

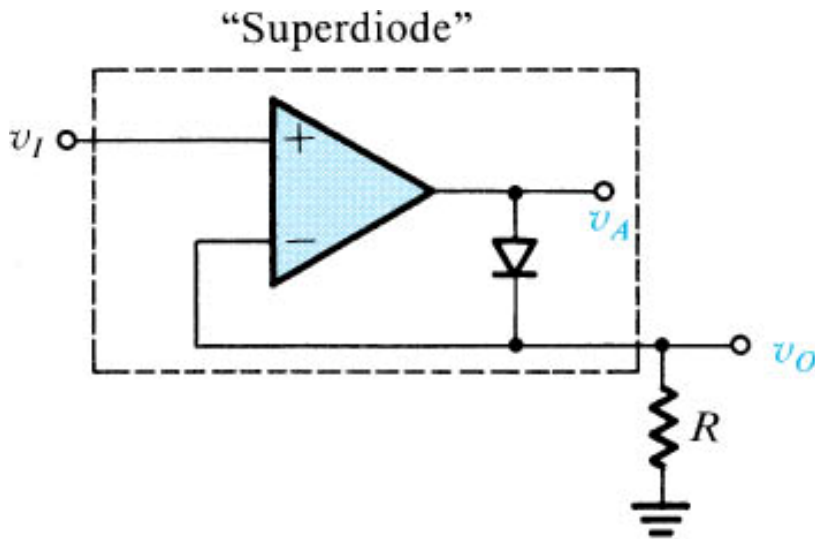
Precision Rectifier Circuits

Rectifier circuits are used in the design of power supply circuits. In such applications, the voltage being rectified are usually much greater than the diode voltage drop, rendering the exact value of the diode drop unimportant to the proper operation of the rectifier.

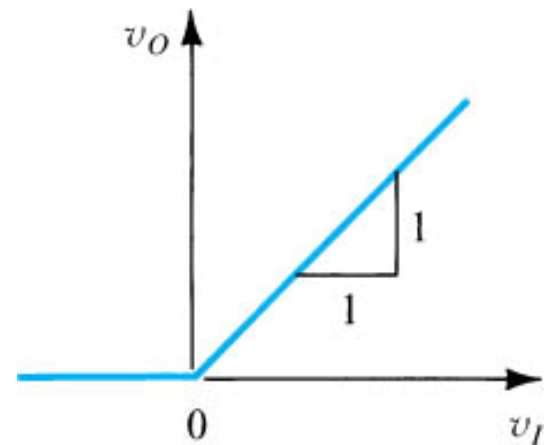
Other applications exists, however, where this is not the case. For example, in instrumentation applications, the signal to be rectified can be of very small amplitude, say 0.1 V, making it impossible to employ the conventional rectifier circuits. Also the need arises for very precise transfer characteristics.

Precision Half-Wave Rectifier- The Superdiode

There are many applications for precision rectifiers, and most are suitable for use in audio circuits. A half wave precision rectifier is implemented using an op amp, and includes the diode in the feedback loop. This effectively cancels the forward voltage drop of the diode, so very low level signals (well below the diode's forward voltage) can still be rectified with minimal error.



(a)



(b)

Limitations

- The circuit has some serious limitations. The main one is speed. It will not work well with high frequency signals.
- For a low frequency positive input signal, 100% negative feedback is applied when the diode conducts. The forward voltage is effectively removed by the feedback, and the inverting input follows the positive half of the input signal almost perfectly.
- When the input signal becomes negative, the op amp has no feedback at all, so the output pin of the op amp swings negative as far as it can.
- When the input signal becomes positive again, the op amp's output voltage will take a finite time to swing back to zero, then to forward bias the diode and produce an output. This time is determined by the op amp's **slew rate**, and even a very fast op amp will be limited to low frequencies.

Exercise 13.24: Consider the operational amplifier in Figure 13.33(a), with $R = 1\text{ k}\Omega$. For $v_I = 10\text{ mV}$, 1 V , and -1 V , what are the voltages that result at the rectifier output and at the output of the op am? Assume that the op amp is ideal and its output saturates at $\pm 12\text{ V}$. The diode has a 0.7-V drop at 1-mA current, and the voltage drop changes by 0.1 V per decade of current change.

$$v_I = 10\text{ mV} \quad v_O = 10\text{ mV}$$

$$i_D = \frac{10\text{ mV}}{R} = 10\text{ }\mu\text{A}$$

Given $i_D = 1\text{ mA} \quad 0.1\text{ mA} \quad 10\text{ }\mu\text{A}$
 $v_O = 0.7\text{ V} \quad 0.6\text{ V} \quad 0.5\text{ V}$

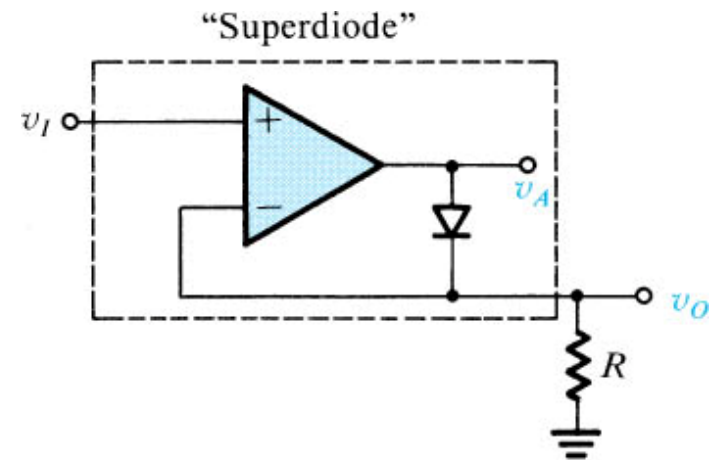
$$v_I = 1\text{ V} \quad v_O = 1\text{ V}$$

$$i_D = 1\text{ mA}, v_D = 0.7\text{ V} \quad v_A = 1.7\text{ V}$$

$$v_I = -1\text{ V}$$

The negative feedback loop is not operative

$$v_O = 0\text{ V} \quad v_A = -12\text{ V}$$

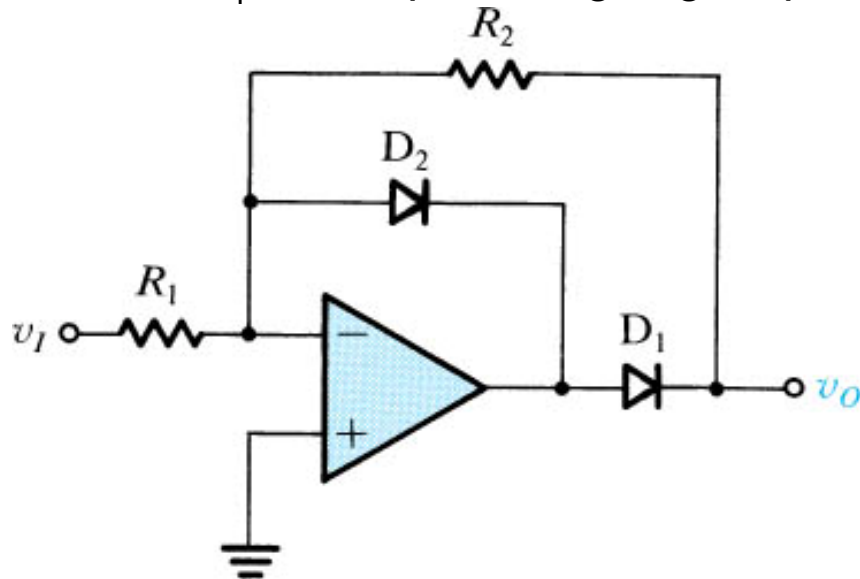


(a)

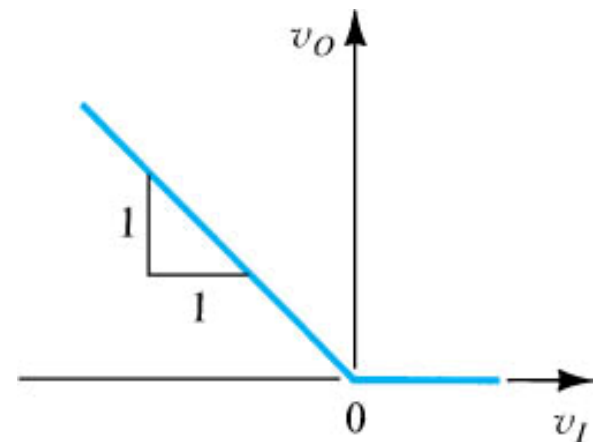
Another Circuit

The circuit below accepts an incoming waveform and as usual with op amps, inverts it. However, only the positive-going portions of the output waveform, which correspond to the negative-going portions of the input signal, actually reach the output. The direct feedback diode shunts any negative-going output back to the "-" input directly, preventing it from being reproduced. The slight voltage drop across the diode itself is blocked from the output by the second

diode. D_1 allows positive-going output voltage to reach the output.



(a)

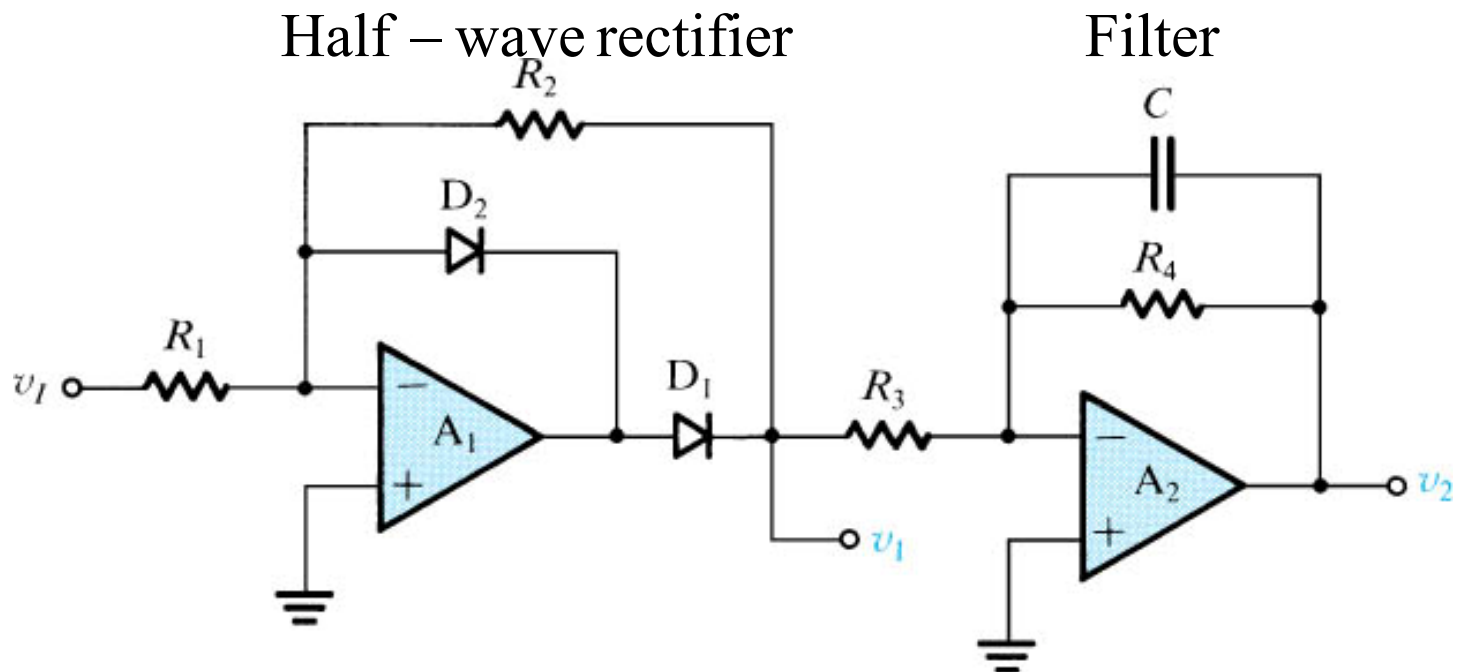


(b)

An Application: Measuring AC Voltages

What is the DC output voltage of the following circuit if $R_1 = 3.24 \text{ k}\Omega$, $R_2 = 10.2 \text{ k}\Omega$, $R_3 = 20 \text{ k}\Omega$ and $R_4 = 20 \text{ k}\Omega$. Assume $V_p = 2 \text{ V}$

$$v_2 = -\frac{V_p}{\pi} \frac{R_2}{R_1} \frac{R_4}{R_3}$$

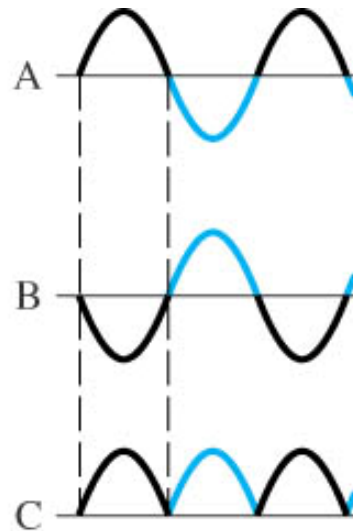
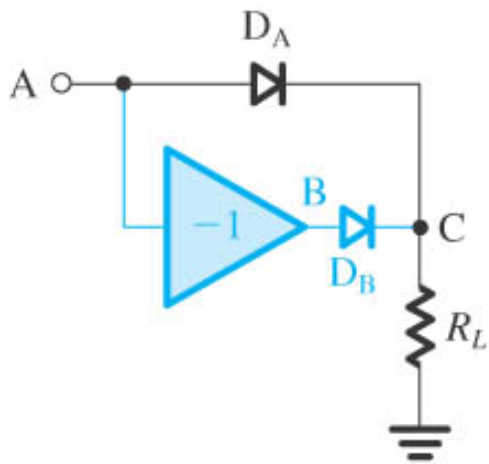


Design Task: Based on the circuit of the AC voltmeter and for a sinusoidal input signal with an amplitude V_p at a frequency ω_0 , find the output voltage v_i described by its Fourier series (average value plus the harmonics of the frequency ω_0 .

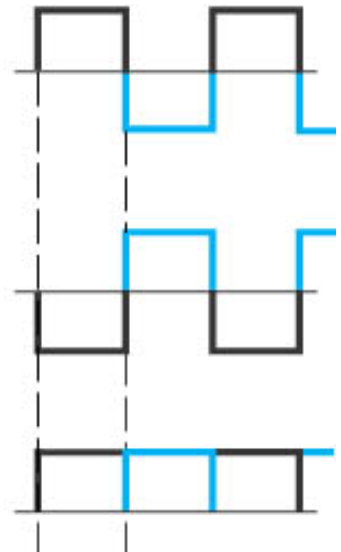
State when the output signal can be described by the DC voltage components (this means reducing the amplitudes of these harmonics to very small level).

A Basic Circuit for Precision Full-Wave Rectifier

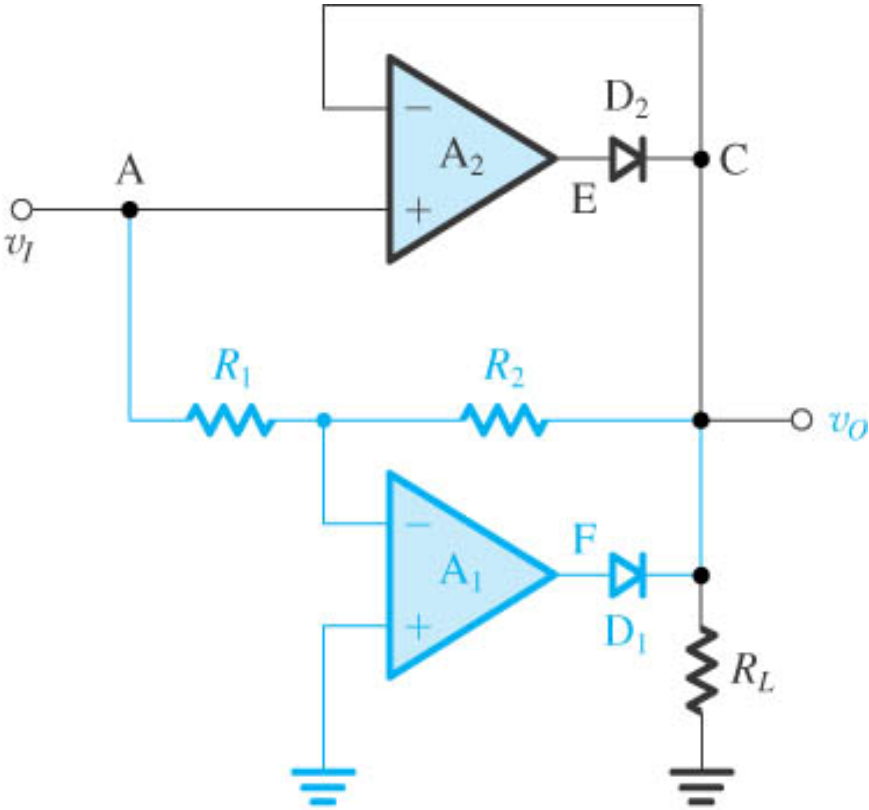
Replace D_A with a superdiode and the diode D_B and the inverting amplifier with the inverting precision half-wave rectifier to get the precision full wave rectifier in the following page.



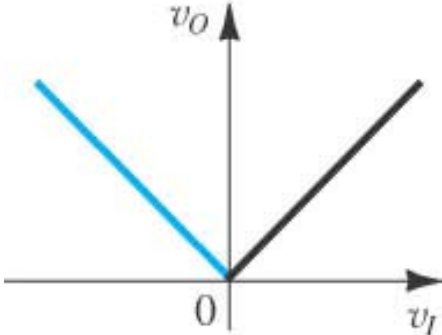
or



Full-Wave Rectifier with the transfer characteristic



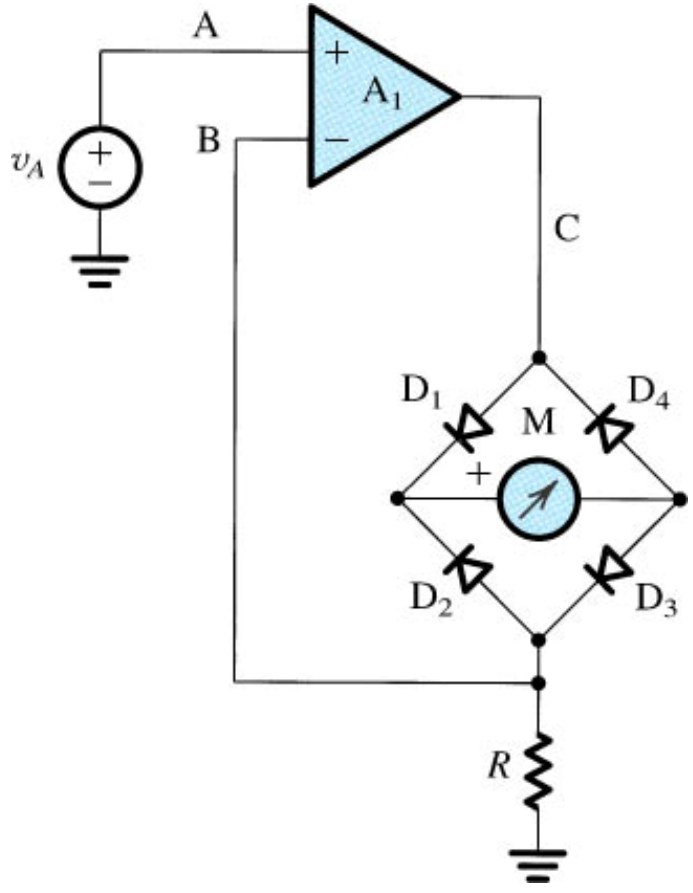
(a)



(b)

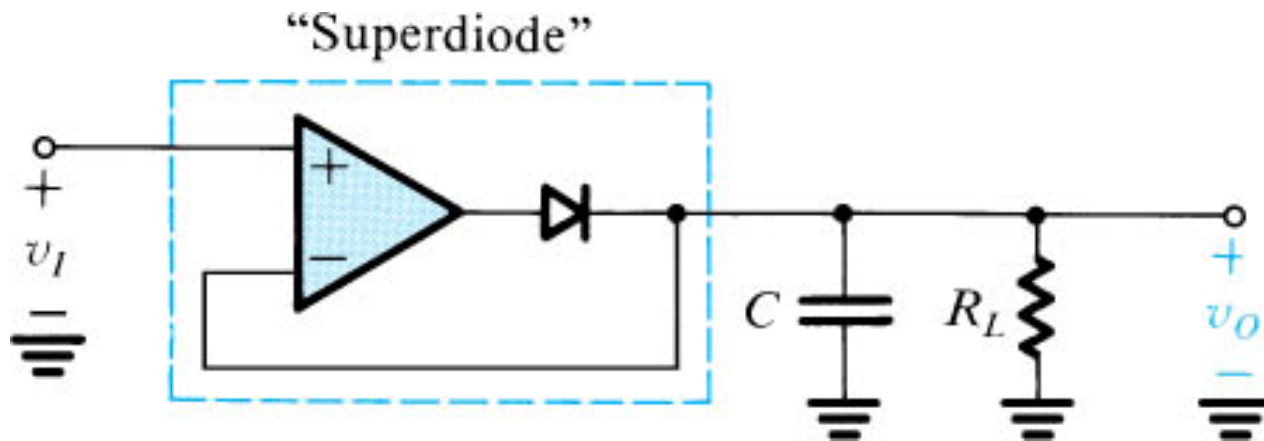
Precision Bridge Rectifier for Instrumentation Applications

AC Voltmeter



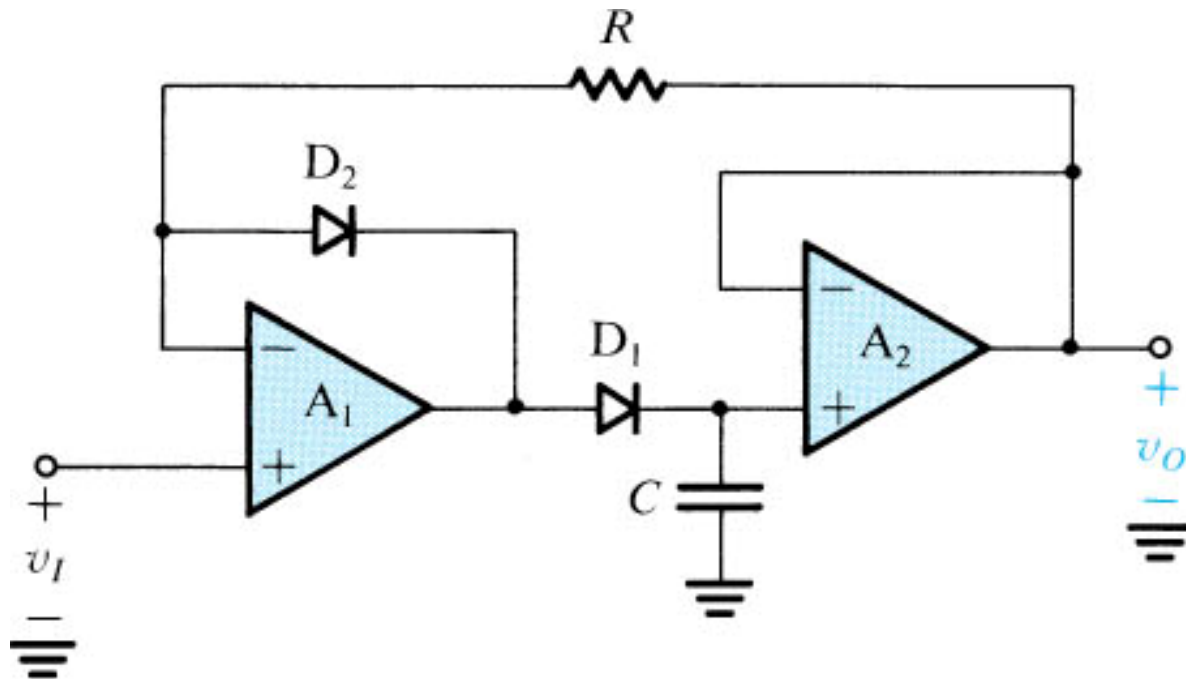
A Precision Peak Rectifier

The capacitor retains a voltage equal to the positive peak of the input



A Precision Peak Detector

When the peak detector required to hold the value of the peak for a long time, the capacitor should be buffered. An op amp A_2 , which should have high input impedance and low input bias current, is connected as a voltage follower. The rest of the circuit is similar to the half-wave rectifier.



A Precision Clamping Circuit

By replacing the diode in the usual clamping circuit with a superdiode the precision clamp is obtained.

