PWM Generator Circuit

TEXAS INSTRUMENTS

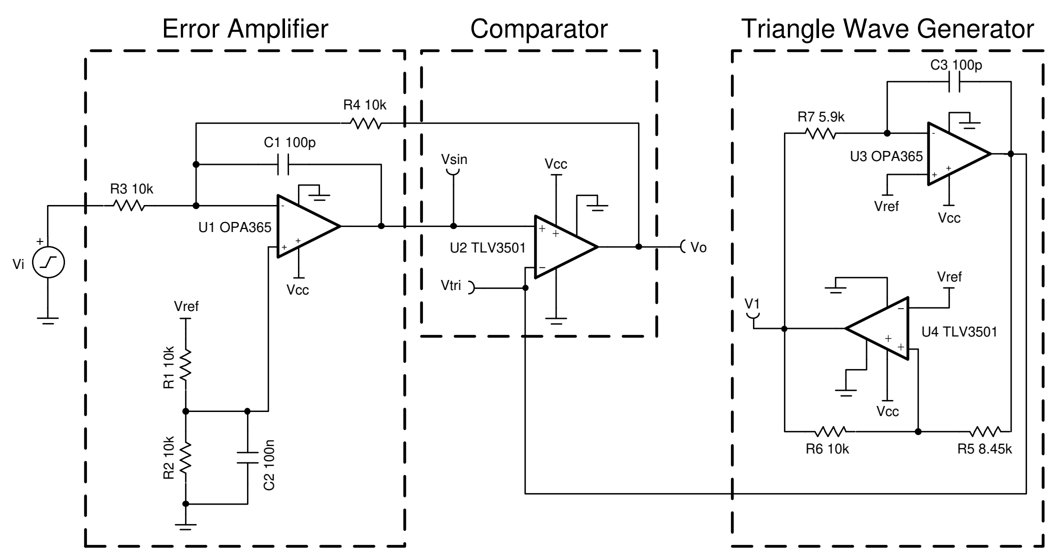
Masashi Miyagawa

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 500kHz 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.

$$\text{Gain} = -\frac{R_4}{R_3} = -1\frac{V}{V}$$

$$\text{Select } R_3 = R_4 = 10\text{k}\Omega$$

2. Determine R_1 and R_2 to divide V_{ref} to cancel the non-inverting gain.

$$V_{o\_dc} = \left(1 + \frac{R_4}{R_3}\right)\left(\frac{R_2}{R_1 + R_2}\right) \times \text{Vref}$$

$$R_1 = R_2 = R_3 = R_4 = 10\text{k}\Omega, V_{o\_dc} = 2.5\text{V}$$

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.

$$V_{tri}\ (\text{Amplitude}) = \frac{R_5}{R_6} \times V_1\left(\text{Amplitude}\right)$$

$$\text{Select } R_6 \text{ to be } 10\text{k}\Omega, \quad \text{then compute } R_5$$

$$R_5 = \frac{V_{tri}(\text{Amplitude}) \times R_6}{V_1\ \ (\text{Amplitude})} = 8.4\text{k}\Omega \approx 8.45\text{k}\Omega\ (\text{Standard Value})$$

4. Set the oscillation frequency to 500kHz.

$$f_t = \frac{R_6}{4 \times R_7 \times R_5 \times C_3}$$

$$\text{Set } C_3 = 100\text{pF}, \text{ then compute } R_7$$

$$R_7 = \frac{R_6}{4 \times f_t \times R_5 \times C_3} = 5.92\text{k}\Omega \approx 5.90\text{k}\Omega\ (\text{Standard Value})$$

5. Choose C_1 to limit amplifier bandwidth to below switching frequency.

$$f_p = \frac{1}{2 \times \pi \times R_4 \times C_1}$$

$$C_1 = 100\text{pF} \rightarrow f_p = 159\text{kHz}$$

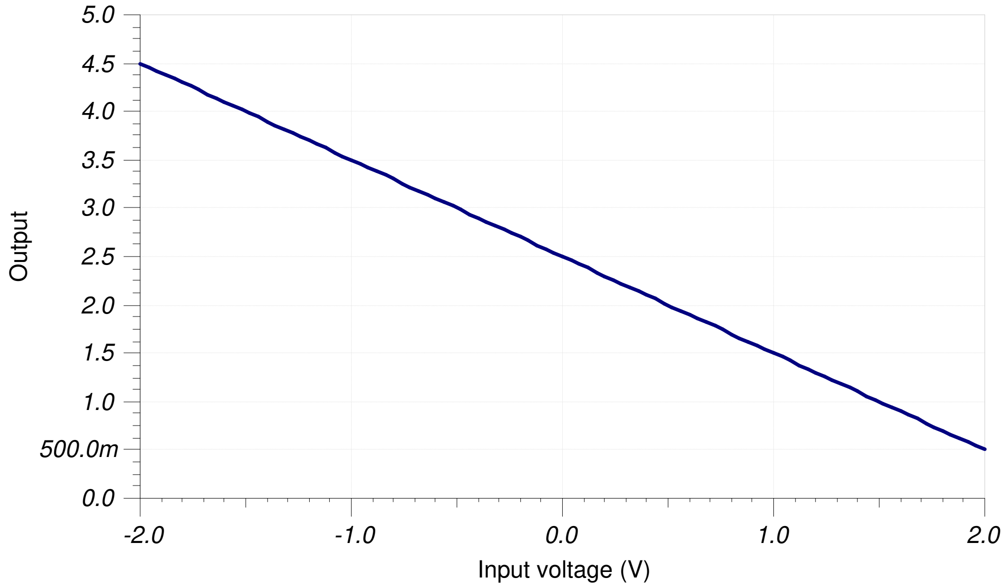
6. Select C_2 to filter noise from V_{ref}.

$$C_2 = 100\text{nF}\ (\text{Standard Value})$$

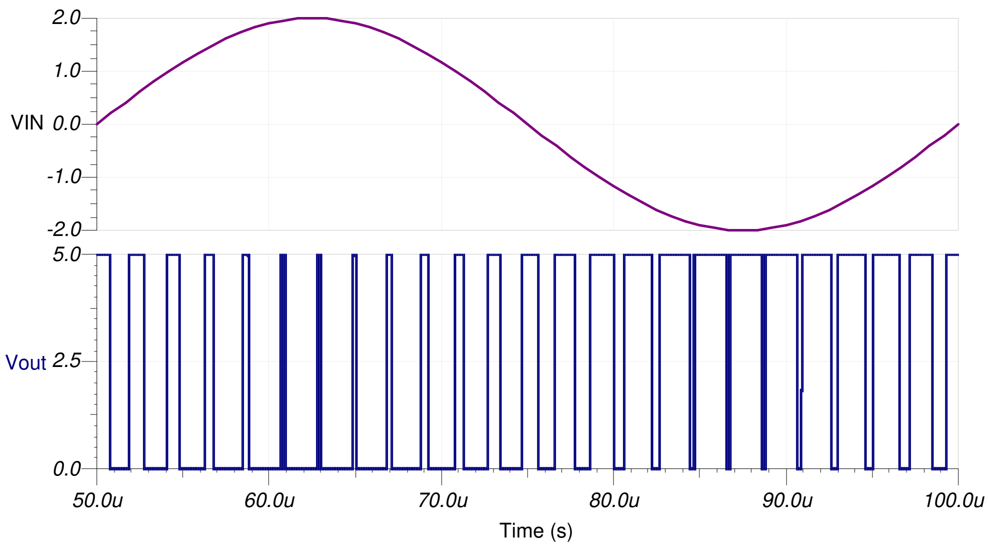
$$f_{div} = \frac{1}{2 \times \pi \times C_2 \times \frac{R_1 \times R_2}{R_1 + R_2}} = 320\text{Hz}$$

Design Simulations

DC Simulation Results



Transient Simulation Results



Design References

Texas Instruments, Simulation for PWM Generator Circuit, circuit SPICE simulation file

Texas Instruments, Analog PWM Generator 5V, 500kHz PWM Output, reference design

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
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
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
OPA2352	

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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 * (January 2018) to Revision A (February 2019)	Page
• Downscale the title and changed title role to 'Amplifiers'. Added link to circuit cookbook landing page	1

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265