Splitting Up

Building a Full-Wave rectifier circuit with a single-supply Op Amp. By Stuart Smith, Principal Member of Technical Staff, and Bich Pham, Senior Member of Technical Staff, Maxim Integrated

When working with single-supply op amps, it can be quite a challenge to implement simple functions in a bipolar signal environment. Oftentimes additional op amps and/or other electronic components are required. Now there is an alternative, thanks to a device with a unique built-in charge pump that permits split-rail performance with only a single supply.

When the input swings negative, X1 is cut off by diode D1, and the OP1 node is again at half the input voltage due to the resistive division, R1 + R2 to R3. Amplifier X2 then provides a further gain of -2V/V to correct the earlier 50% attenuation.

The circuit of Figure 1 uses the MAX44267 single-supply, dual op amp with a true-zero output to implement a full-wave rectifier with only a single supply rail. This circuit has been around for quite a long time.

Figure 1: This circuit implements a full-wave rectifier using single-supply op amps.

Figure 2: VIN (yellow trace) with 1Vp-p at 1kHz; VOUT is the blue trace.
time. It requires a negative supply so the X1 amplifier can output a negative voltage of -0.5 times the input voltage. Note that when the input is positive, X1 has a gain of -0.5V/V plus a diode drop so that the OP1 node is exactly -0.5x the input.

R1, R2, and R3 are standard values, while R4 is easily implemented with two 120kΩ resistors in parallel. The ratios of all four resistors are important: R2 = 0.5 \times R1; R4 = 2 \times R3; and R1 + R2 + R3 = R4. Diode D1 can be any low-leakage signal diode such as 1N914. Capacitor C1 helps to reduce the MAX44267’s charge-pump noise.

At low frequency the output is almost error free. At the output’s zero crossings in Figure 2, there is barely 8mV of

Figure 3: \( V_{IN} = 200\text{mV}_{P-P} \) and at 200Hz (yellow trace); \( V_{OUT} \) has 2mV distortion (blue trace).

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Figure 4: \( V_{IN} = 200\text{mV}_{P-P} \) and at 1kHz (yellow trace); \( V_{OUT} \) has 8mV distortion (blue trace).

Figure 5: \( V_{IN} = 200\text{mV}_{P-P} \) and at 10kHz (yellow trace); \( V_{OUT} \) has 20mV distortion (blue trace).

Figure 6: \( V_{IN} = 4\text{V}_{P-P} \) and at 200Hz (yellow trace); \( V_{OUT} \) has 12mV distortion (blue trace).

As the frequency increases larger distortions start to appear at the output. Figures 3, 4 and 5 are scope shots showing a variety of input amplitudes and frequencies; they show a 200mV\(_{P-P}\) input signal at 200Hz, 1kHz, and 10kHz, respectively. These traces illustrate the frequency limitation of this circuit topology. Specifically, op amp X1 takes a finite time to recover from being open loop and having to slew at its maximum rate to catch up with the input.

So far, only small signals have been shown, but this topology also handles larger signal amplitudes. Note that while the waveforms look much better, the trace scaling hides the errors that were visible on the low-amplitude signals. Figures 6, 7 and 8 show a 4V\(_{P-P}\) input signal at 200Hz, 1kHz, and 10kHz, respectively.
Full-wave rectification of a bipolar input signal usually requires circuitry running from split supplies. The solution shown here runs from a single supply, as found in most systems. Within the limitations of the amplifier’s bandwidth, slew rate, and settling performance, a wide range of signal amplitudes and frequencies can be rectified with little error. The simple ratios for the four resistor values allow trim-free assembly, while the chopper-stabilised amplifier keeps both offset and drift to negligible levels.

Figure 7: $V_{IN} = 4V_{P-P}$ and at 1kHz (yellow trace); $V_{OUT}$ has 24mV distortion (blue trace).

Figure 8: $V_{IN} = 4V_{P-P}$ and at 10kHz (yellow trace); $V_{OUT}$ has 113mV distortion (blue trace).

Figure 9: Starting with the standard MAX442467 evaluation (EV) kit, it did not take a magician to build this circuit.

About the Authors

Stuart Smith joined Maxim Integrated in 2011 as a Product Definer. He has worked for over 30 years as an analog and mixed-signal IC design engineer and has received eight patents during that time. Stuart has a BSC EE from Abertay University and is a Chartered Engineer.

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