Frequency-to-Voltage Conversion Circuit Using a 555 Timer

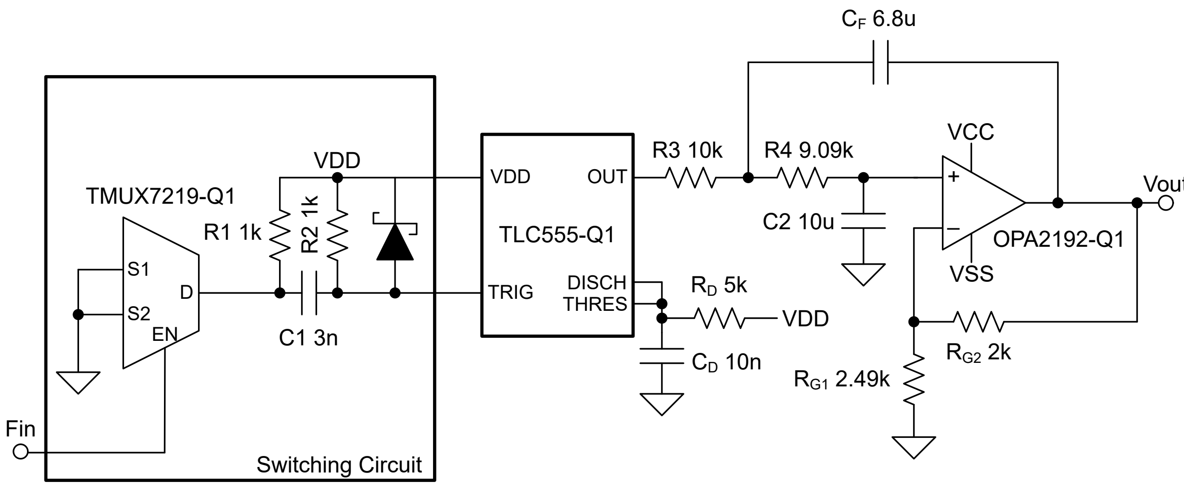
Amplifiers

Design Goals

Input		Output		Supply		
F_{Min}	F_{Max}	V_{oMin}	V_{oMax}	V_{DD}	V_{CC}	V_{SS}
0 Hz	10 kHz	0 V	5 V	5 V	5 V	0 V

Design Description

This circuit consists of a 555 timer configured to convert an input frequency to a respective output voltage. This can be easily applied to any application that requires the sensing of an input waveform, especially for revolutions per minute (rpm) measuring in automotive applications. V_{DD} can range from 5 to 15 V, while V_{CC} and V_{SS} can range up to ±18 V.



Design Notes

1. The switching circuit creates a short low trigger spike for every rising edge of the input waveform. This allows for a range of input duty cycles (10% to 90%) to be used.
2. The TLC555-Q1 creates a precise pulse-width modulation (PWM) output when the device is triggered, allowing for high accuracy conversion.
3. The OPA2192-Q1 is used to create a Butterworth Sallen-Key filter to integrate and scale the PWM output of the TLC555-Q1 into a respective DC voltage.
4. All resistors, outside of the switching circuit, are of 0.1% tolerance. The discharge capacitor of the TLC555-Q1, C_D (is of 1% tolerance).
5. This design uses recommended values for decoupling capacitors on the supplies for each of the TI components to reduce external sources of error.

Design Steps

1. Select a preliminary smaller gain value for the OPA2192-Q1 that has easily available resistor values (this design used a gain of 1.8 V/V).

$$G_{CL} = \frac{R_{G2}}{R_{G1}} + 1$$

$$G_{CL} = 1.8 \quad R_{G1} = 2.49\ k\Omega \quad R_{G2} = 2\ k\Omega$$

2. Calculate the product of the discharge resistor, R_D, and capacitor C_D of the TLC555-Q1.

$$V_{oMax} = G_{CL} \times V_{DD} \times 1.1 \times R_D \times C_D \times F_{max}$$

$$5\ V = 1.8 \times 5\ V \times 1.1 \times R_D \times C_D \times 10\ kHz$$

$$5 \times 10^{-5} \approx R_D \times C_D$$

3. Choose an available standard value for the discharge capacitor, C_D, of the TLC555-Q1 and calculate the respective discharge resistor R_D.

$$C_D = 10\ nF$$

$$R_D = \frac{5 \times 10^{-5}}{C_D}$$

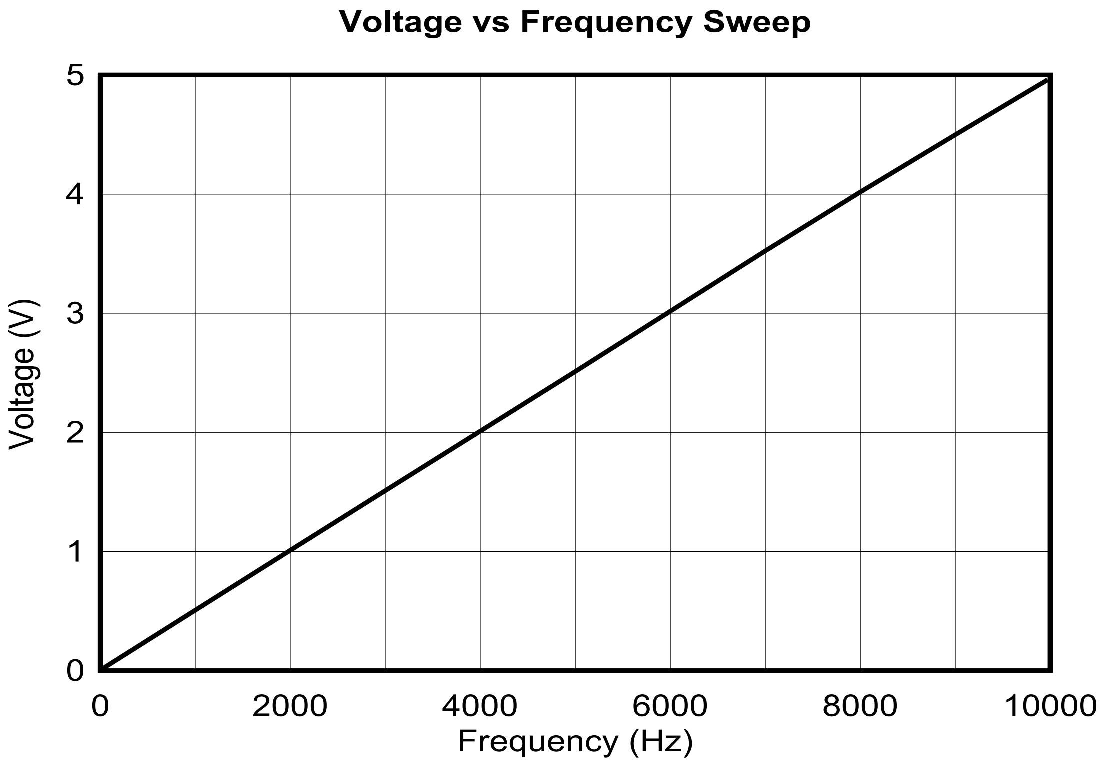
$$R_D = \frac{5 \times 10^{-5}}{10\ nF}$$

$$R_D = 5\ k\Omega$$

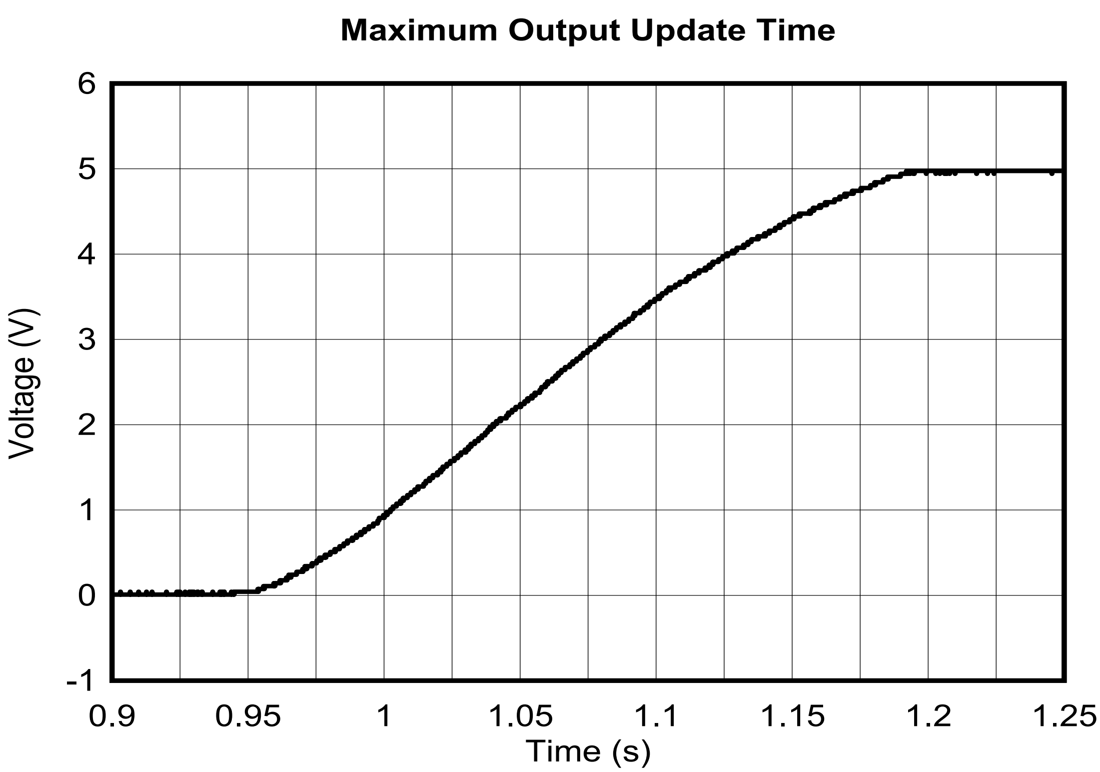
4. Select the closest standard value for the discharge resistor, R_D, or modify the selected capacitor, if necessary.
5. The values for R3, R4, C_F, and C2 for the Butterworth Sallen-Key filter can be calculated using the Texas Instruments Filter Design Tool or done using a manual method. Less noise and ripples are present on the output if a lower cutoff frequency is used, but the output is slower to update when the input frequency changes. This design uses a cutoff frequency of 2.86 Hz.

$$F_C = \frac{1}{2\pi \times \sqrt{R3 \times R4 \times C_F \times C2}}$$

Frequency Sweep Simulation Results



Maximum Output Update Simulation Results



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

See the circuit SPICE simulation file (SBOC605).

Table 1-1. Design Featured Op Amp

OPA2192-Q1	
V_{Supply}	±20 V, (40 V, single-supply)
V_{inCM}	Rail–to–rail
V_{OUT}	Rail–to–rail
V_{os}	5 µV
I_q	1 mA/Ch
I_b	±5 pA
UGBW	10 MHz
SR	20 V/µs
#Channels	1 and 2
OPA2192-Q1	

Table 1-2. Related Device Documentation

Document	Literature Number
OPA2192-Q1 product data sheet	SBOS850
TLC555-Q1 product data sheet	SLFS078
TMUX7219-Q1 product data sheet	SCDS438

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