Analog Engineer's Circuit

Single-Supply, Low-Input Voltage, Full-Wave Rectifier Circuit

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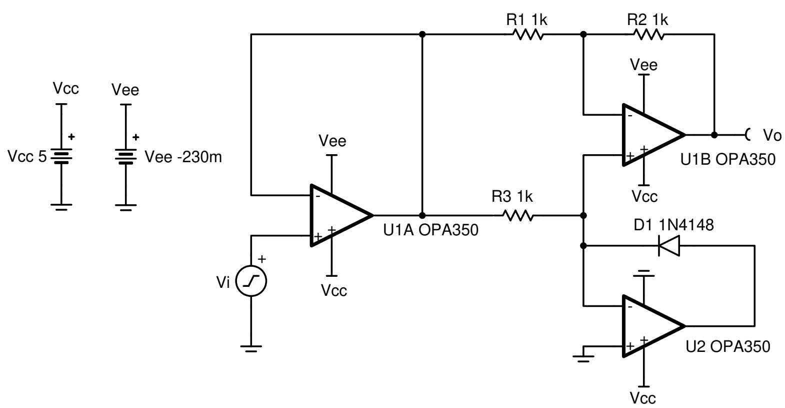
Design Goals

Input		Output		Supply		
V_{iMin}	V_{iMax}	V_{oMin}	V_{oMax}	V_{cc}	V_{ee}	V_{ref}
5mVpp	400mVpp	2.5mVpp	200mVpp	5V	–0.23V	0V

Design Description

This single-supply precision absolute value circuit is optimized for low-input voltages. It is designed to function up to 50kHz and has excellent linearity at signal levels as low as 5mVpp. The design uses a negative charge pump (such as LM7705) on the negative op amp supply rails to maintain linearity with signal levels near 0V.

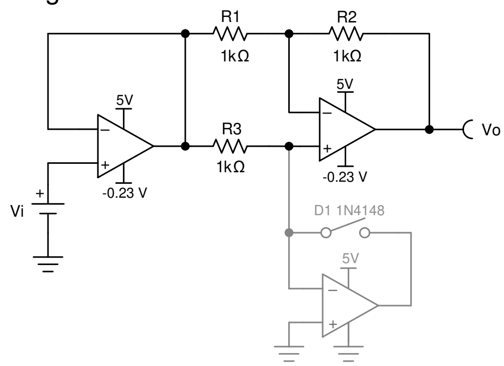


Design Notes

1. Observe common-mode and output swing limitations of op amps.
2. R_3 should be sized small enough that the leakage current from D_1 does not cause errors in positive input cycles while verifying the op amp can drive the load.
3. Use a fast switching diode for D_1.
4. Removing the input buffer allows for input signals with peak-to-peak values twice as large as the supply voltage at the expense of lower input impedance and slight gain error.
5. Use precision resistors to minimize gain error.

Design Steps

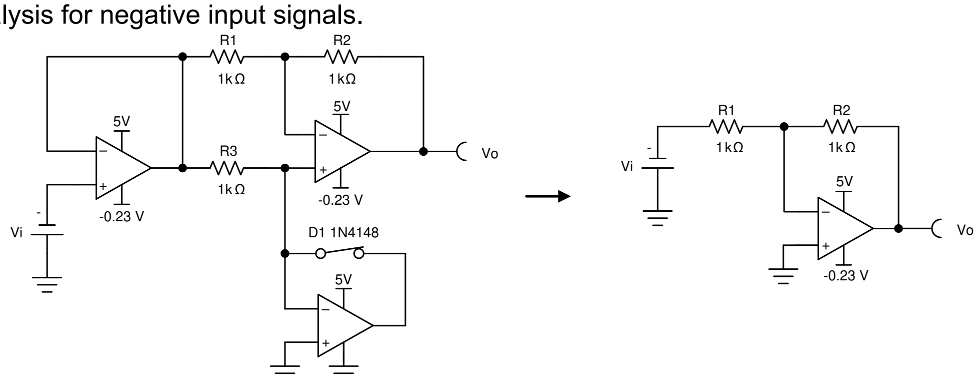
1. Circuit analysis for positive input signals.



$$\frac{V_o}{V_i} = \left(-\frac{R_2}{R_1}\right) + \left(1 + \frac{R_2}{R_1}\right) = 1$$

$$V_o = V_i$$

2. Circuit analysis for negative input signals.



$$\frac{V_o}{V_i} = \left(-\frac{R_2}{R_1}\right) = -1$$

$$V_o = -V_i$$

3. Select R_1, R_2, and R_3.

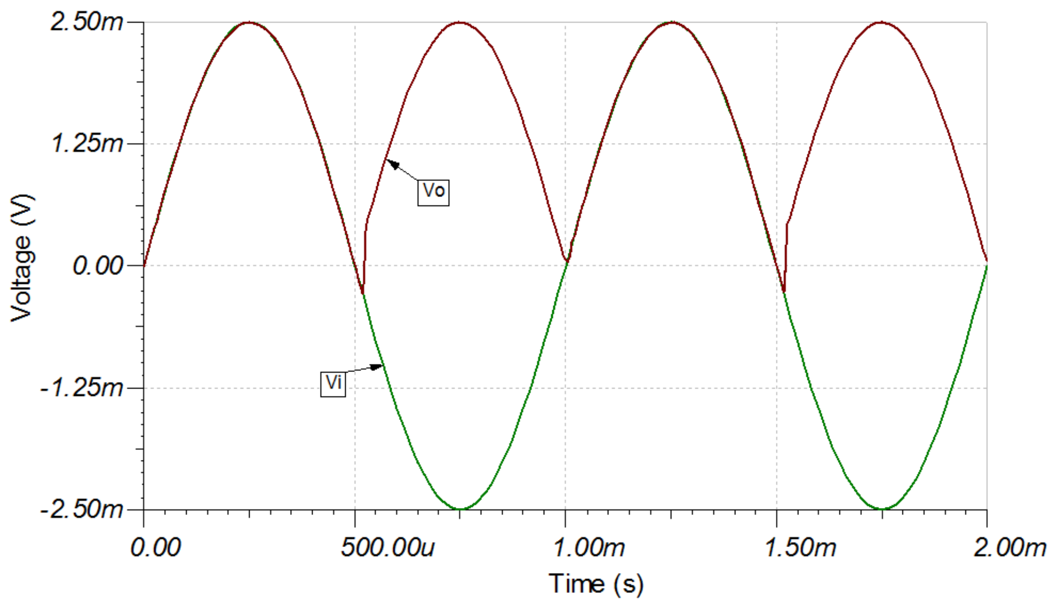
$$\frac{V_o}{V_i} = -\frac{R_2}{R_1}$$

$$\text{If } R_2 = R_1 \quad \text{then } V_o = -V_i$$

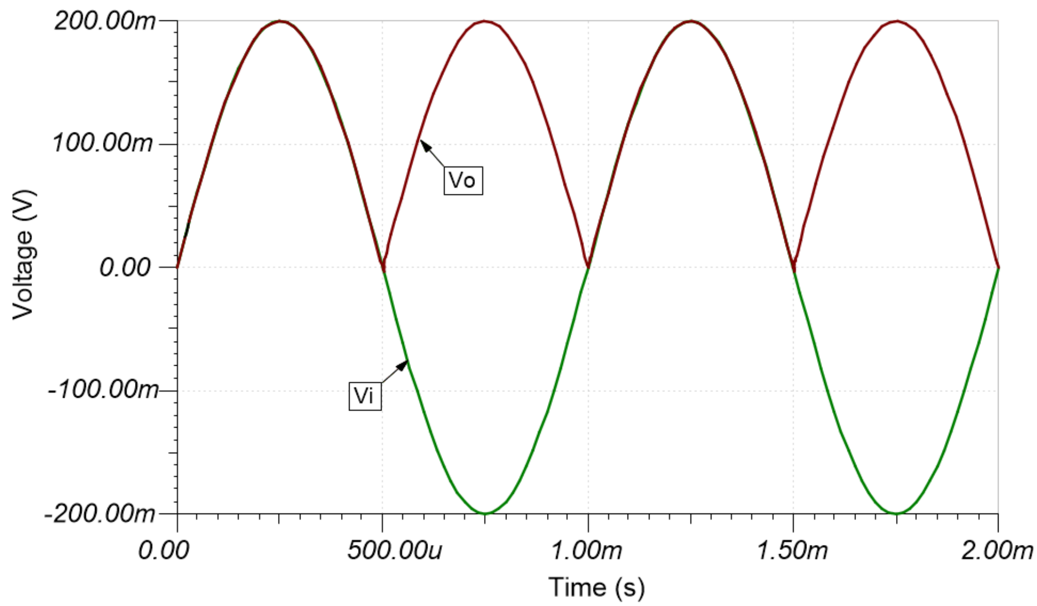
$$\text{Set } R_1 = R_2 = R_3 = 1 \quad k\Omega$$

Design Simulations

Transient Simulation Results



5mVpp at 1kHz Input



400mVpp at 1kHz Input

Design References

Texas Instruments, *Simulation for Single-Supply, Low-Input Voltage Full-Wave Rectifier*, circuit SPICE simulation file

Texas Instruments, *Single-Supply Low-Input Voltage Optimized Precision Full-Wave Rectifier*, reference design

Design Featured Op Amp

OPA350	
V_{ss}	2.7V to 5.5V
V_{inCM}	Rail-to-rail
V_{out}	Rail-to-rail
V_{os}	150µV
I_q	5.2mA/Ch
I_b	0.5pA
UGBW	38MHz
SR	22V/µs
#Channels	1, 2, and 4
OPA350	

Design Alternate Op Amp

OPA353	
V_{ss}	2.7V to 5.5V
V_{inCM}	Rail-to-rail
V_{out}	Rail-to-rail
V_{os}	3mV
I_q	5.2mA
I_b	0.5pA
UGBW	44MHz
SR	22V/µs
#Channels	1, 2, and 4
OPA353	

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Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision A (February 2019) to Revision B (October 2024) **Page**

- Updated the format for tables, figures, and cross-references throughout the document 1

Changes from Revision * (February 2018) to Revision A (February 2019) **Page**

- Downscale the title and changed title role to *Amplifiers*. Added links to circuit cookbook landing page and SPICE simulation file. Updated the formatting of the document..1

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