ELL101: Introduction to Electrical Engineering

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IIT Delhi

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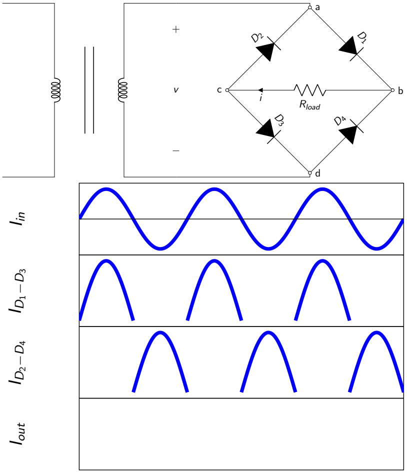
Lecture 15: Rectification and waveshaping circuits

Recap

- Zener diodes. Effect of heavy doping. Tunneling current. Designed breakdown at a specific reverse voltage. Voltage regulation applications.
- The diode as an ideal switch. Abuse of terminology: an ideal switch is not an ideal diode. Knee voltage for Si and Ge. Applications of ideal switches.
- Worked examples of diode circuits. Need for care in identifying the polarity of diode in biasing.
- Half-wave rectification. DC current, load and RMS voltage. Rectification efficiency estimation. Peak inverse voltage. Example of an application.

- Bridge rectifer:



Full-Wave Rectifiers

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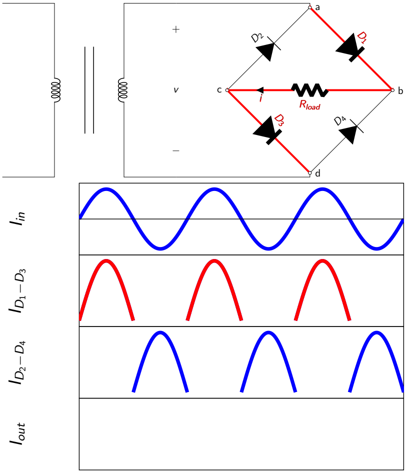
  - $+$ve $1/2$ cycle: D_1 and D_3 conduct: a-b-c-d.



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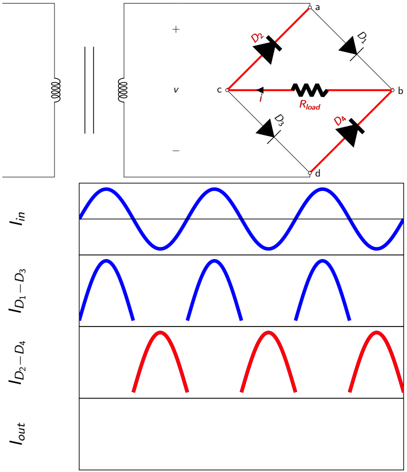

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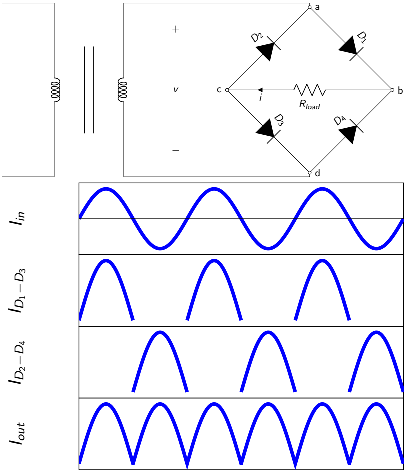

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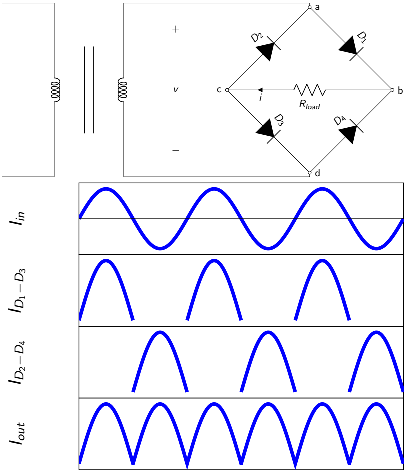

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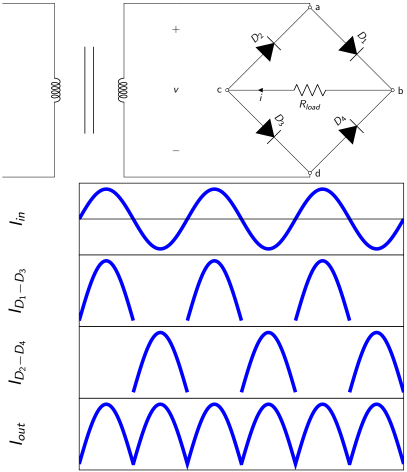
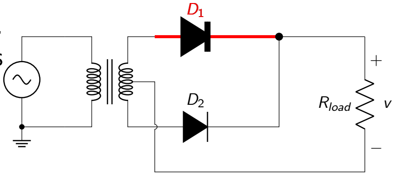
$$\eta = \left(\frac{V_{dc}}{V_{rms}}\right)^2 = \frac{8}{\pi^2} \approx 80\%$$



Center-tapped full-wave rectifier

- $+$ve $1/2$ cycle: D_1 conducts. Top half of the transformer's secondary winding carries current.



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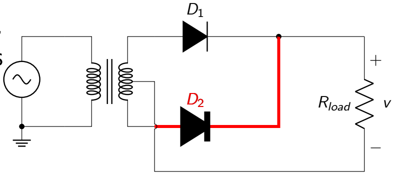

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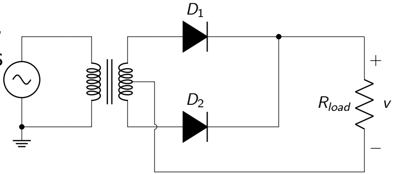

$$V_{DC} = \frac{1}{\pi}\int_0^{\pi} V_m \sin\omega t \; d(\omega t) = \frac{2}{\pi}V_m$$

$$V_{rms} = \sqrt{\frac{1}{\pi}\int_0^{\pi} (V_m \sin\omega t)^2 \, d(\omega t)} = \frac{V_m}{\sqrt{2}}$$

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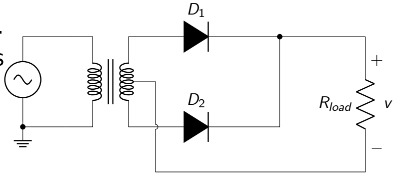
- -ve 1/2 cycle: D_2 conducts. Bottom half of the transformer's secondary winding carries current.
- Peak inverse voltage in each diode $= 2V_m$.
- 2 diodes needed. Less power dissipation / higher efficiency. More expensive transformer needed (generally found only in low-power applications).



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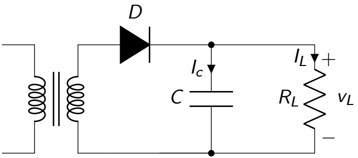
Rectification

- Counting DC o/p from every 360° of input. Half-wave rectifier: 1-pulse. Full-wave rectifier: 2-pulse.
- Ripple voltage: AC voltage superposed on rectifier pure DC output. Undesirable.
- Can be reduced through filtering for low power.

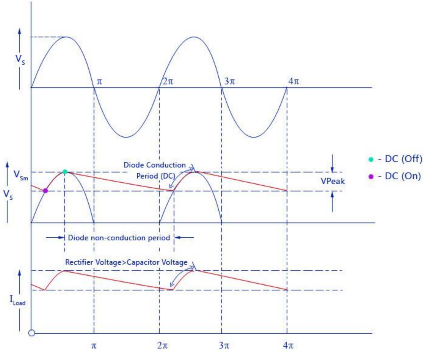
Capacitor filter with half-wave rectifier



$$\tau = R_L C \gg T$$

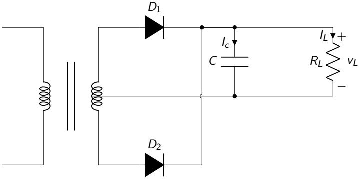
$$V_r = \frac{\Delta q}{C} \approx \frac{I_{dc} T}{C}$$

$$= \frac{I_{dc}}{fC} = \frac{V_{dc}}{fR_L C} = \frac{V_{dc}}{f\tau}$$



Output voltage remains almost constant

Capacitor filter with full-wave rectifier



Discharge time is halved ($T/2$).

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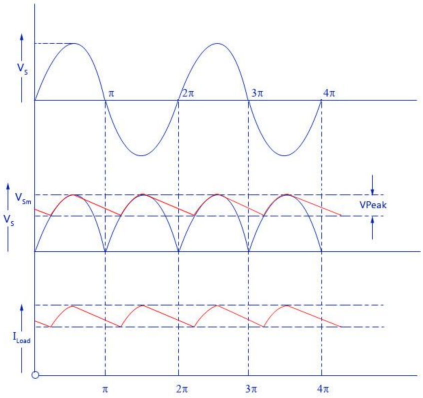
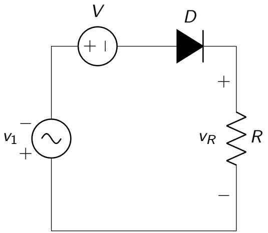
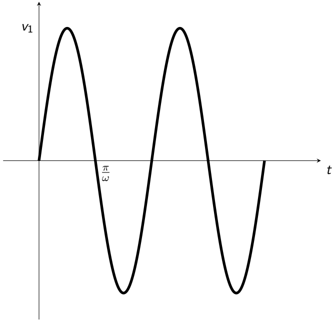


Waveshaping circuits: clipper





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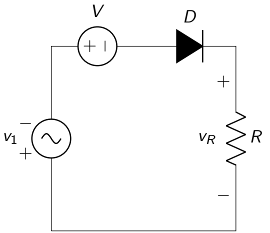

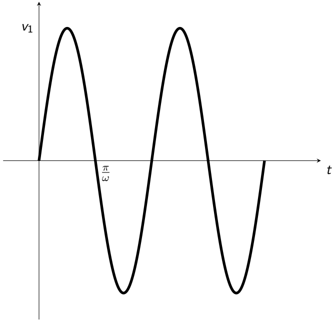

$$v_1 = V + v_D + v_R$$

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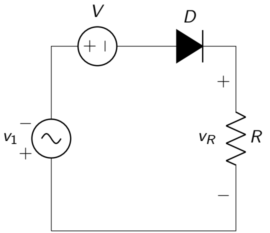

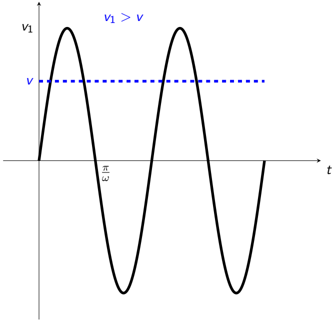

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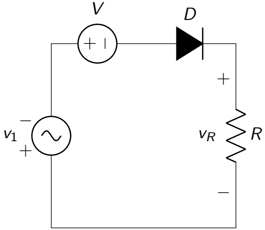

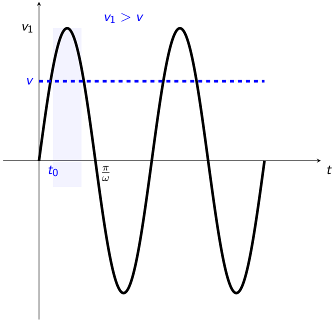

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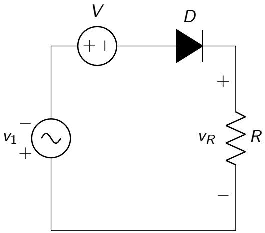

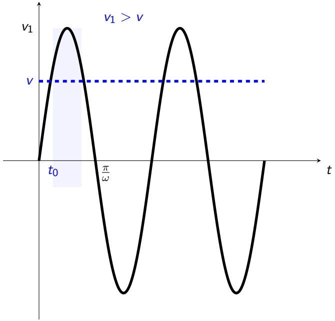

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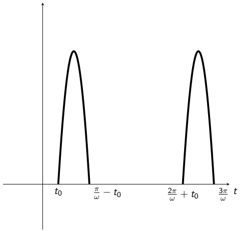

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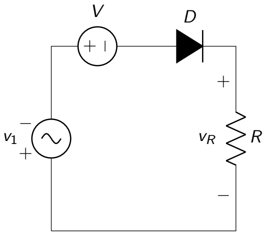

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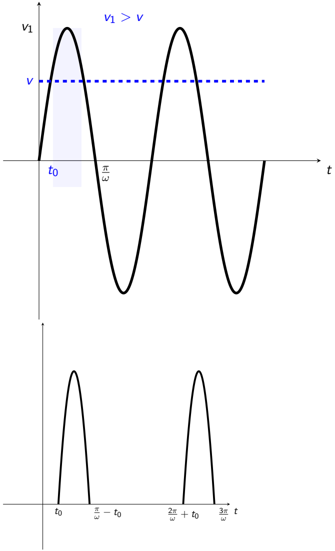
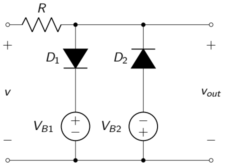


Negative clipper

Two-way clipping



- To get an undistorted signal to v_{out}, both D_1 and D_2 branches need to be open circuited.
- D_1 is FB when $V > V_{B1}$.
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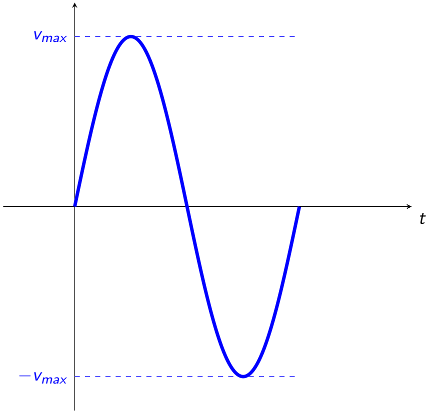

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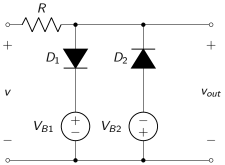

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- D_1 is FB when $V > V_{B1}$.
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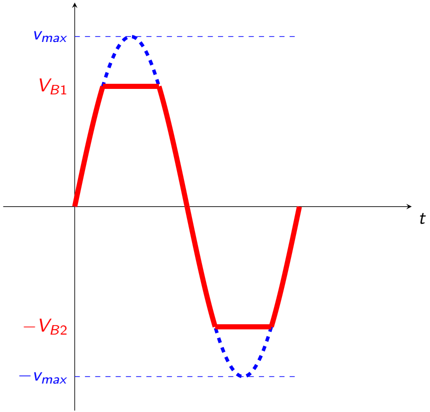
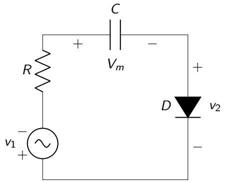
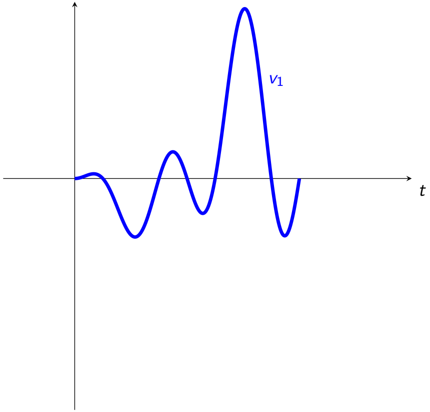
- Outside of $[-V_{B2}, V_{B1}]$, voltage is clipped to the voltage in the respective branch.



Waveshaping circuits: clamping





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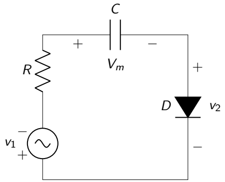

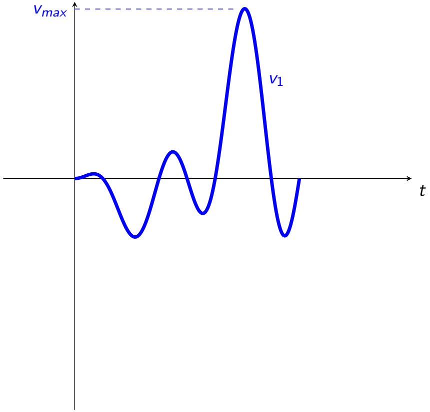

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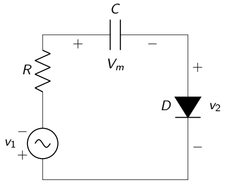

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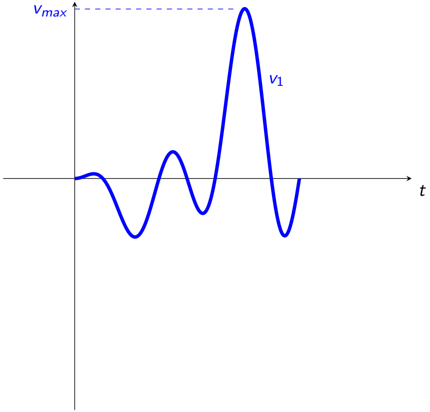

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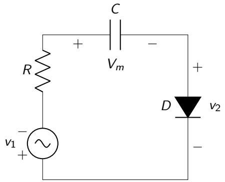

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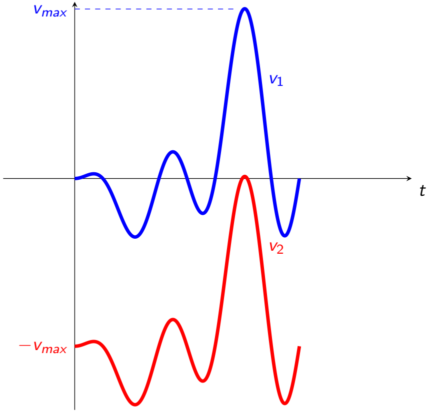

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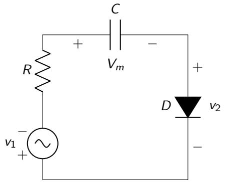

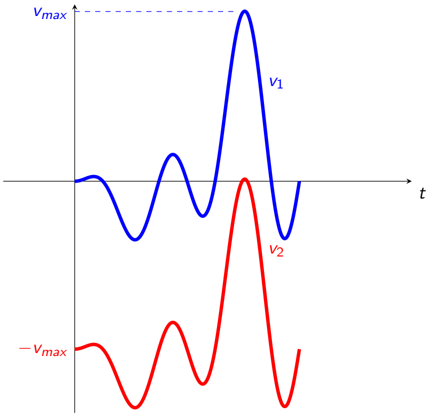

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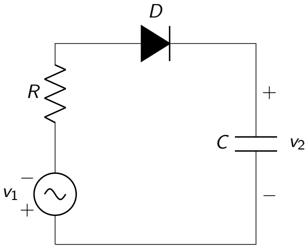
- Effect: shifting the AC signal by an amount dependent on its magnitude.
- Clamp down circuit. To clamp-up, flip diode.

Waveshaping circuits: peak detector

- Peak detector.



Waveshaping circuits: peak detector

- Peak detector.
- Peak to peak detector.