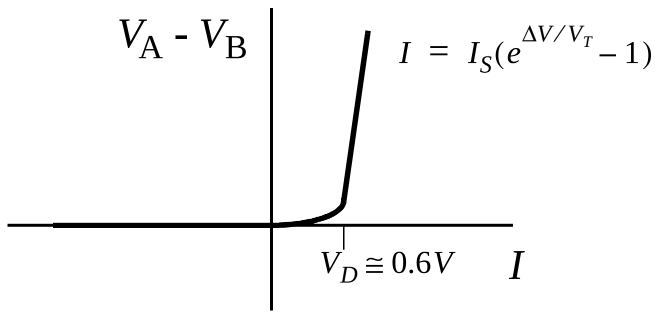
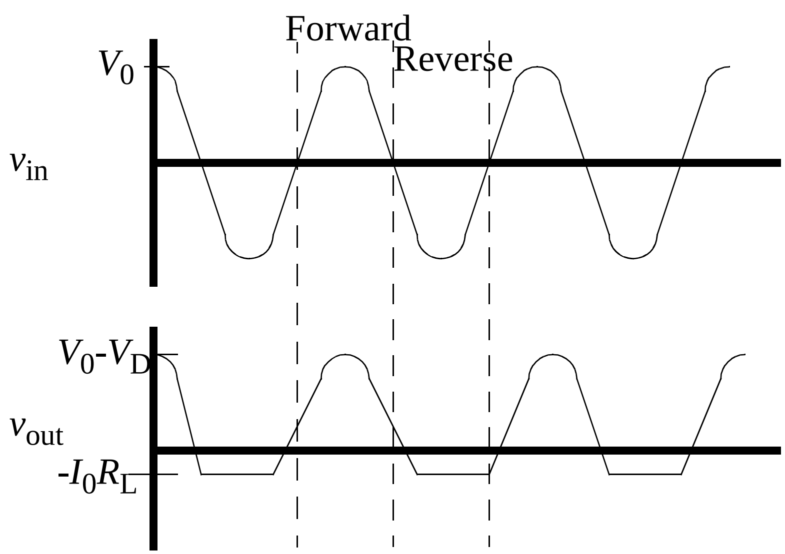
Active Rectifiers

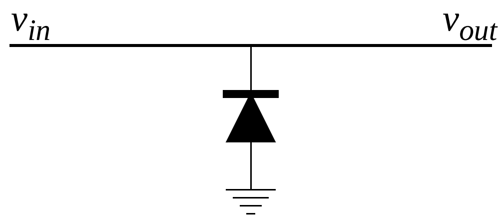
- Op amps can be used with diodes to create better properties.
- Real diodes have a forward “diode drop” and small reverse current.



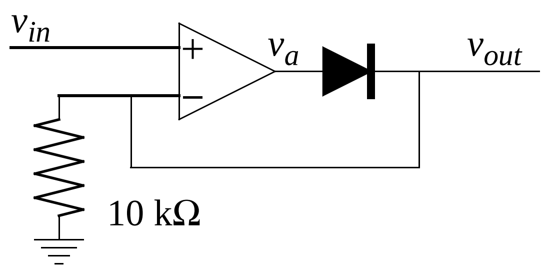


Ideal Diode

- The simple rectifier uses a diode to short signals



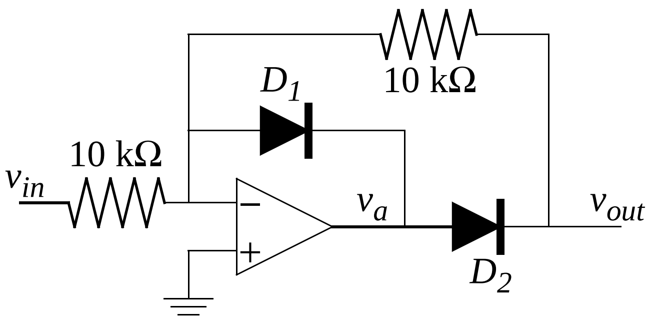
- This cannot rectify signals less than 0.6 V.
- Feedback can be used to make an "ideal" diode.



- If $v_{in} > 0$, $v_{out} = v_+ = v_- = v_{in}$, $v_a = v_{in} + 0.6$ V.
- If $v_{in} < 0$, $v_a < 0$, the diode is non-conducting and $v_{out} = 0$ V.
- This circuit is slew rate limited, for negative signals it goes to $-V_{EE}$.

Faster Rectifier

- The op-amp can be protected from going to $-V_{EE}$.

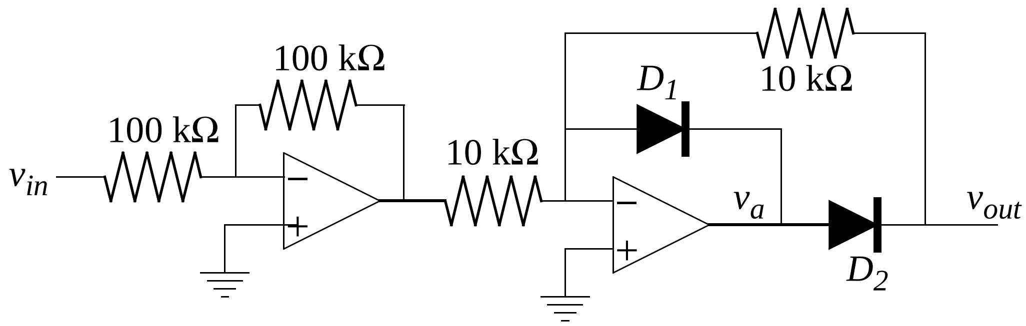


- If $v_{in} < 0$, $v_{out} = -v_{in}$, $v_a = v_{out} + 0.6$ V, D_2 is conducting.
- If $v_{in} > 0$, $v_a < 0$, D_1 is conducting, $v_a = v_{in} - 0.6$ V, $v_{out} = 0$.
- As v_{in} goes from negative to positive, v_a goes from +0.6 to -0.6 V.

- This is faster than going from - 15 V to + 0.6 V for the same slew rate.

Two Stage Rectifier

- Add a x1 inverter before this circuit to make a conventional rectifier that passes positive signals only.

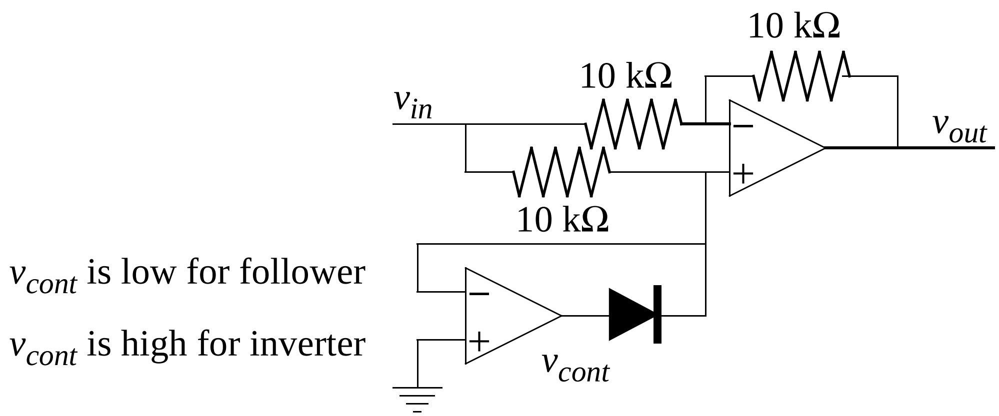


The first amplifier stage provides a -1 inverter with 100 kΩ input impedance.

The second amplifier acts as a half wave rectifier.

Active Full-wave Rectifier

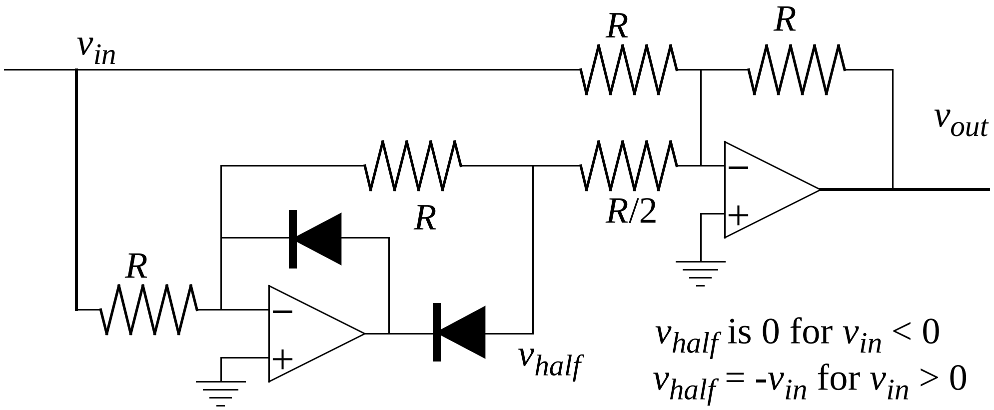
- Two amplifiers can be used to make a full-wave rectifier.
- A switchable inverter/buffer can use an op-amp as the switch.



- If $v_{in} < 0$, $v_{cont} = 0.6$, and the circuit inverts.
- If $v_{in} > 0$, the diode is non-conducting, so no feedback.

Faster Full-Wave

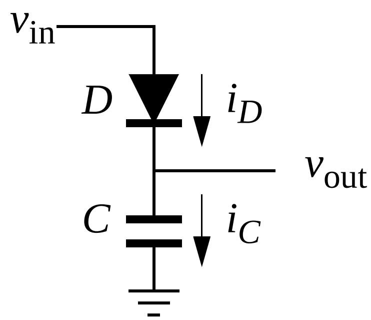
- The fast half-wave rectifier can be used with an inverter.



- The first stage produces v_{half}.
- The second amplifier is an inverting summation circuit with the upper line (v_{in}) summing at x1 and the lower line (v_{half}) summing at x2.
- The net effect of the second inverter is $v_{out} = -(v_{in} - 2v_{half})$.
- For $v_{in} > 0$, $v_{half} = -v_{in}$, $v_{out} = v_{in}$.
- For $v_{in} < 0$, $v_{half} = 0$, $v_{out} = -v_{in}$.

Peak Detector

- A diode and a capacitor can be used as a peak detector.



$$i_C = C\frac{dv_{out}}{dt}$$

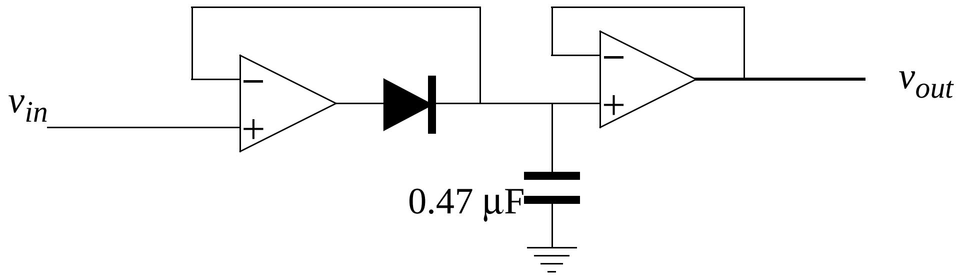
If $v_{out} < v_{in} - 0.6\ V$, $v_{out} = v_{in} - 0.6\ V$

If $v_{out} > v_{in} - 0.6\ V$, $i_C = 0$, $v_{out} = const.$

- The voltage through the diode is stored on the capacitor.
- The voltage is stored as a charge $V = Q/C$ until a higher value comes along.
- The diode drop matters; v_{in} - 0.6 V is stored on the capacitor.

Active Peak Detector

- An active rectifier can be combined with a capacitor to store the true input voltage.



- The first amplifier is set up as an ideal diode.
- Positive voltage through the diode is stored at the capacitor. The response is limited by the slew rate and output current, I_{max}, of the first amplifier.

$$\left.\frac{dv_{out}}{dt}\right|_{max} = \frac{1}{C}\frac{dQ}{dt} = \frac{I_{max}}{C}$$

- The second amplifier is a x1 buffer and the large input impedance (related to I_B) prevents the capacitor from draining too rapidly.

$$\left.\frac{dv_{out}}{dt}\right|_{droop} = \frac{I_B}{C}$$