

Analog Engineer's Circuit

Charge Amplifier Circuit



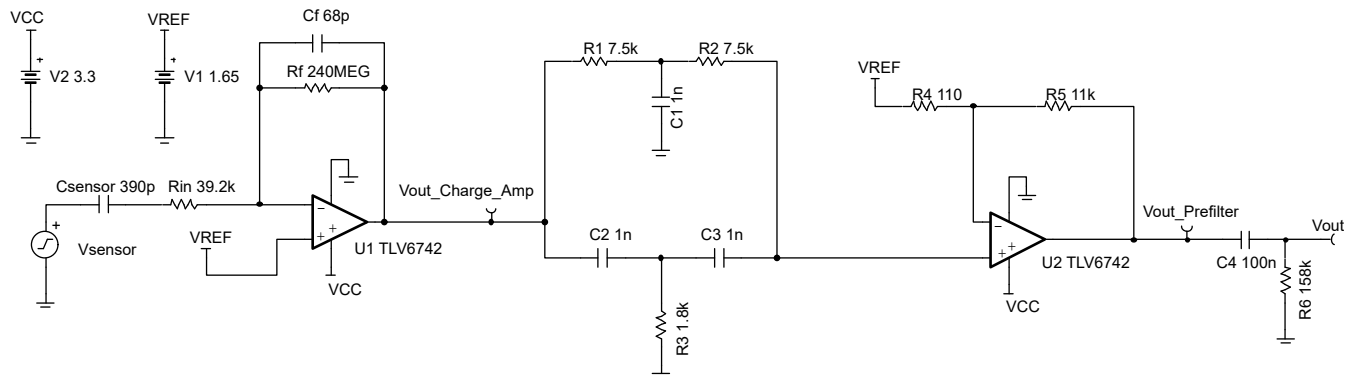
Amplifiers

Design Goals

Input		Output		Frequency		Supply		
V_{iMin}	V_{iMax}	V_{oMin}	V_{oMax}	f_{low}	f_{high}	V_{cc}	V_{ee}	V_{ref}
0V	1.3mV	-500mV	500mV	10Hz	10kHz	3.3V	0V	1.65V

Design Description

This design amplifies a 1.3-mV signal between the frequency band of 10Hz to 10kHz. The output of the charge amplifier signal is filtered from the resonance frequency of the sensor and amplified for the expected stable output of $\pm 500\text{mV}$ (1G shock). The common-mode voltage is half of the power supply, noted as VREF. The design implements a charge sensor amplifier intended to detect excessive force or shock, such as what occurs when an object is dropped or exposed to mechanical shock. The output of the detector can be acquired with an ADC and sampled by a controller to initiate the necessary protective steps.



Design Notes

1. Use the op amp in a linear operating region. Linear output swing is usually specified under the A_{OL} test conditions.
2. Select a high feedback resistor (R_f) to minimize noise impact. [Signal conditioning for piezoelectric sensors](#) may be referenced for further information.
3. Sensor sensitivity increases with higher capacitance and in turn increases the op amp voltage noise gain. This trade-off must be kept in mind when selecting a sensor. The [Murata PKGS-00GXP1-R sensor](#) has the following characteristics: 0.35 pC/G sensor sensitivity, 390-pF capacitance, 31-kHz resonance frequency.
4. An amplifier with low input voltage noise and low input current noise is preferred to minimize signal to noise ratio (SNR).
5. Low input bias current and high input impedance will minimize offset error and provide a suitable sensor interface. The output should swing from rail-to-rail to allow simple biasing and large output voltage swing with a low single supply voltage.

Design Steps

1. Select the highest value resistor for R_f to minimize noise impact:

$$R_f = 240 \text{ M}\Omega$$

2. Calculate C_f for low frequency cutoff (f_{low}) of 10Hz.

$$C_f = \frac{1}{2\pi R_f f_{low}} = \frac{1}{2\pi(240\text{M}\Omega)(10\text{Hz})} = 66.3\text{pF} \cong 68\text{pF} \quad (\text{Standard Value})$$

3. Calculate R_{in} for high frequency cutoff (f_{high}) of 10kHz with sensor capacitance.

$$R_{in} = \frac{1}{2\pi C_{sensor} f_{high}} = \frac{1}{2\pi(390\text{pF})(10\text{kHz})} = 40.8\text{k}\Omega \cong 39.2\text{k}\Omega \quad (\text{Standard Value})$$

4. Compute the expected output of the charge amplifier:

$$V_{out} = \frac{Q}{C_f} = \frac{0.35 \text{ pC/G}}{68\text{pF}} = 5.14\text{mV}$$

5. To avoid resonance from the sensor, which has a resonance frequency of 31kHz, place a [Twin-T Notch filter](#) with a stop band at 31kHz. For simplicity, assume all three capacitors are equal 1nF (C1, C2, C3).

$$R_1 = 7.5\text{k}\Omega, \quad R_2 = 7.5\text{k}\Omega, \quad R_3 = 1.8\text{k}\Omega$$

6. Use a second op amp in a noninverting configuration to scale V_{out} to $\pm 500\text{mV}$. Select $R_4=110\Omega$

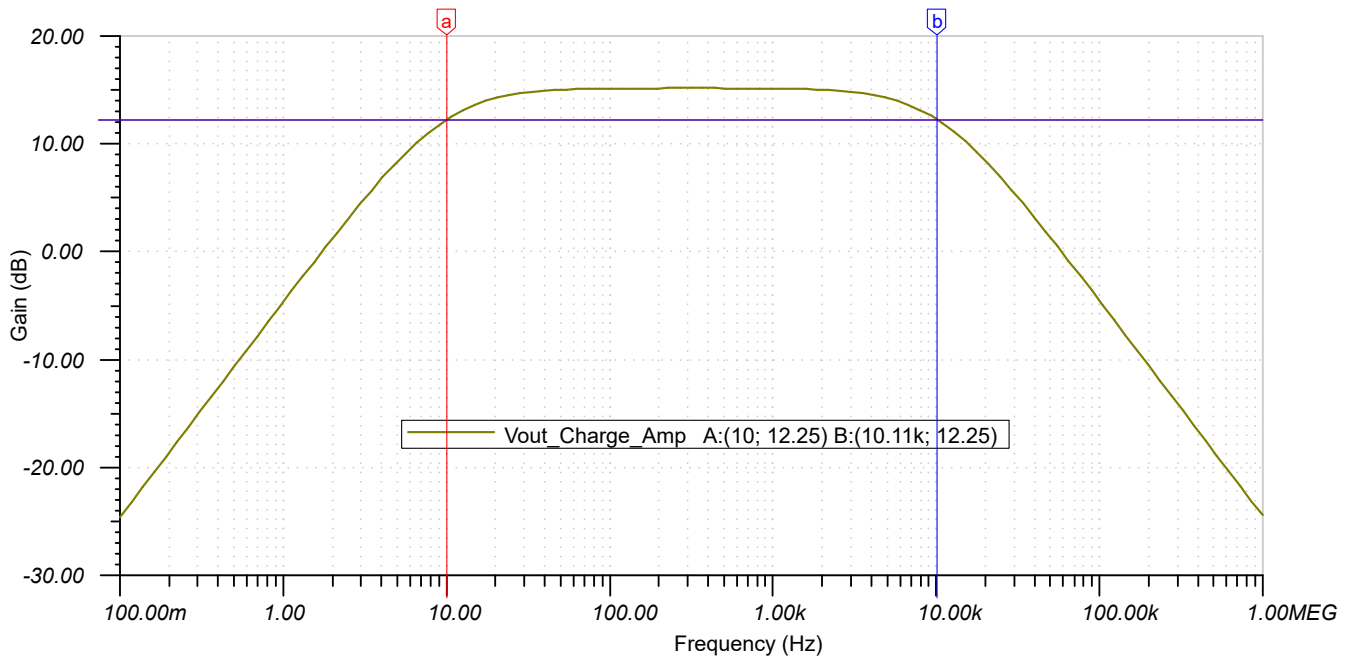
$$R_5 = \left(\frac{V_o}{V_i} - 1\right) \times R_4 = \left(\frac{500\text{mV}}{5.14\text{mV}} - 1\right) \times 110\Omega = 11\text{k}\Omega \quad (\text{Standard Value})$$

7. Add a high-pass filter on the output with a center frequency of 10 Hz, select a low capacitor value, $C_4 = 0.1\mu\text{F}$.

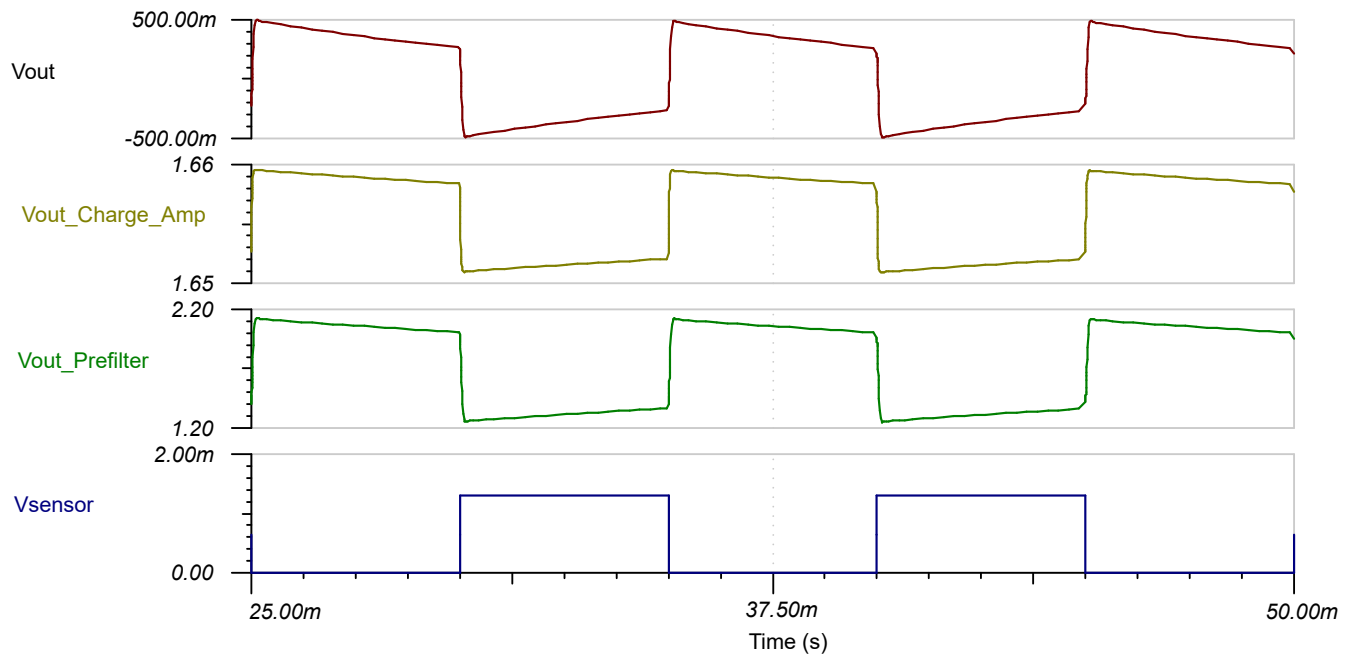
$$R_6 = \frac{1}{2\pi C_4 f_{low}} = \frac{1}{2\pi(0.1\mu\text{F})(10\text{Hz})} = 159.15\text{k}\Omega \cong 158\text{k}\Omega \quad (\text{Standard Value})$$

Design Results

AC Simulation Results



Transient Simulation Results



References:

1. [Analog Engineer's Circuit Cookbooks](#)
2. SPICE Simulation File [SBOMBX8](#)
3. [TI Precision Labs](#)

Design Featured Devices

TLV6742	
V_{SS}	1.7V to 5.5V
V_{inCM}	(V-) to (V+)-1.2V
V_{out}	Rail-to-rail
V_{os}	0.15mV
I_q	990 μ A
I_b	10pA
UGBW	10MHz
SR	4.5V/ μ s
#Channels	1, 2, and 4
TLV6742	

Design Alternative Devices

OPA392	
V_{SS}	1.7V to 5.5V
V_{inCM}	Rail-to-rail
V_{out}	Rail-to-rail
V_{os}	1 μ V
I_q	1.22mA
I_b	0.01pA
UGBW	13MHz
SR	4.5V/ μ s
#Channels	1, 2, and 4
OPA392	

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