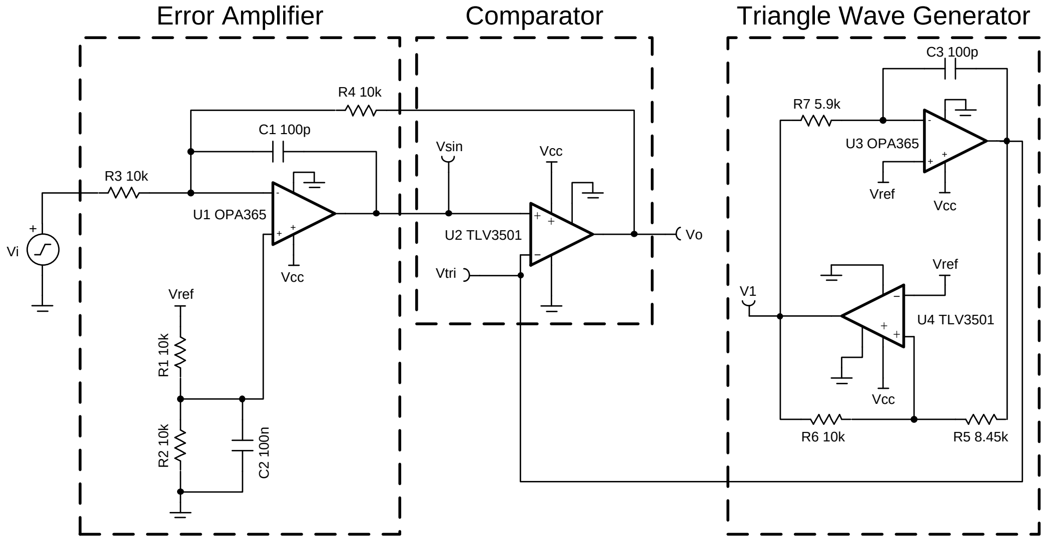
PWM generator circuit

Design Goals

Input		Output		Supply		
V_{iMin}	V_{iMax}	V_{oMin}	V_{oMax}	V_{cc}	V_{ee}	V_{ref}
–2.0V	2.0V	0V	5V	5V	0V	2.5V

Design Description

This circuit utilizes a triangle wave generator and comparator to generate a 500 kHz pulse-width-modulated (PWM) waveform with a duty cycle that is inversely proportional to the input voltage. An op amp and comparator (U_3 and U_4) generate a triangle waveform which is applied to the inverting input of a second comparator (U_2). The input voltage is applied to the non-inverting input of U_2. By comparing the input waveform to the triangle wave, a PWM waveform is produced. U_2 is placed in the feedback loop of an error amplifier (U_1) to improve the accuracy and linearity of the output waveform.



Design Notes

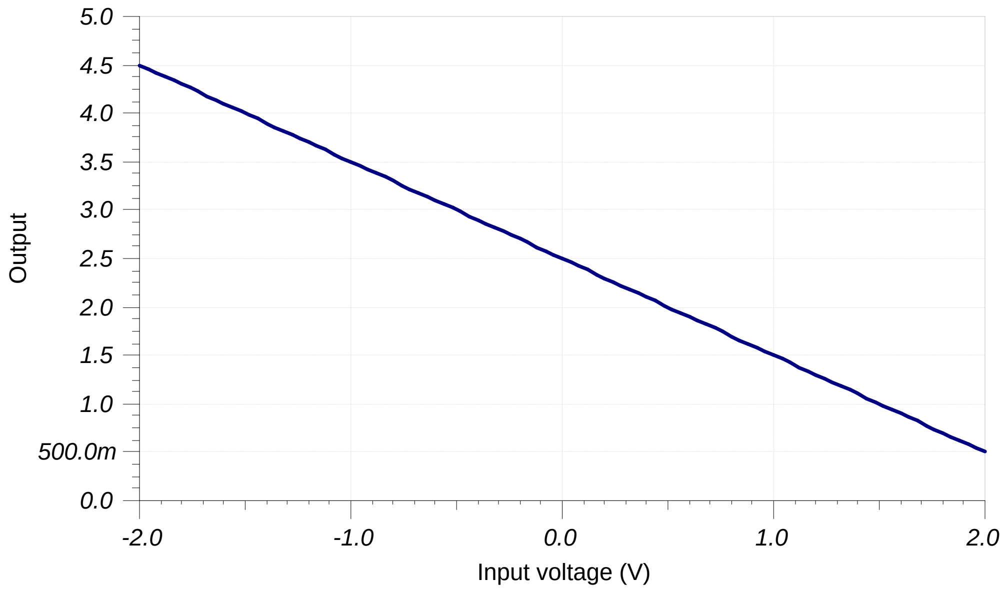
1. Use a comparator with push-pull output and minimal propagation delay.
2. Use an op amp with sufficient slew rate, GBW, and voltage output swing.
3. Place the pole created by C_1 below the switching frequency and well above the audio range.
4. V_{ref} must be low impedance (for example, output of an op amp).

Design Steps

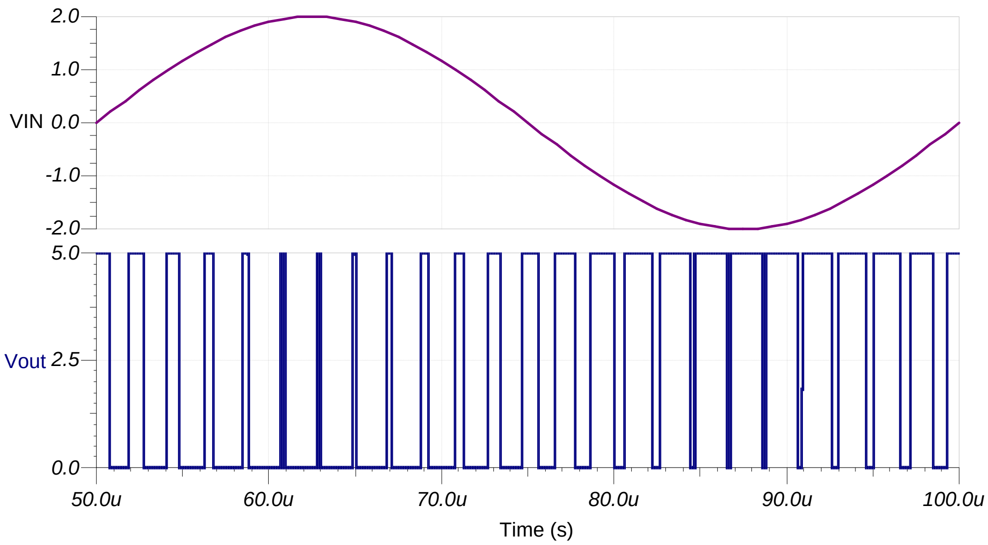
1. Set the error amplifier inverting signal gain.
   $$\text{Gain} = -\frac{R_4}{R_3} = -1\frac{V}{V}$$
   $$\text{Select } R_3 = R_4 = 10k\Omega$$
2. Determine R_1 and R_2 to divide V_{ref} to cancel the non-inverting gain.
   $$V_{o\_dc} = \left(1 + \frac{R_4}{R_3}\right)\left(\frac{R_2}{R_1 + R_2}\right) \times Vref$$
   $$R_1 = R_2 = R_3 = R_4 = 10k\Omega,\ V_{o\_dc} = 2.5V$$
3. The amplitude of V_{tri} must be chosen such that it is greater than the maximum amplitude of V_i (2.0V) to avoid 0% or 100% duty cycle in the PWM output signal. Select V_{tri} to be 2.1V. The amplitude of V_1 = 2.5V.
   $$V_{tri}\ (\text{Amplitude}) = \frac{R_5}{R_6} \times V_1(\text{Amplitude})$$
   $$\text{Select } R_6 \text{ to be } 10k\Omega, \quad \text{then compute } R_5$$
   $$R_5 = \frac{V_{tri}(\text{Amplitude}) \times R_6}{V_1\ (\text{Amplitude})} = 8.4k\Omega \approx 8.45k\Omega\ (\text{Standard Value})$$
4. Set the oscillation frequency to 500kHz.
   $$f_t = \frac{R_6}{4 \times R_7 \times R_5 \times C_3}$$
   $$\text{Set } C_3 = 100pF, \text{ then compute } R_7$$
   $$R_7 = \frac{R_6}{4 \times f_t \times R_5 \times C_3} = 5.92k\Omega \approx 5.90k\Omega\ (\text{Standard Value})$$
5. Choose C_1 to limit amplifier bandwidth to below switching frequency.
   $$f_p = \frac{1}{2 \times \pi \times R_4 \times C_1}$$
   $$C_1 = 100pF \rightarrow f_p = 159kHz$$
6. Select C_2 to filter noise from V_{ref}.
   $$C_2 = 100nF\ (\text{Standard Value})$$
   $$f_{div} = \frac{1}{2 \times \pi \times C_2 \times \frac{R_1 \times R_2}{R_1 + R_2}} = 320Hz$$

Design Simulations

DC Simulation Results



Transient Simulation Results



Design References

See *Analog Engineer's Circuit Cookbooks* for TI's comprehensive circuit library.

See circuit SPICE simulation file SBOC502.

See TIPD108, www.ti.com/tool/tipd108

Design Featured Op Amp

OPA2365	
V_{ss}	2.2V to 5.5V
V_{inCM}	Rail-to-rail
V_{out}	Rail-to-rail
V_{os}	100µV
I_q	4.6mA
I_b	2pA
UGBW	50MHz
SR	25V/µs
#Channels	2
www.ti.com/product/opa2365	

Design Comparator

TLV3502	
V_{ss}	2.2V to 5.5V
V_{inCM}	Rail-to-rail
V_{out}	Rail-to-rail
V_{os}	1mV
I_q	3.2mA
I_b	2pA
UGBW	-
SR	-
#Channels	2
www.ti.com/product/tlv3502	

Design Alternate Op Amp

OPA2353	
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	2
www.ti.com/product/opa2353	

Revision History

Revision	Date	Change
A	January 2019	Downscale the title and changed title role to 'Amplifiers'. Added link to circuit cookbook landing page.