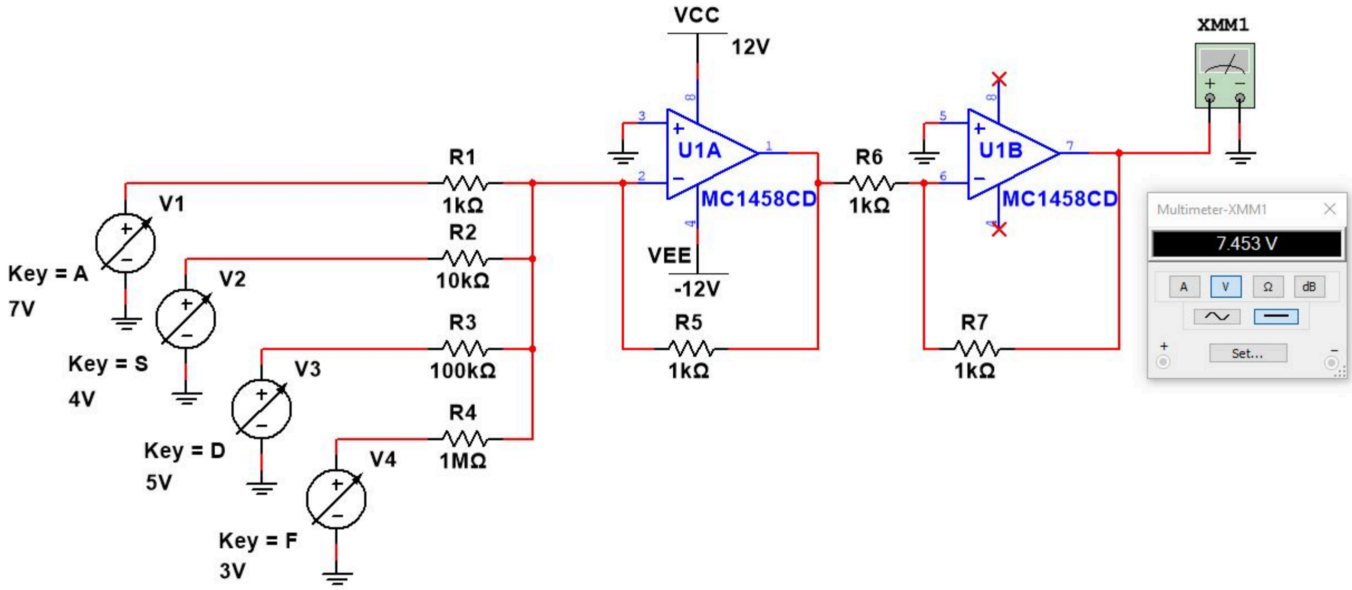
The previous example demonstrated that the output from a summing amplifier is based upon the sum of the currents into the summing point. This next example will help to formalize the theory behind the summing amplifier a bit further.

Using Multisim, build the following circuit.

V_1, V_2, V_3, and V_4 are all "Sources" -> "SIGNAL_VOLTAGE_SOURCES" -> "DC_INTERACTIVE_VOLTAGE". Set these to a Maximum of 10 V and and Increment of 10%. This makes the step size suitable; however, you won't want to go over 9 V on any of the inputs.



Set the input voltages to the values in the following table, and record the associated output voltages to the nearest millivolt.

V_1, V	V_2, V	V_3, V	V_4, V	V_{out}, V
7	4	5	3	7.453
1	9	2	0	1.92
9	9	9	9	9.999
2	5	7	6	2.576
0	0	0	0	0

By comparing the input voltage combinations to the output voltages, it should be clear to you that the outputs represent the decimal-weighted inputs in millivolts. Since we already know about Inverse Transfer Functions, let's write one for this circuit that gives us the whole number represented by the output voltage:

N = 1000 x V_{out}

Now for the circuit analysis:

What is the gain of the second amplifier, U1B? -1

This amplifier is used to:

○ increase the magnitude of the signal

○ decrease the magnitude of the signal

● invert the signal presented to it

For the first example, as shown in the schematic, determine the current supplied by each of the input voltage sources in microamps.

From V_1, I_1 = 7000 μA

From V_2, I_2 = 400 μA

From V_3, I_3 = 50 μA

From V_4, I_4 = 3 μA

What is the total incoming current? 7453 μA

Since none of this current can enter the high-impedance input of the op amp, all of it must go through the feedback resistor. From this, determine the voltage seen at the output of the first amplifier, U1A. -7.453 V

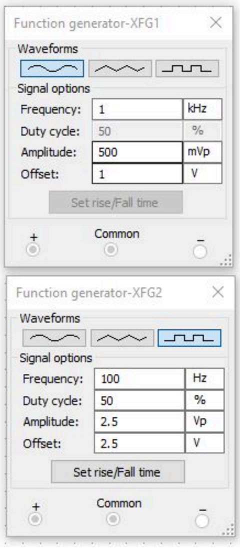
Here's the theory behind this amplifier configuration.

1. Since the inverting input is a Virtual Ground (0 V), current from each of the sources flows through each input resistor to "ground", and therefore does not affect the reference of any of the other input sources. In essence, the Virtual Ground Summing Point isolates all the input sources from each other.
2. There is only one available path for current entering the summing point: Through the feedback resistor. Therefore, the sum of the incoming currents must flow through this one path.
3. The output voltage is therefore the inverted product of the feedback resistor value and the sum of the currents.

In the form of an equation, this can be shown, as the general formula for all summing amplifiers, as

$$V_{out} = -R_f \cdot \left(\frac{V_{in1}}{R_{i1}} + \frac{V_{in2}}{R_{i2}} + \frac{V_{in3}}{R_{i3}} + \ldots \right)$$

Here's a worked example in which the DC offsets generated by two inputs needs to be cancelled using a third input.



Function generator-XFG1

Waveforms: sine

Signal options

Frequency: 1 kHz

Duty cycle: 50 %

Amplitude: 500 mVp

Offset: 1 V

Function generator-XFG2

Waveforms: square

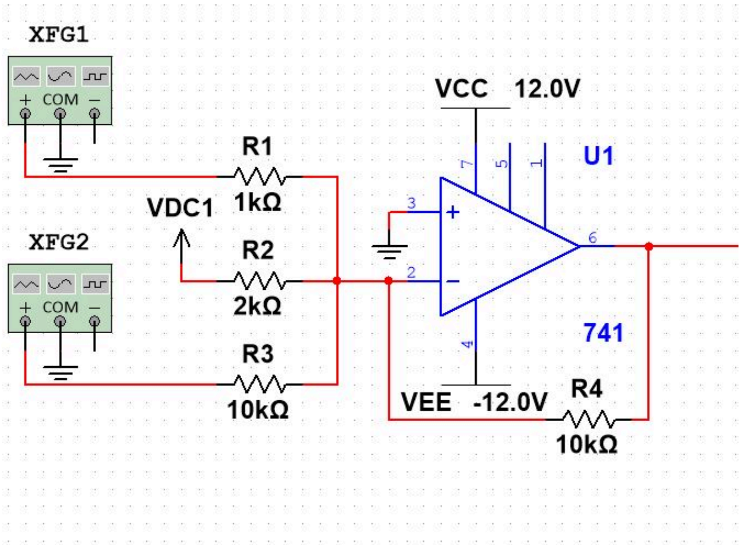
Signal options

Frequency: 100 Hz

Duty cycle: 50 %

Amplitude: 2.5 Vp

Offset: 2.5 V



In this case, both of the function generators contain DC offsets, which will add together in the output signal.

The DC component in the output from XFG1 will be

$$1.0\ VDC \cdot \left(-\frac{10\ k\Omega}{1\ k\Omega}\right) = -10\ \ VDC$$

The DC component in the output from XFG2 will be

$$2.5\ VDC \cdot \left(-\frac{10\ k\Omega}{10\ k\Omega}\right) = -2.5\ \ VDC$$

The combined DC voltage at the outputs from these two supplies will be -12.5 VDC.

If the DC in the output component is to be cancelled by VDC1, the DC component at the output from this supply would have to be +12.5 VDC. Consequently, the input voltage would be calculated as follows:

$$VDC1 = \frac{12.5\ \ VDC}{\left(-\frac{10\ k\Omega}{2\ k\Omega}\right)} = -2.5\ \ VDC$$

As a quick check, we could determine the combined DC output voltage using the general formula:

$$VDC_{out} = -10\ k\Omega \cdot \left(\frac{1\ \ VDC}{1\ k\Omega} + \frac{-2.5\ \ VDC}{2\ k\Omega} + \frac{2.5\ \ VDC}{10\ k\Omega}\right) = 0\ \ VDC$$

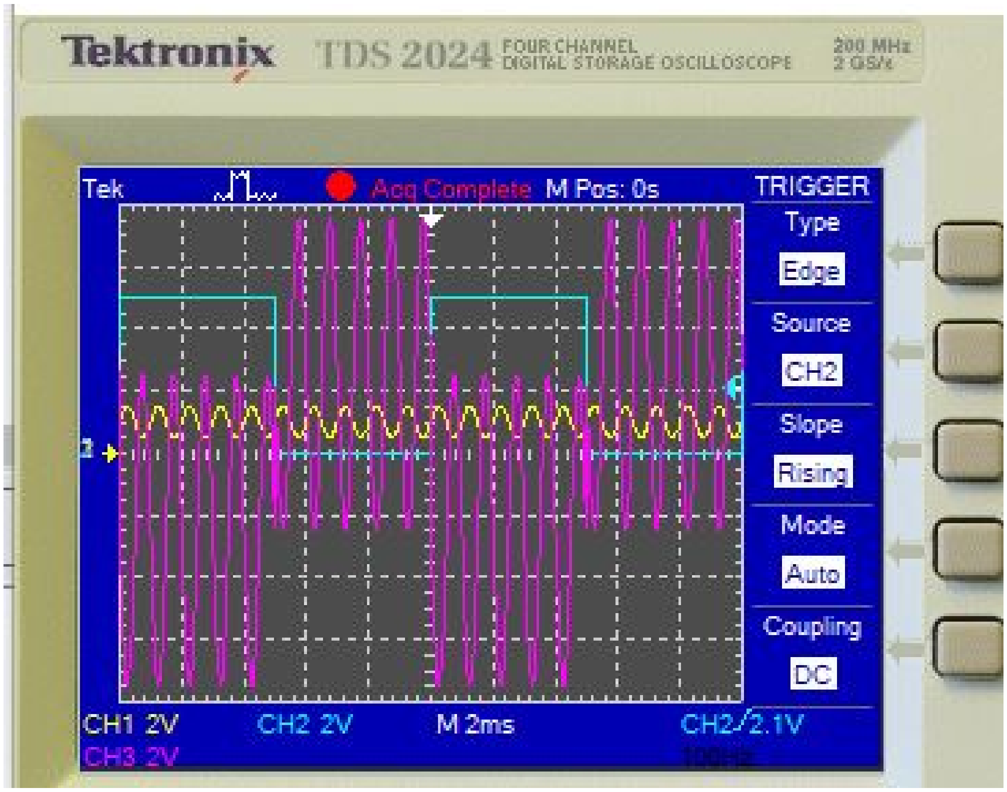
While we're at it, we could determine that the amplitude of the sine wave from XFG1 would be

$$v_{out1} = 500\ mV_p \cdot \left(-\frac{10\ k\Omega}{1\ k\Omega}\right) = 5\ V_p,\ inverted$$

The amplitude of the square wave from XFG2 would be

$$v_{out2} = 2.5\ V_p \cdot \left(-\frac{10\ k\Omega}{10\ k\Omega}\right) = 2.5\ V_p,\ inverted$$

The oscilloscope display below, with all channels set to 2 V/div, shows the expected results:



The input signal from XFG1 shows a DC offset of +1 VDC and an amplitude of 1.0 $V_{p\text{-}p}$, or the expected 500 mV_p

At the output, this signal covers five divisions, or 10 $V_{p\text{-}p}$ (i.e. 5.0 V_p), matching the expected gain of 10; also note that when the input signal is at a maximum, the output signal is negative, matching the prediction that the gain for the XFG1 signal is inverted; so the gain is actually -10.

The input signal from XFG2 shows an average voltage of +2.5 VDC and a "peak to peak" amplitude of 5.0 $V_{p\text{-}p}$.

Its contribution to the output signal can be determined from the averages of the upper and lower "bursts" of the sine wave. The upper part of the signal is centered around +2.5 V, and the lower part is centered around -2.5 V; so its amplitude is 5.0 $V_{p\text{-}p}$ or 2.5 V_p, indicating a gain of 1.0 as predicted from the resistors. Also, note that when the input is at a maximum, the lower burst of sine wave appears, and when the input is at a minimum the upper burst of sine wave appears, so this component is also inverted. Hence, the gain for the XFG2 signal is -1.0.