CSE 251

Electronic Devices and Circuits

Lecture 1-10 Overview

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Lecture 1: Introduction

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

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

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

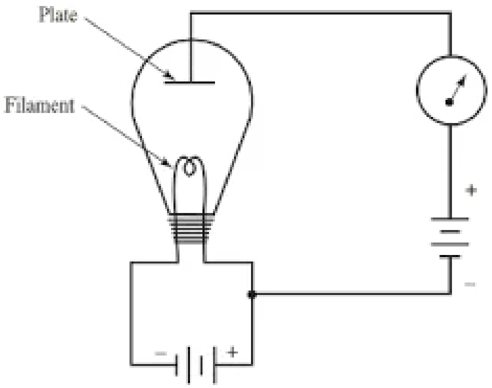
(C, C++, etc.) (x86, ARM, CUDA, etc.) (100110) (RISC, CISC, etc.)

…Architecture → System level → Gate → Transistor

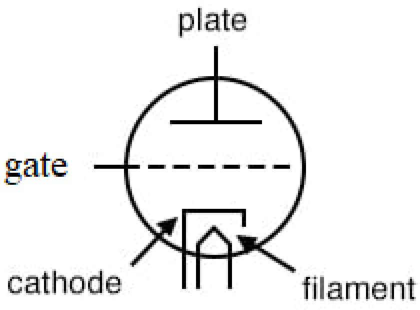
(Register, Mux) (AND, OR, etc.)

Lecture 1: Introduction

- **Vacuum tube**



Diode

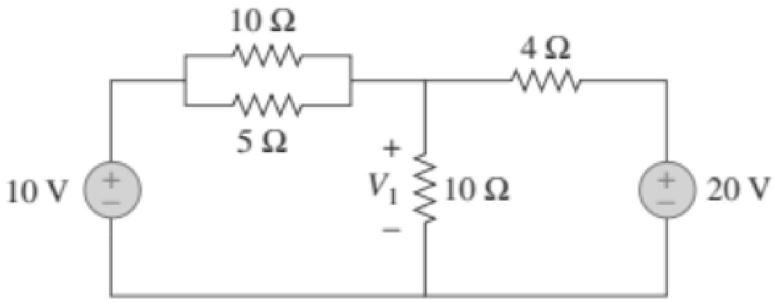


Triode

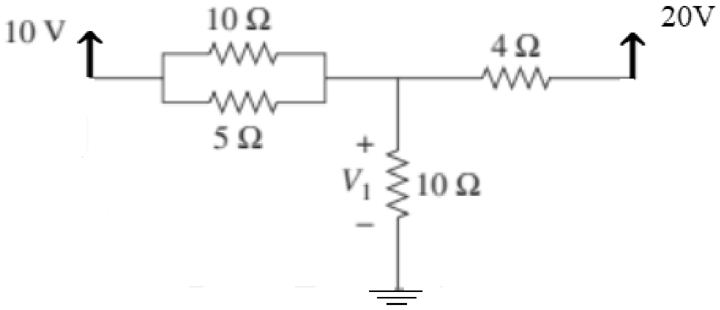
- To ensure current passes along one direction and stops flowing in the other direction
- Gate allows us to control this is a more robust way

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



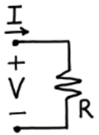
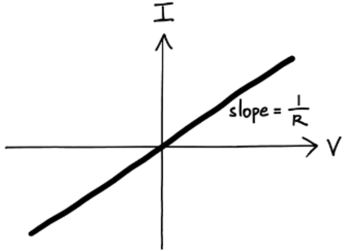
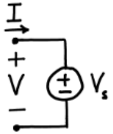
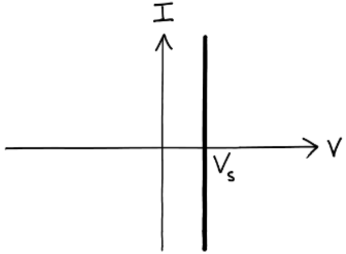
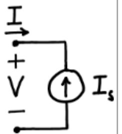
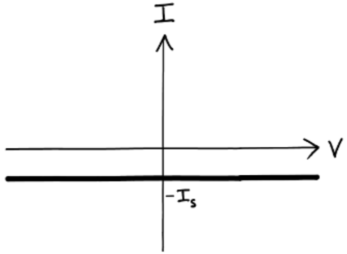
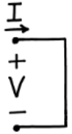
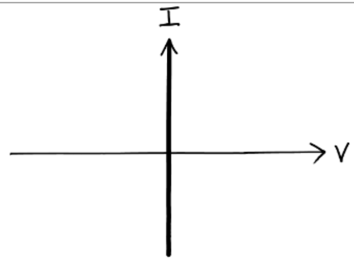
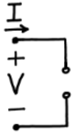
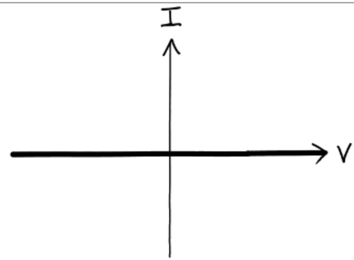
Loop representation



Alternate representation

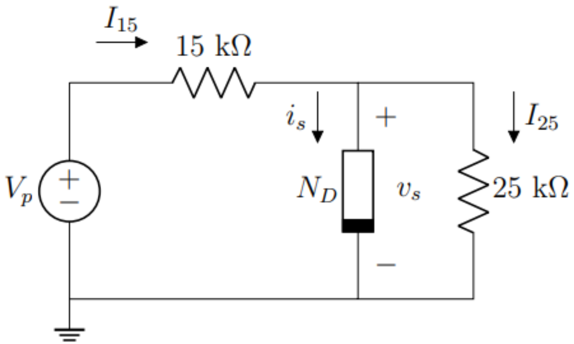
- We shall try to use a common ground for all the sources, minimizing the number of floating sources
- KCL remains the same in both types of representations. KVL works along a line in the alternate representation, not in a loop

Lecture 3: I-V characteristics

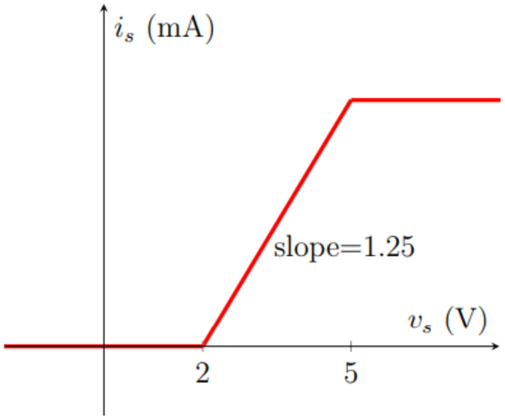
Element	Diagram	I-V Characteristic	Explanation
Resistor			A resistor R satisfies Ohm's law $I = V/R$, so its I-V characteristic goes through the origin and has slope $1/R$.
Voltage Source			A voltage source V_s maintains a fixed voltage drop and can allow any current, so its I-V characteristic is a vertical 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

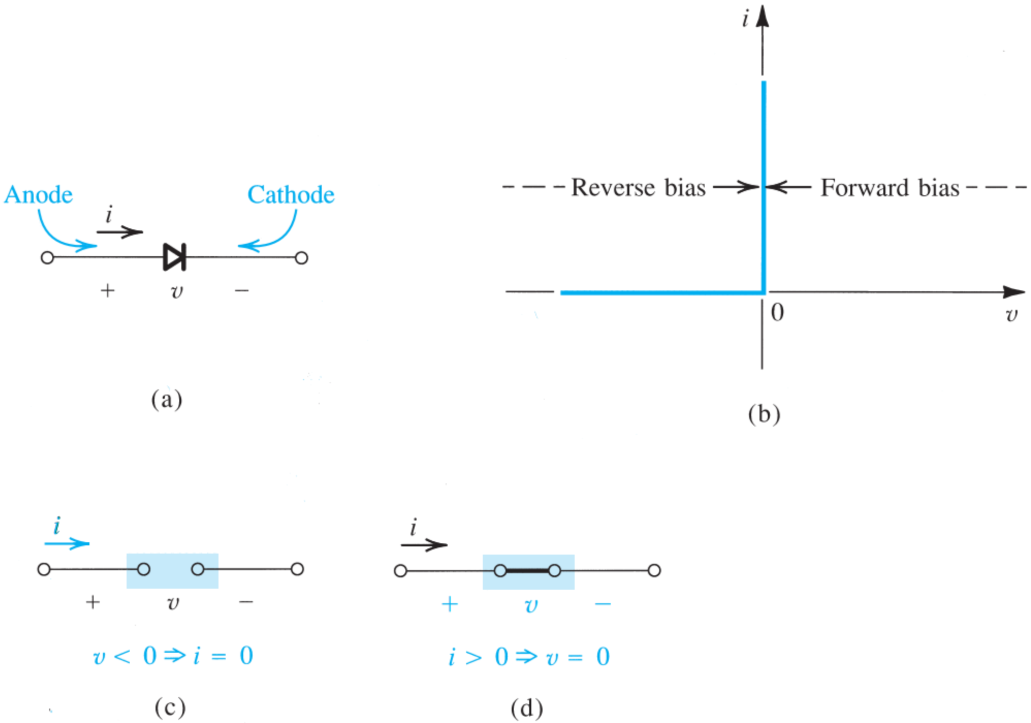


Figure 4.1 The ideal diode: **(a)** diode circuit symbol; **(b)** i–v characteristic; **(c)** equivalent circuit in the reverse direction; **(d)** equivalent circuit in the forward direction.

Lecture 5: AC to DC conversion

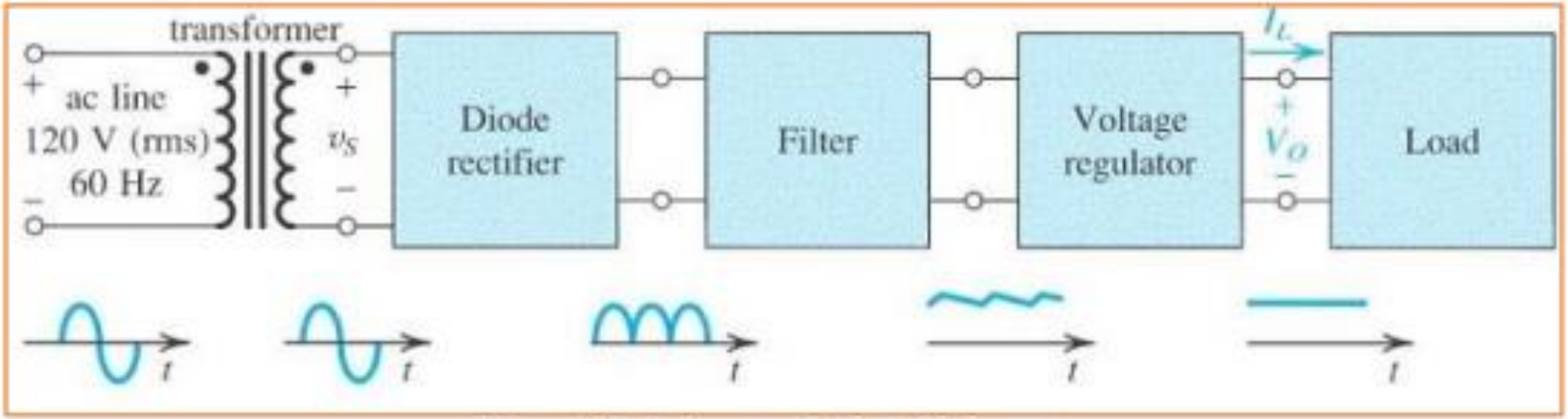


Figure 4 Block diagram of AC to DC Converter

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

Lecture 5: AC to DC conversion

The Ideal-Diode Model

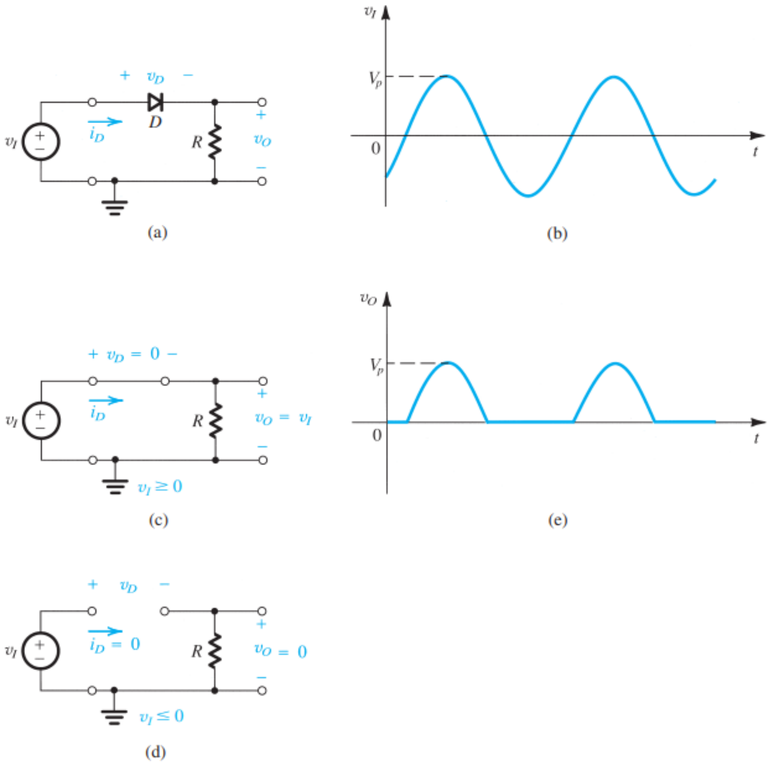


Figure 4.3 **(a)** Rectifier circuit. **(b)** Input waveform. **(c)** Equivalent circuit when $v_I \geq 0$. **(d)** Equivalent circuit when $v_I \leq 0$. **(e)** Output waveform.

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)

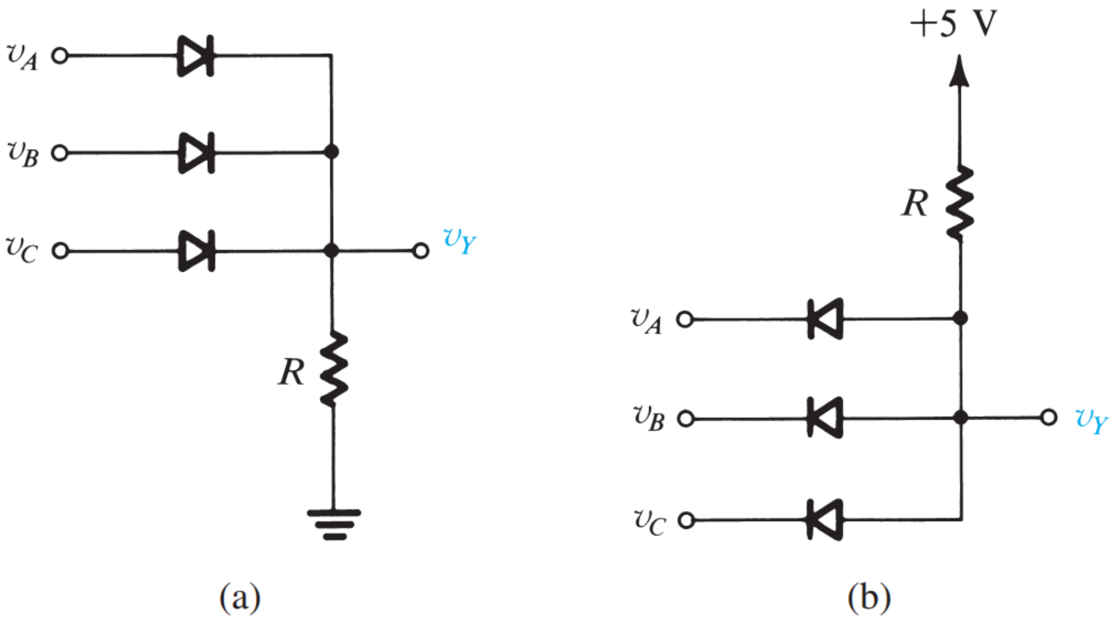
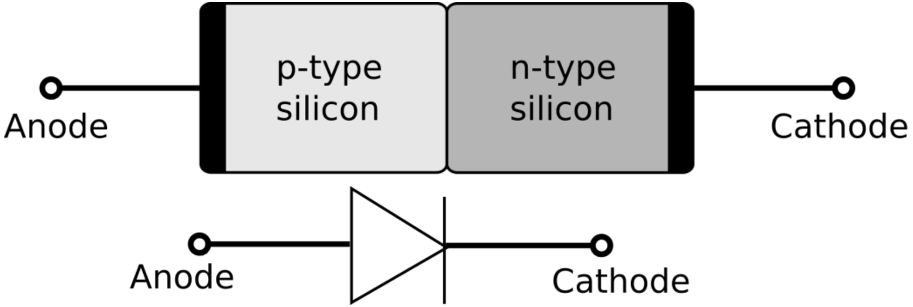


Figure 4.5 Diode logic gates: **(a)** OR gate; **(b)** AND gate (in a positive-logic system).

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



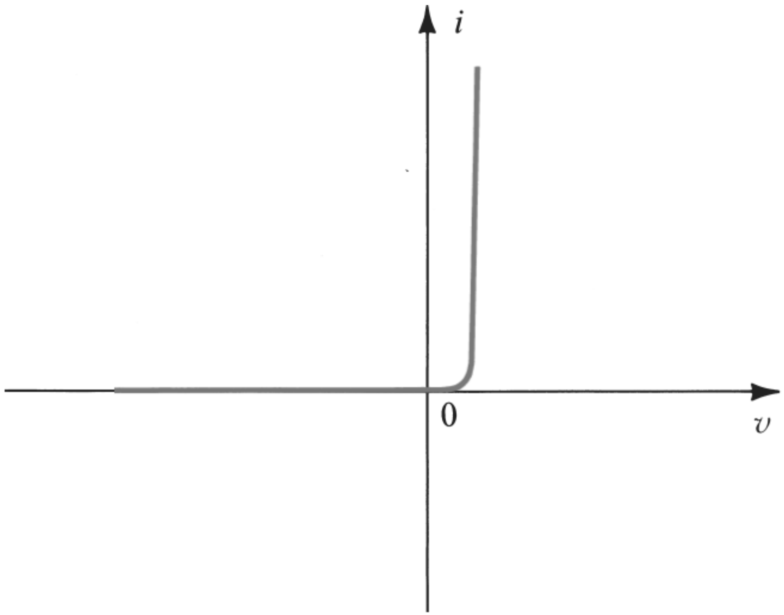


Figure 4.7 The i–v characteristic of a silicon junction diode.

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

The Constant-Voltage-Drop Model

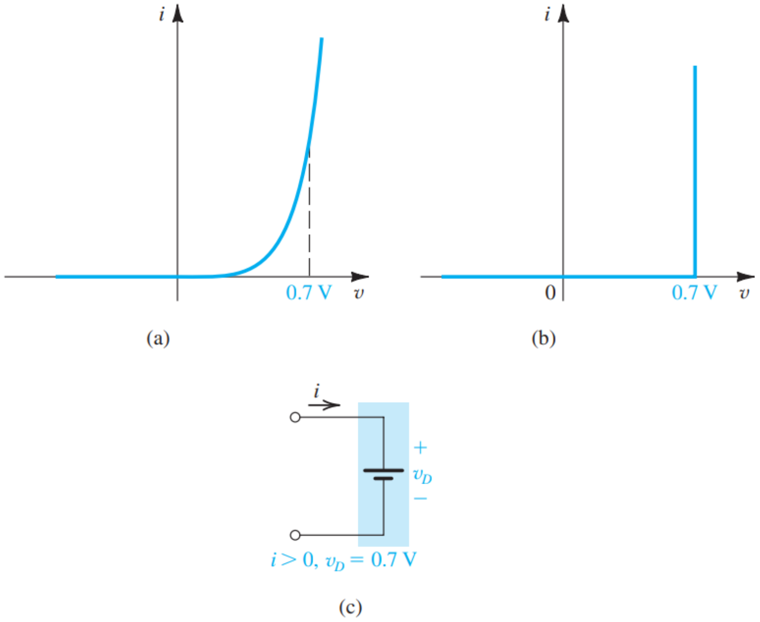
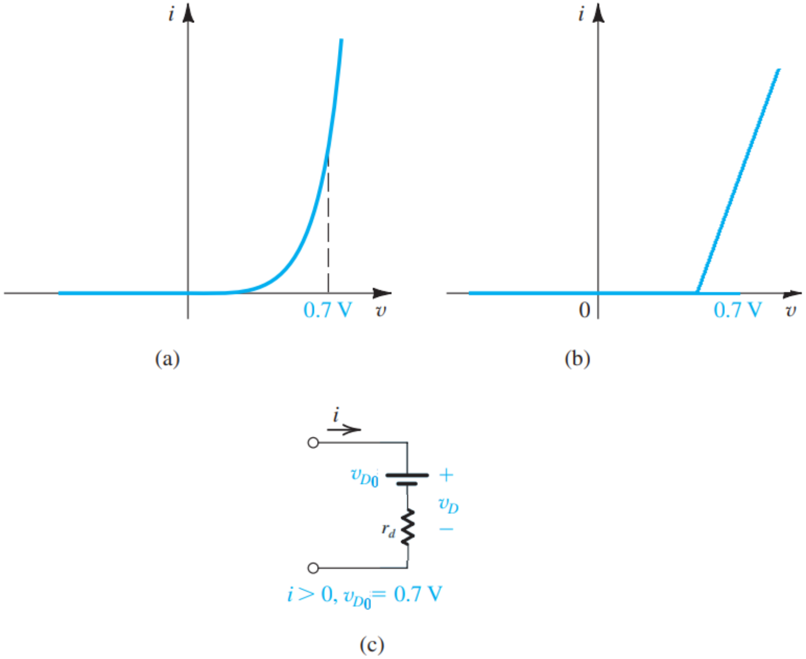


Figure 4.12 Development of the diode constant-voltage-drop model: **(a)** the exponential characteristic; **(b)** approximating the exponential characteristic by a constant voltage, usually about 0.7 V_i; **(c)** the resulting model of the forward-conducting diodes.

The Constant-Voltage-Drop+R Model



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

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Example 4.2

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

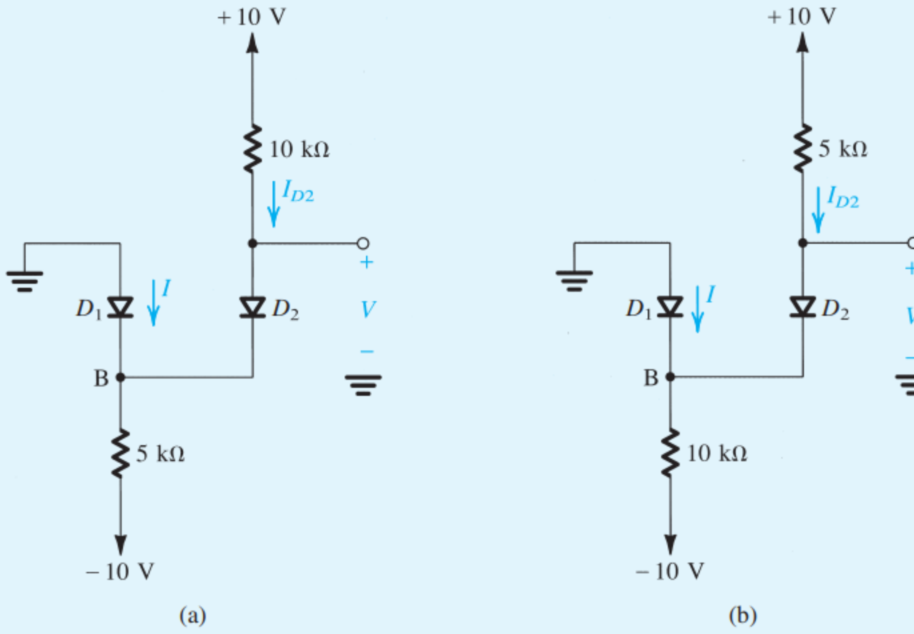


Figure 4.6 Circuits for Example 4.2.

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.

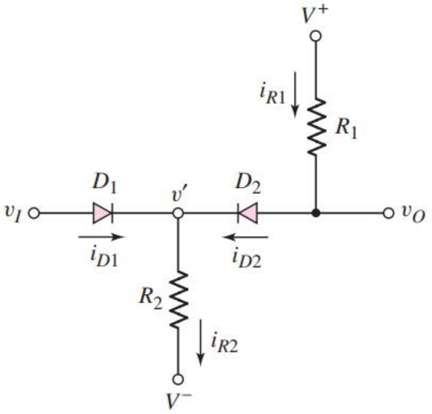
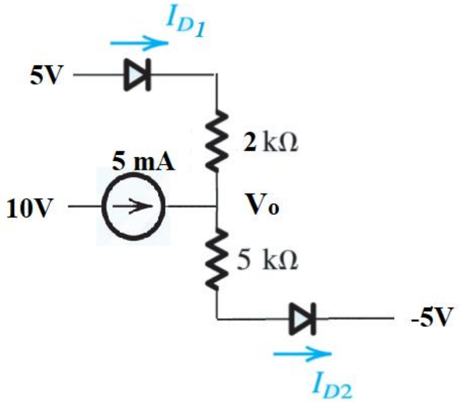
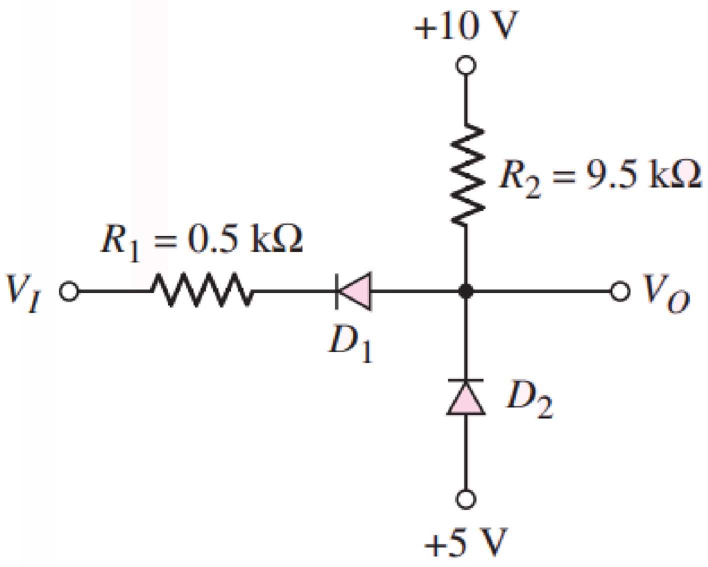


Figure 2.35 A two-diode circuit



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]***

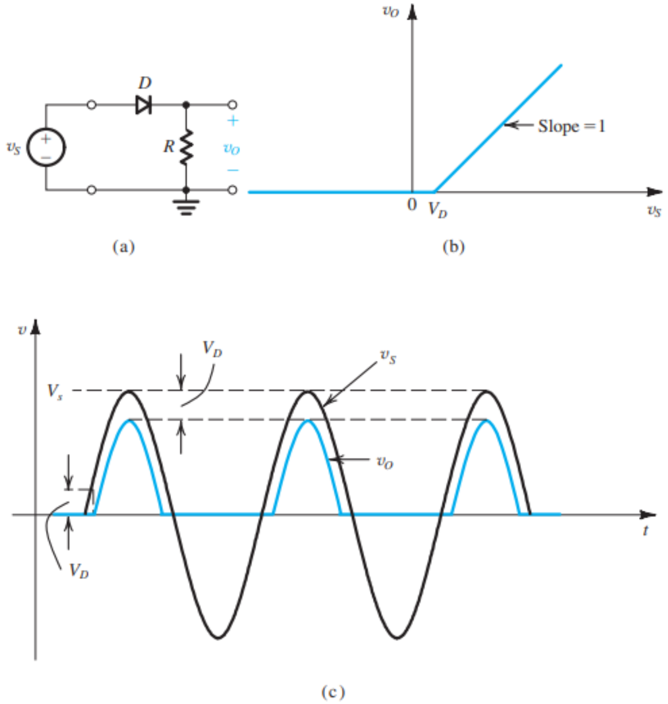
Lecture 8: Method of assumed state



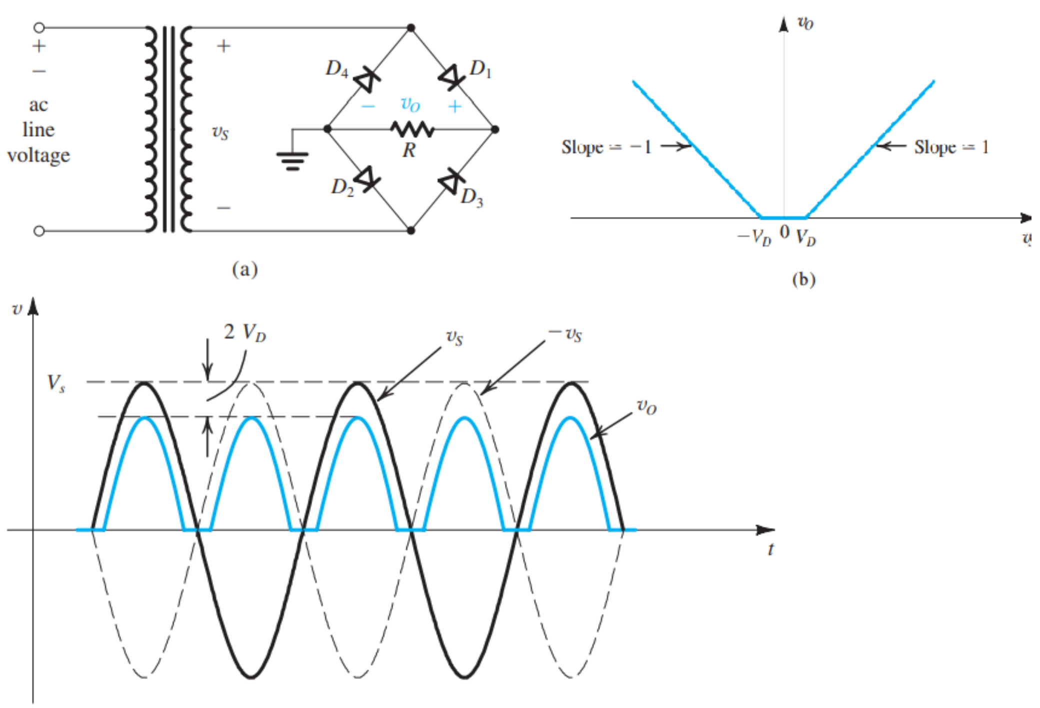
Example: Find the values of I_{D1}, I_{D2}, and V_o in the circuit shown below assuming the diodes to be Non-ideal. Here V_i=2V. ***[Hints: use constant voltage drop model with V_{D0}=0.7 V].***

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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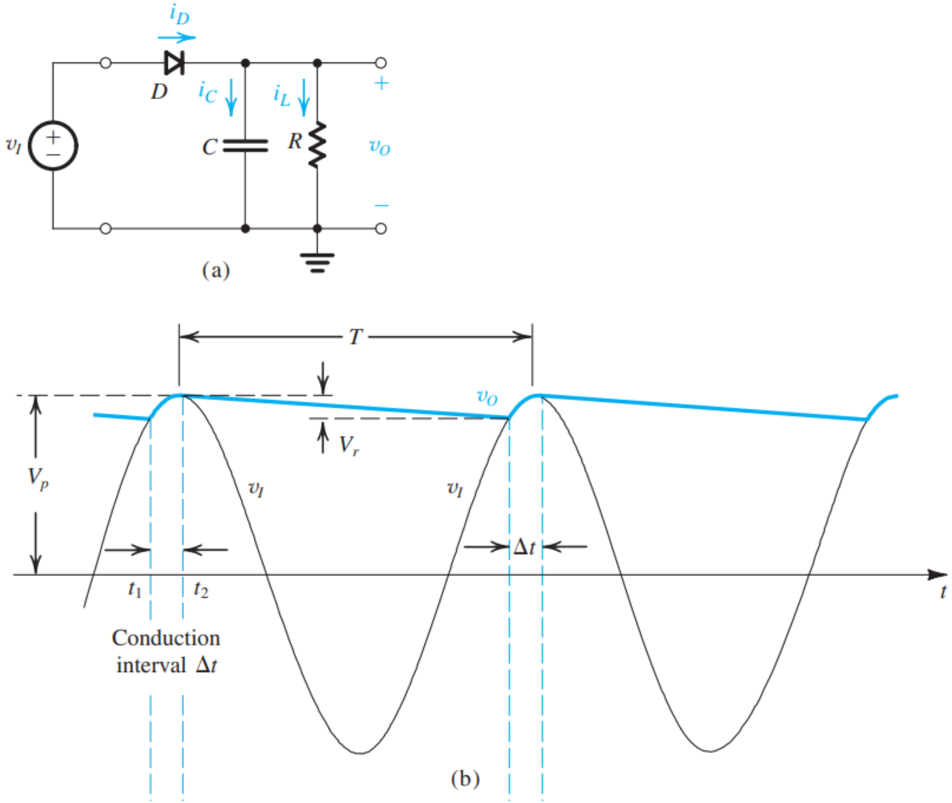
Lecture 10: Filtering and calculating ripple values



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Lecture 10: Filtering and calculating ripple values

Without capacitor

Rectifier	i/p peak	o/p peak	average
H/W	V_M	V_P	$V_{avg}=V_{DC}=\frac{1}{\pi}V_M-\frac{1}{2}V_{Do}$
F/W	V_M	V_P	$V_{avg}=V_{DC}=\frac{2}{\pi}V_M-2V_{Do}$

With capacitor

Rectifier	i/p peak	o/p peak	frequency	Ripple voltage	average
H/W	V_M	$V_P=V_M-V_{Do}$	$f_r=f_i$	$V_r=\frac{V_P}{f_r R C}$	$V_{avg}=V_{DC}=V_P-\frac{1}{2}V_r$
F/W	V_M	$V_P=V_M-2V_{Do}$	$f_r=2f_i$	$V_r=\frac{V_P}{f_r R C}$	$V_{avg}=V_{DC}=V_P-\frac{1}{2}V_r$

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