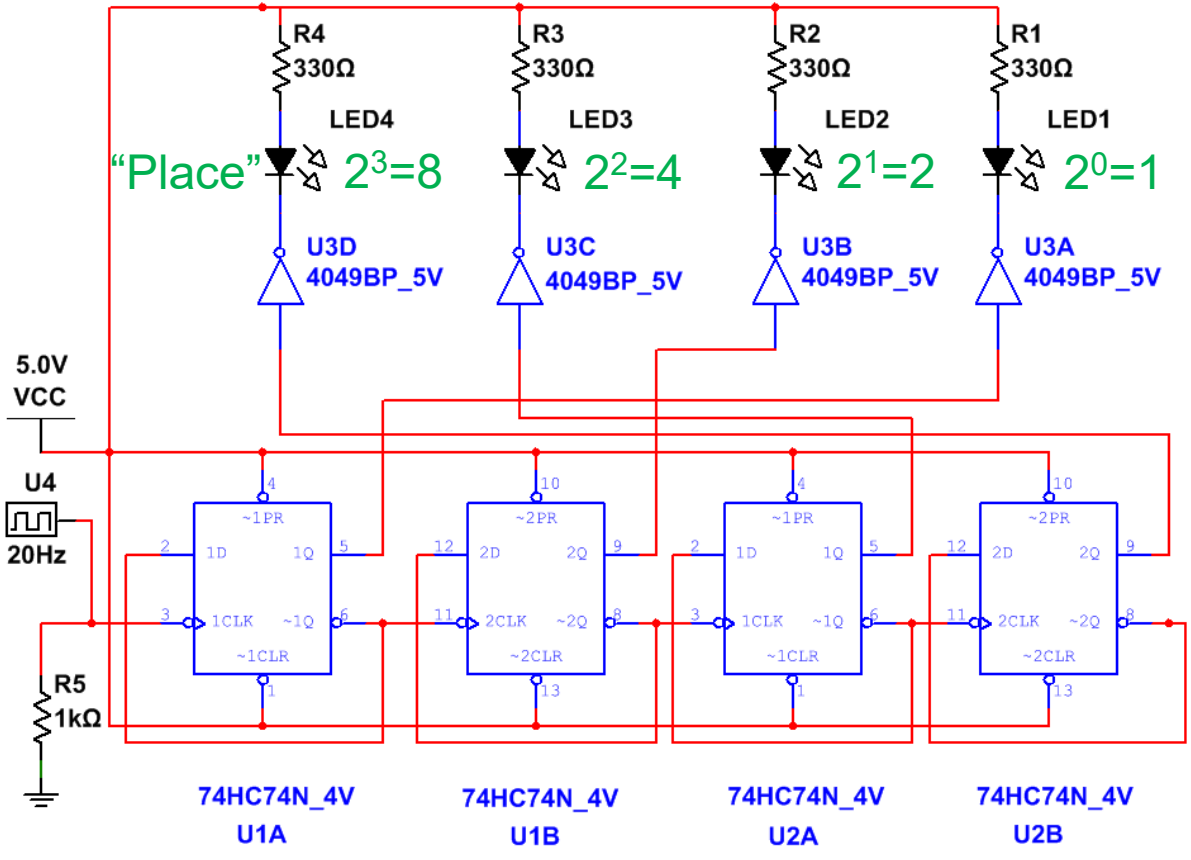
Flip-Flop – 74HC74





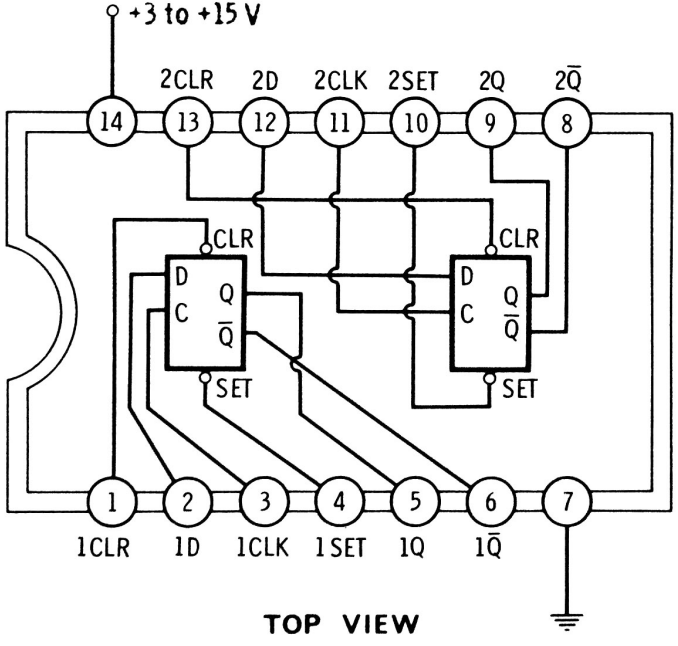
In this configuration, with each clock pulse, the output *Q* alternates between 1 and 0, effectively halving the clock frequency. (*$\bar{Q}$ is simply the complement – or opposite, of Q.)*

4 Bit Binary Counter with Buffer Drivers …



Available Logic Gates in the 74HC74…

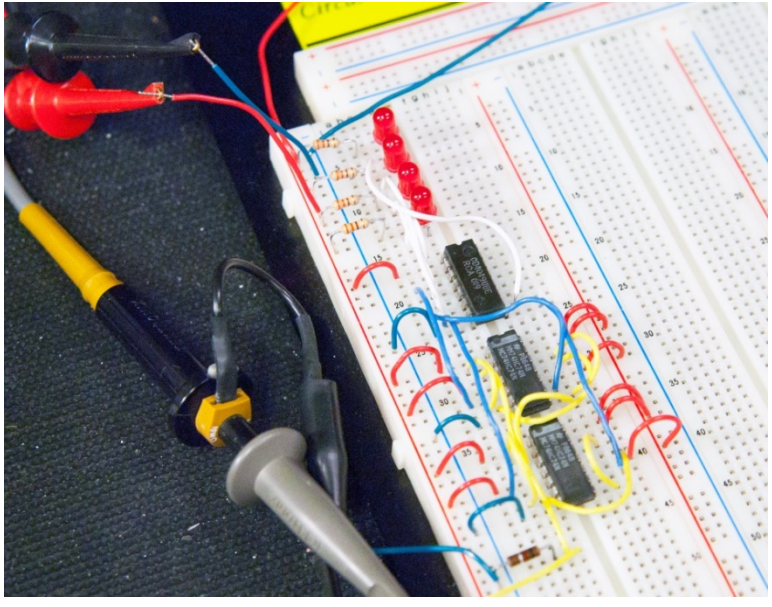
DUAL D EDGE-TRIGGERED FLIP-FLOP (With Preset and Preclear)

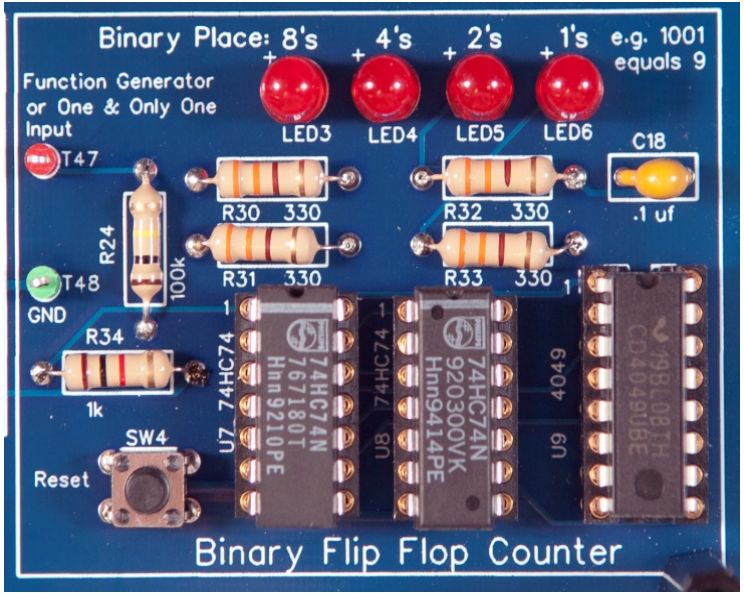


In addition to this D-Flip-Flop, there are also JK Flip-Flops

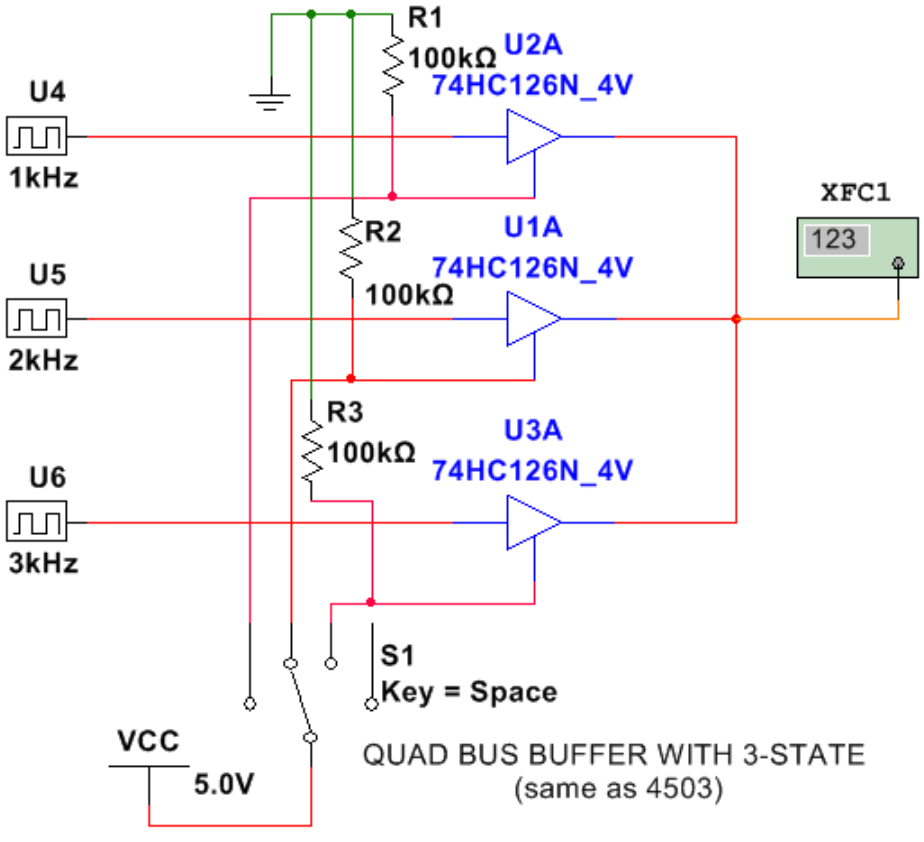
Lancaster, D. and Berlin, H.M. *CMOS Cookbook*. H.W. Sams, Indianapolis, IN (1988)

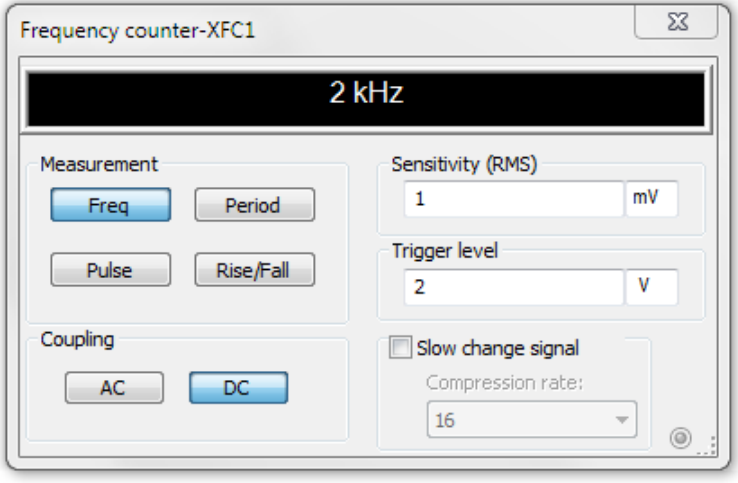
Counter on Breadboard & Lab Trainer Board





Tri-State Logic – 74HC126



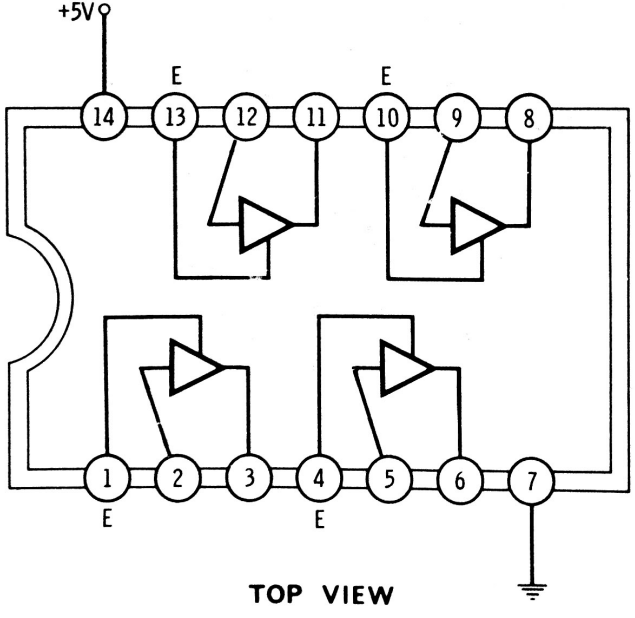


Inputs		Output
A	C	Y
L	H	L
H	H	H
X	L	Hi-Z

H = HIGH Logic Level
L = LOW Logic Level
X = Either LOW or HIGH Logic Level
Hi-Z = 3-STATE (Outputs are disabled)

Available Logic Gates in the 74HC126…

QUAD TRI-STATE® DRIVER
(High Enable)



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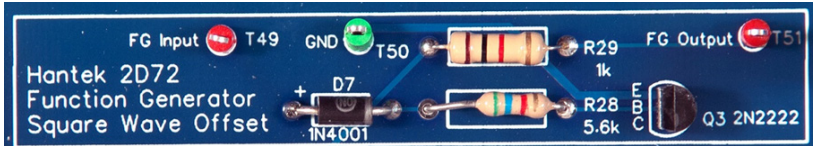
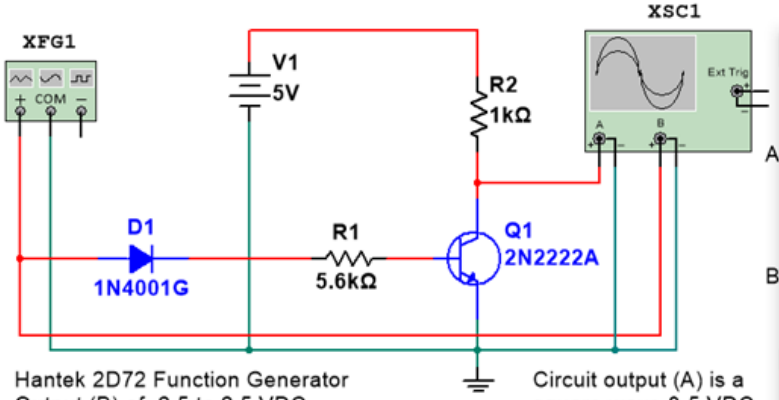
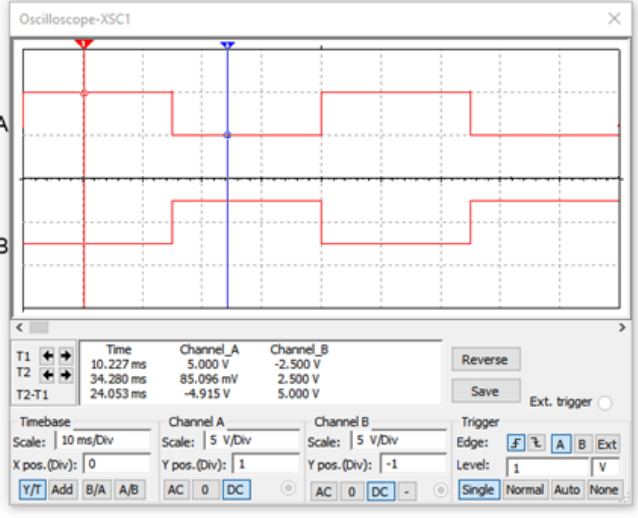
5V Square Wave from a Hantek 2D72

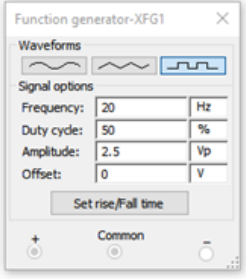




Hantek 2D72 Function Generator Output (B) of -2.5 to 2.5 VDC

Circuit output (A) is a square wave 0-5 VDC





These settings simulate the Hantek 2D72 output of -2.5 to 2.5 VDC. (Vp is Peak = 2.5, Vpp = 5VDC)

Summary

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- Boolean logic.
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- “Bus” for addressing and data transfer.