CSE 251
Electronic Devices and Circuits

Lecture 1

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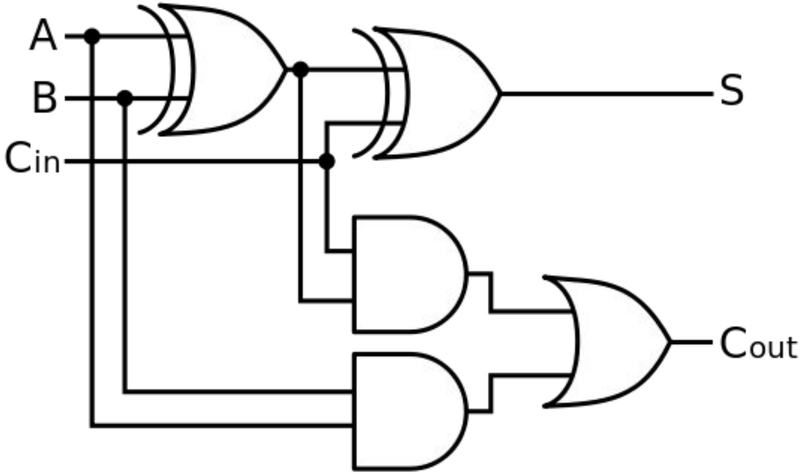
Mathematical Operations

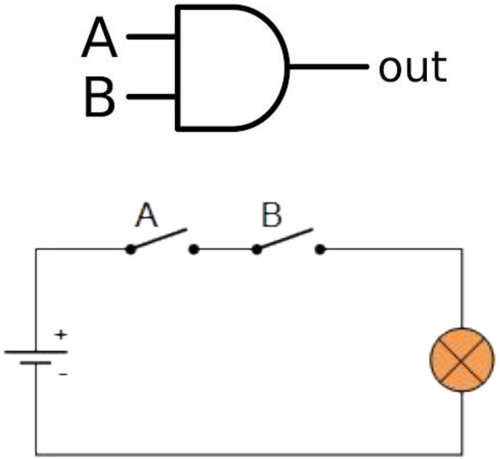
- Addition:4 + 5 □ 9   (0100 + 0101 □ 1001)
- Subtraction: 10 – 9 □ 1 (1010 + 0111 □ 0001)
- Multiplication: 5x4 = 4+4+4+4+4 = 20
- Division: 10/2 = 2 can be subtracted from 10, 5 times

Digital Logic Circuit

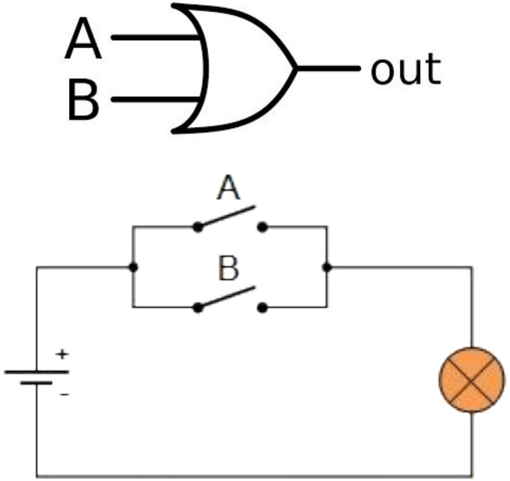
Addition: 4 + 5 □ 9 (0100 + 0101 □ 1001)



Logic gates are basically switches



AND Gate



OR Gate

The faster you can operate these switches, the faster you can complete the functions!!!

How can we make these switches?

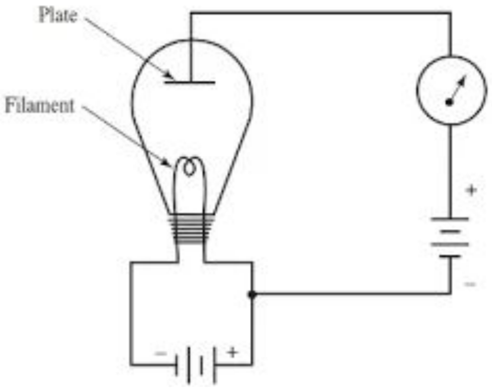
- **Mechanical switch**
  - Bulky and heavy
  - Mechanical wear over time
  - Noisy
  - Ultra slow
  - Requires lots of energy to operate

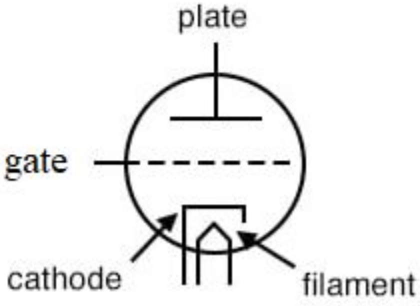
SPST Switch

Electromechanical Relay

How can we make these switches?

- **Vacuum tube**



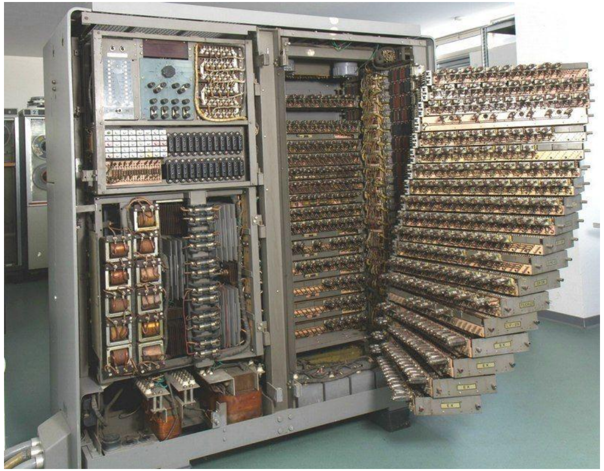


- To ensure current passes along one direction and stops flowing in the other direction
- Gate allows us to control this is a more robust way

Image: From All Abouts Circuits Chapter 13 - Electron Tubes. Available online: allaboutcircuits.com/textbook/semiconductors/chpt-13/the-triode/ and Vacuum Tubes: The World Before Transistors. enginnering.com. Available online: engineering.com/story/vacuum-tubes-the-world-before-transistors

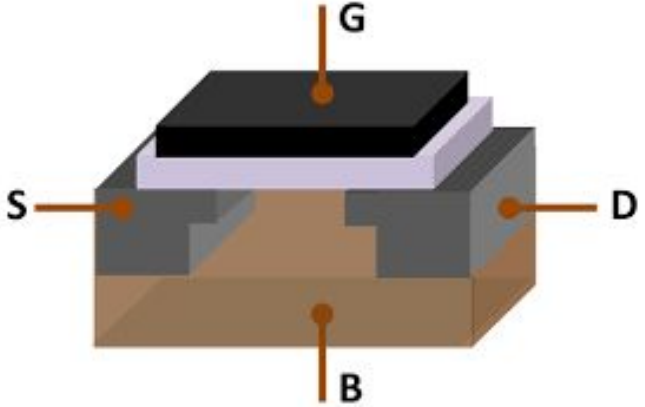
How can we make these switches?

- **Vacuum tubes**
  - Bulky
  - Lots of energy
  - Not scalable



How can we make these switches?

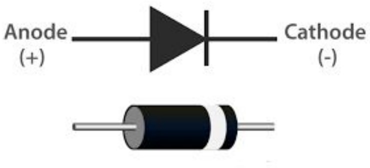
- **Electronic switches**
  - No moving parts
  - Scalable
  - High speed



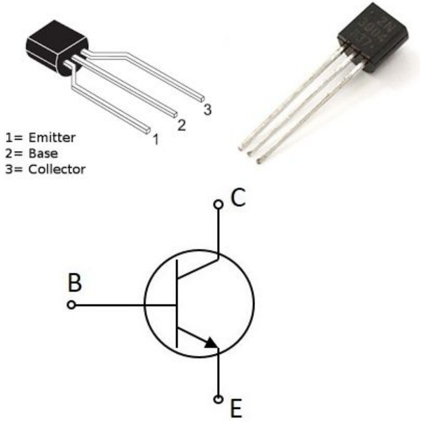
5GHz computer 5 billion operations per second !!!

What are electronic circuits?

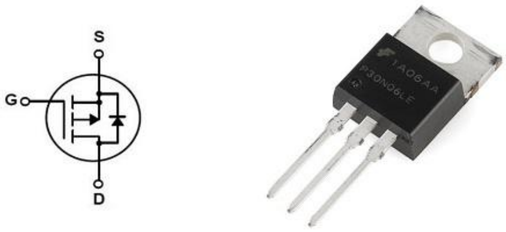
- Any circuit consisting of semiconductors.



Diode



BJT



MOSFET

- **Transistor:** probably the most impactful invention of the present world

- **Why do we need this course?**

High Level Programming → **Assembly language** → **Machine language** → **Architecture**

(C, C++, etc.) (x86, ARM, CUDA, etc.) (100110) (RISC, CISC, etc.)

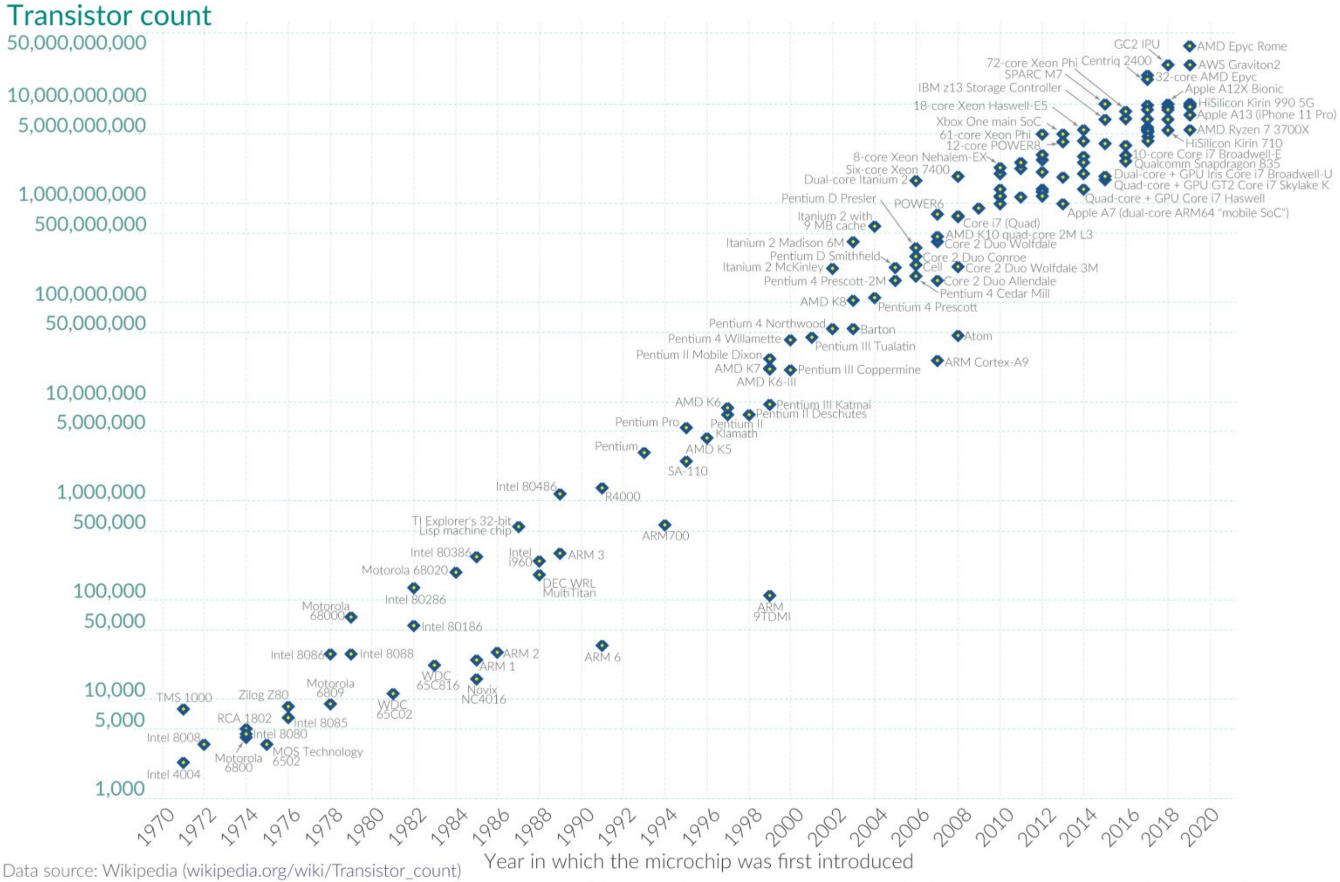
…Architecture → **System level** → **Gate** → **Transistor**

(Register, Mux) (AND, OR, etc.)

Moore's Law: The number of transistors on microchips doubles every two years

Our World in Data

Moore's law describes the empirical regularity that the number of transistors on integrated circuits doubles approximately every two years. This advancement is important for other aspects of technological progress in computing – such as processing speed or the price of computers.



Data source: Wikipedia (wikipedia.org/wiki/Transistor_count)

OurWorldinData.org – Research and data to make progress against the world's largest problems.

Why do we need electronic circuits?

Digital Electronics

- Boolean logic
- Addition, subtraction, multiplication, division

Analog Electronics

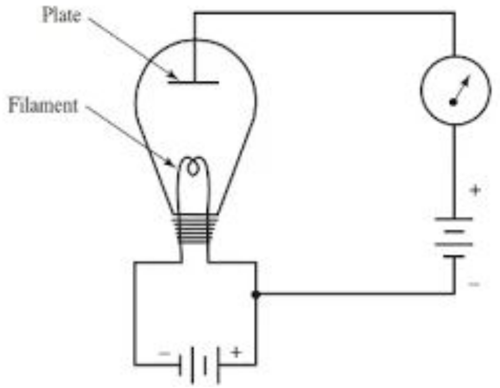
- Amplifiers, radio transmitter and receivers, modulator

Power Electronics

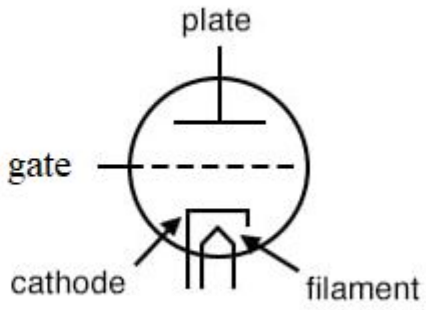
- Motor control
- AC to DC conversion or vice versa
- HVDC circuits
- Charge control circuits

Lecture 1: Introduction

- **Vacuum tube**



Diode

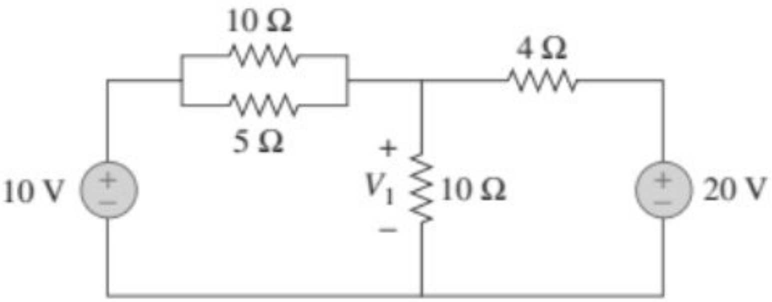


Triode

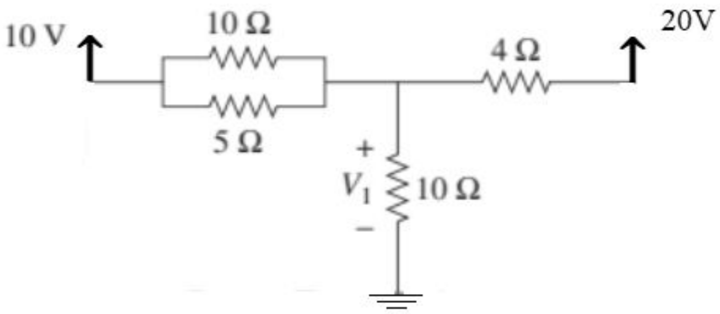
- To ensure current passes along one direction and stops flowing in the other direction
- Gate allows us to control this is a more robust way

Image: From All Abouts Circuits Chapter 13 - Electron Tubes. Available online: allaboutcircuits.com/textbook/semiconductors/chpt-13/the-triode/ and Vacuum Tubes: The World Before Transistors. enginnering.com. Available online: engineering.com/story/vacuum-tubes-the-world-before-transistors

Lecture 2: Alternate circuit representation



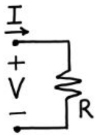
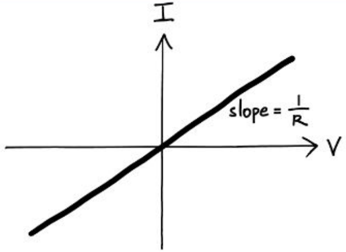
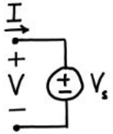
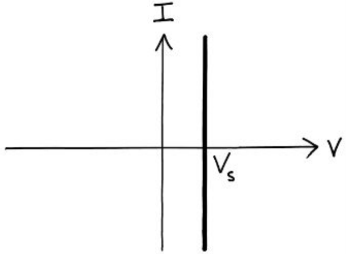
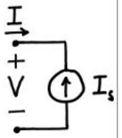
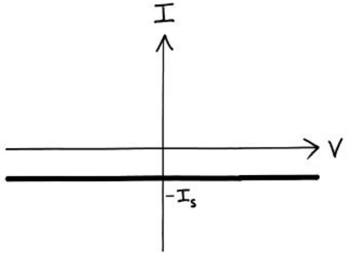
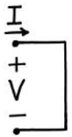
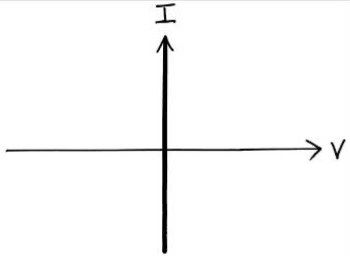
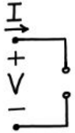
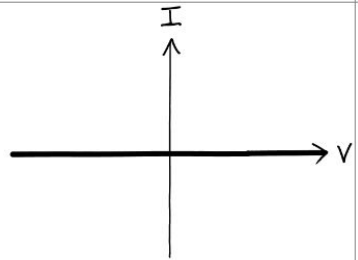
Loop representation



Alternate representation

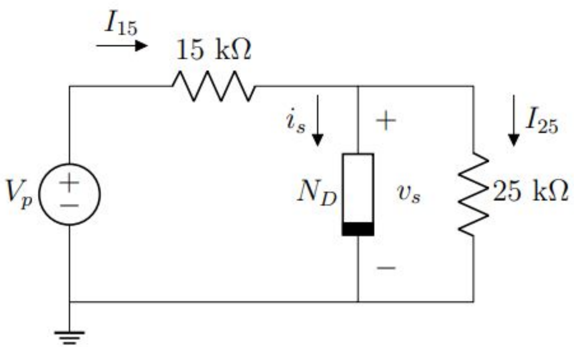
- We shall try to use a common ground for all the sources, minimizing the number of floating sources
- KCL remains the same in both types of representations. KVL works along a line in the alternate representation, not in a loop

Lecture 3: I-V characteristics

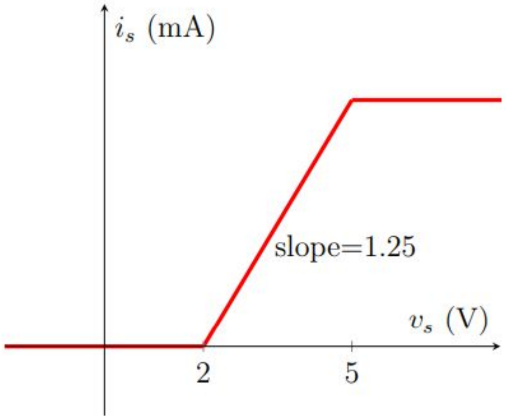
Element	Diagram	I-V Characteristic	Explanation
Resistor			A resistor R satisfies Ohm's law $I = V/R$, so its I-V characteristic goes through the origin and has slope $1/R$.
Voltage Source			A voltage source V_s maintains a fixed voltage drop and can allow any current, so its I-V characteristic is a vertical line at $V = V_s$.
Current Source			A current source I_s maintains a fixed current and can allow any voltage drop, so its I-V characteristic is a horizontal line at $I = -I_s$. Note that there is a negative sign because the current arrow labels on I and I_s are in opposite directions.
Short Circuit			A short circuit is a direct connection between two terminals. The short circuit maintains zero voltage drop and can allow any current, so its I-V characteristic is a vertical line at $V = 0$. Notice that a short circuit behaves identically to a zero voltage source with $V_s = 0$ V.
Open Circuit			An open circuit is the absence of a connection between two terminals. The open circuit maintains zero current and can allow any voltage drop, so its I-V characteristic is a horizontal line at $I = 0$. Notice that an open circuit behaves identically to a zero current source with $I_s = 0$ A.

From: https://faculty.math.illinois.edu/~dpv/ECE110Notes/content/course_notes/course_notes_files/IVCharacteristics.html. Used for academic purposes only.

Lecture 3: I–V characteristics



(a) A circuit with a non-linear device N_D



(b) IV Characteristics of the non-linear device N_D

(a) **Identify** the equivalent linear circuit models for the 3 linear segments in the IV characteristics of the non-linear device N_D and **calculate** the model parameters. [3]

(b) **Show** the alternative representation of the circuit in Figure (a). [2]

(c) **Detect** the operating region for the device when $v_s = 3$ V and **calculate** the current through the device, i_s, for this voltage. [2]

(d) **Apply** KVL and KCL to calculate the value of voltage source V_p when $v_s = 3$ V. [3]

From: Mid, Spring 2022

Lecture 4: Introduction to diodes

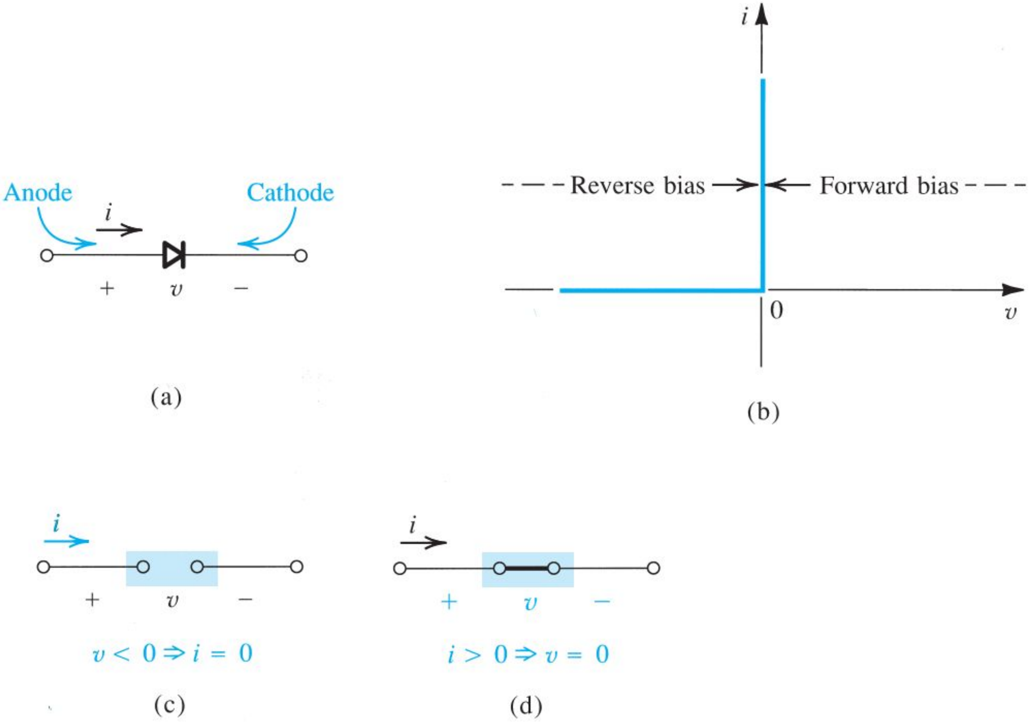


Figure 4.1 The ideal diode: **(a)** diode circuit symbol; **(b)** i–v characteristic; **(c)** equivalent circuit in the reverse direction; **(d)** equivalent circuit in the forward direction.

Lecture 5: AC to DC conversion

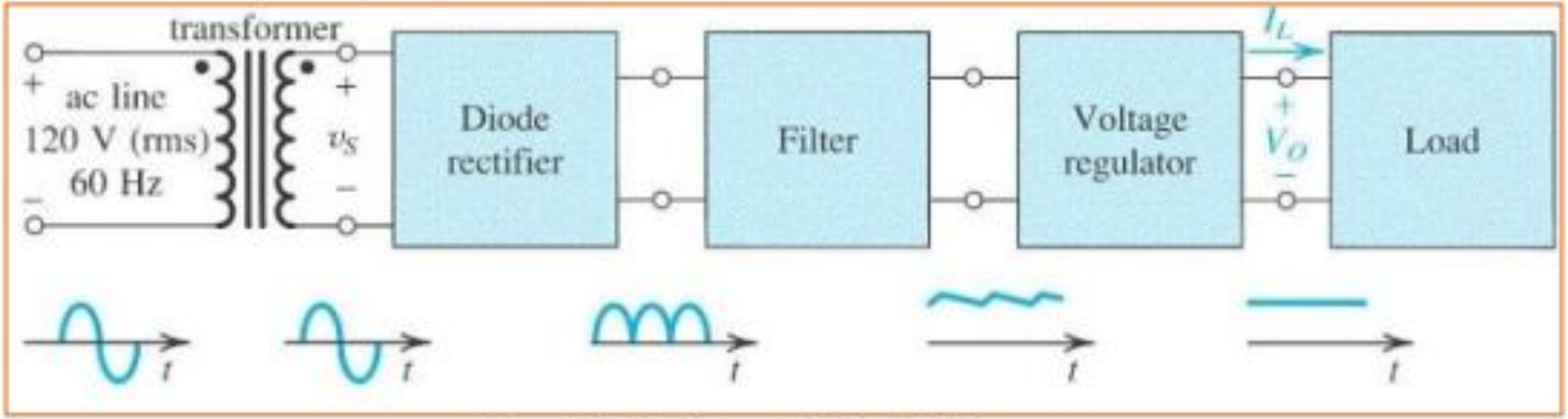


Figure 4 Block diagram of AC to DC Converter

NOTE: V_i can be sinusoidal (generally), triangular, rectangular, etc. Read the question carefully.

Lecture 5: AC to DC conversion

The Ideal-Diode Model

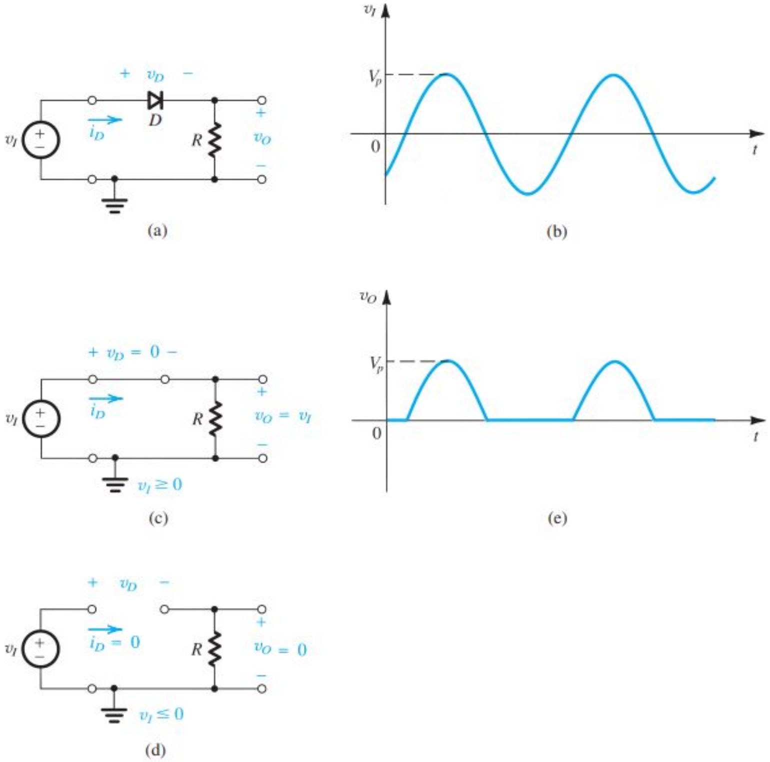


Figure 4.3 (a) Rectifier circuit. (b) Input waveform. (c) Equivalent circuit when $v_I \geq 0$. (d) Equivalent circuit when $v_I \leq 0$. (e) Output waveform.

From Microelectronic Circuits by Adel S. Sedra & Kenneth C. Smith: Chapter 4. 7th edition. Published by Oxford University Press. Used for educational purposes only.

Lecture 6: Ideal diodes and building logic gates

- **Max/OR and Min/AND operation:**

(remember the conditions when they are applicable)

- Learn to implement AND, OR logics using them

(like implement y=a+bx using ideal diodes)

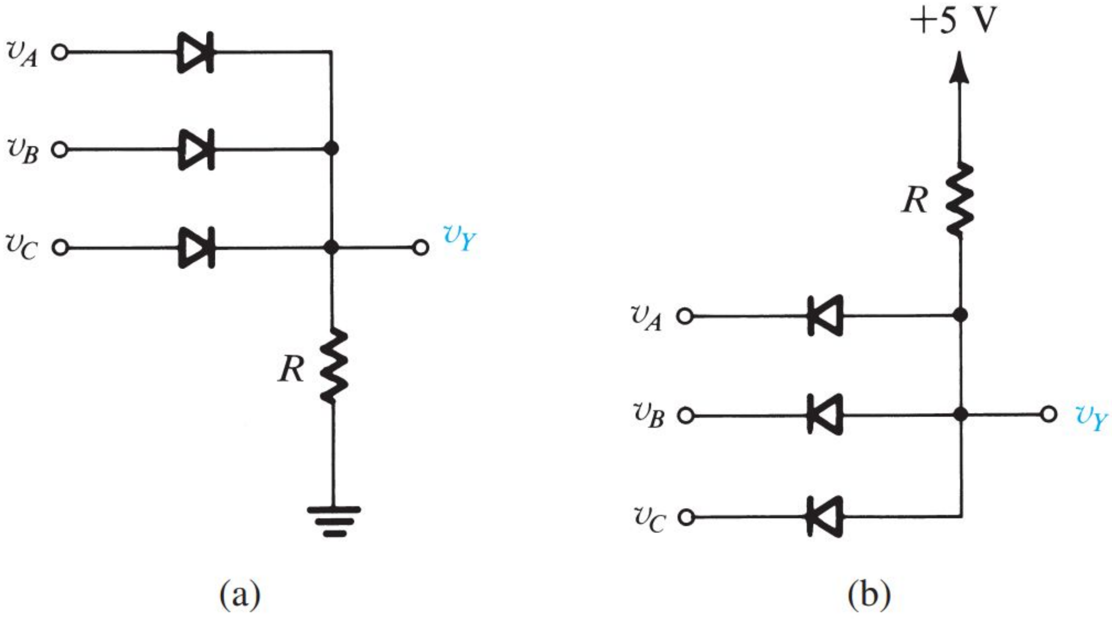
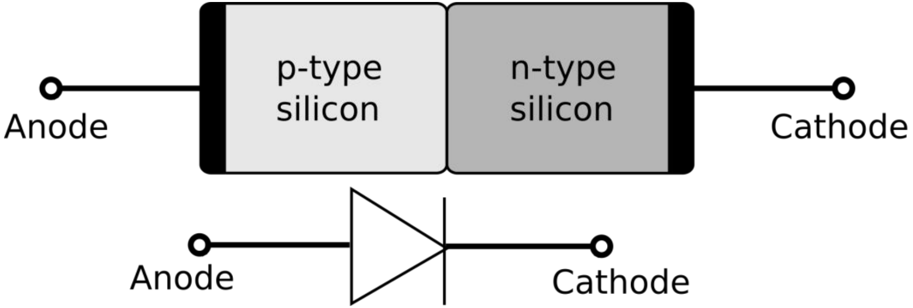


Figure 4.5 Diode logic gates: **(a)** OR gate; **(b)** AND gate (in a positive-logic system).

Lecture 7: p-n junction, 3 models of diode



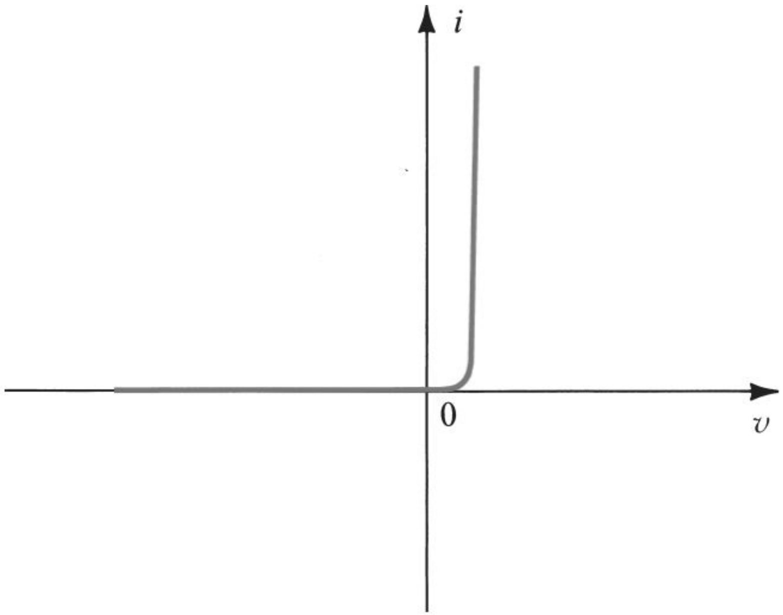


Figure 4.7 The i–v characteristic of a silicon junction diode.

Lecture 7: p-n junction, 3 models of diode

The Constant-Voltage-Drop Model

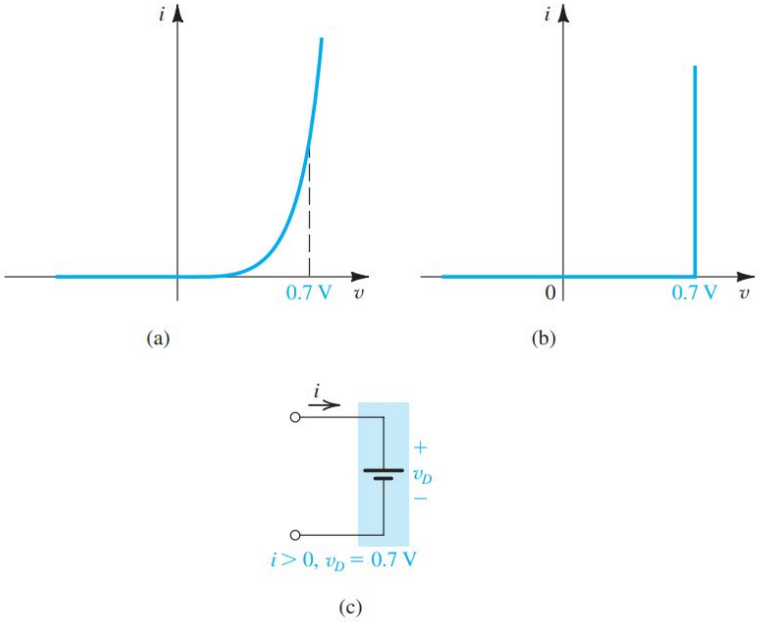
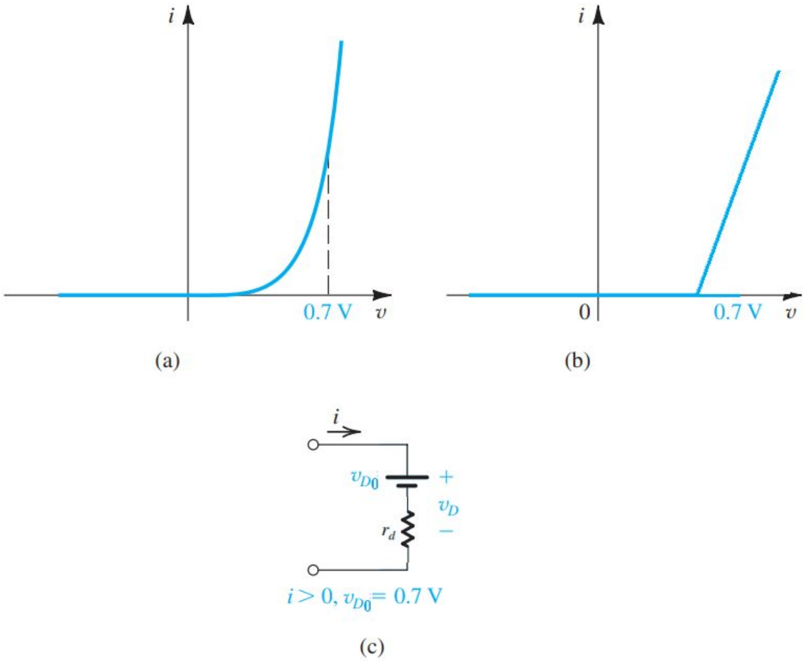


Figure 4.12 Development of the diode constant-voltage-drop model: **(a)** the exponential characteristic; **(b)** approximating the exponential characteristic by a constant voltage, usually about 0.7 V$_i$; **(c)** the resulting model of the forward-conducting diodes.

The Constant-Voltage-Drop+R Model



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Lecture 7: p-n junction, 3 models of diode

Example 4.2

Assuming the diodes to be ideal, find the values of I and V in the circuits of Fig. 4.6.

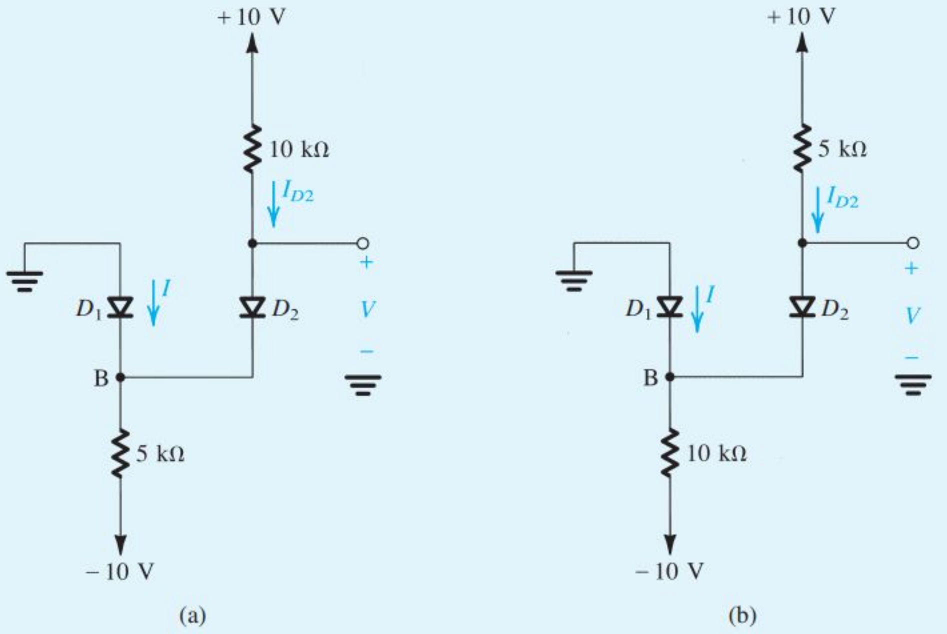

Figure 4.6 Circuits for Example 4.2.

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Lecture 8: Method of assumed state

EXAMPLE 2.9

Objective: Determine the output voltage and diode currents for the circuit shown in Figure 2.35, for two values of input voltage.

Assume the circuit parameters are $R_1 = 5\ \text{k}\Omega$, $R_2 = 10\ \text{k}\Omega$, $V_\gamma = 0.7$ V, $V^+ = +5$ V, and $V^- = -5$ V. Determine v_O, i_{D1}, and i_{D2} for $v_I = 0$ and $v_I = 4$ V.

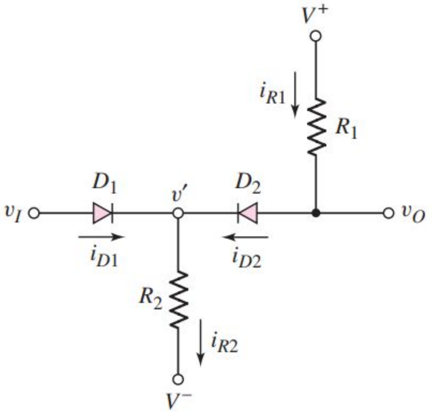
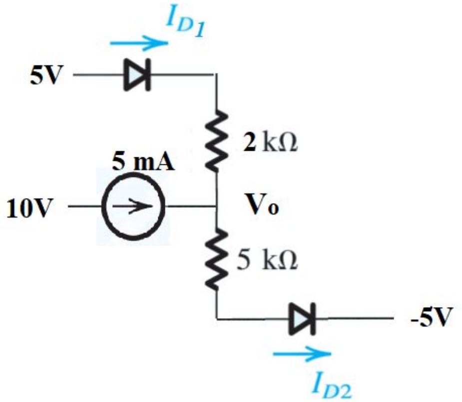
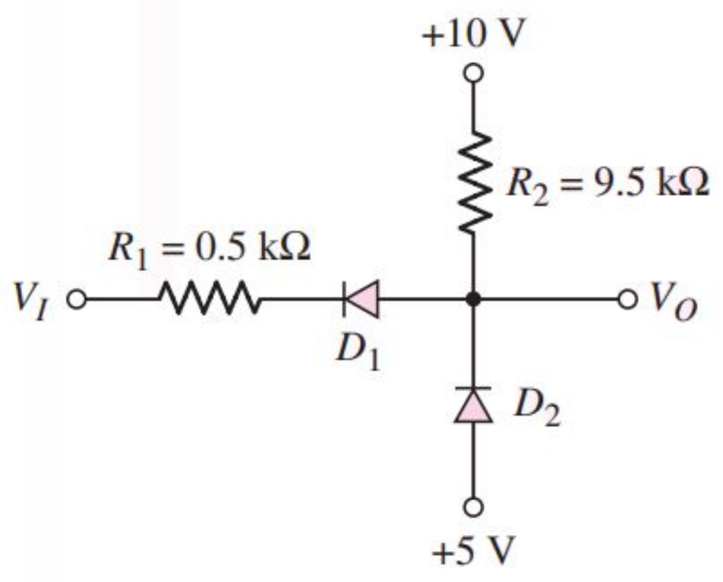


Figure 2.35 A two-diode circuit



Example: Find the values of I_{D1}, I_{D2}, and V_o in the circuit shown below assuming the diodes to be non-ideal ***[Hints: use constant voltage drop model with V_{D0}=0.7 V]***

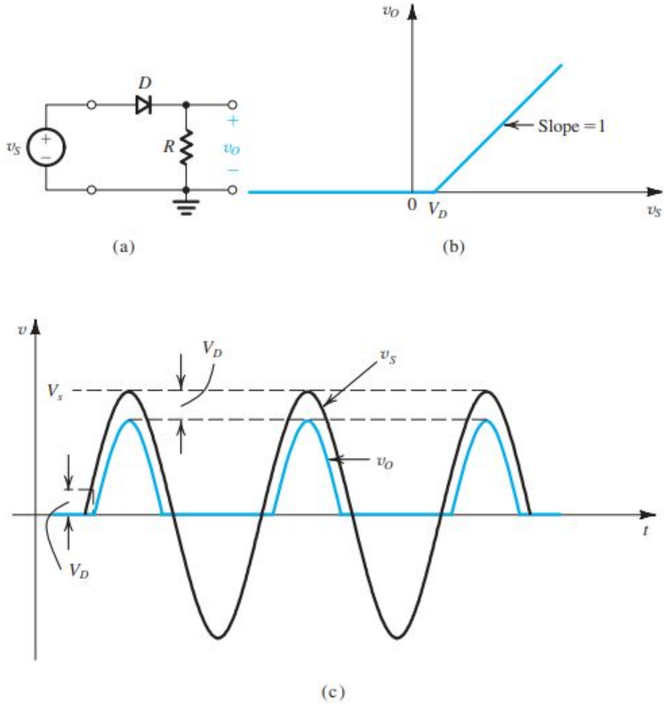
Lecture 8: Method of assumed state

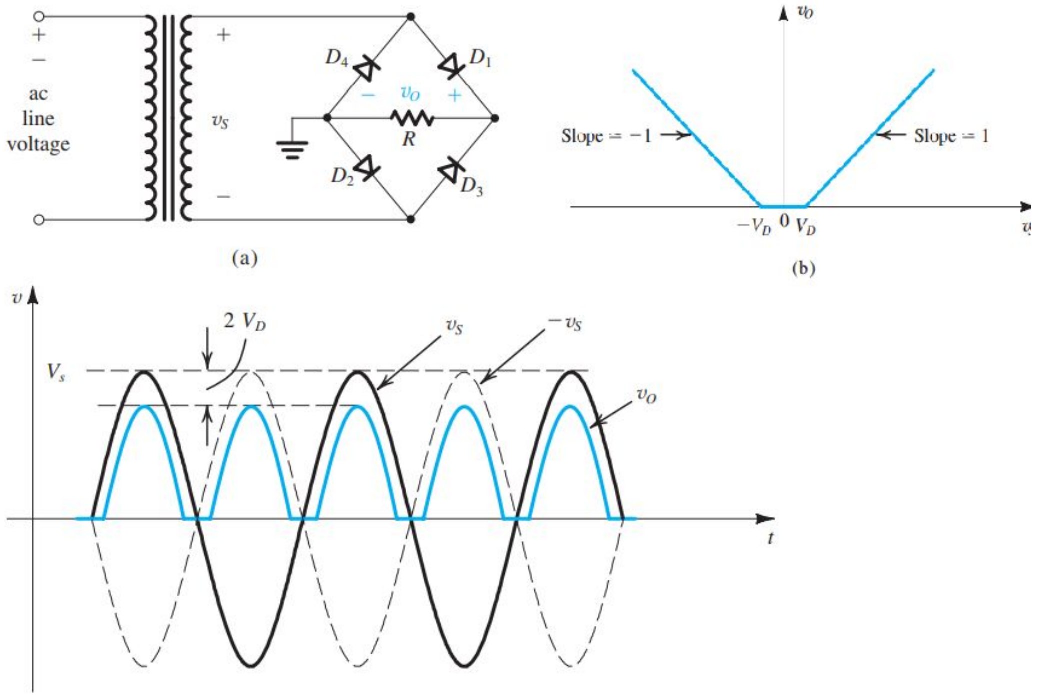


Example: Find the values of I_{D1}, I_{D2}, and V_o in the circuit shown below assuming the diodes to be Non-ideal. Here V_i=2V. ***[Hints: use constant voltage drop model with V_{D0}=0.7 V].***

NOTE: Changing the values of R or V_i may change the condition of diodes being ON or OFF

Lecture 9: Half-wave and Full-wave rectifier





Half-wave

Full-wave

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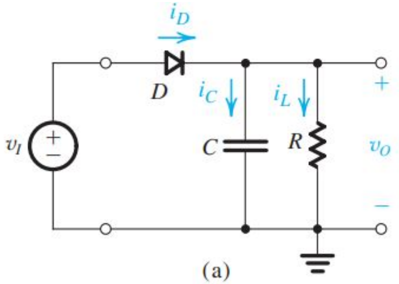
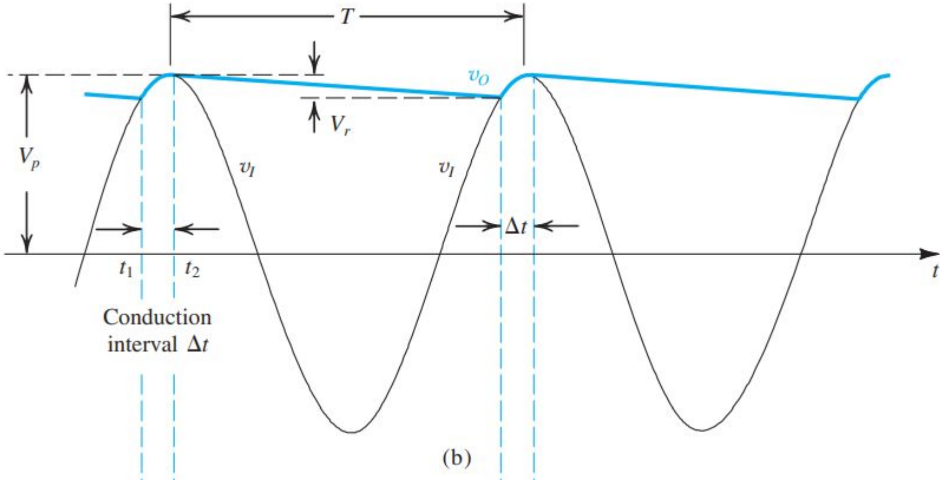
Lecture 10: Filtering and calculating ripple values





Lecture 10: Filtering and calculating ripple values

Without capacitor

Rectifier	i/p peak	o/p peak	average
H/W	V_M	V_P	
F/W	V_M	V_P	

With capacitor

Rectifier	i/p peak	o/p peak	frequency	Ripple voltage	average
H/W	V_M		$f_r=f_i$		
F/W	V_M		$f_r=2f_i$		

$$I_{o,avg}=V_{o,avg}/R,\ V_{rms}=V_p/\sqrt{2}$$

Lecture 11: Voltage regulation

- A voltage regulator is a circuit whose purpose is to provide a constant dc voltage between its output terminals.
- The output voltage is required to remain as constant as possible in spite of
    - changes in the dc power-supply voltage that feeds the regulator circuit **(evaluated as line regulation)**
    - changes in the load current drawn from the regulator output terminal **(evaluated as Load regulation)**
- Since the forward-voltage drop of the diode remains almost constant at **approximately 0.7 V** while the current through it varies by relatively large amounts, a forward-biased diode can make a simple voltage regulator.

Lecture 11: Voltage regulation

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Example 4.6

Consider the circuit shown in Fig. 4.17. A string of three diodes is used to provide a constant voltage of about 2.1 V. We want to calculate the percentage change in this regulated voltage caused by (a) a ±10% change in the power-supply voltage, and (b) connection of a 1-kΩ load resistance.

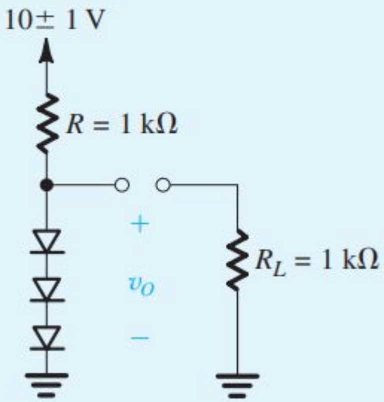
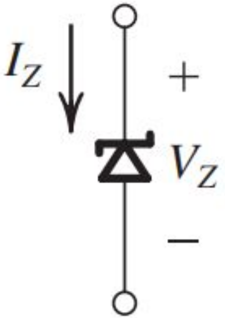
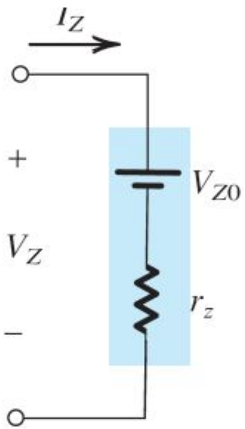


Figure 4.17 Circuit for Example 4.6.

Lecture 12: Zener diode and voltage regulation





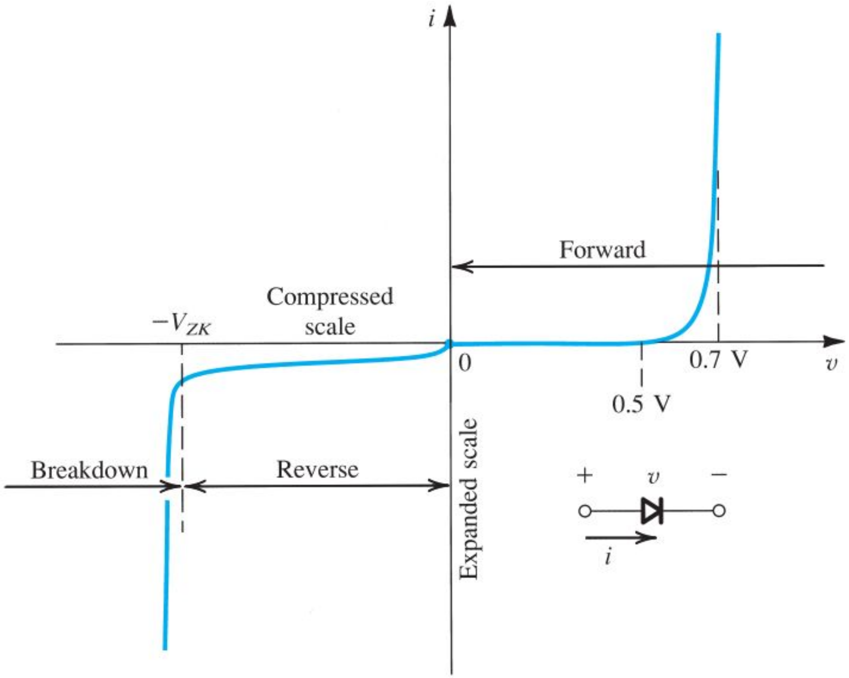


Figure 4.8 The diode i–v relationship with some scales expanded and others compressed in order to reveal details.

Lecture 12: Zener diode and voltage regulation

Example 4.7

The 6.8-V zener diode in the circuit of Fig. 4.21(a) is specified to have $V_Z = 6.8$ V at $I_Z = 5$ mA, $r_z = 20\ \Omega$, and $I_{ZK} = 0.2$ mA. The supply voltage V^+ is nominally 10 V but can vary by ± 1 V.

(a) Find V_O with no load and with V^+ at its nominal value.

(b) Find the change in V_O resulting from the ± 1-V change in V^+. Note that $(\Delta V_O / \Delta V^+)$, usually expressed in mV/V, is known as **line regulation**.

(c) Find the change in V_O resulting from connecting a load resistance R_L that draws a current $I_L = 1$ mA, and hence find the **load regulation** $(\Delta V_O / \Delta I_L)$ in mV/mA.

(d) Find the change in V_O when $R_L = 2$ kΩ.

(e) Find the value of V_O when $R_L = 0.5$ kΩ.

(f) What is the minimum value of R_L for which the diode still operates in the breakdown region?

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Practice

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Practice

Thank you

and

Good luck!