Diode and Diode Logic
4190.309
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Motivation

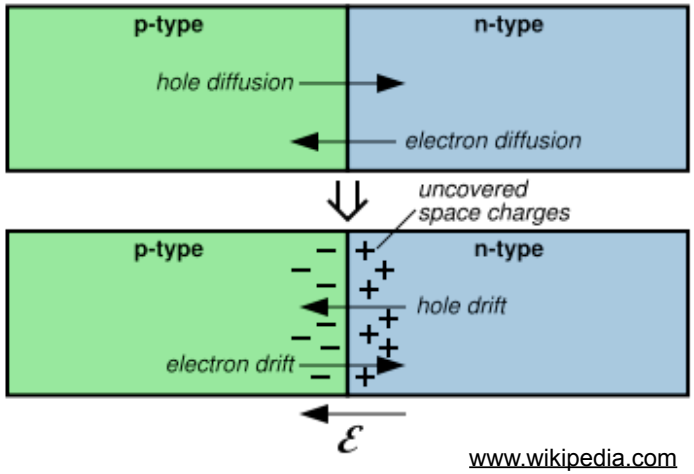
- Series of lectures
  - Diodes and transistors
  - Logic gates
    - RTL
    - DTL
    - TTL
  - Special logic gates
    - Open-collector
    - Three-state output
    - Schmitt trigger input
  - Modern logic families and logic standards

Motivation

- Modeling and characterization
  - Fidelity versus complexity
    - Linear versus non-linear
- Proper fidelity for digital system design
  - Logic design level
  - Analog circuit design level
  - Lumped circuit assumption
  - Microwave approach

Semiconductor basics

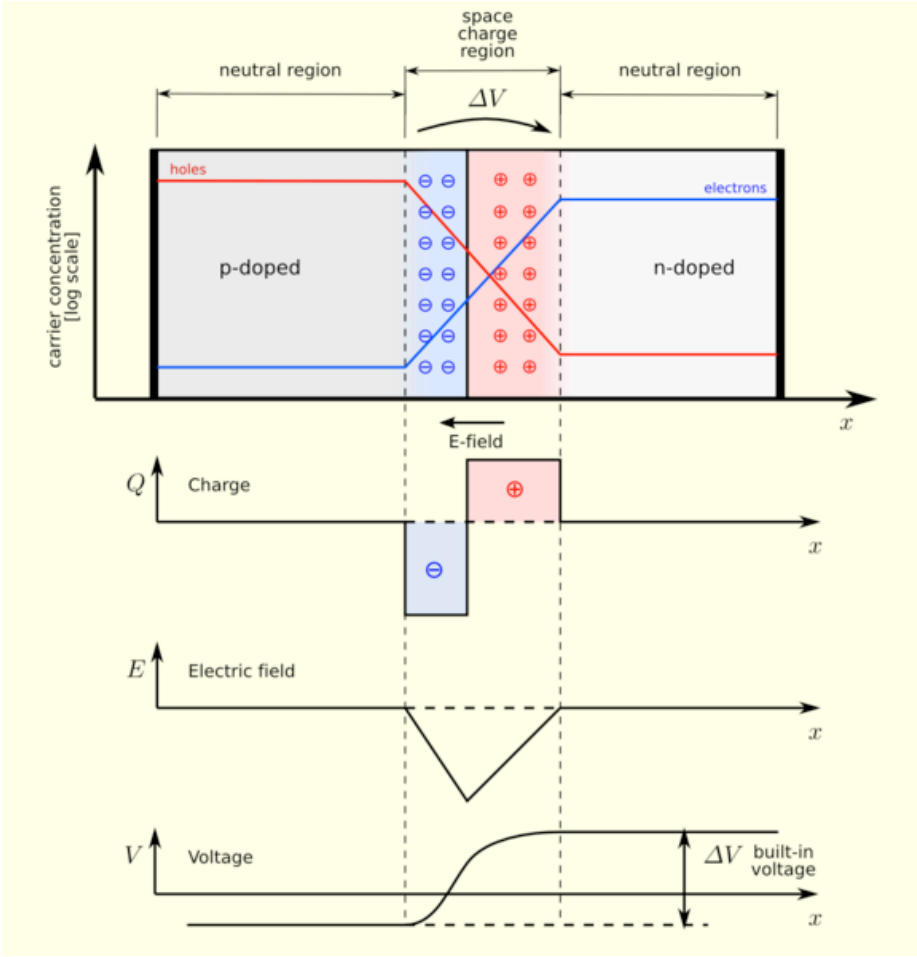
- Depletion region
  - N-type semiconductor has an excess of free electrons compared to the P-type region
  - P-type has an excess of holes compared to the N-type region
  - Electrons diffuse into the P-side
  - Holes diffuse into the N-side



www.wikipedia.com

Semiconductor basics

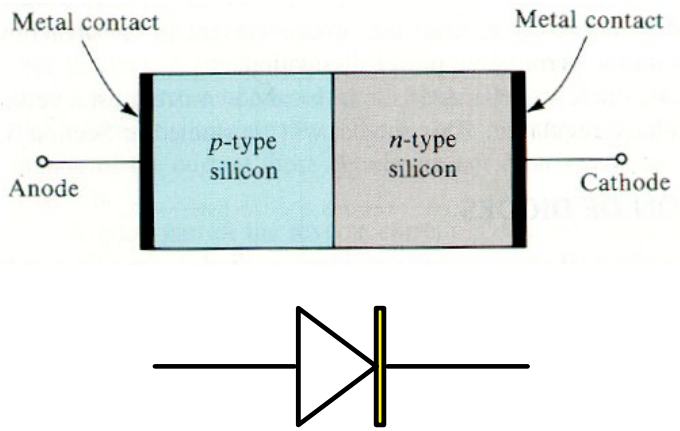
- Depletion region
  - Injected electrons and holes are recombined, leaving behind the charged ions adjacent to the interface
  - Creates an electric field that provides a force opposing the continued diffusion, built-in voltage
  - Under reverse bias, the potential drop across the depletion region increases

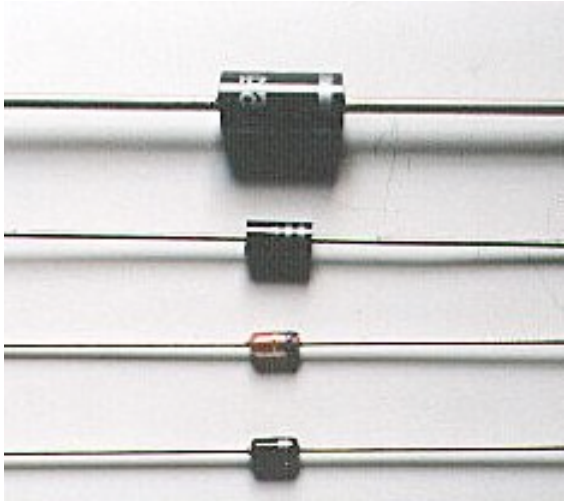


www.wikipedia.com

Diode (1)

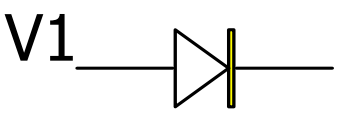
- P-N junction diode
  - 1N4148

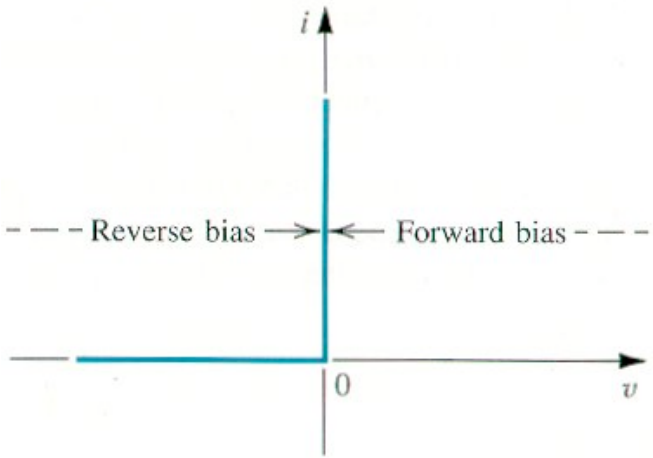




Diode (2)

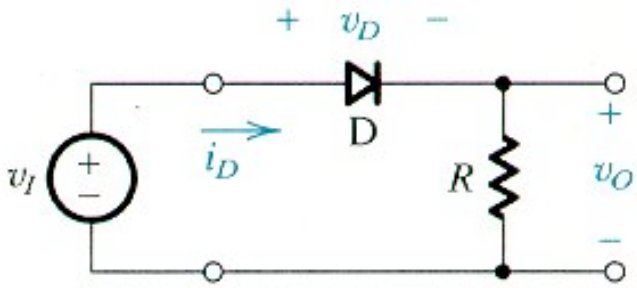
- Ideal diode
  - Forward bias: V1 > V2
  - Reverse bias: V1 < V2

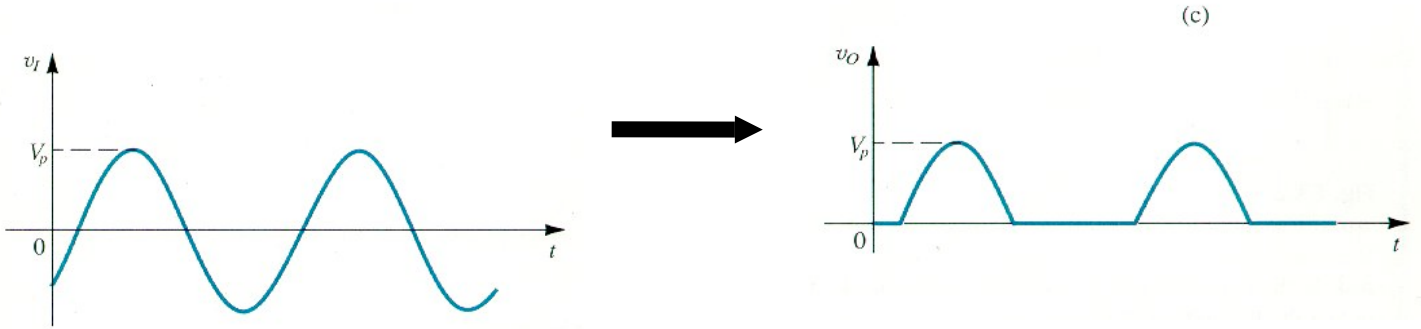




Diode (3)

- Ideal diode (contd.)





Diode (4)

- Real diode
  - Break down
- Silicon Diode
- Germanium Diode

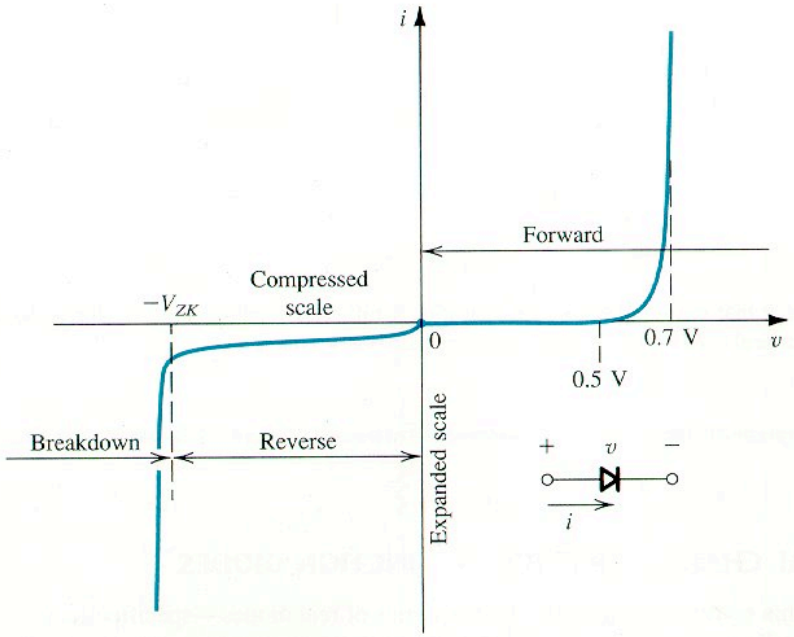
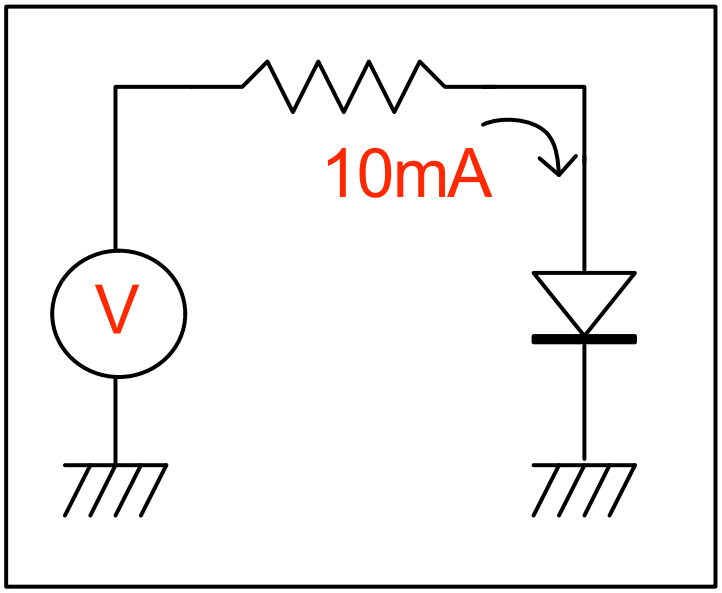
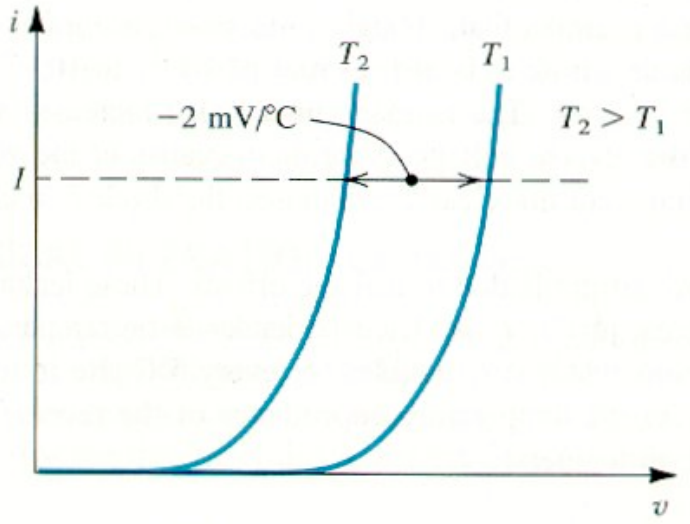


Fig. 3.8 The diode i–v relationship with some scales expanded and others compressed in order to reveal details.

Diode (5)

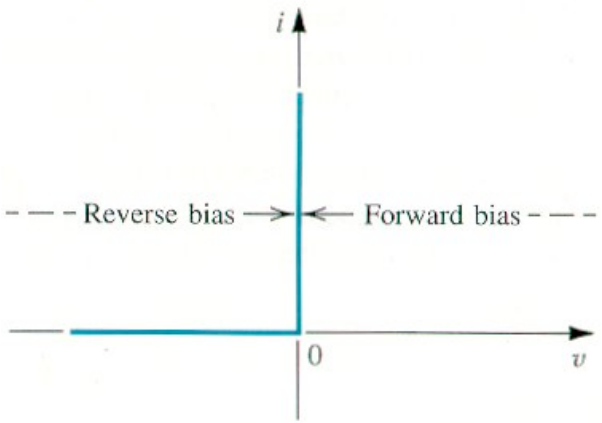
- Temperature dependence of the forward bias current

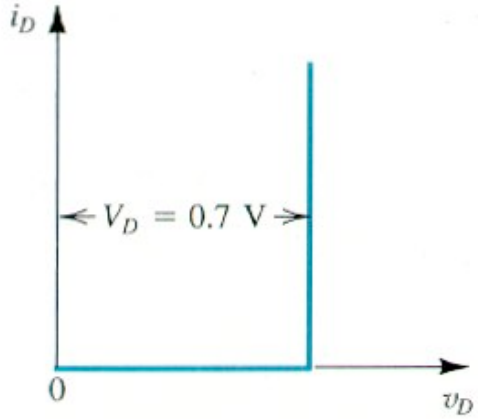


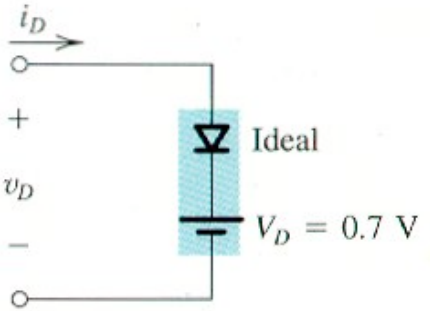


Diode (6)

- Diode in digital circuits
  - Silicon Diode: switching and rectification
  - Germanium Diode: detection

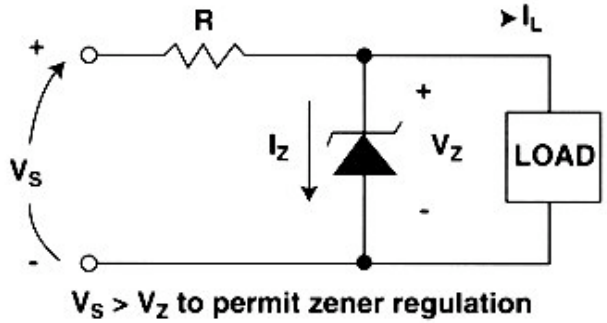






Diode (7)

- Special Diodes
  - Light emitting diode
    - GaP, GaAs, GaAlAs
  - Schottky diode
  - Zener diode
- Forward bias current
- Reverse bias voltage



$V_S > V_Z$ to permit zener regulation

Diode (8)

- Visible LED

Color	Material	Device	Absolute Maximum Ratings					Electrical/Optical characteristic							
			DC Forward If	Reverse Voltage Vr	Power Dissipation Pd	Operating Temperature Topr	Stotage Temperature Tstg	Forward Voltage Vf			Reverse Current Ir		Peak light Emitting Wave length λP	Spectral half Wave width Δλ	
								TYP	MAX	IF	MAX	Vr	MAX	TYP	If
Red	GaP	NNV-R51AD	15	5	36	-25~85	-25~100	2.0	2.4	20	10	4	695	50	20
		NNV-R31AD	15	5	36	-25~85	-25~100	2.0	2.4	20	10	4	695	50	20
Green	GaP	NNV-G51AD	20	5	84	-25~85	-25~100	2.1	2.8	20	10	4	565	30	20
		NNV-G31AD	30	5	84	-25~85	-25~100	2.1	2.8	20	10	4	565	30	20
Yellow	GaAsP GaP	NNV-Y51AD	20	5	84	-25~85	-25~100	2.0	2.8	20	10	4	585	30	20
		NNV-Y31AD	30	5	84	-25~85	-25~100	2.0	2.8	20	10	4	585	30	20
S-RED	GaAlAs GaAs	NNV-S51A2	50	5	120	-25~85	-25~100	1.8	2.2	20	10	4	660	20	20
U-RED	GaAlAs GaAlAs	NNV-U51AD	50	5	120	-25~85	-25~100	1.8	2.5	20	10	5	660	20	20
		NNV-R31AT	50	5	120	-25~85	-25~100	1.8	2.5	20	10	5	660	20	20
			mA	V	mV	℃	℃	V		mA	uA	V	nm	nm	mA

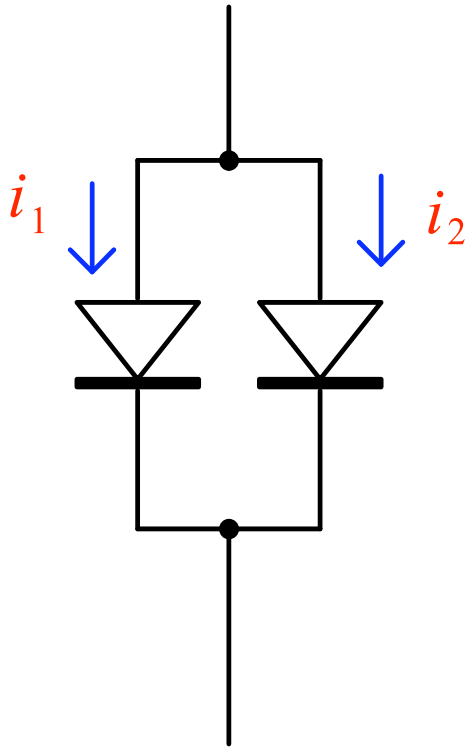
Diode (9)

- Infrared LED

Color	Material	Device	Absolute Maximum Ratings					Electrical/Optical characteristic							
			DC Forward If	Reverse Voltage Vr	Power Dissipation Pd	Operating Temperature Topr	Stotage Temperature Tstg	Forward Voltage Vf			Reverse Current Ir		Peak light Emitting Wave length λP	Spectral half Wave width Δλ	
								TYP	MAX	IF	MAX	Vr	MAX	TYP	If
W-Clear	GaAlAs GaAs	NNI-R31AT	100	5	150	-25~85	-25~100	1.4	1.5	20	100	10	940	45	100
		NNI-R51A1T	100	5	150	-25~85	-25~100	1.4	1.5	20	100	10	940	45	100
		NNI-R51A2T	100	5	150	-25~85	-25~100	1.4	1.5	20	100	10	940	45	100
		NNI-R51A3T	100	5	150	-25~85	-25~100	1.4	1.5	20	100	10	940	45	100
		NNI-R51C3T	100		150	-25~85	-25~100	1.4	1.5		100	10	940	45	100
W-Clear	GaAlAs GaAlAs	NNI-E51A3	100	5	190	-25~85	-25~100	1.65	2.0	20	100	10	880	80	100
			mA	V	mV	℃	℃	V		mA	uA	V	nm	nm	mA

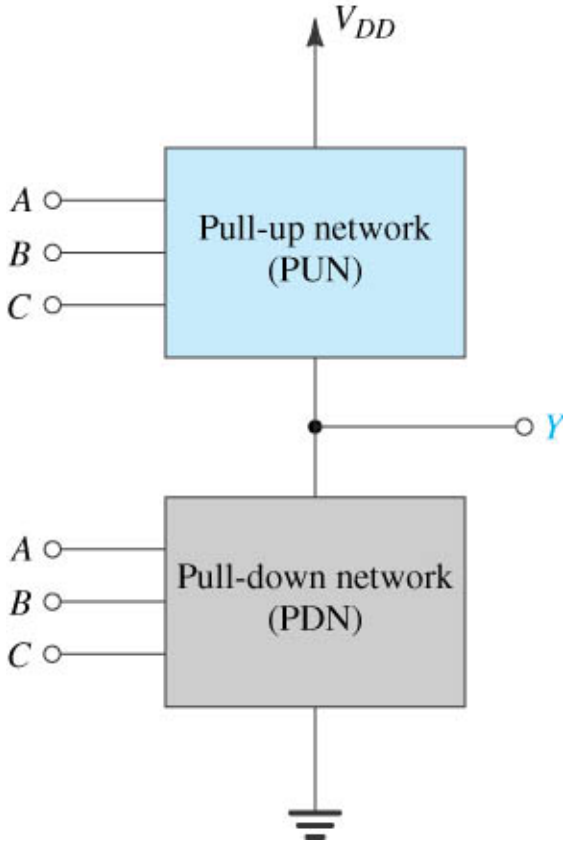
Diode (10)

- Series connection
- Parallel connection
  - Current hogging



Digital logic gates

- Pull-up and pull-down networks
  - Logic high (1)
    - Pull-up network is on
    - Pull-down network is off
  - Logic low (0)
    - Pull-up network is off
    - Pull-down network is on

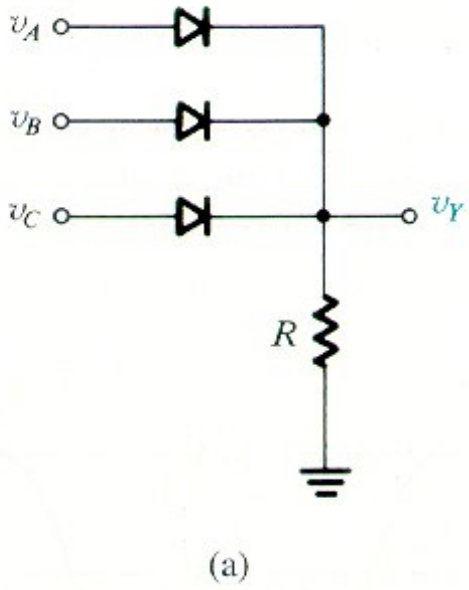


Digital logic gates

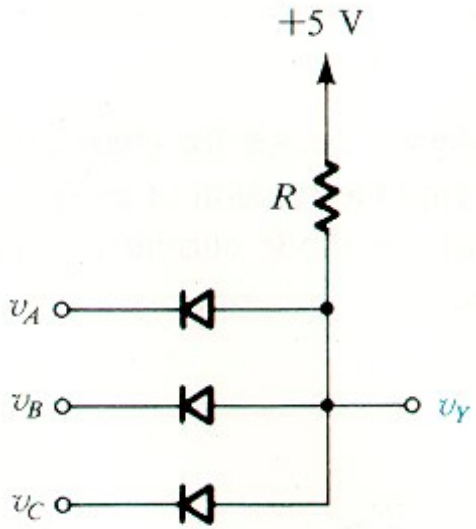
- Ratioed logic
  - Either pull-up or pull-down network has a constant resistance
    - Neither on, nor off
  - Usually pull-up network has a constant resistance
    - Only the pull-down network determines the logic value
  - Logic high (1)
    - Pull-down network is off
  - Logic low (0)
    - Pull-down network is on

Diode logic

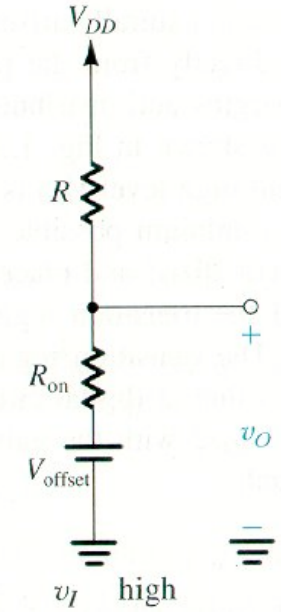
- Diode switches
  - Ratioed logic



(a)



(b)



v_I high

Note: Some figures are from Microelectronic Circuits fourth edition by Sedra and Smith, Oxford.