

# Analog Engineer's Circuit

## Relaxation Oscillator Circuit

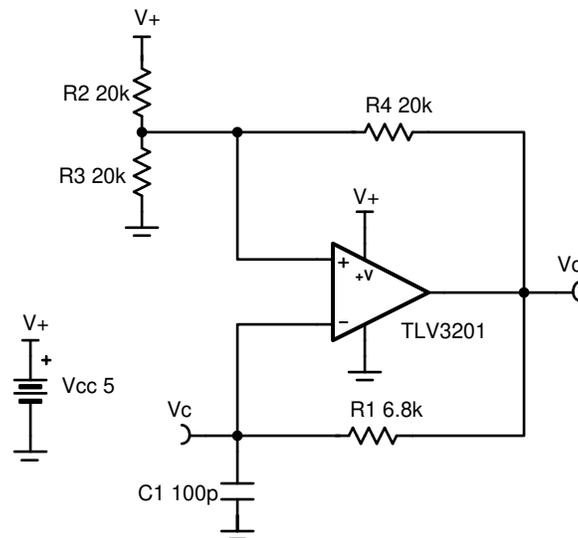


### Design Goals

Supply		Oscillator Frequency
$V_{cc}$	$V_{ee}$	f
5 V	0 V	1 MHz

### Design Description

The oscillator circuit generates a square wave at a selected frequency. This is done by charging and discharging the capacitor,  $C_1$  through the resistor,  $R_1$ . The oscillation frequency is determined by the RC time constant of  $R_1$  and  $C_1$ , and the threshold levels set by the resistor network of  $R_2$ ,  $R_3$ , and  $R_4$ . The maximum frequency of the oscillator is limited by the toggle rate of the comparator and the capacitance load at the output. This oscillator circuit is commonly used as a time reference or a supervisor clock source.



### Design Notes

1. Comparator toggle rate and output capacitance are critical considerations when designing a high-speed oscillator.
2. Select  $C_1$  to be large enough to minimize the errors caused by stray capacitance.
3. If using a ceramic capacitor, select a COG or NPO type for best stability over temperature.
4. Select lower value resistors for the  $R_2$ ,  $R_3$ ,  $R_4$  resistor network to minimize the effects of stray capacitance.
5.  $R_2$ ,  $R_3$ , and  $R_4$  can be adjusted in order to create a duty cycle other than 50%.

## Design Steps

- When  $R_2 = R_3 = R_4$ , the resistor network sets the oscillator trip points of the non-inverting input at one-third and two-thirds of the supply.
- When the output is high, the upper trip point will be set at two-thirds of the supply to bring the output back low.

$$V_o = V_s \left( \frac{R_3}{(R_2 \parallel R_4) + R_3} \right) = \frac{2}{3} V_s = 3.33V$$

- When the output is low, the lower trip point will be set at one-third of the supply in order to bring the output back high.

$$V_o = V_s \left( \frac{R_3 \parallel R_4}{(R_3 \parallel R_4) + R_2} \right) = \frac{1}{3} V_s = 1.67V$$

- The timing of the oscillation is controlled by the charging and discharging rate of the capacitor  $C_1$  through the resistor  $R_1$ . This capacitor sets the voltage of the inverting input of the comparator. Calculate the time to discharge the capacitor.

$$V_c = V_i e^{-\frac{t}{R_1 C_1}}$$

$$\frac{1.67}{3.33} = e^{-\frac{t}{R_1 C_1}}$$

$$t = 0.69 R_1 C_1$$

- Calculate the time to charge the capacitor.

$$V_i = V_c \left( 1 - e^{-\frac{t}{RC}} \right)$$

$$1.67 = 3.33 \left( 1 - e^{-\frac{t}{RC}} \right)$$

$$\frac{1.67}{3.33} = e^{-\frac{t}{RC}}$$

$$t = 0.69 R_1 C_1$$

- The time for the capacitor to charge or discharge is given by  $0.69 R_1 C_1$ . With a target oscillator frequency of 1 MHz, the time to charge or discharge should be 500 ns.

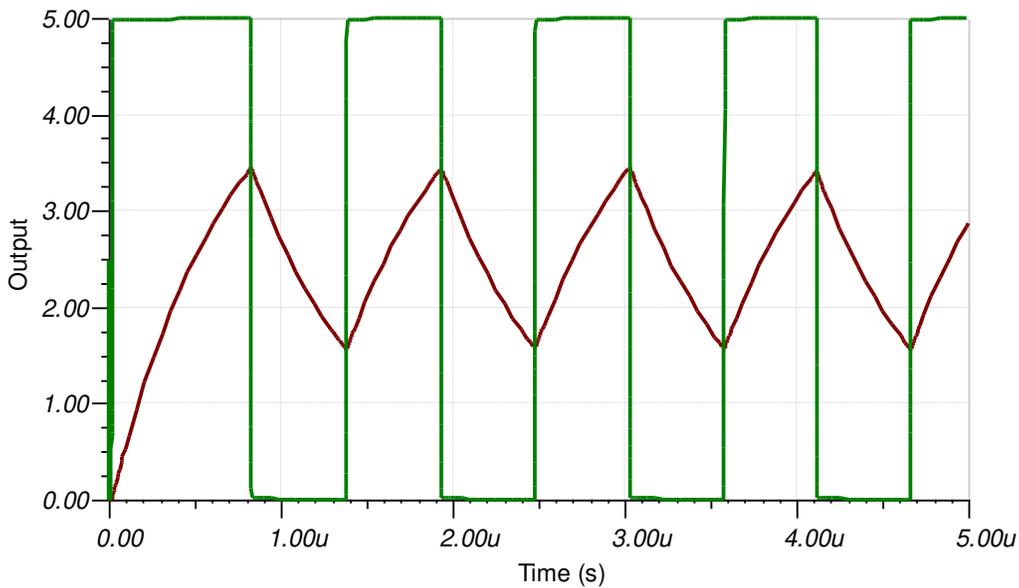
$$0.69 R_1 C_1 = 500 \text{ ns}$$

$$R_1 C_1 = 724 \text{ ns}$$

- Select  $C_1$  as 100 pF and  $R_1$  as 6.8 k $\Omega$  (the closest real world value).

## Design Simulations

### Transient Simulation Results



### Design References

See [Analog Engineer's Circuit Cookbooks](#) for TI's comprehensive circuit library.

See circuit spice simulation file, [SBOMAO3](#).

For more information on many comparator topics including hysteresis, propagation delay and input common mode range please see, [TI Precision Labs](#).

### Design Featured Comparator

TLV3201	
$V_{SS}$	2.7 V to 5.5 V
$V_{inCM}$	Rail-to-rail
$t_{pd}$	40 ns
$V_{os}$	1 mV
$V_{HYS}$	1.2 mV
$I_q$	40 $\mu$ A
Output Type	Push-Pull
#Channels	1
<a href="#">TLV3201</a>	

## Design Alternate Comparator

TLV7011	
$V_{SS}$	1.6 V to 5.5 V
$V_{inCM}$	Rail-to-rail
$t_{pd}$	260 ns
$V_{os}$	0.5 V
$V_{HYS}$	4 mV
$I_q$	5 $\mu$ A
<b>Output Type</b>	Push-Pull
<b>#Channels</b>	1
<a href="#">TLV7011</a>	

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