EEE225 - DIGITAL

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Lectures – hand-out of slides
Problem classes – problem sheets

A set of notes is what you make after attending the lecture and reading up on the topics presented!

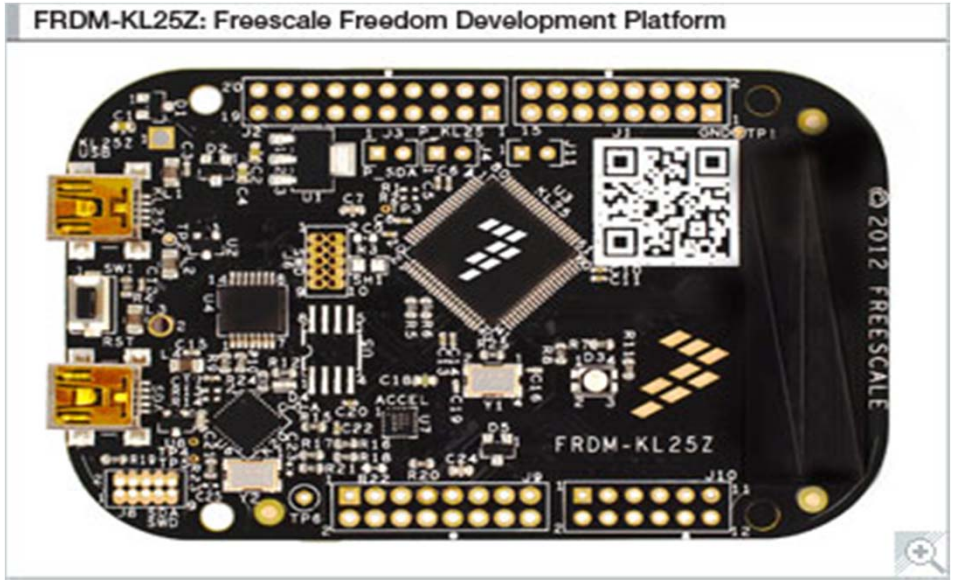
Useful books:

Digital Fundamentals 10/E: Floyd
Digital Design Principles and Practices 4/E: Wakerly
Principles of Digital Design: Gajski

Content

- Logic Families and logic gate circuits
- Electrical aspects of digital circuits
- Input & Output Structures
- Conversion between Analog and Digital
- Semiconductor Memories – types and uses
- Bus Structures & Interfaces
- Development Boards – FPGA & Microcontroller


BASYS 2
DIGILENT
BEYOND THEORY


FRDM-KL25Z: Freescale Freedom Development Platform
FRDM-KL25Z
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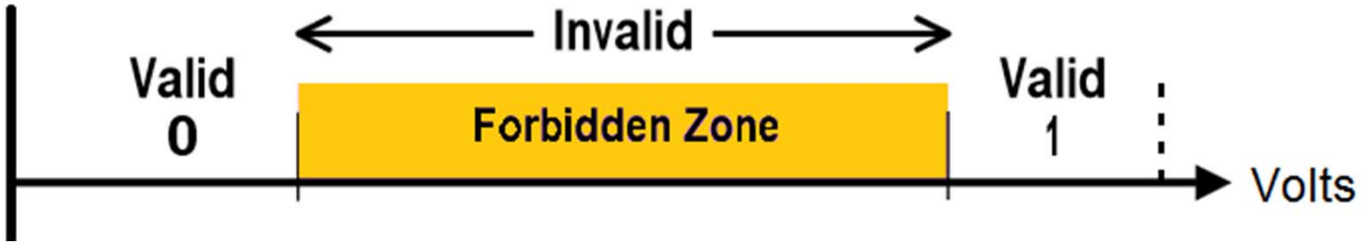
Introduction

- Analog quantities vary continuously with time and at any point in time can take one of an infinite number of possible values. They are represented by voltages and currents in circuits.
- Errors are introduced in circuits due to noise. Sources of noise can be internal or external.

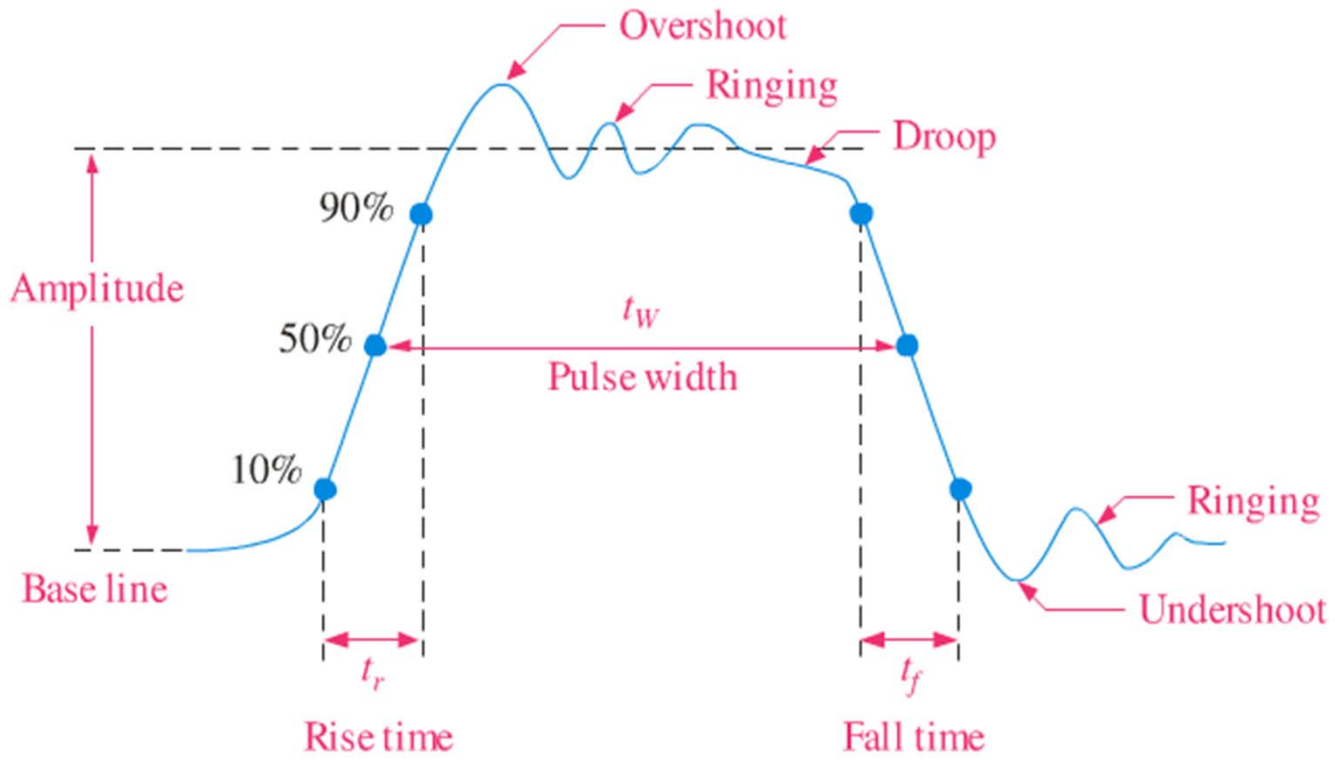
  - Internal: thermal, avalanche etc.
  - External: crosstalk, atmospheric, cosmic, electromagnetic interference, radio frequency interference etc.

- In the digital world we can overcome many of these problems.
- Signals are sampled to provide a set of discrete values.
- These values are encoded using binary digits (bits).
- A *bit* can take the value '**0**' or '**1**'
- Voltages are used to represent the *bits*.
- A range of voltages is used to represent the two values and safety margins are built in to ensure high reliability.

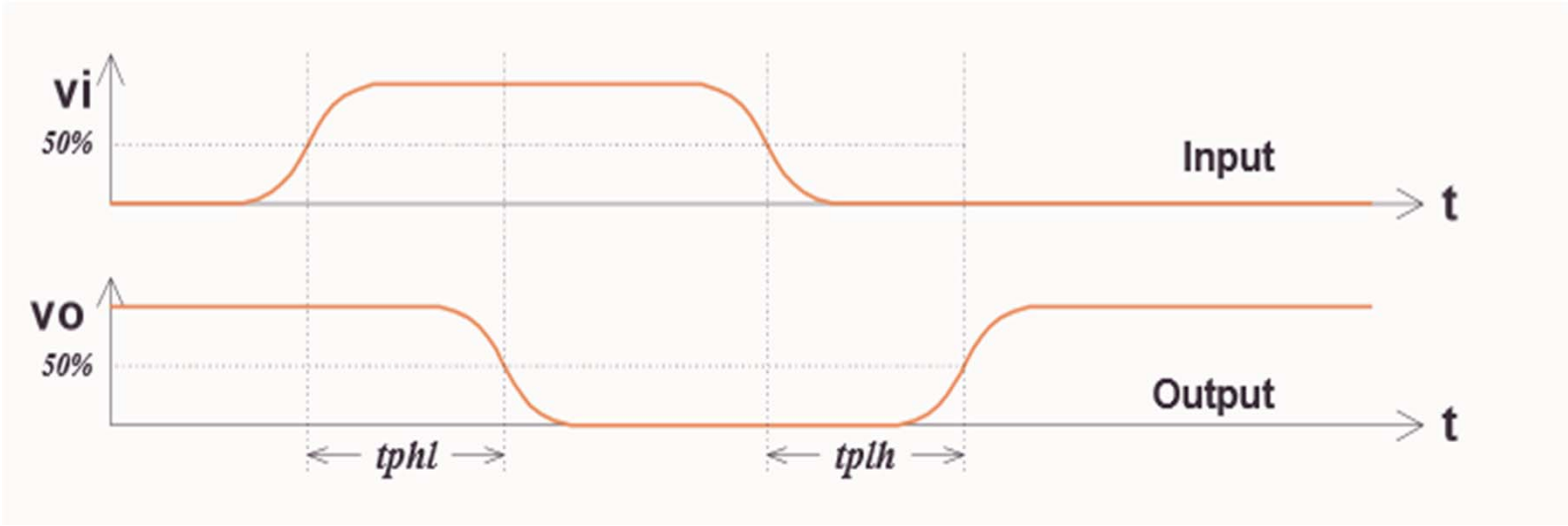


Digital Logic

- Two possible states: HIGH = 1, LOW = 0
- Represented by voltage levels which depend on the technology used.



Propagation Delay



tphl is the time for the output to reach 50% of its nominal value on the H-to-L transition after the input signal reached 50% of its nominal value.

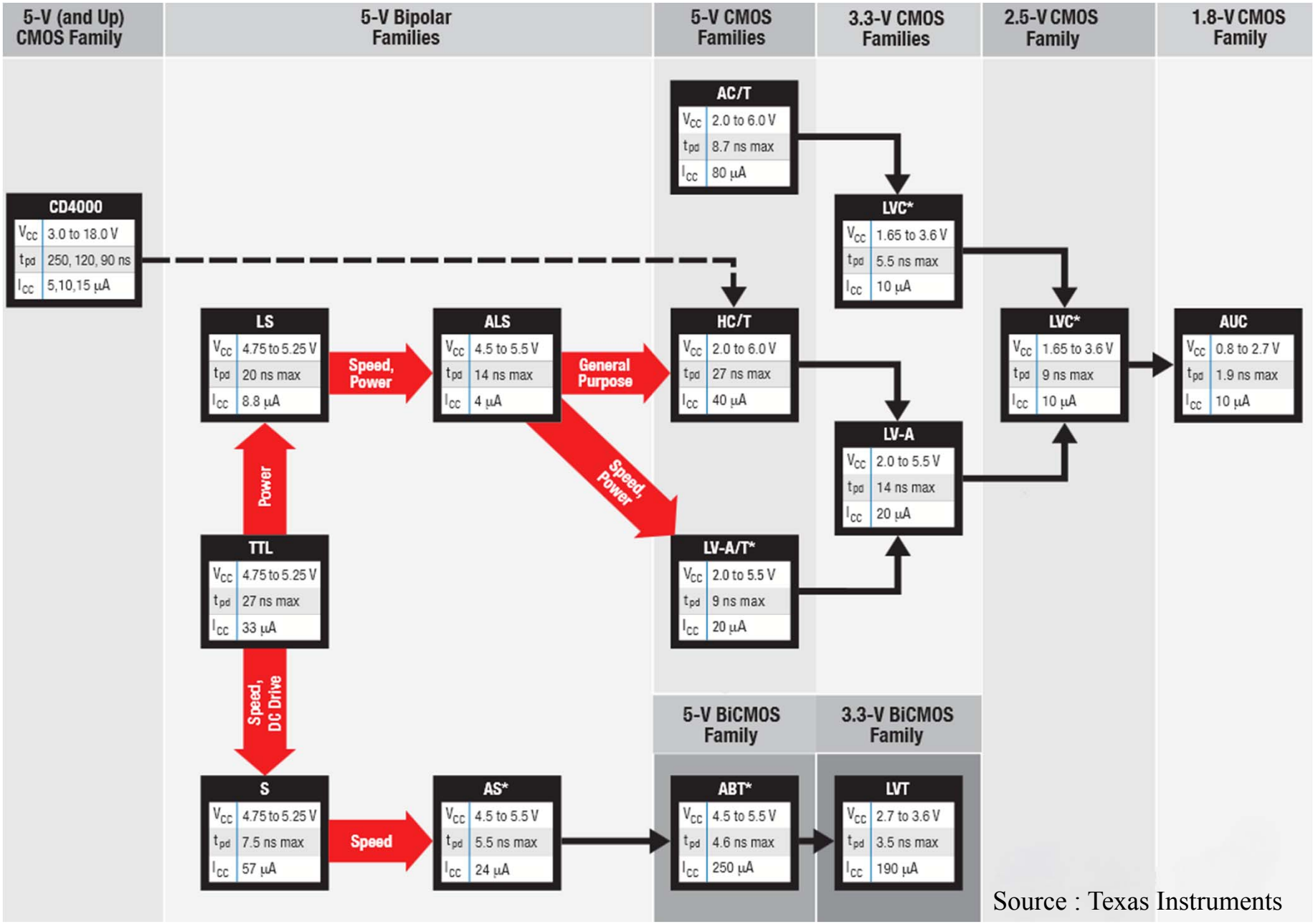
tplh is the time for the output to reach 50% of its nominal value on the L-to-H transition after the input signal reached 50% of its nominal value.

$$t_p = (tphl + tplh) / 2$$

The propagation delay limits the speed at which a logic circuit can operate.

Logic Family Characteristics

- Voltage levels
- Built in safety margins
- Speed of operation (delay)
- Power dissipation
- Drive capability



Source : Texas Instruments

Digital Logic Families

- Digital logic circuits can be formed from transistors to carry out Boolean logic functions.
- These logic circuits have analog characteristics.
- Different technologies are available to build the circuits. The most common are Transistor-Transistor Logic (TTL) and Complementary Metal-Oxide Semiconductor (CMOS).
- Each technology will give circuits with the same functionality like for like but with different characteristics.

TTL Logic Families

- Constructed using Bipolar Junction Transistors (BJT) and resistors.
- Introduced in 1964 (Texas Instruments) with the 7400 series. (5400 mil-spec)
- Several variations followed giving variations on the properties of the original series e.g. 74LS.
- Basic logic gates and flip-flops to counters and arithmetic units e.g. 74LS00 contains four NAND gates.

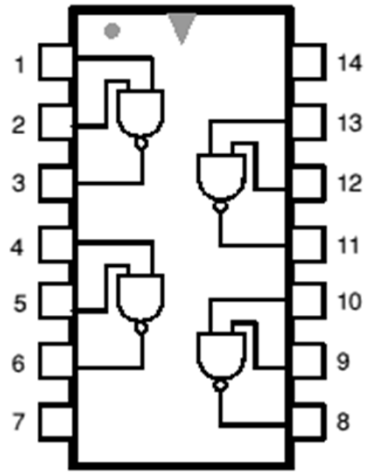
74 Series Families

74 - Standard TTL
74H - High speed
74LS - Low Power Schottky
74ALS - Advanced Low Power Schottky
74F - Fast (faster than normal Schottky, similar to AS)
74L - Low power (very slow)
74S - Schottky (obsolete)
74AS - Advanced Schottky

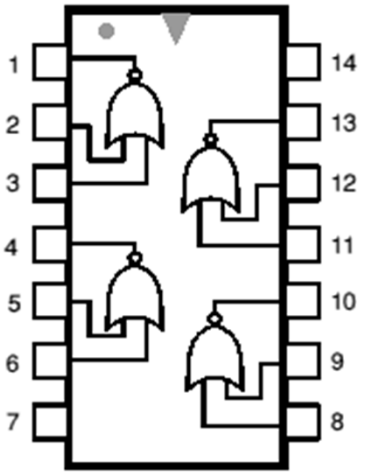
Part Numbering

Starts at 7400. Check Texas Instruments 74 series catalog.

7400 Quad NAND Gate



7402 Quad NOR Gate



Diode Logic (AND gate)

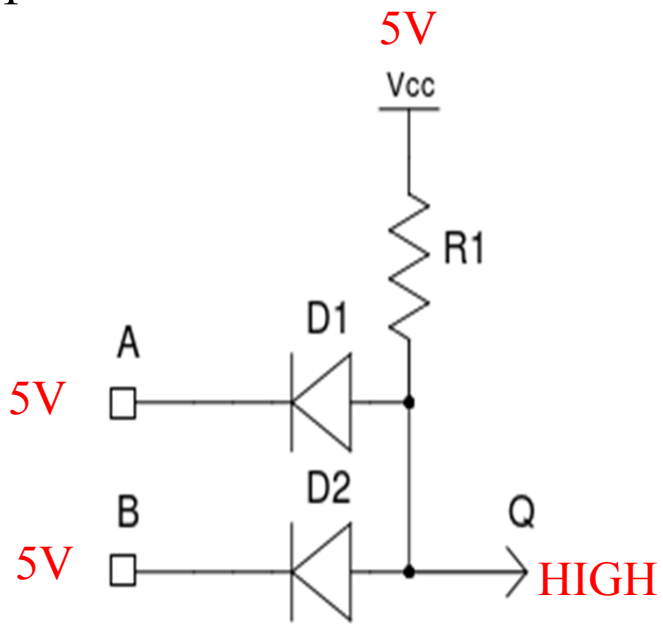
Logic gates can be produced from combinations of diodes and resistors. Consider the circuit shown, with V_{cc} = 5V and the logic levels:

Voltage Level	Logic Level	Binary Value
0 – 2 volts	LOW	0
2 – 3 volts	forbidden area	undefined
3 – 5 volts	HIGH	1

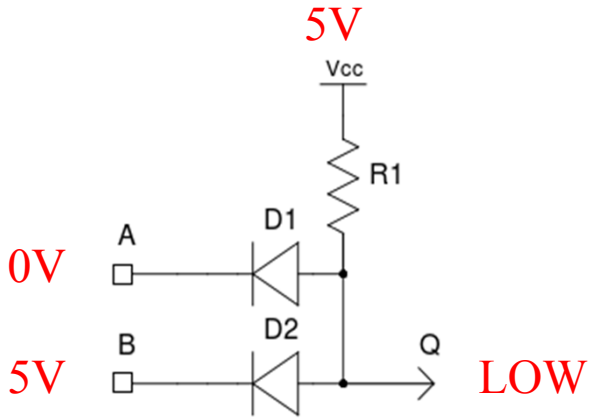
Consider the A and B inputs to both be HIGH. Both diodes are reverse biased and hence cut-off.

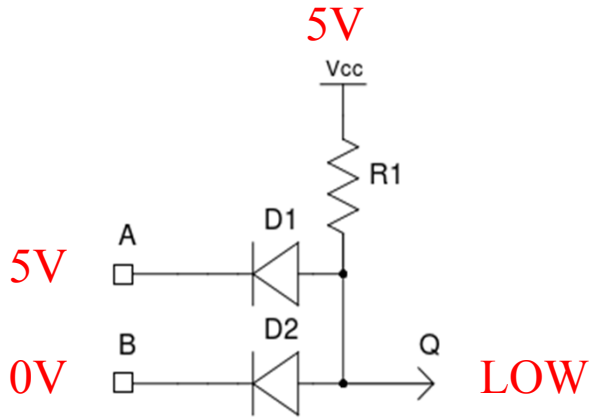
Ideally, no current will flow through the resistor R1 and the output Q will be HIGH.

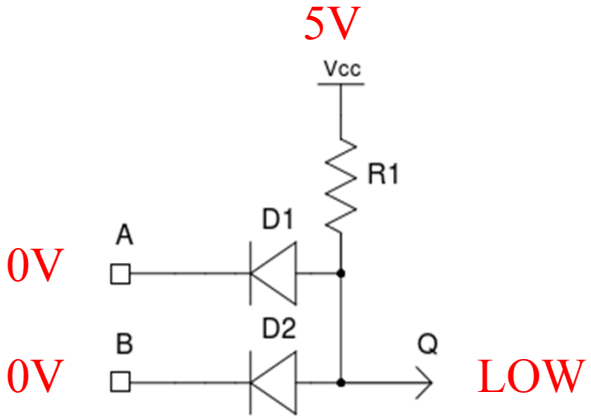
What happens if the inputs are both 4V ?



Consider the cases where one or both inputs are 0V. At least one of the diodes will be forward biased and conducting with a forward volt drop of about 0.7V







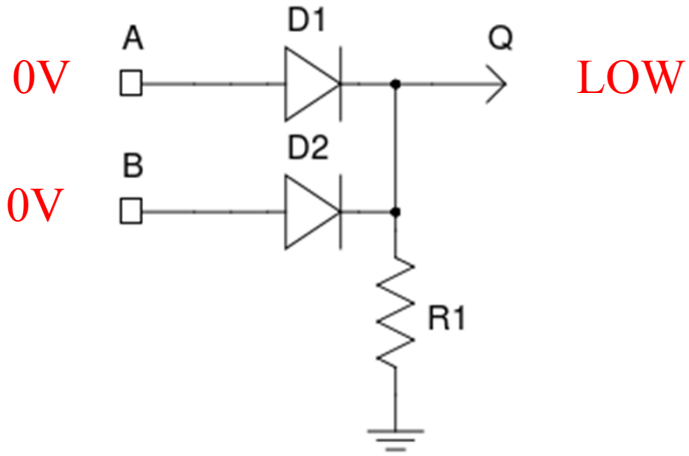
A	B	A.B
0	0	LOW
0	1	LOW
1	0	LOW
1	1	HIGH

This is the AND function.

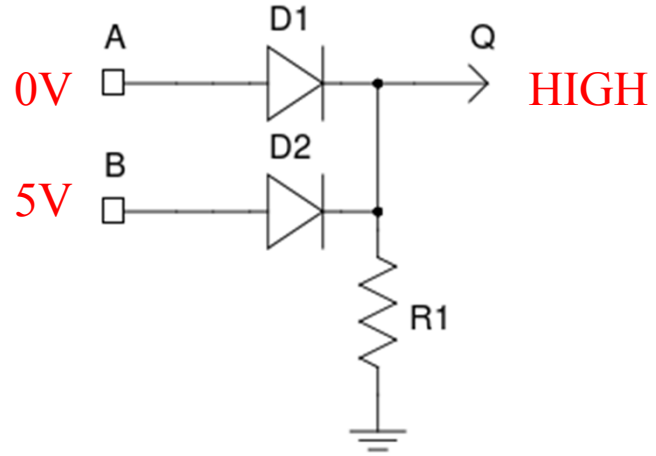
Diode Logic (OR gate)

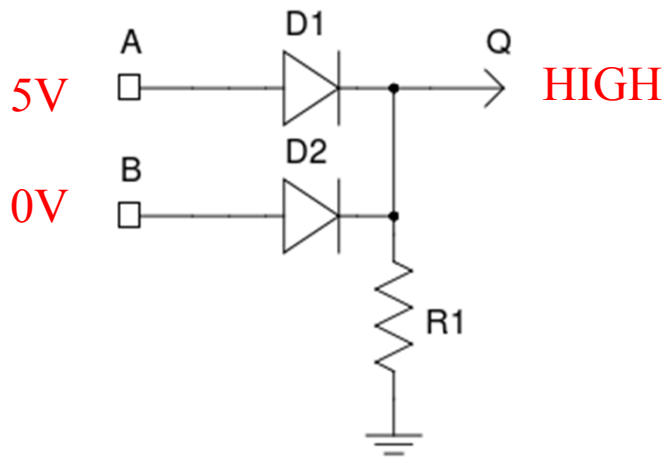
Consider the A and B inputs to both be LOW. Both diodes are reverse biased and hence cut-off.

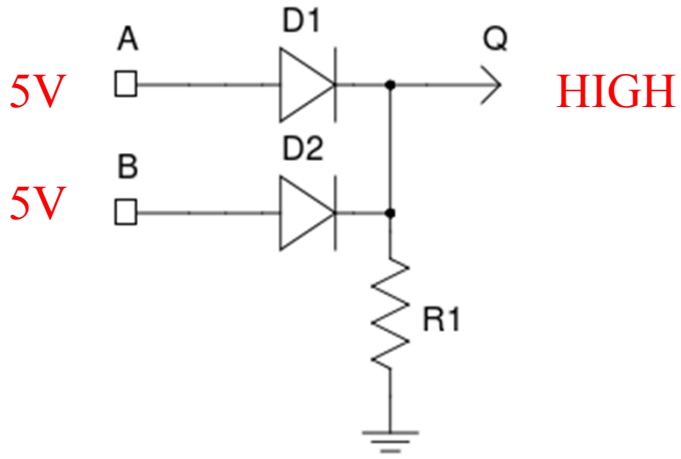
The output Q will thus be LOW.



Consider the cases where one or both inputs are 5V. At least one of the diodes will be forward biased and conducting with a forward volt drop of about 0.7V giving about 4.3V at the output.







A	B	A.B
0	0	LOW
0	1	HIGH
1	0	HIGH
1	1	HIGH

This is the OR function.

Diode Logic Problems

- It is not possible to create the NOT function.
- When logic units are cascaded, the diode volt drops add up and degrade the output voltage.
- In practice, diode logic circuits require an active transistor output stage to restore the logic levels.
- This leads us on to TTL logic circuits.