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Introduction to Electronics

An introduction to electronic components and a study of circuits containing such devices.

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Week 5:
Diodes Part 2

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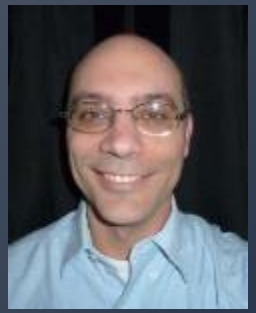

Introduction to Electronics

Dr. Allen Robinson
Academic Professional
School of Electrical and Computer Engineering

An introduction to electronic components and a study of circuits containing such devices.

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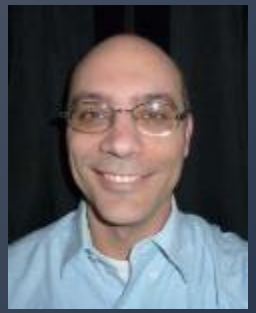
Half-Wave Rectifiers



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Introduce diode half-wave rectifiers

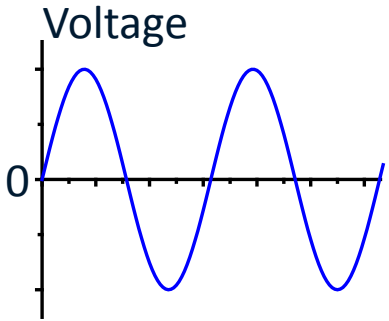
Lesson Objectives

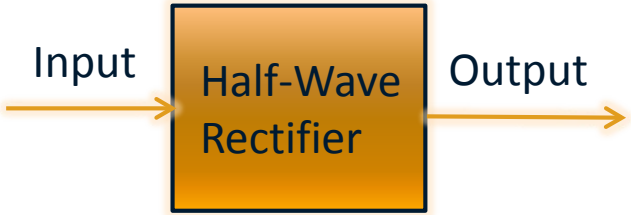
- Introduce half-wave rectifiers
- Examine their behavior for sinusoidal inputs
- Analyze a diode rectifier circuit

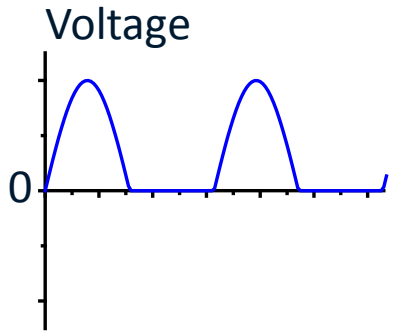
Rectifier

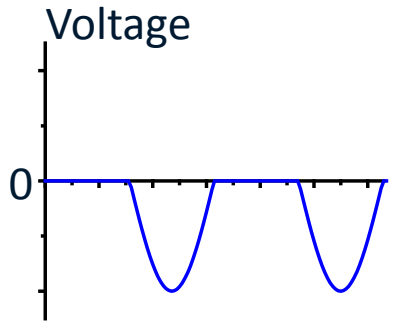
- A non-linear device that modifies an input voltage such that the output voltage is greater than or less than a threshold value

Sinusoidal Input Voltages

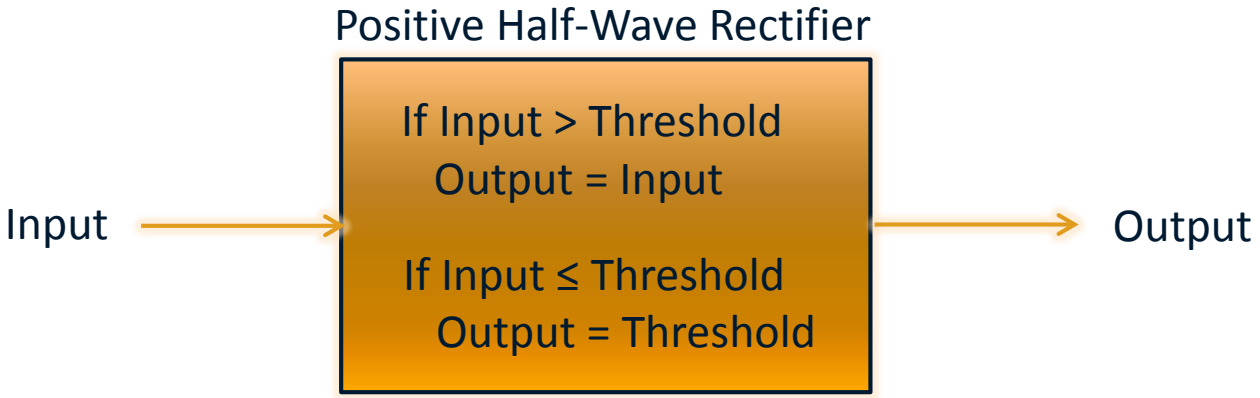




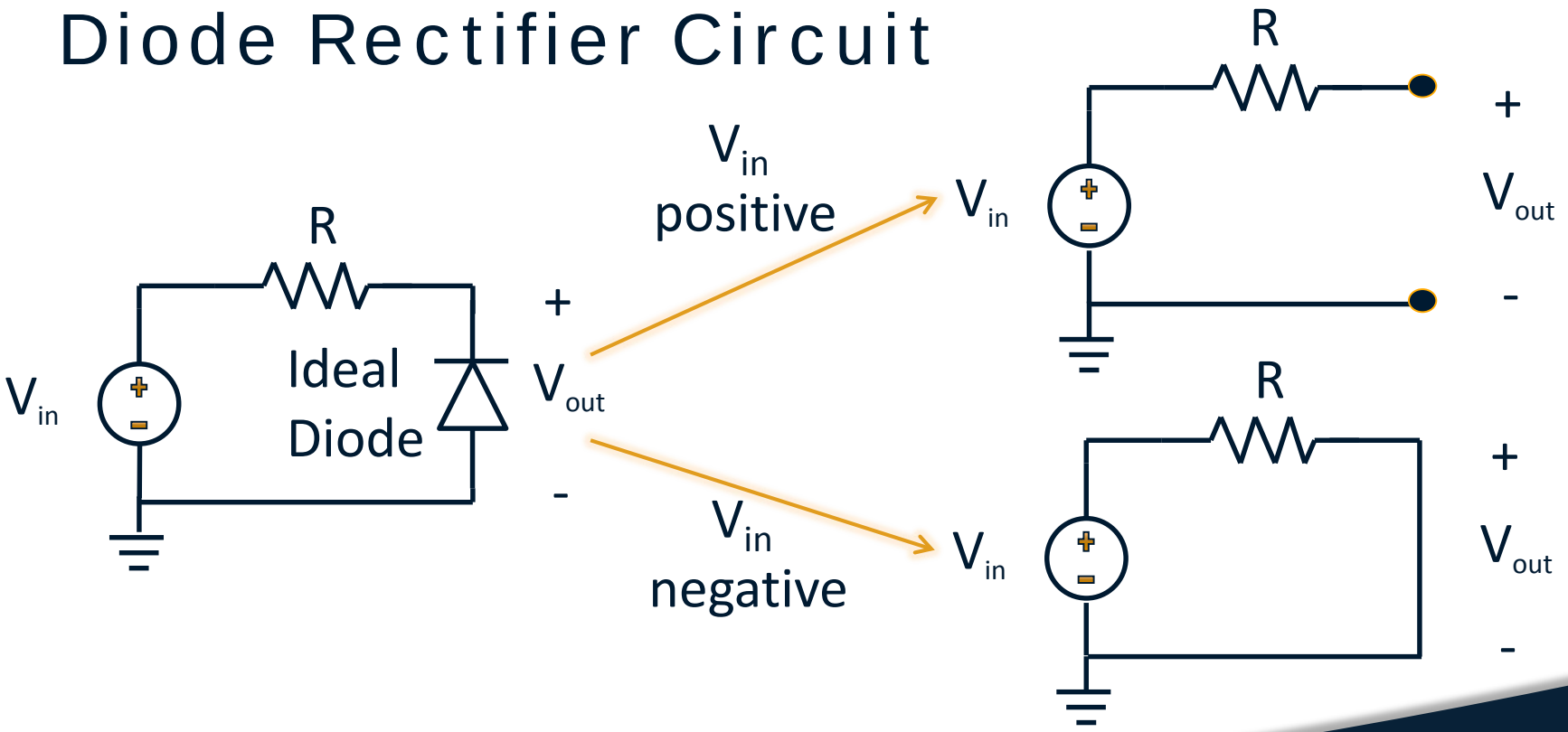




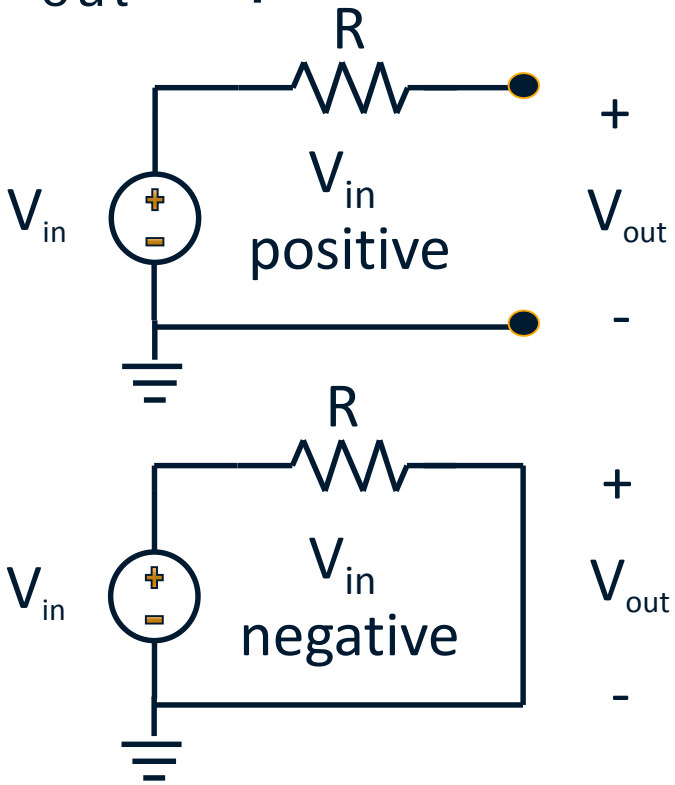
Half-Wave Rectifier



Diode Rectifier Circuit

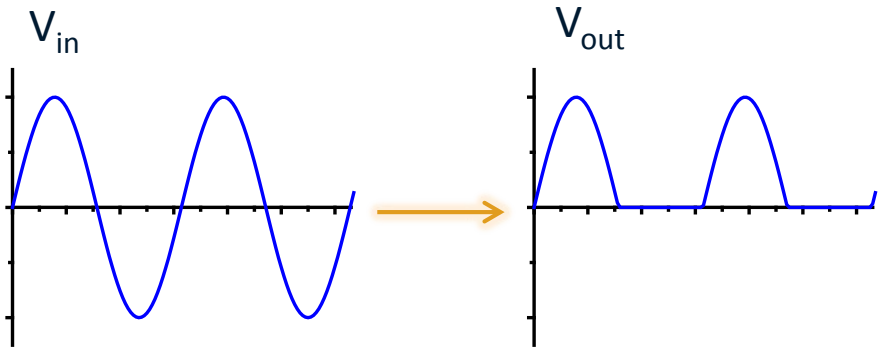


V_{out} Equations



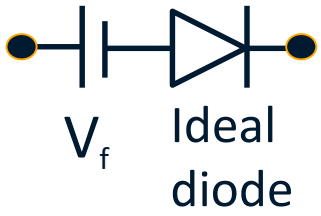
Positive Half-Wave Rectifier

$$V_{out} = \begin{cases} V_{in} & V_{in} > 0 \\ 0 & V_{in} \leq 0 \end{cases}$$

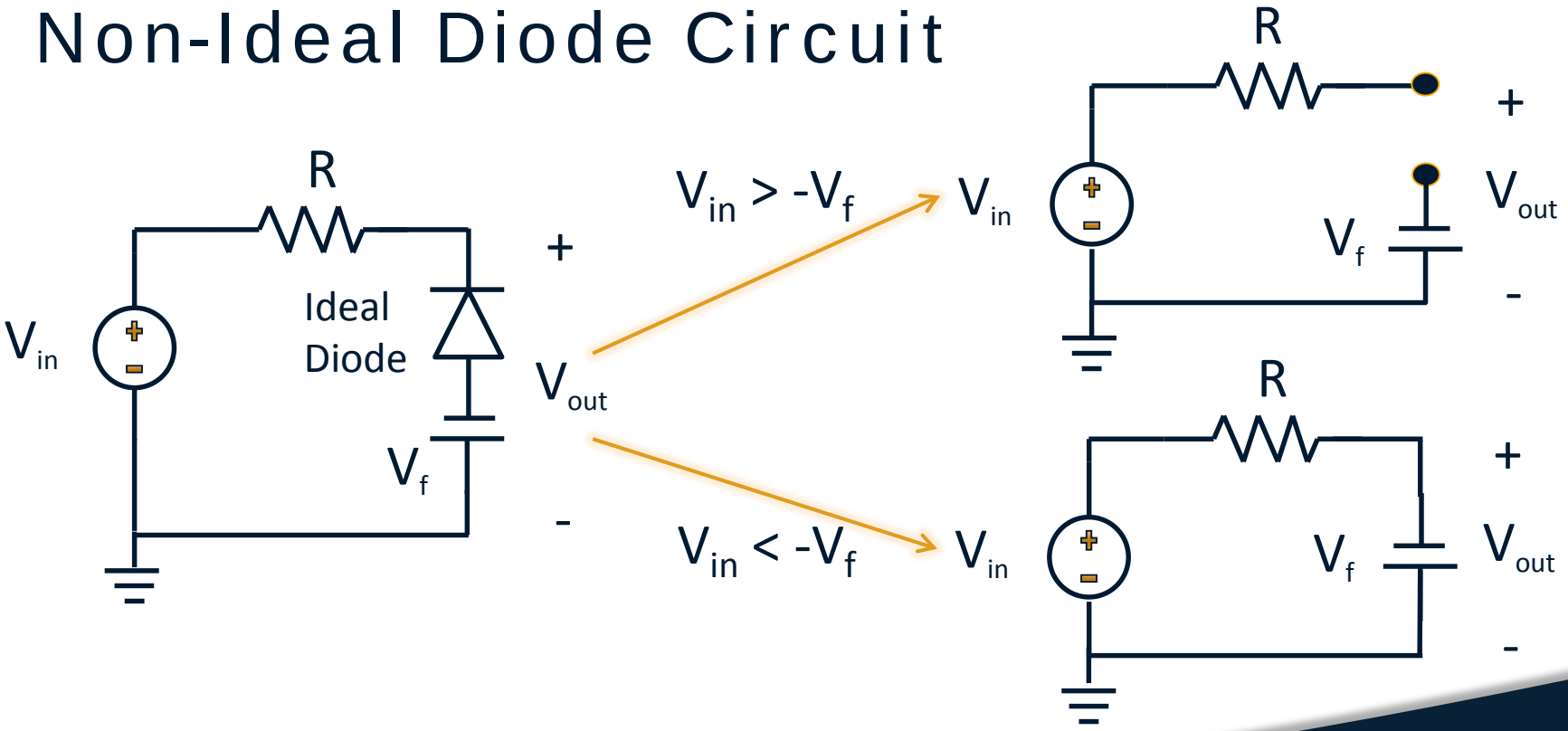


Non-Ideal Diode

- How does a non-ideal diode change the behavior of the circuit?
- Include the forward voltage drop V_f by modeling the diode as an ideal diode in series with a voltage source



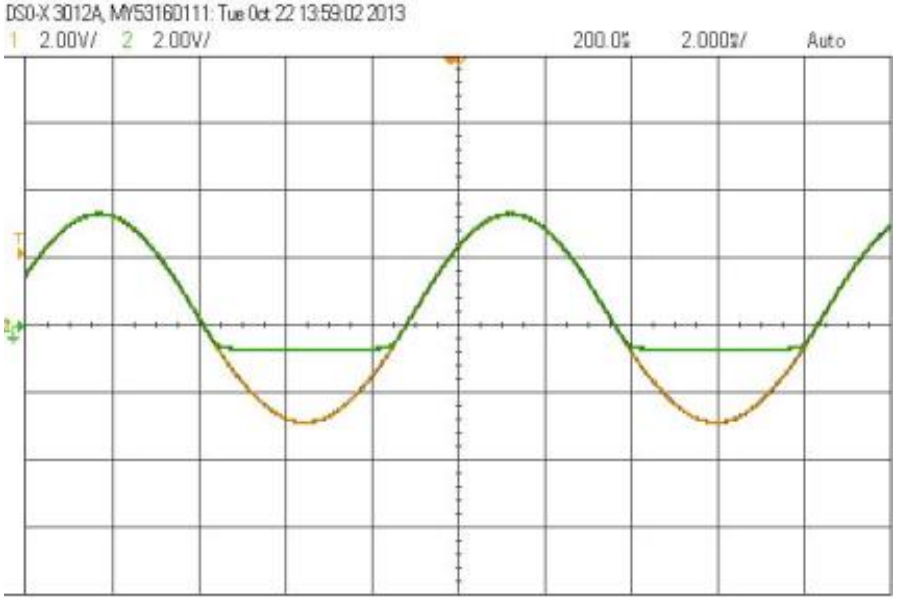
Non-Ideal Diode Circuit



Measured Output

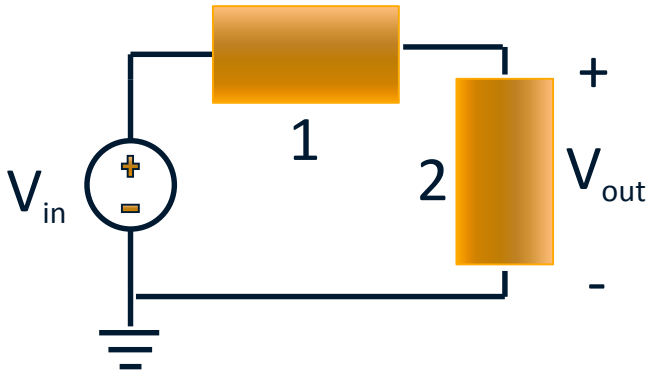
$V_{out} = \begin{cases} V_{in} & V_{in} > -V_f \\ -V_f & V_{in} \leq -V_f \end{cases}$

V_{in} and V_{out}



Other Possible Circuits

- Four different rectifiers can be constructed using a resistor and a diode.



Other Possible Circuits

- Can you determine the equation for V_{out} in terms of V_{in} for each of the possible circuits assuming both ideal and non-ideal diodes?
- How does the output of each circuit change if it is taken across element 1 rather than element 2?

Summary

- Rectification
- Half-Wave Rectifiers

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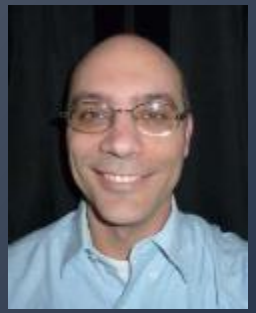
Full-Wave Rectifiers



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Introduce diode full-wave rectifiers

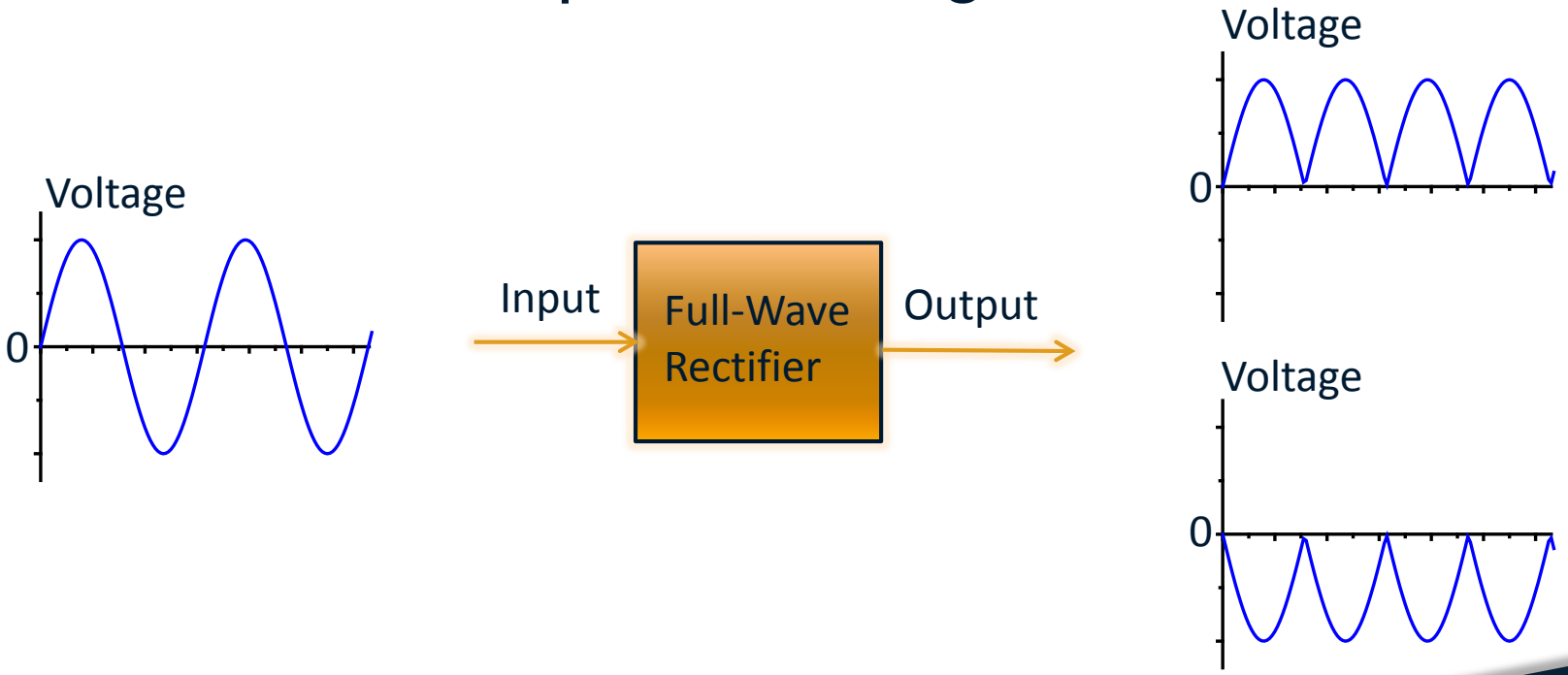
Lesson Objectives

- Introduce full-wave rectifiers
- Examine their behavior for sinusoidal inputs
- Analyze diode full-wave rectifier circuit

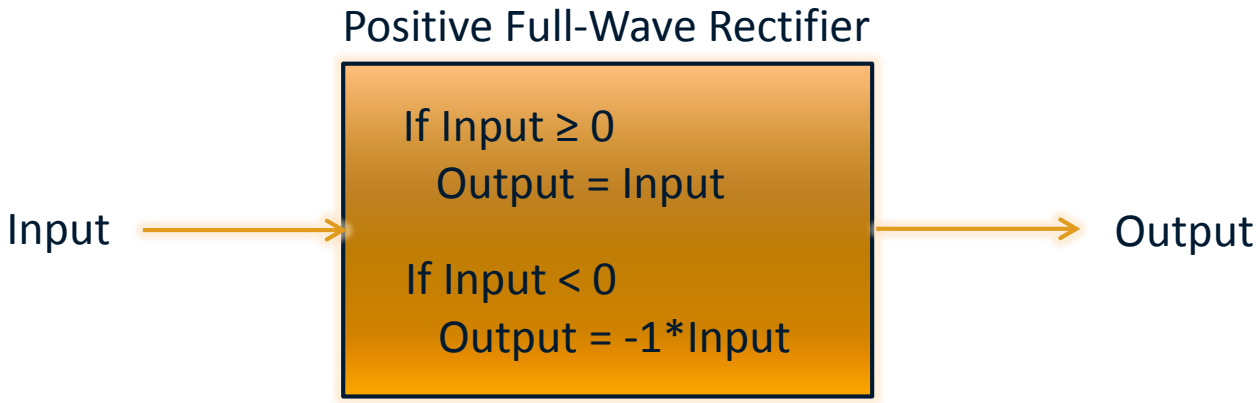
Rectifier

- A non-linear device that modifies an input voltage such that the output voltage is greater than or less than a threshold value

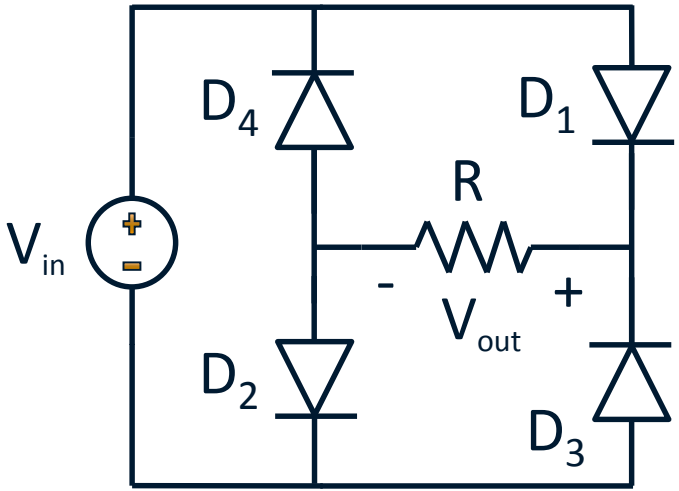
Sinusoidal Input Voltages



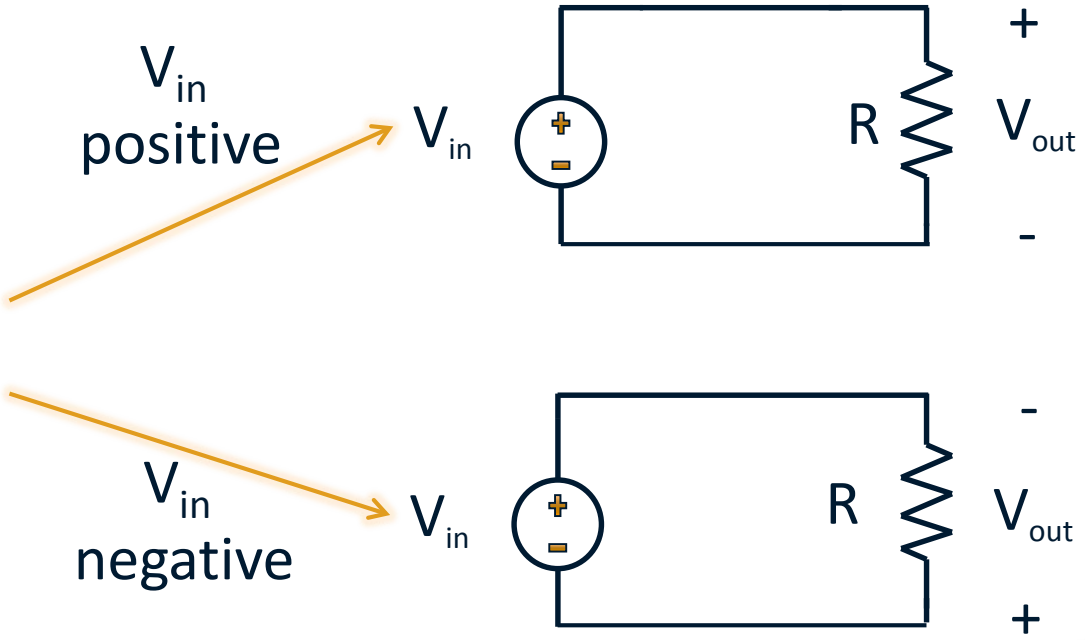
Full-Wave Rectifier



Full-Wave Rectifier Circuit



Ideal Diodes



V_{out} Equation

- A full-wave rectifier is also known as an absolute value circuit

$$V_{out} = \begin{cases} V_{in} & V_{in} \geq 0 \\ -V_{in} & V_{in} < 0 \end{cases}$$

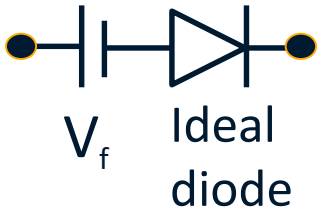
D_1 and D_2 on
D_3 and D_4 off

D_1 and D_2 off
D_3 and D_4 on

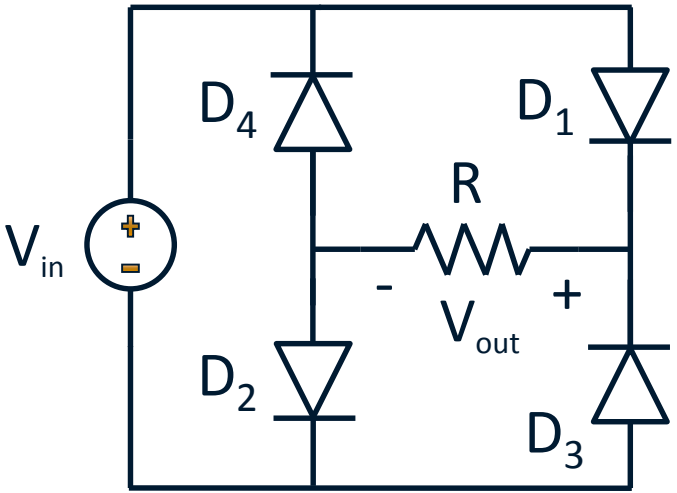
$$V_{out} = |V_{in}|$$

Non-Ideal Diode

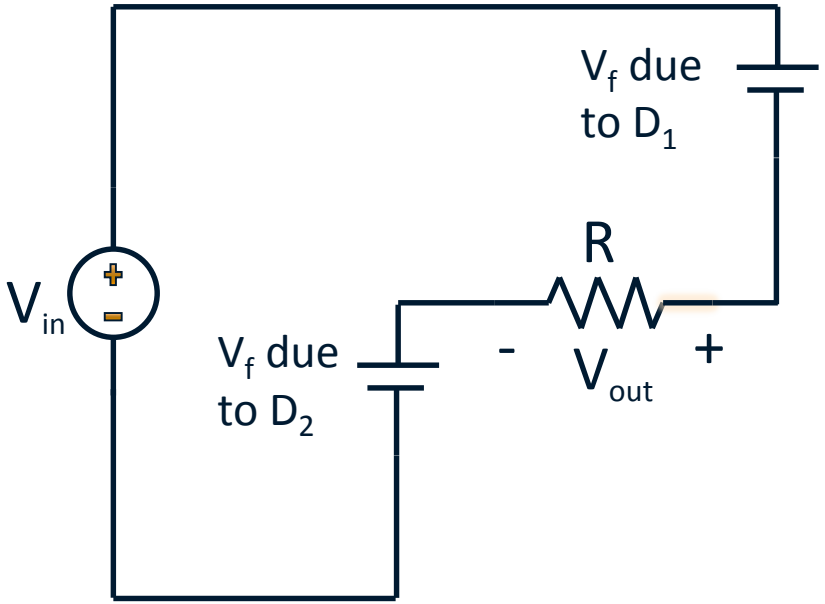
- How does a non-ideal diode change the behavior of the circuit?
- Include the forward voltage drop V_f by modeling the diode as an ideal diode in series with a voltage source



Non-Ideal Diode Circuit



D_1 and D_2 on
D_3 and D_4 off



Circuit for D_1 and D_2 On

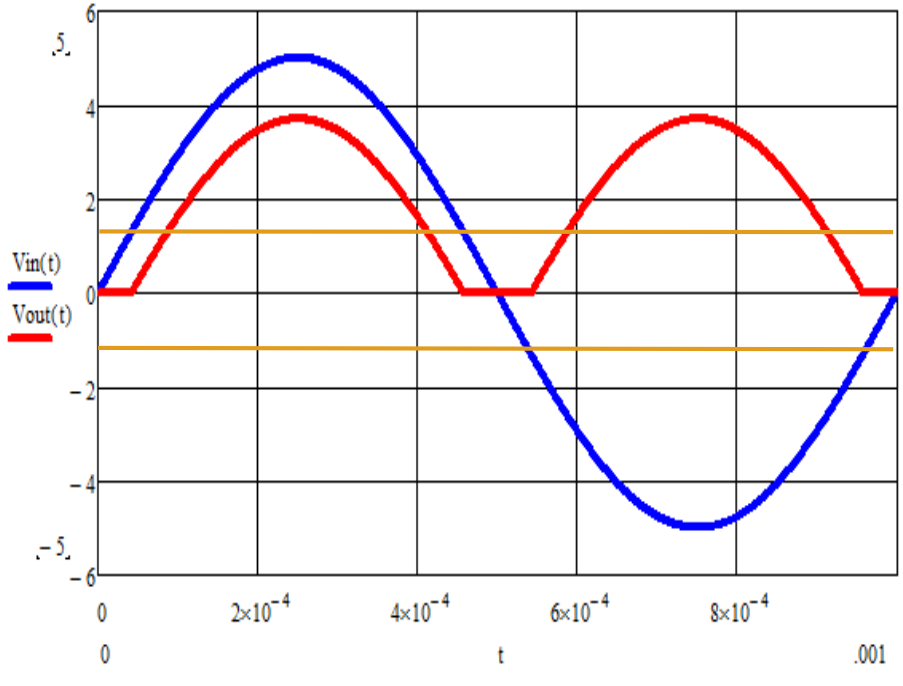
$V_{in} > 2V_f$

Circuit for D_3 and D_4 On

$V_{in} < -2V_f$

V_{out} Equation

$$V_{out} = \begin{cases} V_{in} - 2V_f & V_{in} > 2V_f \\ -V_{in} - 2V_f & V_{in} < -2V_f \\ 0 & \text{Otherwise} \end{cases}$$



Other Possible Configurations

- How does the output voltage change if the directions of all diodes are reversed?
- How does the output voltage change if the direction of any one diode is reversed?

Summary

- Full-Wave Rectifiers

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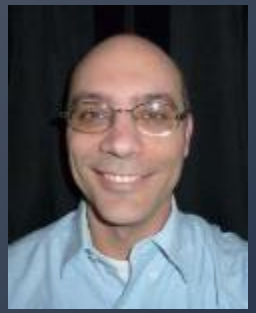
Voltage Transfer Characteristics



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Introduce voltage transfer characteristics

Lesson Objectives

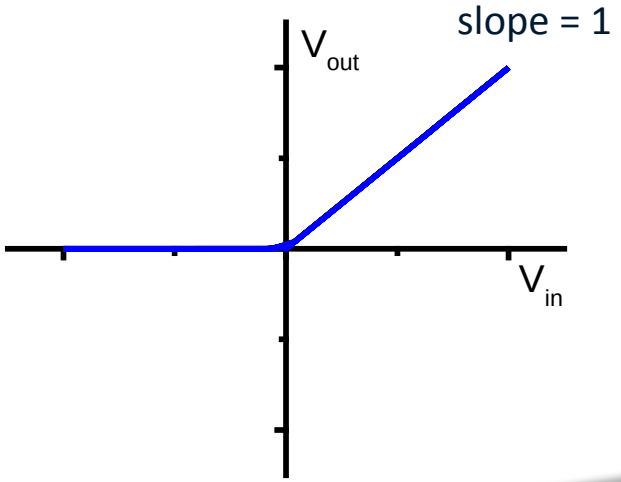
- Introduce voltage transfer characteristics (VTCs)
- Use VTC to determine output for given input
- Determine VTC from given input and output plots

Voltage Transfer Characteristic (VTC)

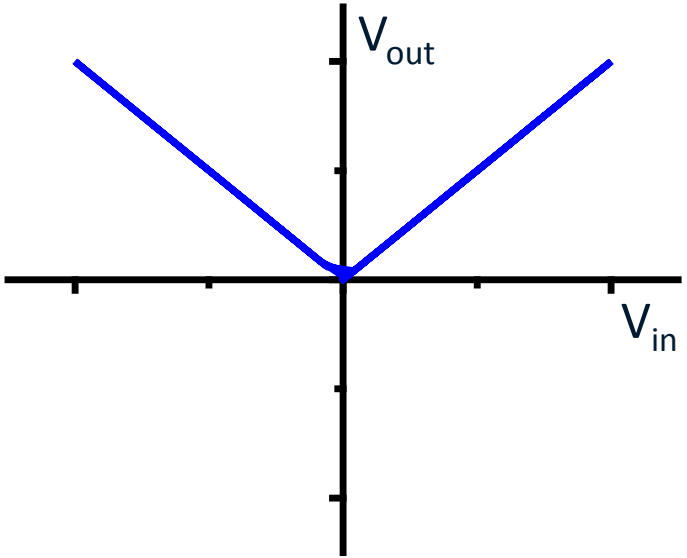
- A graphical description of the behavior of a nonlinear circuit
- A plot of output voltage versus input voltage

Positive Half-Wave Rectifier

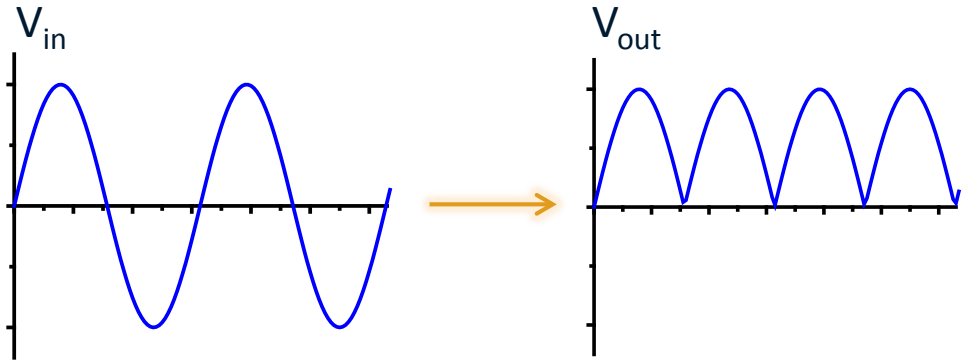
$$V_{out} = \begin{cases} V_{in} & V_{in} > 0 \\ 0 & V_{in} \leq 0 \end{cases}$$



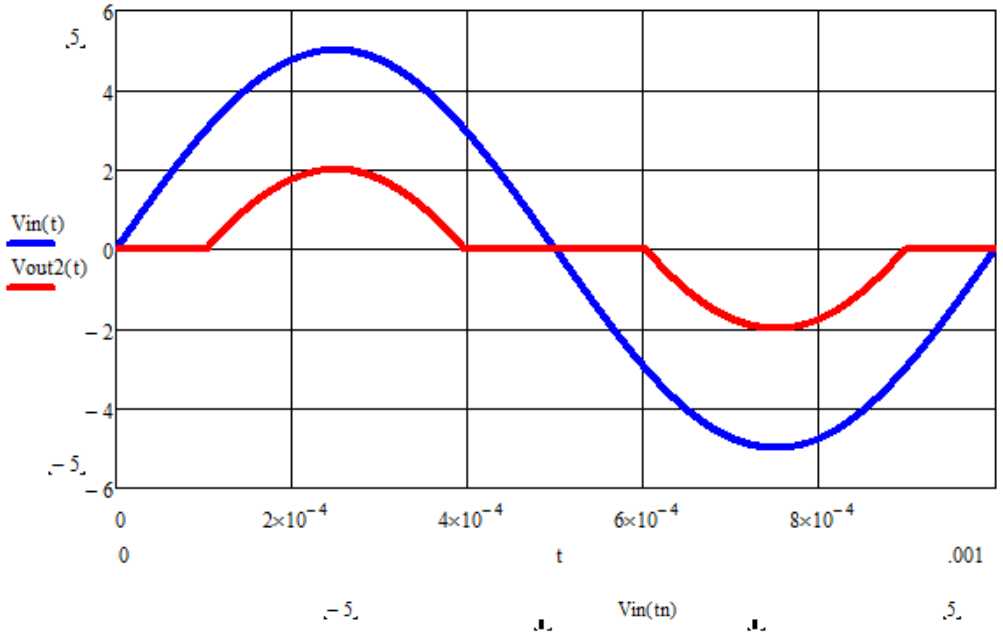
Example VTC

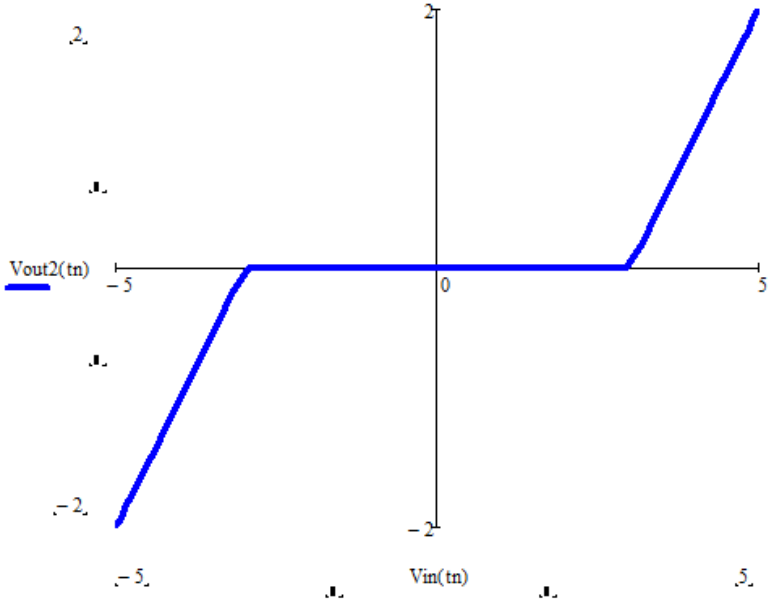


Positive Full-Wave Rectifier

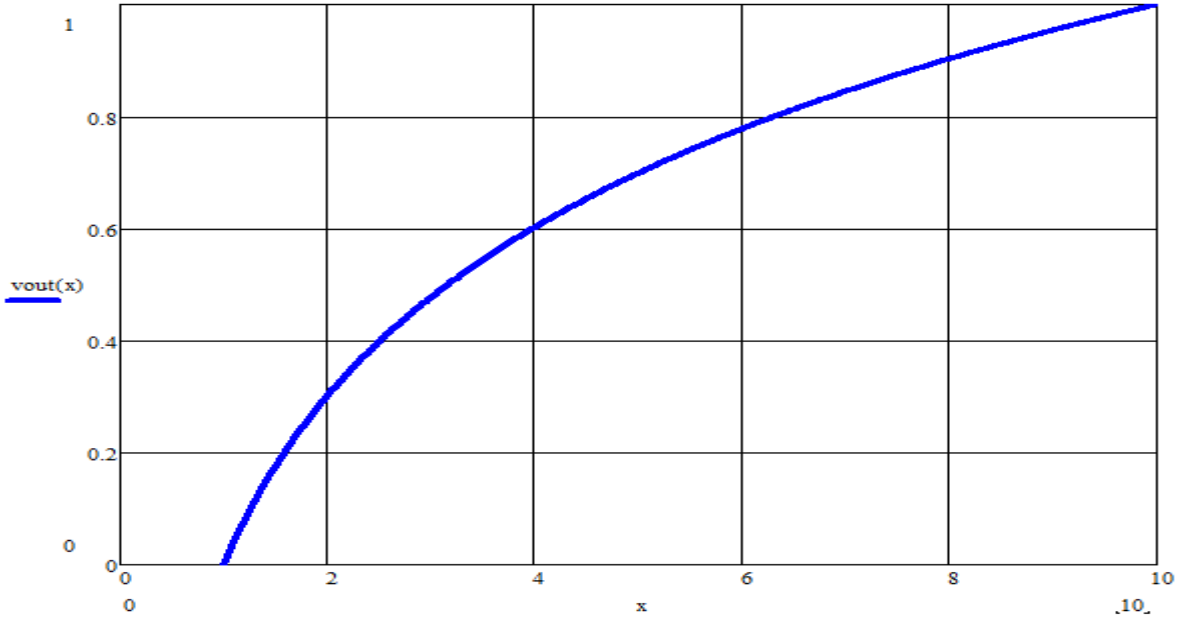


VTC from Input and Output Waveforms





Designing with a VTC



Summary

- Voltage transfer characteristics are plots of output voltage versus input voltage
- VTCs quickly indicate a circuit's behavior

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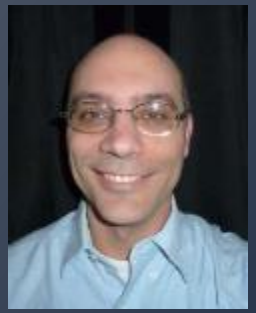

AC to DC Conversion

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Introduce ac to dc conversion

Lesson Objectives

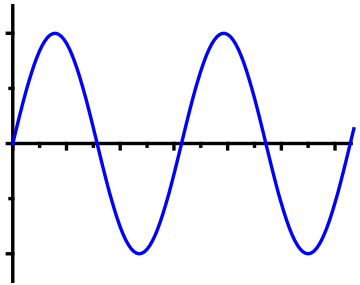
- Introduce ac to dc conversion
- Examine circuits that perform this conversion

AC to DC Conversion

- AC used in power transmission
- DC used to power electronics
- Diode rectifiers are used in converting an alternating current to a direct current

Sinusoidal Input Voltage

Voltage varying with time



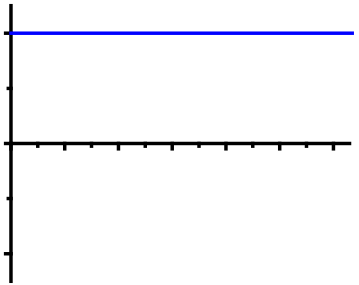
AC Input

AC to DC Converter

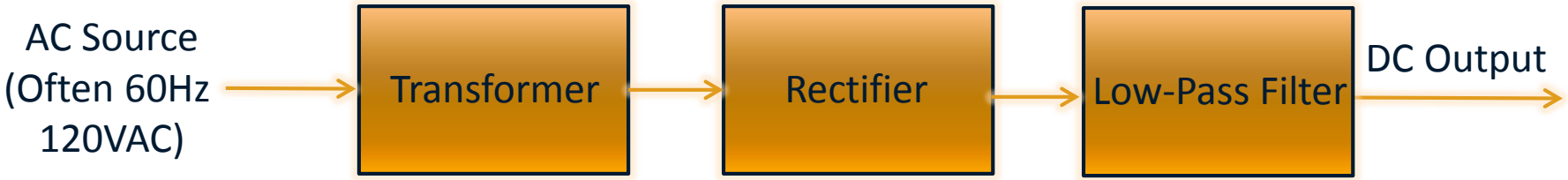
(DC Power Supply)

DC Output

Voltage constant with time



DC Power Supply Components

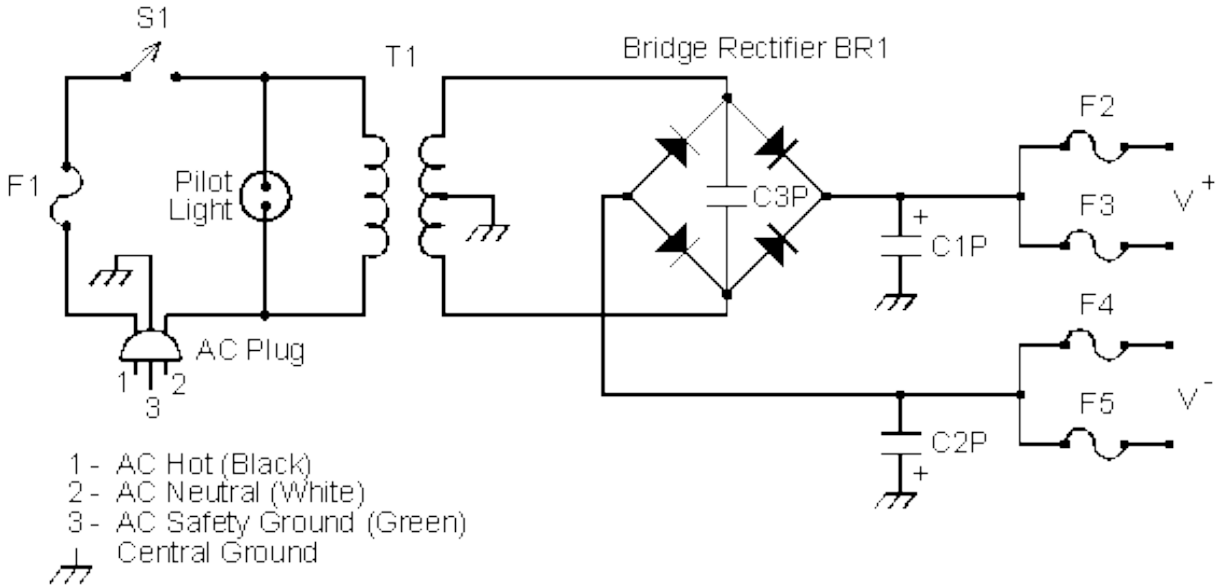


Steps voltage up or down

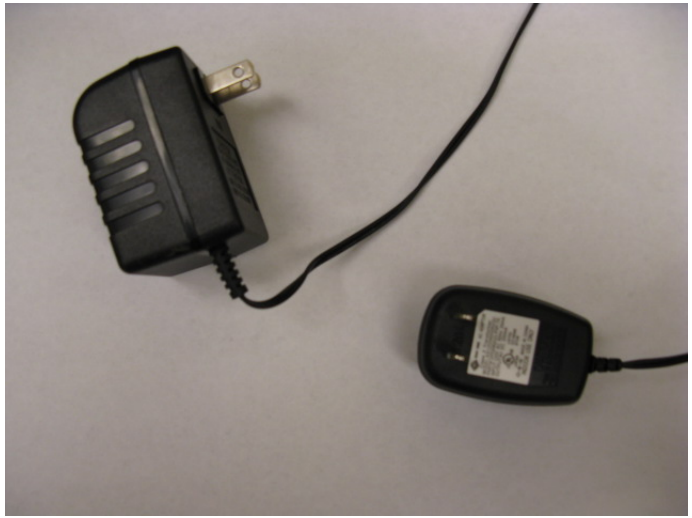
Introduces DC component

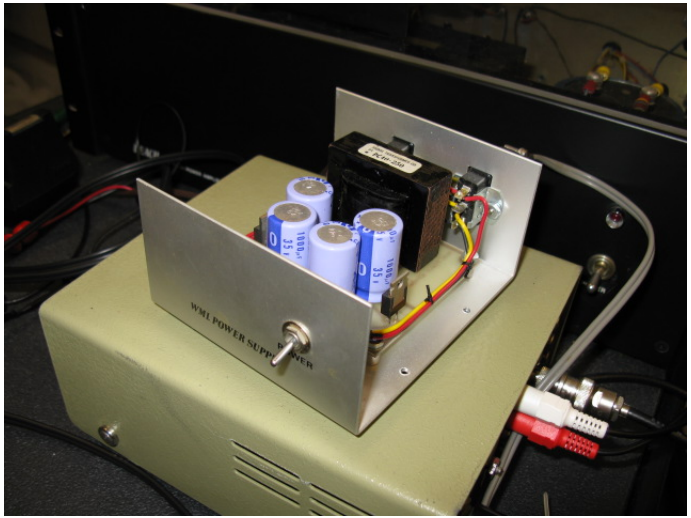
Reduces AC component To smooth output

Bipolar DC Power Supply Schematic

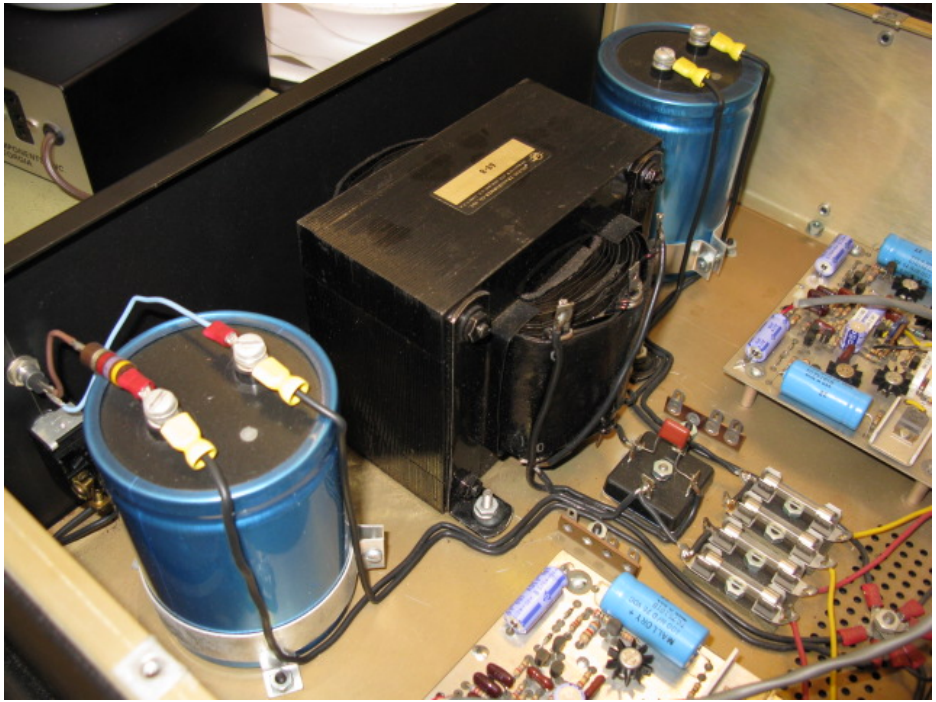


Example DC Power Supplies

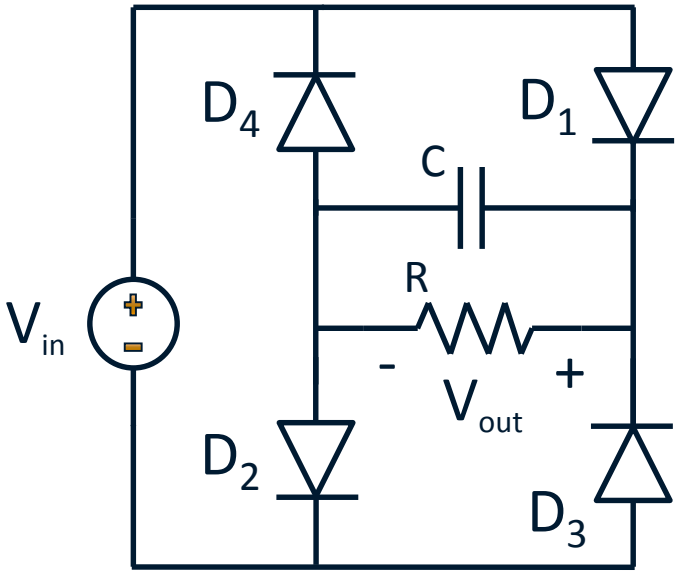




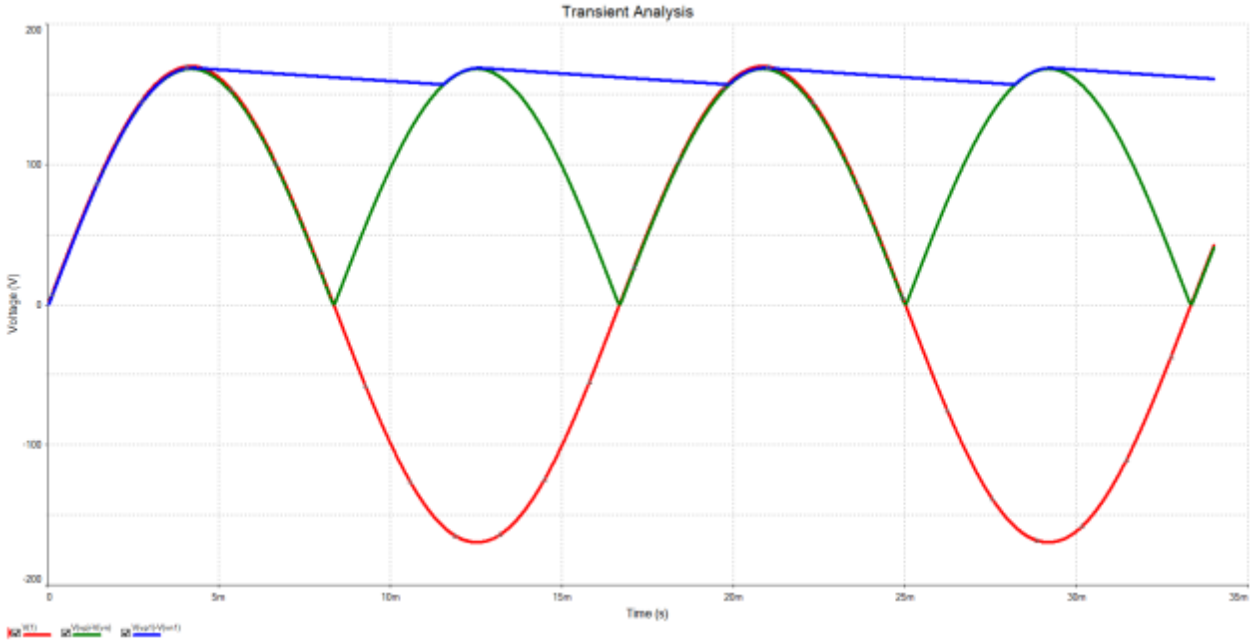
Example DC Power Supplies



Rectifier with Filter Capacitor

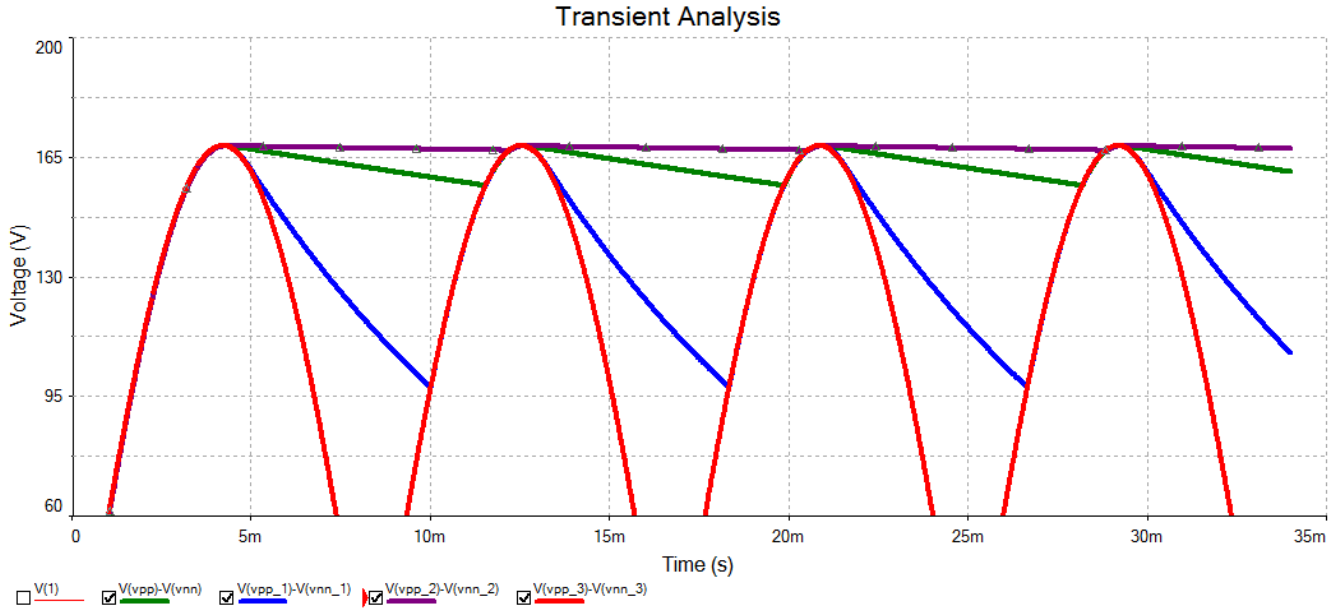


Circuit Voltages



Varying Capacitor Values

$\tau = RC$



- Larger time constant = slower discharge
- Smaller time constant = faster discharge

Output Voltage Level

For a sine wave: $V_{peak} = V_{rms} * \sqrt{2}$

Two diode voltage drops are lost in the full-wave rectifier

$V_{DC} = V_{peak} - 2V_f$

$V_{DC} = V_{rms} * \sqrt{2} - 2V_f$

$V_{DC} = 120 * \sqrt{2} - 2(0.65) = 168.4\ V$

Summary

- AC to DC conversion is performed using a transformer, a rectifier, and a filter capacitor
- Larger filter capacitors result in a smoother output voltage

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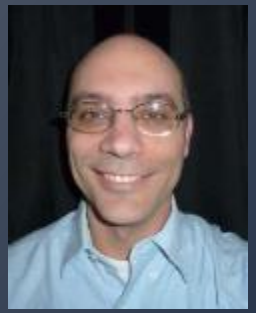
Limiters



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Introduce diode limiters

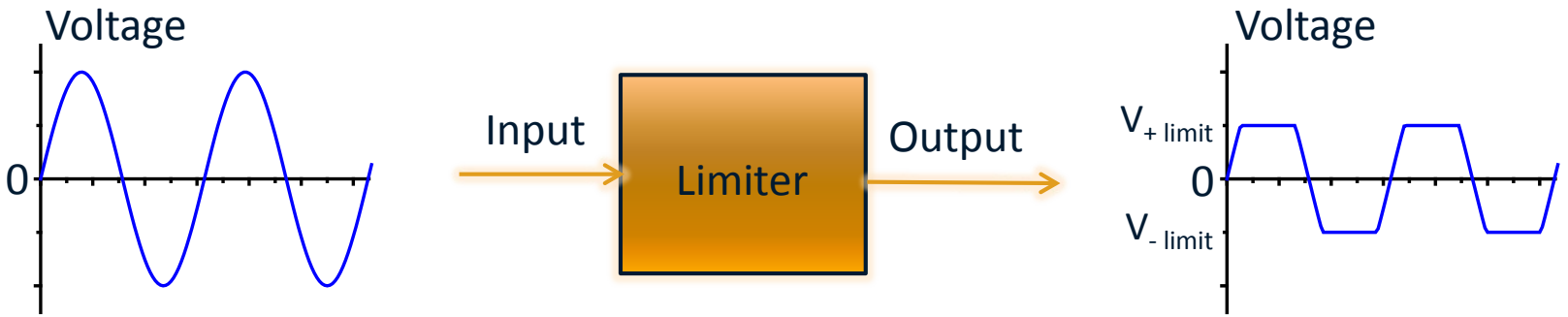
Lesson Objectives

- Introduce limiters
- Examine their behavior for sinusoidal inputs
- Analyze limiter circuits

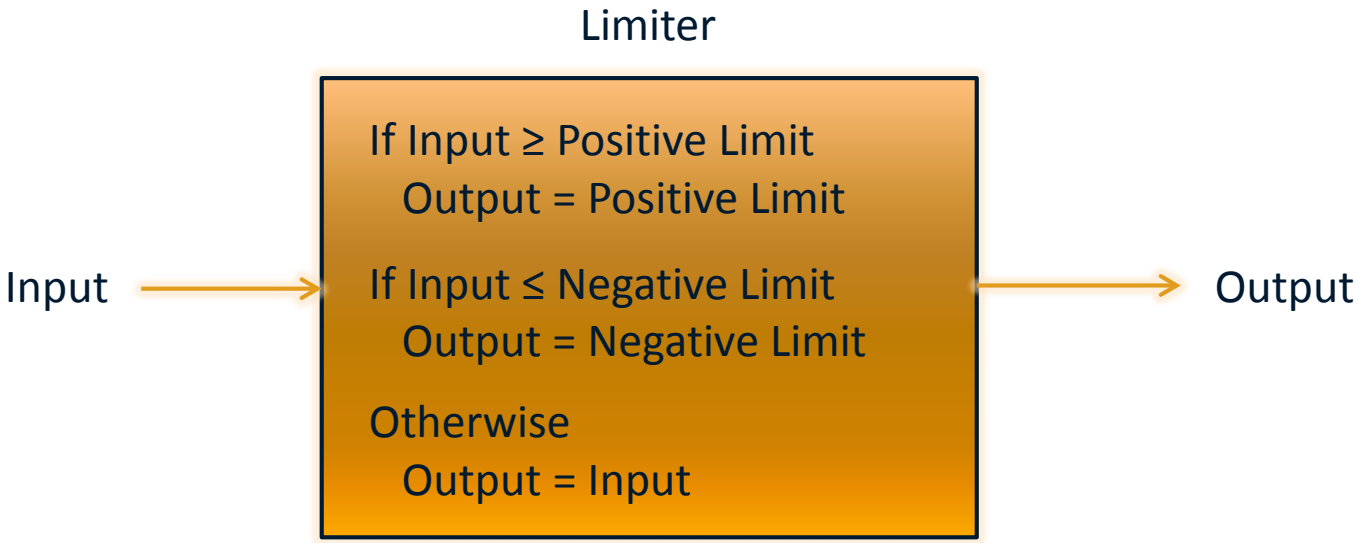
Limiter (or Clipper)

- A non-linear device that limits the output voltage to a particular level

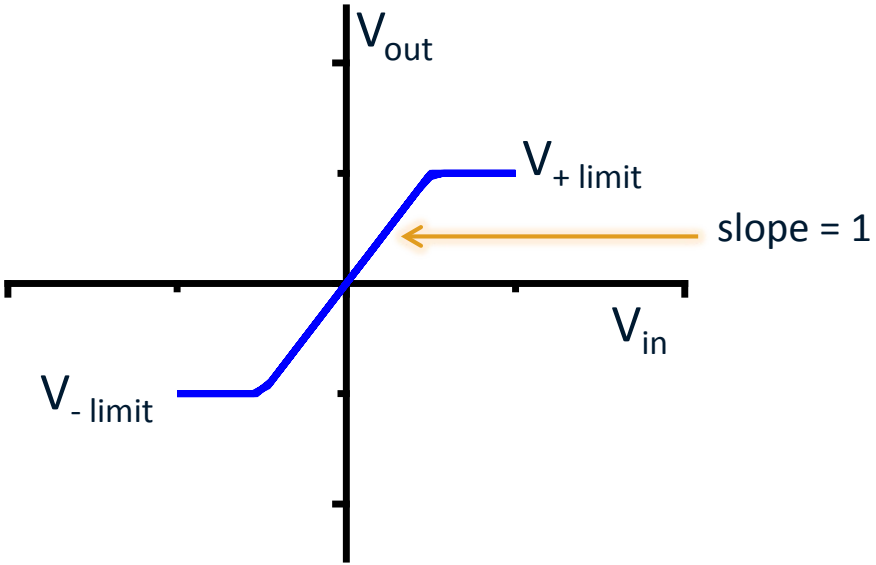
Sinusoidal Input Voltages



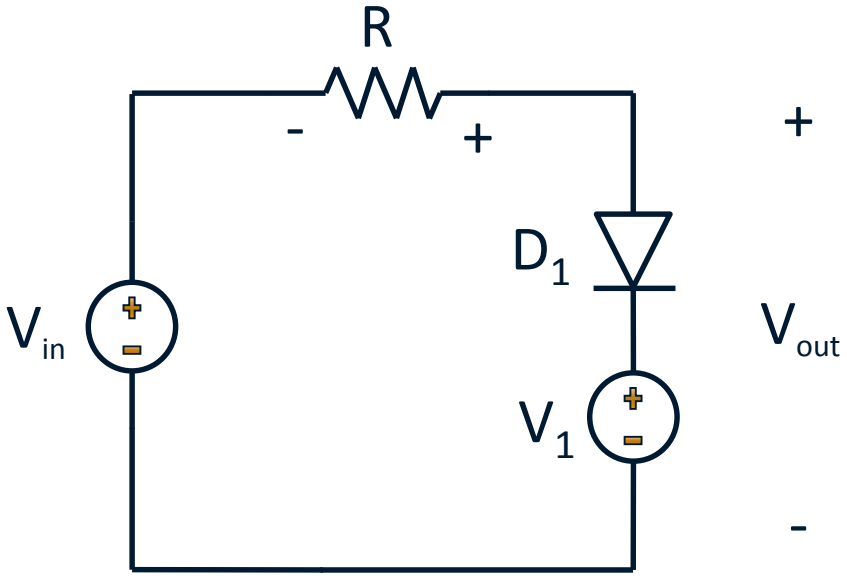
Limiter


Limiter
If Input ≥ Positive Limit
Output = Positive Limit
If Input ≤ Negative Limit
Output = Negative Limit
Otherwise
Output = Input
Input
Output

Voltage Transfer Characteristic

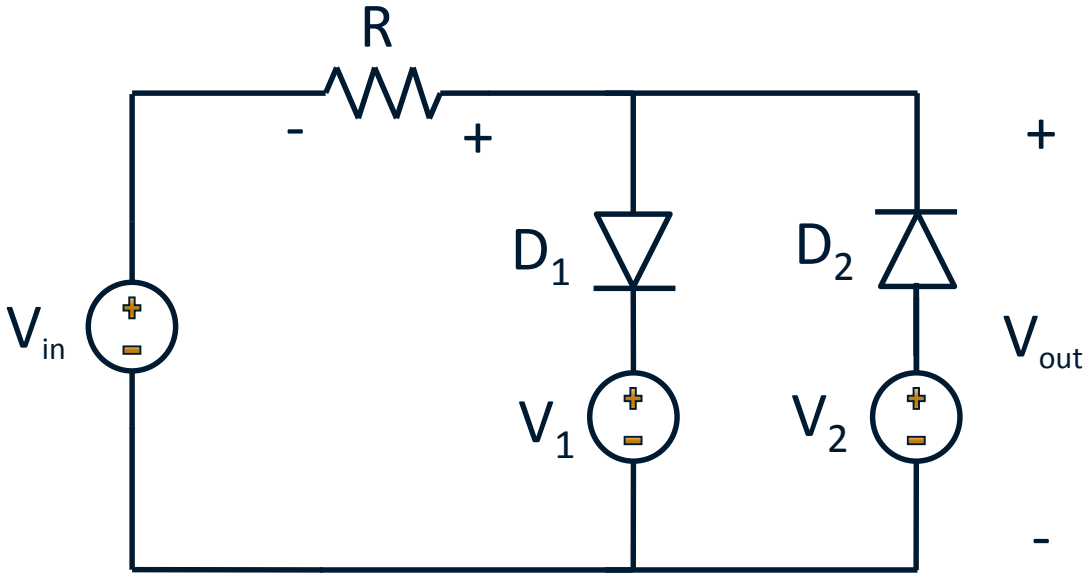


Positive Limiter Circuit



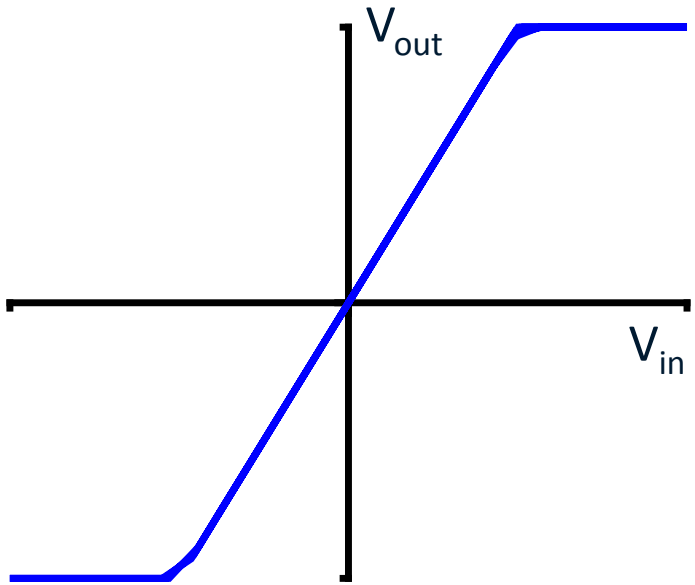
Ideal Diode

Positive and Negative Limiter Circuit



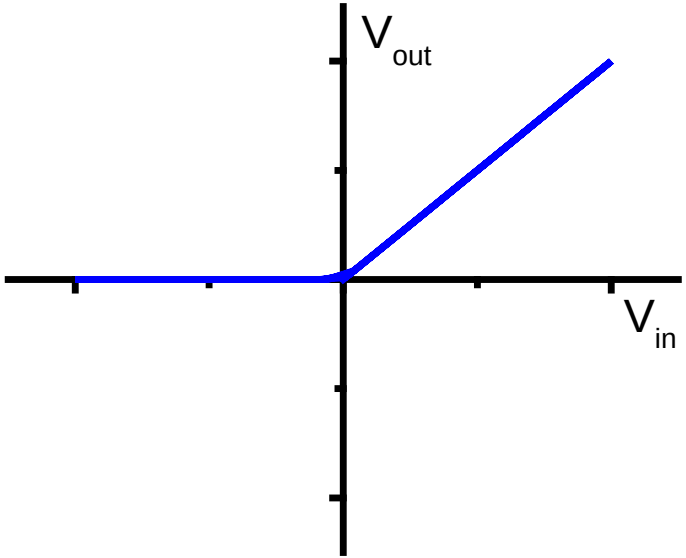
Ideal Diodes $V_1 > V_2$

Voltage Transfer Characteristic



Half-Wave Rectifier

- A special case of a limiter



Summary

- Limiter operation
- Limiter circuits

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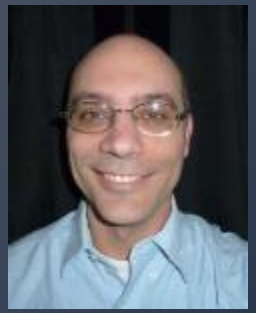

Voltage Regulators

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Introduce diode voltage regulators

Lesson Objectives

- Introduce voltage regulation
- Examine diode regulator circuits

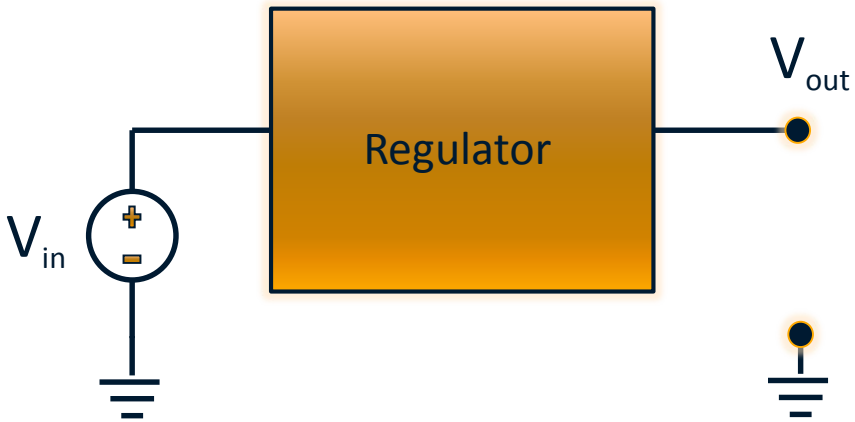
Ideal DC Voltage Regulator

- A device that maintains a constant dc output voltage regardless of variations in input voltage or load

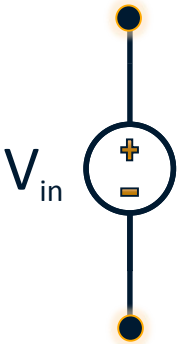
DC Regulator

Line Regulation = $\Delta V_{out} / \Delta V_{in}$

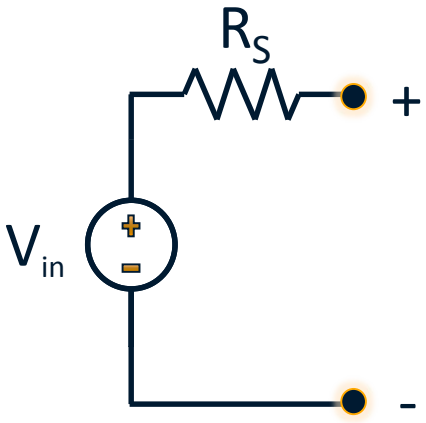
Load Regulation = $\Delta V_{out} / \Delta I_L$



Ideal and Real Voltage Sources

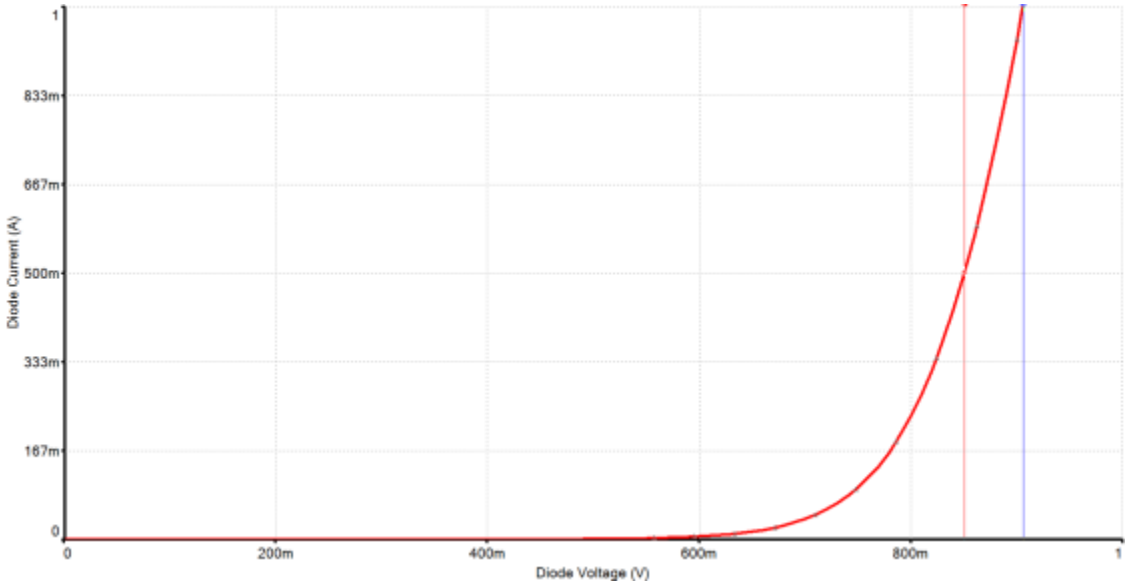


Ideal Voltage Source

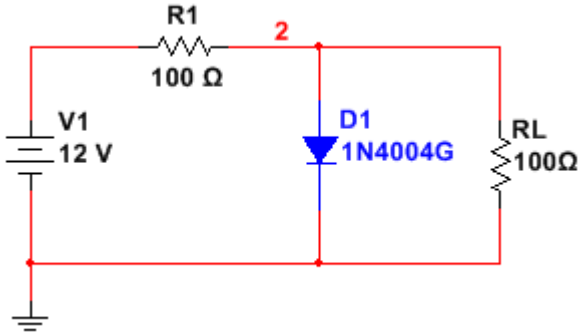


Real Voltage Source

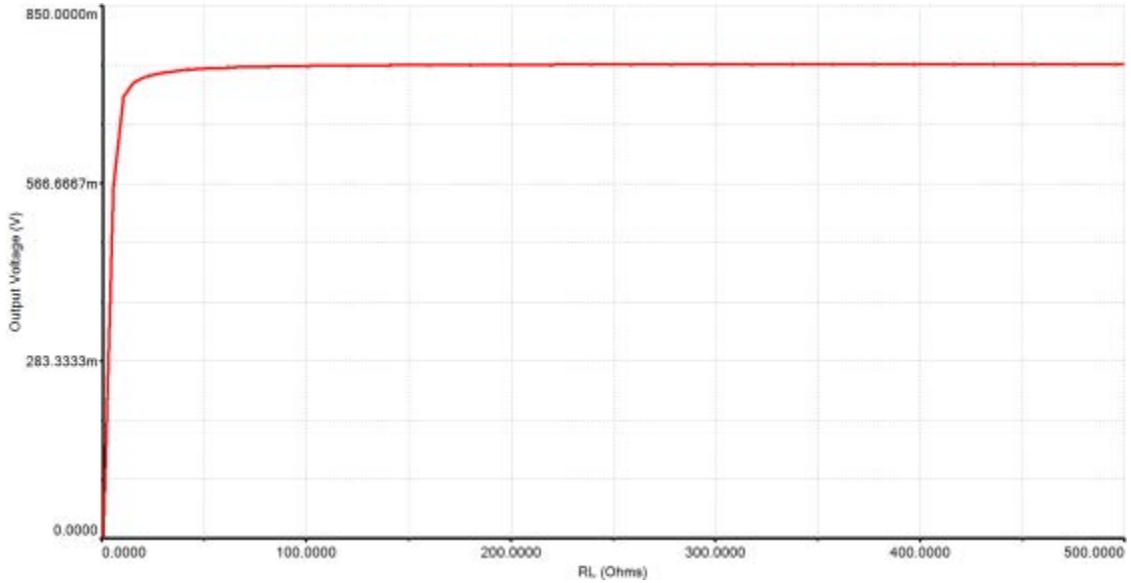
Diode I-V Curve



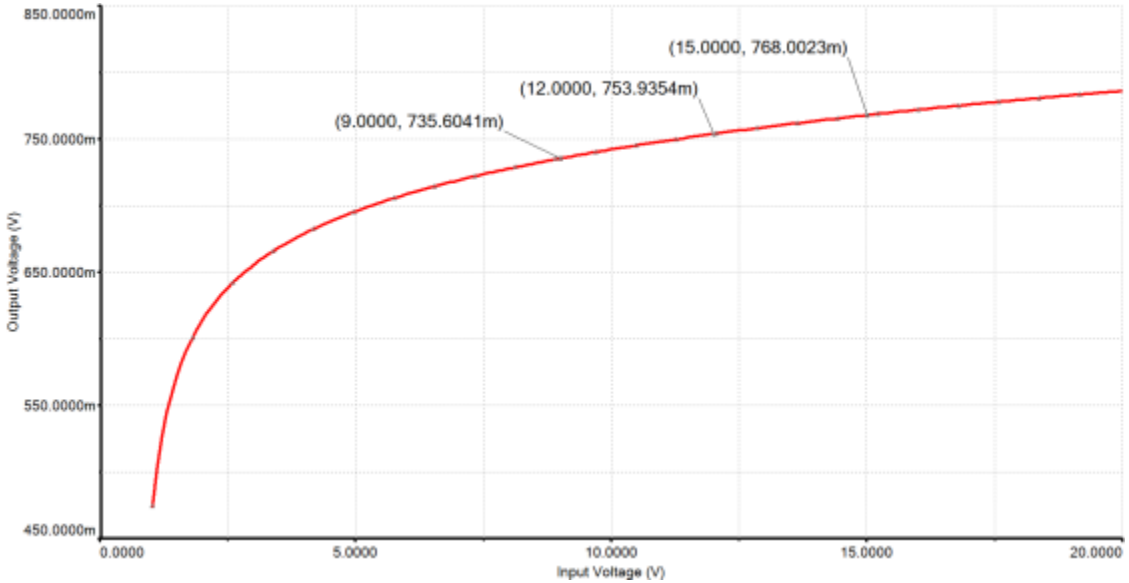
Diode Regulator



Output Voltage vs. Load Resistance

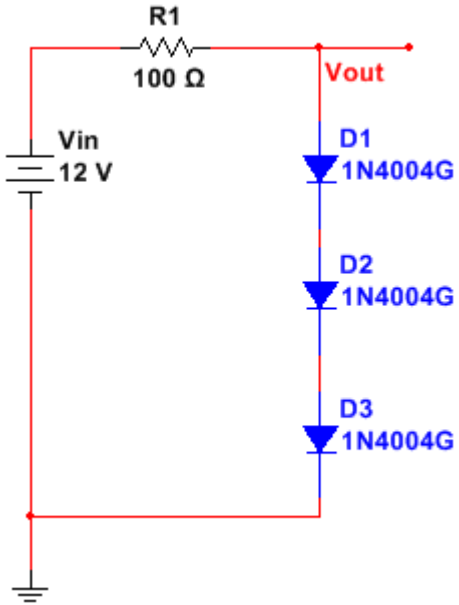


Output Voltage vs. Input Voltage



Higher Output Voltage

- How can the output voltage be increased?



Component of DC Power Supply

Summary

- Introduced voltage regulation
- Examined diode regulator circuit

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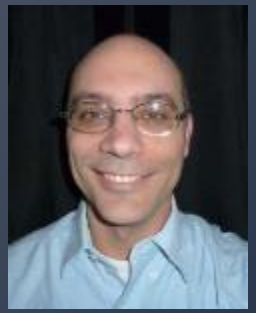

Envelope Detector Demonstration

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Demonstrate demodulation of an amplitude modulated waveform

Lesson Objectives

- Introduce amplitude modulation and demodulation
- Introduce envelope detector circuit

Amplitude Modulation (AM)

- Modification of the amplitude of a waveform by variation of a second waveform

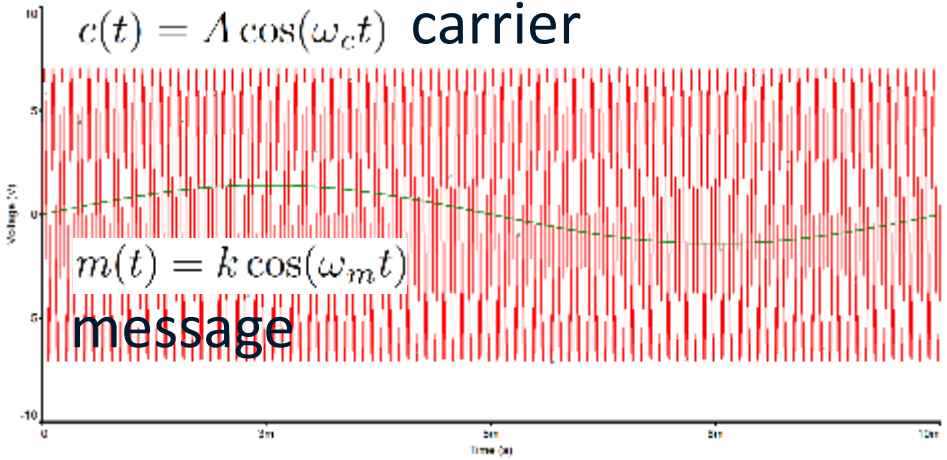
$$c(t) = A\cos(\omega_c t) \quad \text{carrier}$$

$$m(t) = k\cos(\omega_m t) \quad \text{message}$$

$$s(t) = [1 + k\cos(\omega_m t)]\, A\cos(\omega_c t) \quad \text{signal}$$

Waveforms

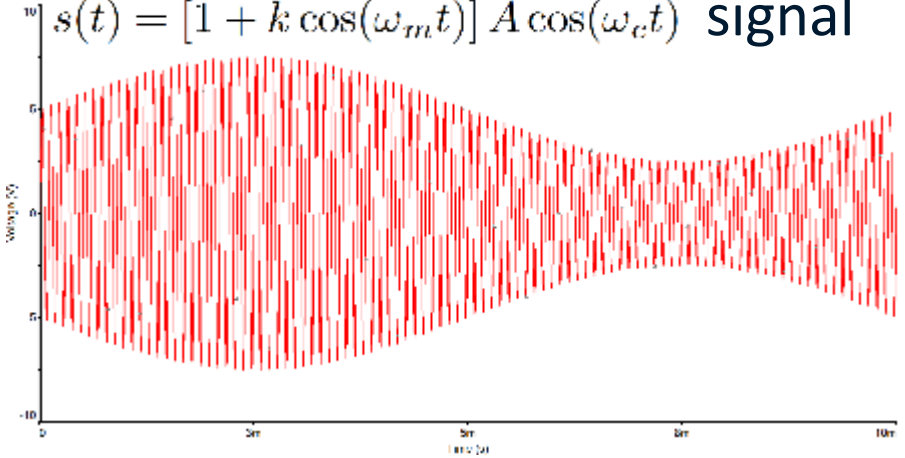
$c(t) = A\cos(\omega_c t)$ carrier



$m(t) = k\cos(\omega_m t)$

message

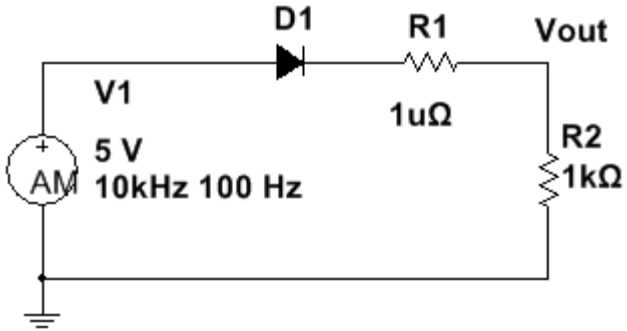
$s(t) = [1 + k\cos(\omega_m t)]\, A\cos(\omega_c t)$ signal

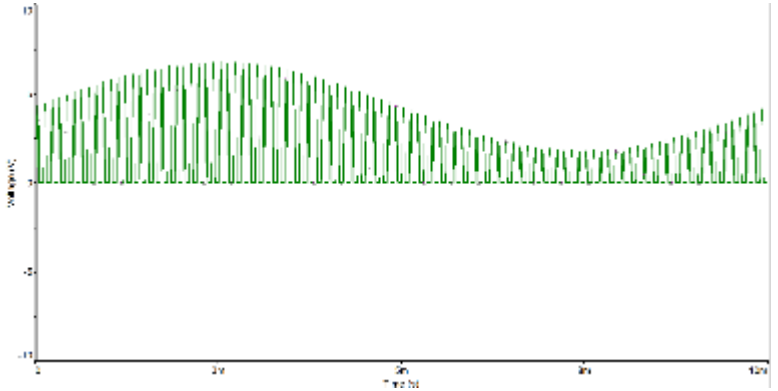


AM Uses

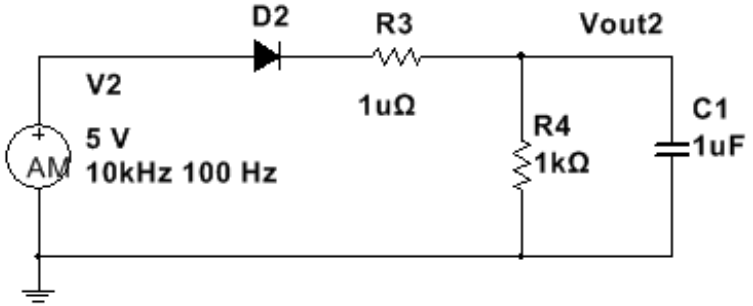
- Transmitting information (AM Radio)
- Creating sound effects

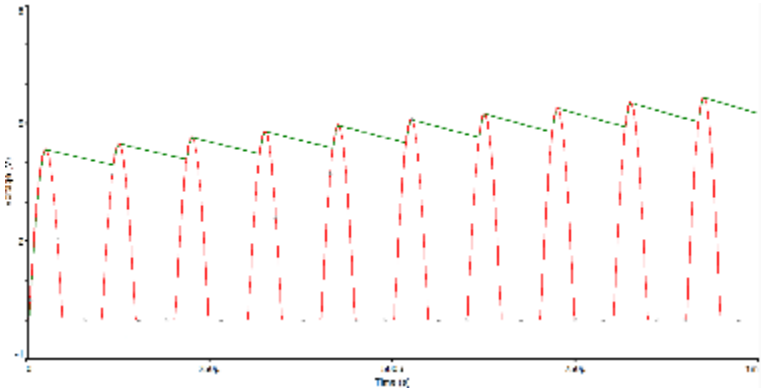
Envelope Detector (AM Demodulator)

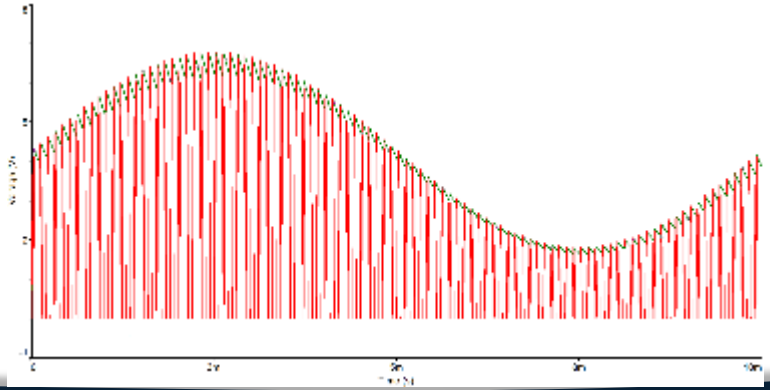


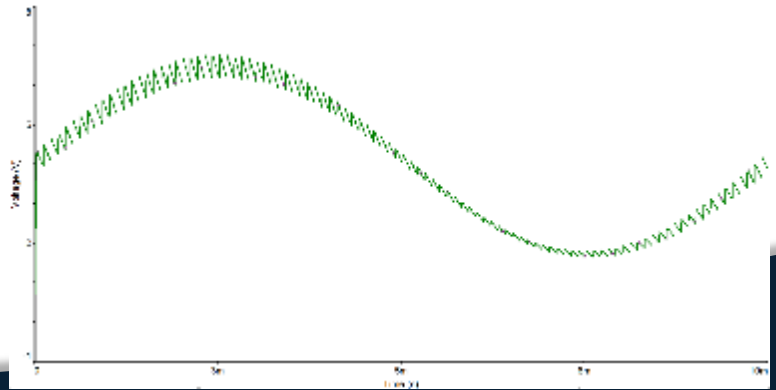


Envelope Detector (AM Demodulator)

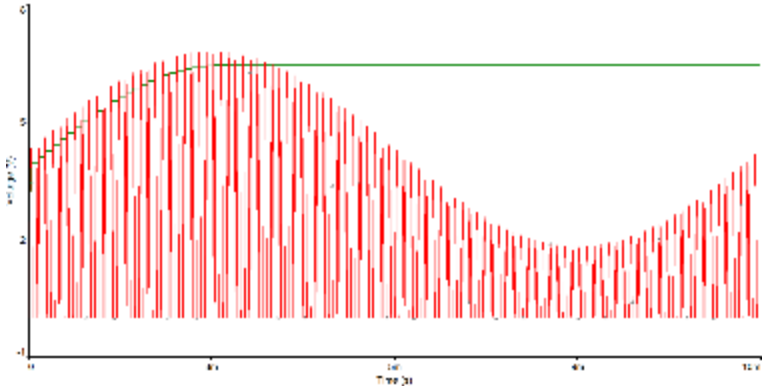








AC to DC Conversion



Summary

- Introduced amplitude modulation and demodulation
- Examined diode envelope detector circuit