



M. B. Patil

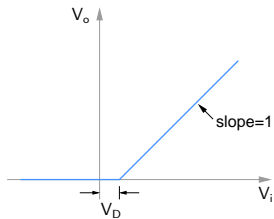
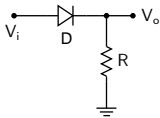
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Indian Institute of Technology Bombay

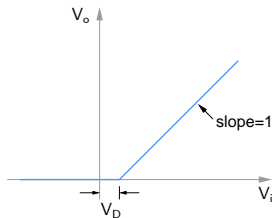
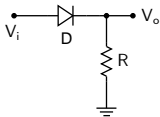
Half-wave rectifier

Consider a diode rectifier:



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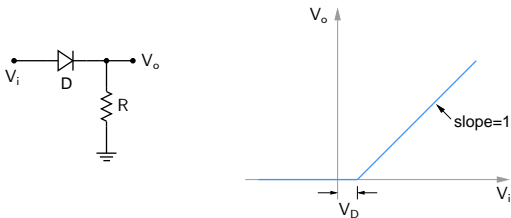


If $V_i \gg V_D$, the diode drop can be ignored.

However, if V_i is small, e.g., $V_i = 0.2 \sin \omega t$ V, then the circuit does not rectify, and $V_o(t) = 0$ V.

Half-wave rectifier

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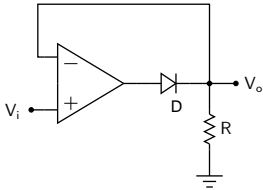


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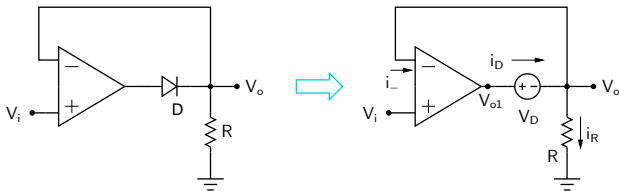
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Precision rectifier circuits overcome this drawback.

Half-wave precision rectifier



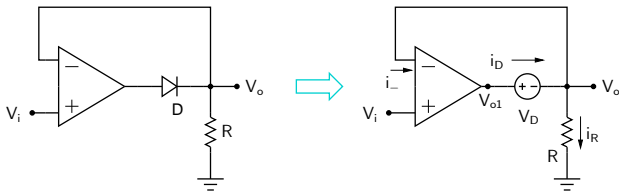
Half-wave precision rectifier



Consider two cases:

- (i) D is conducting: The feedback loop is closed, and the circuit looks like (except for the diode drop) the buffer we have seen earlier.

Half-wave precision rectifier



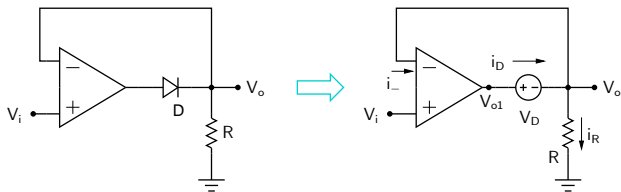
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Since the input current $i_- \approx 0$, $i_R = i_D$.

$$\text{Further, } V_+ - V_- = \frac{V_{o1}}{A_V} = \frac{V_o + 0.7 \text{ V}}{A_V} \approx 0 \text{ V} \rightarrow V_o = V_i.$$

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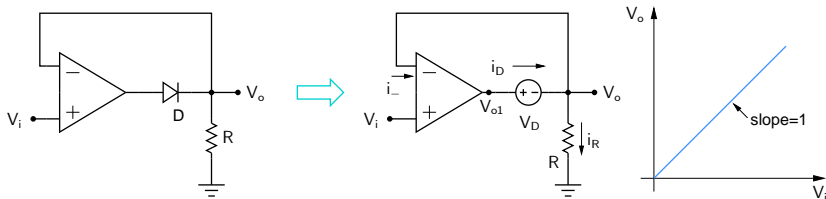
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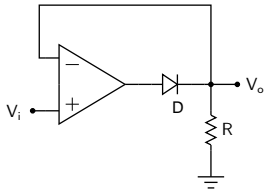
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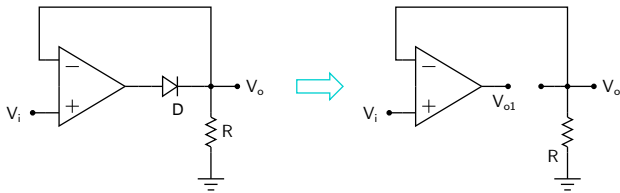
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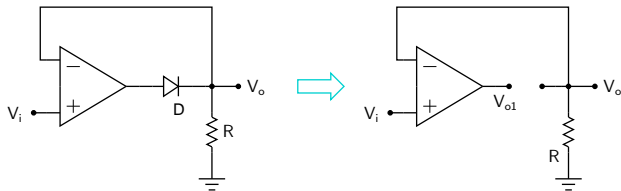


Half-wave precision rectifier



(ii) D is not conducting $\rightarrow V_o = 0 \text{ V}$.

Half-wave precision rectifier

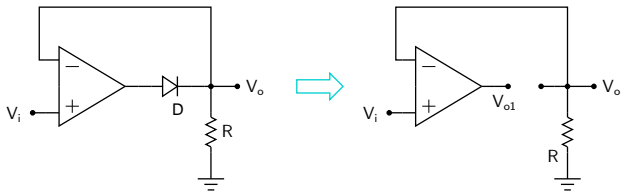


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What about V_{o1} ?

Since the Op Amp is now in the open-loop configuration, a very small V_i is enough to drive it to saturation.

Half-wave precision rectifier



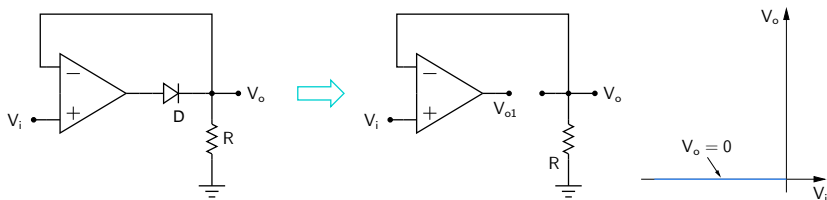
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Half-wave precision rectifier



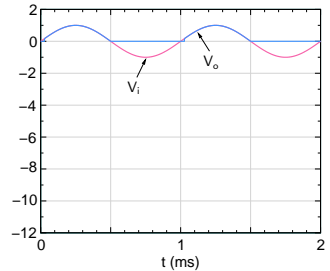
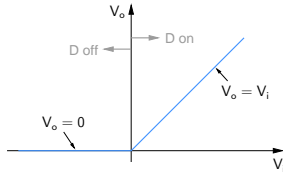
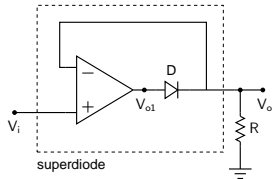
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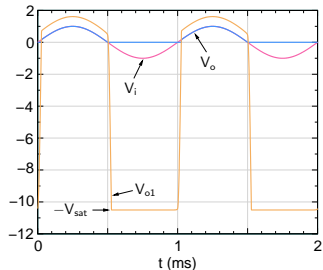
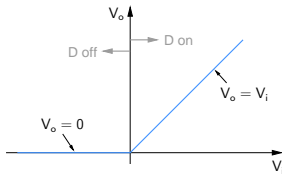
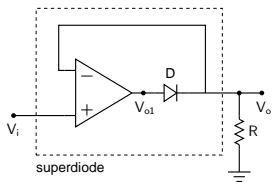
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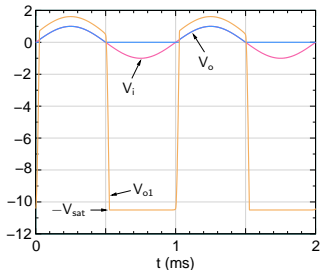
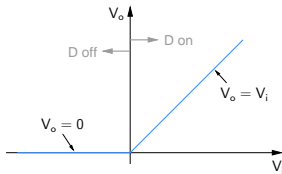
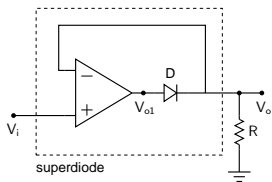
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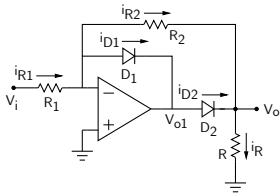
Half-wave precision rectifier



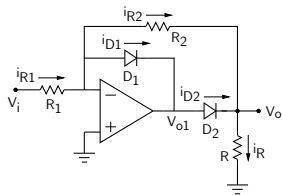
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SEQUEL file: precision_half_wave_1.sqproj

Improved half-wave precision rectifier

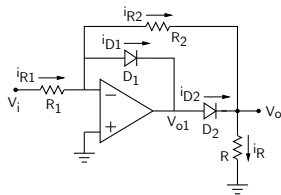


Improved half-wave precision rectifier



(i) D_1 conducts: $V_- = V_+ = 0\text{ V}$, $V_{o1} = -V_{D1} \approx -0.7\text{ V}$.

Improved half-wave precision rectifier

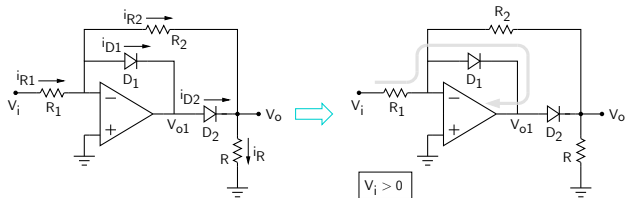


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D_2 cannot conduct (show that, if it did, KCL is not satisfied at V_o).

$\rightarrow i_{R2} = 0$, $V_o = V_- = 0\text{ V}$.

Improved half-wave precision rectifier

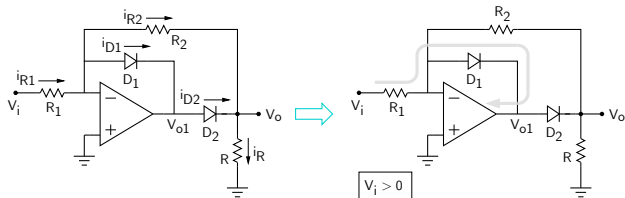


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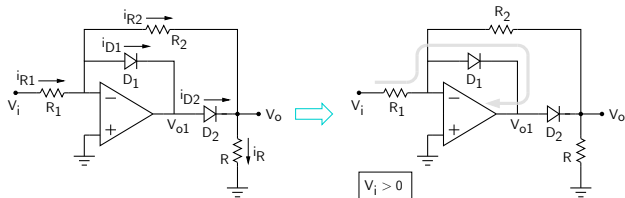
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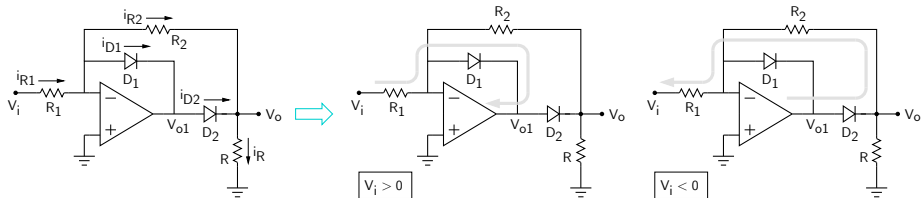
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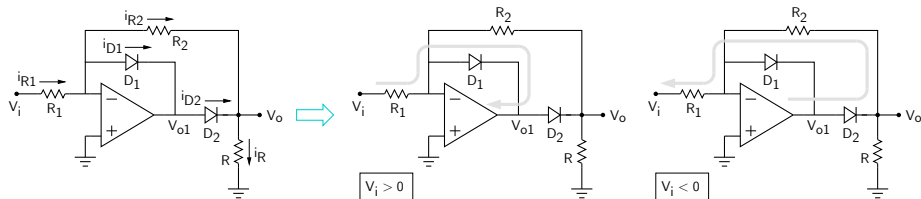
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In this case, D_2 conducts and closes the feedback loop through R_2 .

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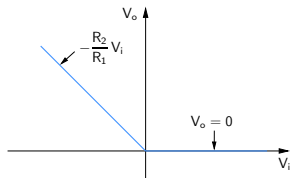
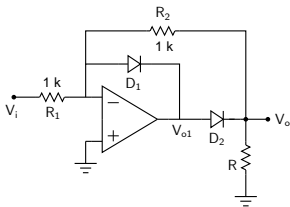
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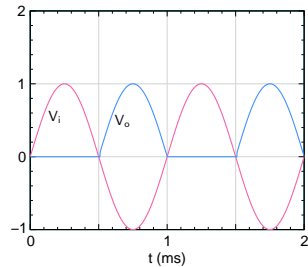
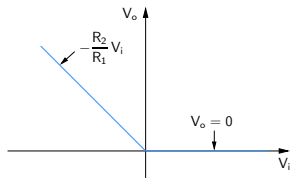
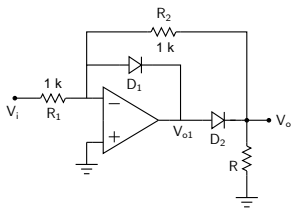
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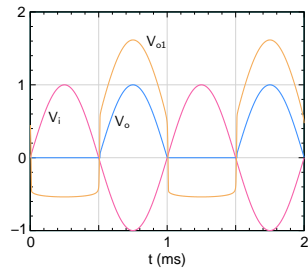
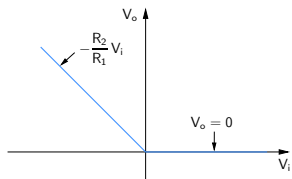
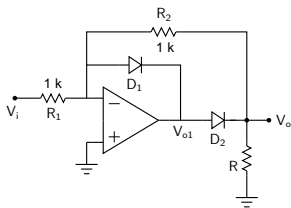
Improved half-wave precision rectifier



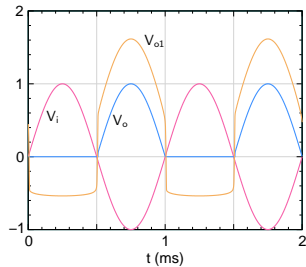
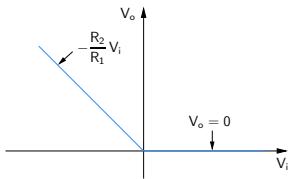
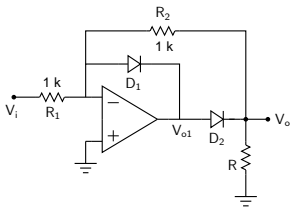
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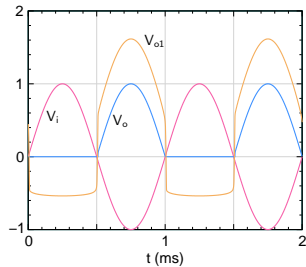
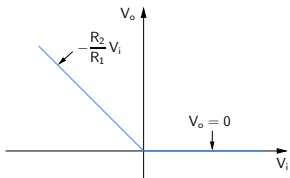
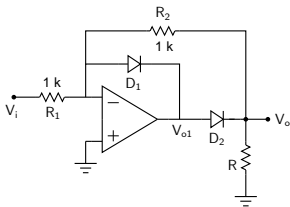


Improved half-wave precision rectifier



- * Note that the Op Amp does not enter saturation since a feedback path is available for $V_i > 0$ V and $V_i < 0$ V.

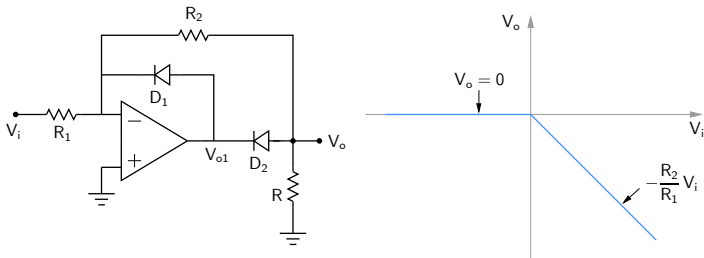
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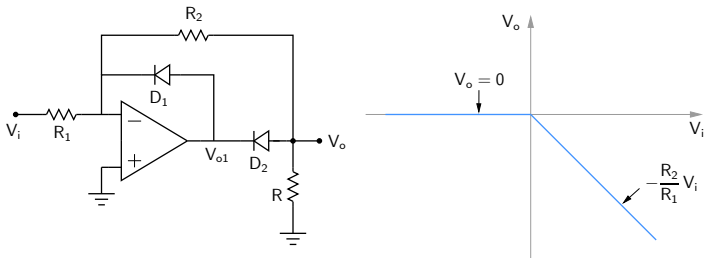
SEQUEL file: `precision_half_wave.sqproj`

Improved half-wave precision rectifier



The diodes are now reversed.

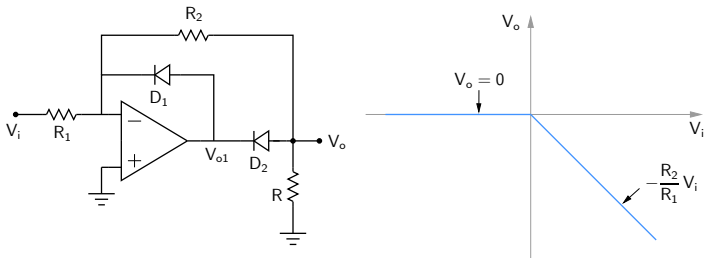
Improved half-wave precision rectifier



The diodes are now reversed.

By considering two cases: (i) D_1 on, (ii) D_1 off, the V_o versus V_i relationship shown in the figure is obtained (show this).

Improved half-wave precision rectifier

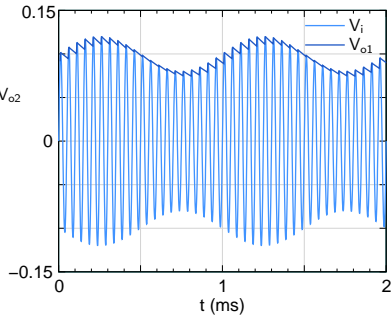
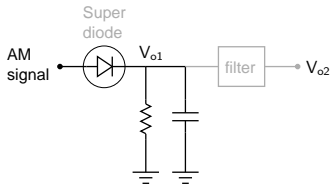


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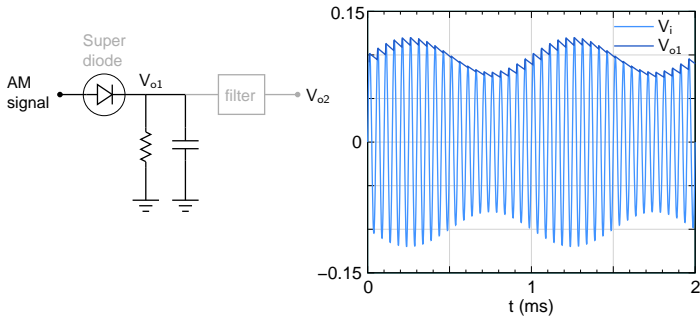
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SEQUEL file: `precision_half_wave_2.sqproj`

AM demodulation using a peak detector

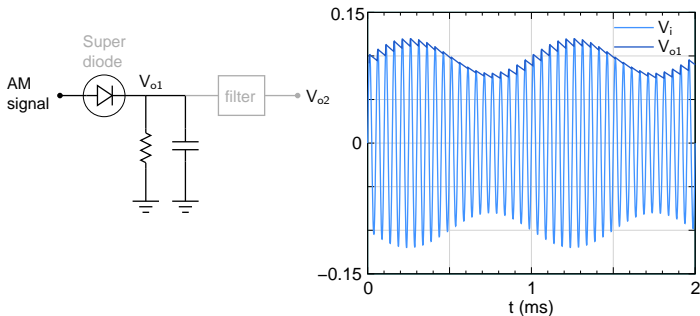


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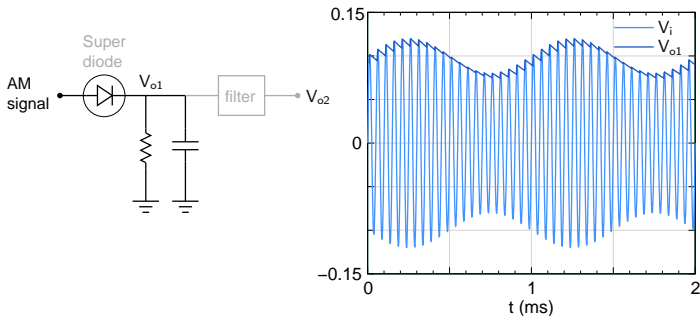
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AM demodulation using a peak detector



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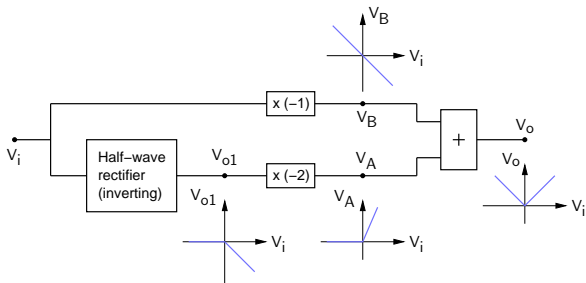
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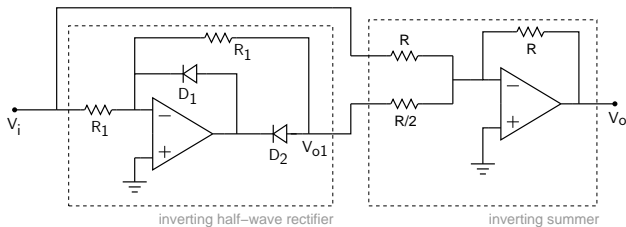
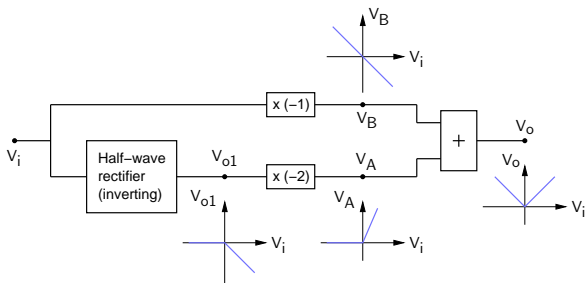
- * charging through superdiode, discharging through resistor
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SEQUEL file: `super_diode.sqproj`

Full-wave precision rectifier

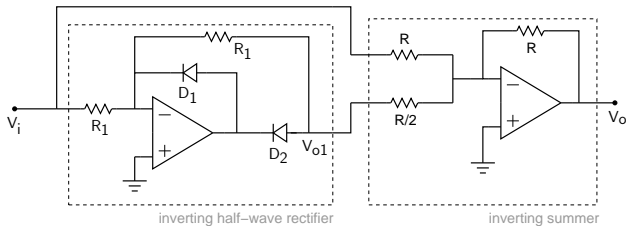
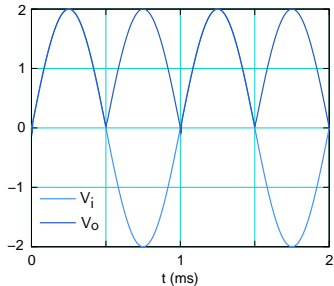
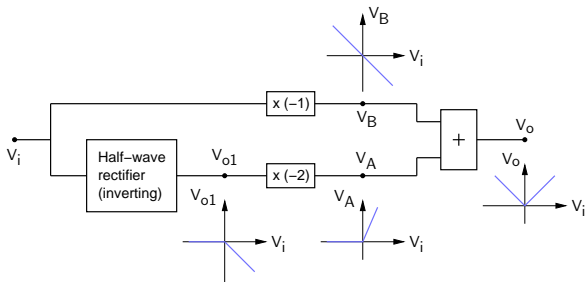


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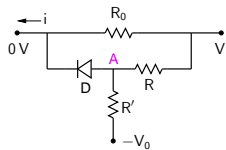
(SEQUEL file: precision_full_wave.sqproj)

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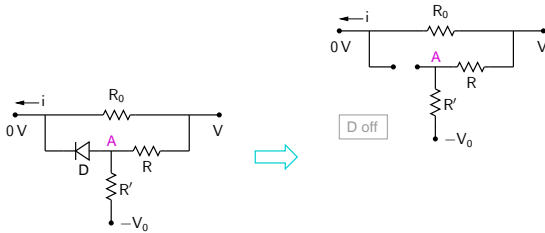


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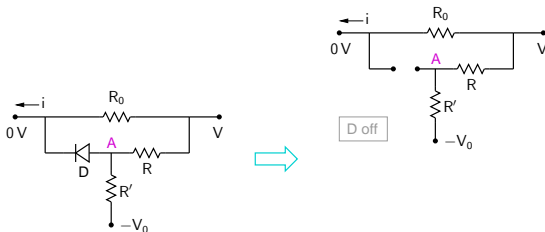
Wave shaping with diodes



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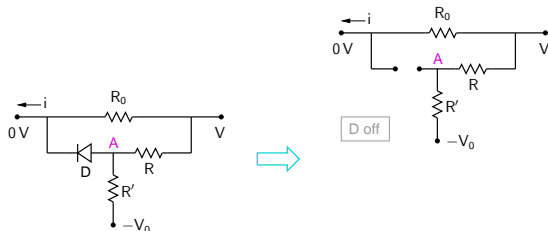
Wave shaping with diodes



When D is off, V_A is (by superposition),

$$V_A = V \frac{R'}{R + R'} - V_0 \frac{R}{R + R'}.$$

Wave shaping with diodes

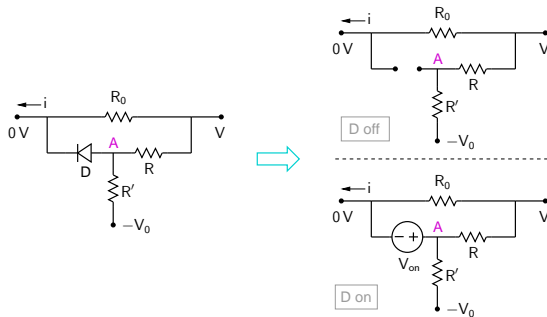


When D is off, V_A is (by superposition),

$$V_A = V \frac{R'}{R + R'} - V_0 \frac{R}{R + R'} .$$

For D to turn on, $V_A = V_{\text{on}} \approx 0.7 \text{ V} \rightarrow V \equiv V_{\text{break}} = \frac{R}{R'} (V_0 + V_{\text{on}}) + V_{\text{on}} .$

Wave shaping with diodes

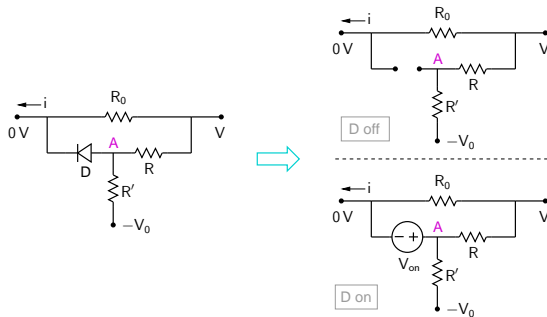


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Wave shaping with diodes



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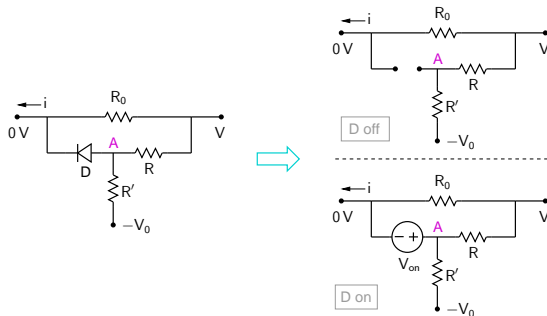
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When D is on,

$$\begin{aligned} i &= \frac{V}{R_0} + \frac{V - V_{on}}{R} + \frac{-V_0 - V_{on}}{R'} \\ &= V \left[\frac{1}{R_0} + \frac{1}{R} \right] + (\text{constant}) \end{aligned}$$

Wave shaping with diodes



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$$V_A = V \frac{R'}{R + R'} - V_0 \frac{R}{R + R'}.$$

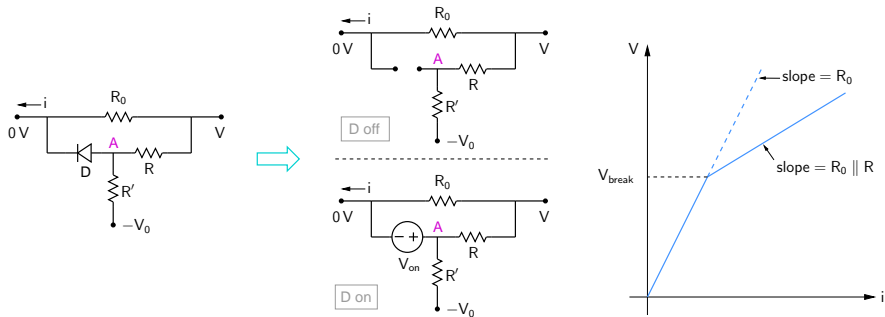
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i.e., $V = (R_0 \parallel R) i + (\text{constant}).$

Wave shaping with diodes



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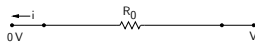
For D to turn on, $V_A = V_{on} \approx 0.7 V \rightarrow V \equiv V_{break} = \frac{R}{R'} (V_0 + V_{on}) + V_{on}.$

When D is on,

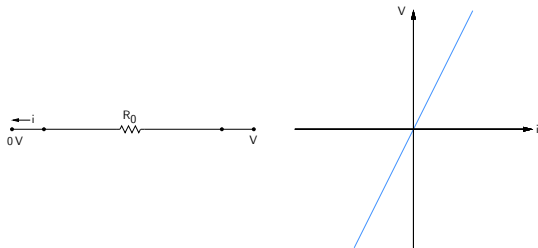
$$\begin{aligned} i &= \frac{V}{R_0} + \frac{V - V_{on}}{R} + \frac{-V_0 - V_{on}}{R'} \\ &= V \left[\frac{1}{R_0} + \frac{1}{R} \right] + (\text{constant}) \end{aligned}$$

i.e., $V = (R_0 \parallel R) i + (\text{constant}).$

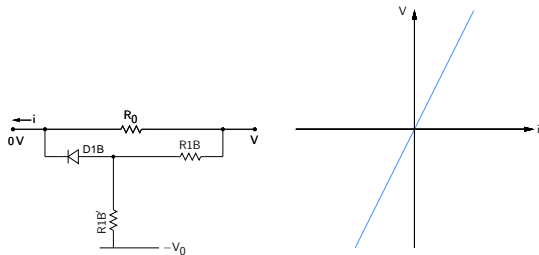
Wave shaping with diodes



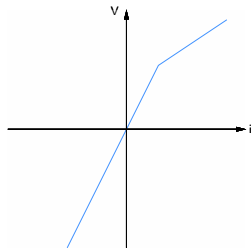
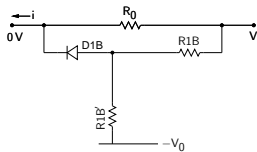
Wave shaping with diodes



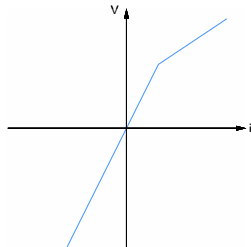
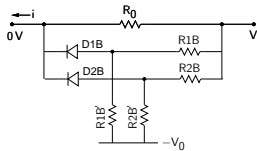
Wave shaping with diodes



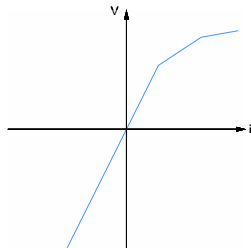
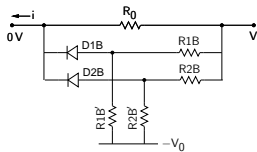
Wave shaping with diodes



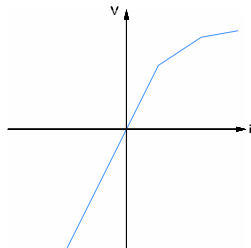
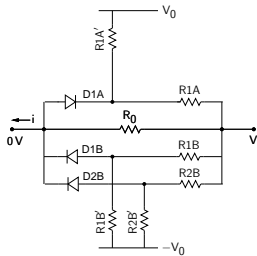
Wave shaping with diodes



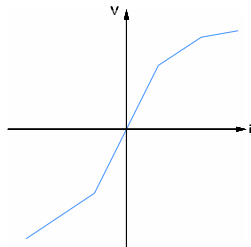
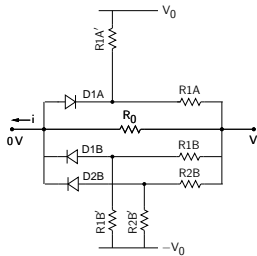
Wave shaping with diodes



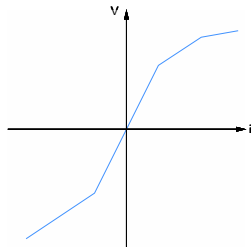
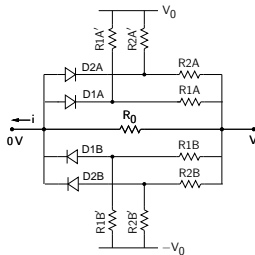
Wave shaping with diodes



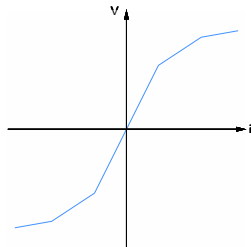
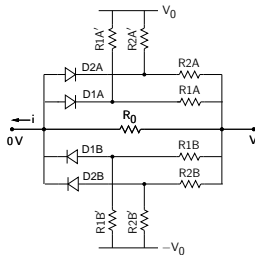
Wave shaping with diodes



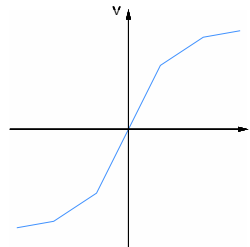
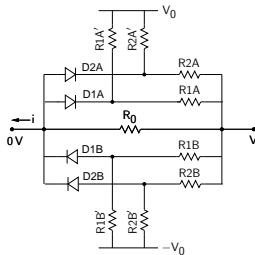
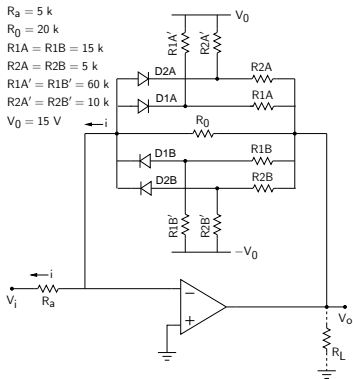
Wave shaping with diodes



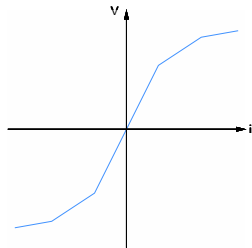
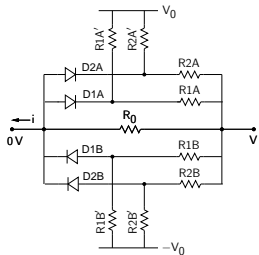
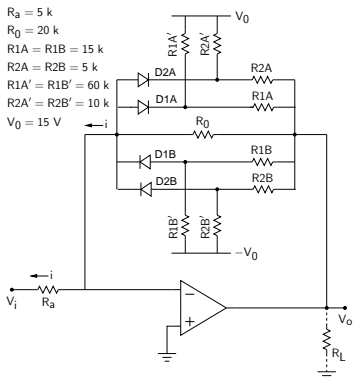
Wave shaping with diodes



Wave shaping with diodes

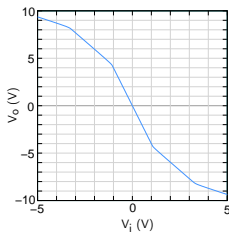
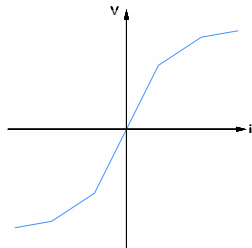
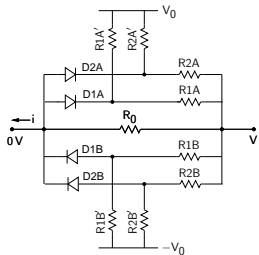
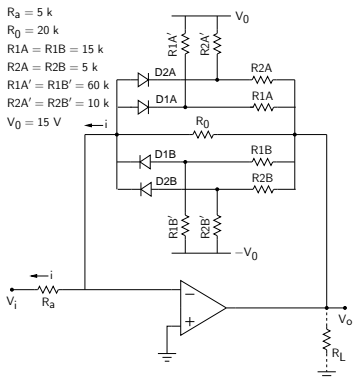


Wave shaping with diodes



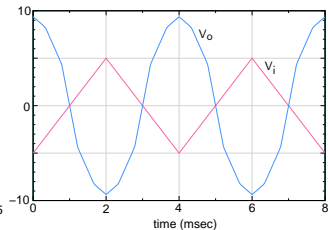
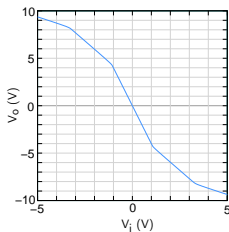
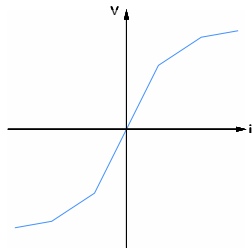
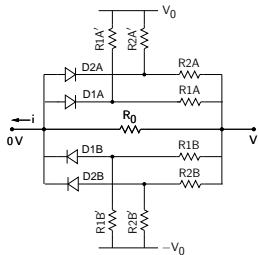
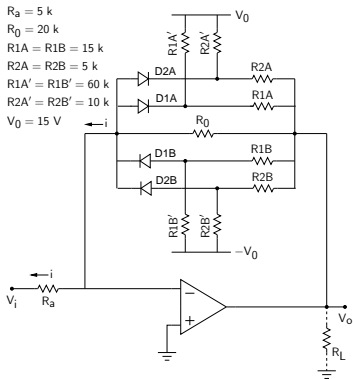
Since $V_i = -R_a i$, the V_o versus V_i plot is similar to the V versus i plot, except for the $(-R_a)$ factor.

Wave shaping with diodes



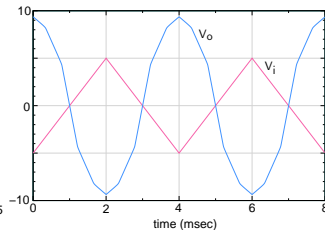
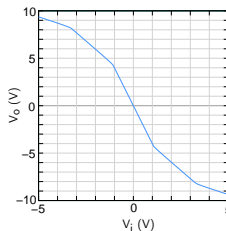
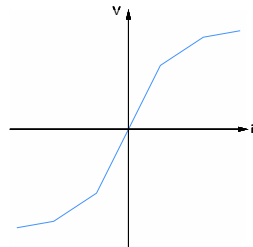
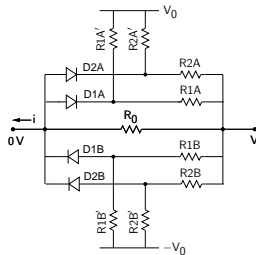
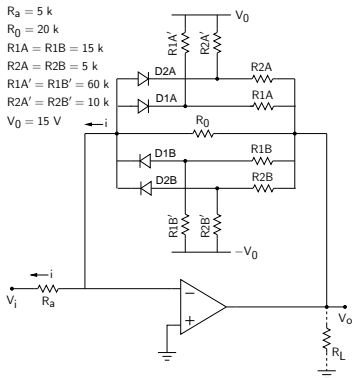
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Wave shaping with diodes



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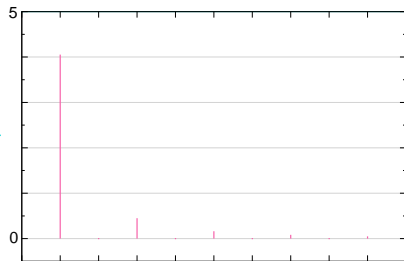
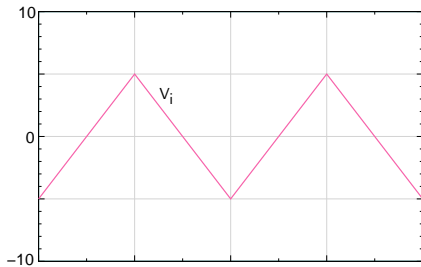
Wave shaping with diodes



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SEQUEL file: ee101_wave_shaper.sqproj

Wave shaping with diodes: spectrum



Wave shaping with diodes: spectrum

