

Half Wave Rectifier

by Hank Zumbahlen,
Analog Devices, Inc.

IN THIS MINI TUTORIAL

The half wave rectifier is typically used to create a dc level from an ac input. This rectifier is one in a set of discrete circuits incorporating operational amplifiers (op amps) described in a series of mini tutorials.

The half wave rectifier is typically used to create a dc level from ac input. This is often used to measure the amplitude of the ac signal.

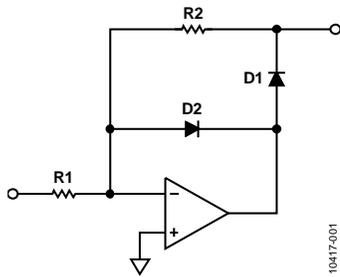


Figure 1. Half Wave Rectifier

To understand the operation of the half wave rectifier, assume that the theoretical op amp and diodes have no forward voltage.

For positive input voltages, the output tries to go negative. This turns D2 on and D1 off. Assuming a short for D2, this holds the output at ground potential, since the action of the op amp forces the input voltages of the op amp to the same level.

For negative input voltages, the output goes positive, D1 turns on, and D2 turns off. The output is then an inverting amplifier (see MT-213) with gain set by $R2/R1$. The result is an output that follows the negative half cycle of the input (inverted) with an output of 0 V for the positive half cycle.

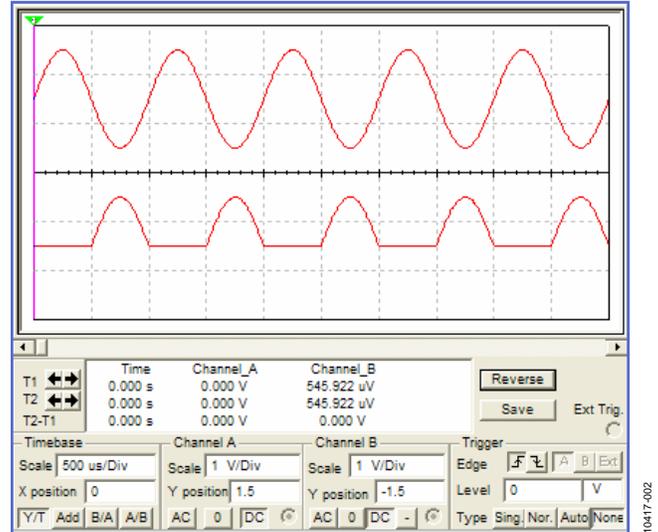


Figure 2. Half Wave Rectifier Waveforms

Figure 2 shows the waveforms of the half wave rectifier. The top trace is the input and the bottom trace is the output.

In Figure 3, the output of the op amp is shown. Note that in a practical circuit the output of the op amp is actually running open loop until the forward voltage of D2 is reached. This is shown in the bottom trace (Channel C).

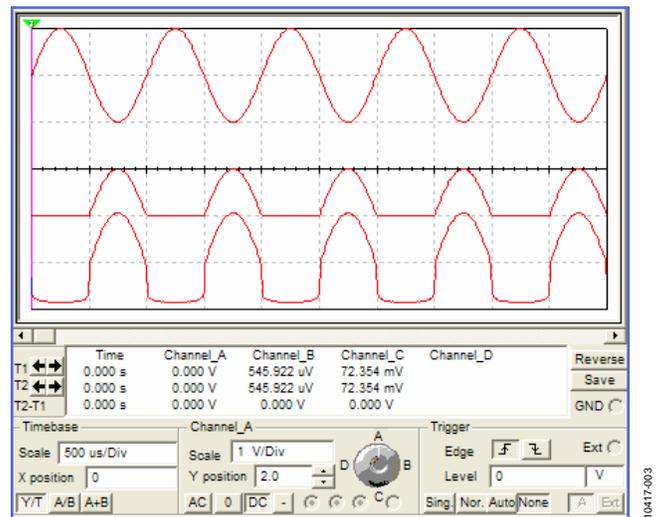


Figure 3. Half Wave Rectifier Waveforms with Op Amp Output

A filter to develop the dc level often follows the output of the half wave rectifier. The corner frequency of the filter should be set low enough to limit the ac ripple on the output, but high enough not to seriously impact the transient response speed of the circuit. The output spectrum of the output is shown in Figure 4.

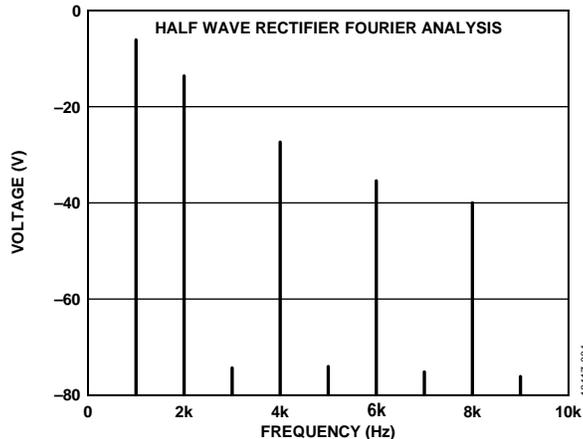


Figure 4. Half Wave Rectifier Output Spectrum

The polarity of the output can be change to a negative going by reversing both of the diodes.

Error terms are the same as for the inverting amplifier (see [MT-213](#)). Most significant is the offset term. The frequency response of the circuit is set primarily by the open-loop gain of the op amp. The shunt capacitance of the diodes and the diode turn-on/ turn-off time can also affect the frequency response, but the affect is much less than that of the op amp.

One limitation of the half wave rectifier is that it only operates on one-half cycle of the input. For inputs symmetric around the center line, such as a sine wave, this is not necessarily a real problem. An improvement to the circuit to counteract this limitation is the full wave rectifier. (see [MT-211](#)).

For operation with a single power supply voltage, the non-inverting input is biased to a reference voltage, typically at $\frac{1}{2}$ the supply voltage. The zero input signal output is then at the reference voltage.

REVISION HISTORY

4/12—Revision 0: Initial Version

Figure 5 shows a single supply half wave rectifier with a reference voltage (the voltage at the noninverting input to the op amp) at +4 V. On the display ground is at the bottom.

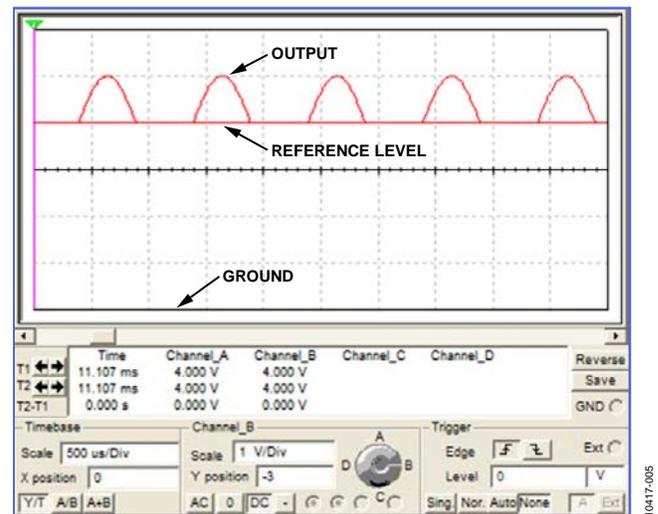


Figure 5. Single Supply Half Wave Rectifier Waveforms

The input is still ground referenced, so the input must be ac coupled using a series capacitor. The low end of the frequency is determined by the RC time constant set by the input coupling capacitor and the input resistor R1. With bipolar supplies the circuit response is to dc. Alternatively, if the preceding circuit is referenced to the same reference voltage the input may be dc coupled. Care should be taken if gain is taken in the circuit. The frequency response requirements on the op amp are determined by the maximum signal input frequency. There must be enough open-loop gain for the diodes to be biased. Thus, one can apply the rule of thumb that the bandwidth of the op amp should be at least 20 dB at the maximum frequency of the input signal.