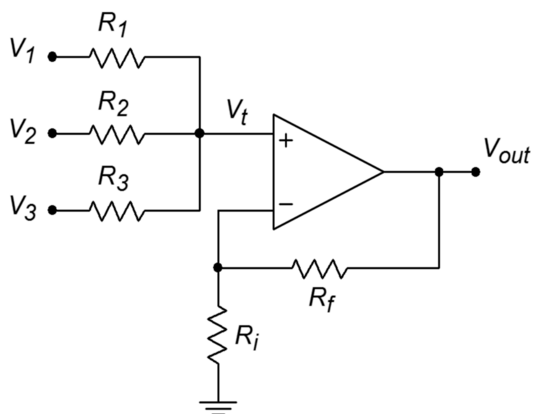
Example 4a

A noninverting summer shown in given figure is used to combine three signals. $V_1 = 1$ VDC, $V_2 = -0.2$ VDC, and V_3 is a 2 V peak 100 Hz sine wave. Determine the output voltage if $R_1 = R_2 = R_3 = R_f = 20\ \text{k}\Omega$ and $R_i = 5\ \text{k}\Omega$.



Because all of the input resistors are equal, we can use the general form of the summing equation.

$$V_{out} = \left(1 + \frac{R_f}{R_i}\right) \frac{V_1 + V_2 + \ldots + V_n}{\text{Number of channels}}$$

$$V_{out} = \left(1 + \frac{20\,\text{k}}{5\,\text{k}}\right) \frac{1\,\text{VDC} + (-0.2\,\text{VDC}) + 2\sin 2\pi\,100\,t}{3}$$

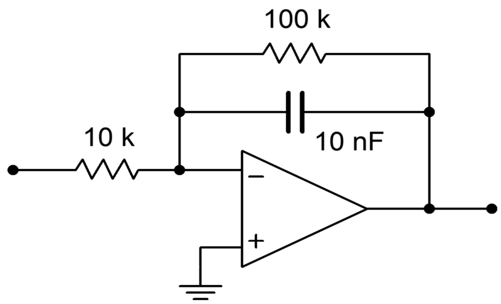
$$V_{out} = 5 \quad \frac{0.8\,\text{VDC} + 2\sin 2\pi\,100\,t}{3}$$

$$V_{out} = 1.33\,\text{VDC} + 3.33\sin 2\pi\,100\,t$$

So we see that the output is a 3.33 V peak sine wave riding on a 1.33 VDC offset.

Example 4b

Determine the equation for V_{out}, and the lower frequency limit of integration for the circuit of Figure.



The general form of the output equation is given by Equation 10.6.

$$V_{out}(t) = -\frac{1}{R_i C}\int V_{in}(t)\,dt$$

$$V_{out}(t) = -\frac{1}{10\,\mathrm{k}\times 10\,\mathrm{nF}}\int V_{in}(t)\,dt$$

$$V_{out}(t) = -10^4\int V_{in}(t)\,dt$$

The lower limit of integration is set by f_{low}.

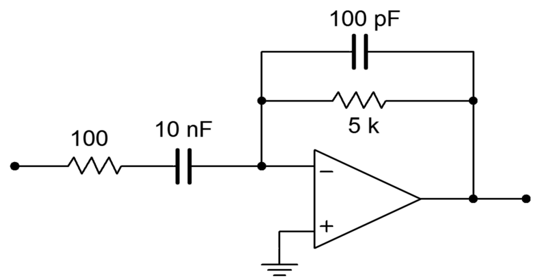
$$f_{low} = \frac{1}{2\pi R_f C}$$

$$f_{low} = \frac{1}{2\pi\, 100\,\mathrm{k}\times 10\,\mathrm{nF}}$$

$$f_{low} = 159\,\mathrm{Hz}$$

This represents our 50% accuracy point. For 99% accuracy, the input frequency should be at least one decade above f_{low}, or 1.59 kHz. Accurate integration will continue to higher and higher frequencies.

Determine the useful range for differentiation in the circuit of given Figure. Also determine the output voltage if the input signal is a 2 V peak sine wave at 3 kHz.



The upper limit of the useful frequency range will be determined by the lower of the two *RC* networks.

$$f_{high(fdbk)} = \frac{1}{2\pi R_f C_f}$$
$$f_{high(fdbk)} = \frac{1}{2\pi \times 5\,\text{k} \times 100\,\text{pF}}$$
$$f_{high(fdbk)} = 318.3\,\text{kHz}$$

$$f_{high(in)} = \frac{1}{2\pi R_i C}$$
$$f_{high(in)} = \frac{1}{2\pi \times 100 \times 10\,\text{nF}}$$
$$f_{high(in)} = 159.2\,\text{kHz}$$

Therefore, the upper limit is 159.2 kHz. Remember, the accuracy at this limit is relatively low, and normal operation will typically be several octaves lower than this limit. Note that the input frequency is 3 kHz, so high accuracy should result. First, write V_{in} as a time-domain expression:

$$V_{in}(t) = 2\sin 2\pi 3000 t$$

$$V_{out}(t) = -R_f C \frac{dV_{in}(t)}{dt}$$
$$V_{out}(t) = -5\,\text{k} \times 10\,\text{nF} \frac{d\, 2\sin 2\pi 3000 t}{dt}$$
$$V_{out}(t) = -10^{-4} \frac{d \sin 2\pi 3000 t}{dt}$$
$$V_{out}(t) = -1.885 \cos 2\pi 3000 t$$

This tells us that the output waveform is also sinusoidal, but it lags the input by 90°. Note that the input frequency has not changed, but the amplitude has. The differentiator operates with a 6 dB per octave slope, thus it can be seen that the output amplitude is directly proportional to the input frequency. If this example is rerun with a frequency of 6 kHz, the output amplitude will be double the present value.