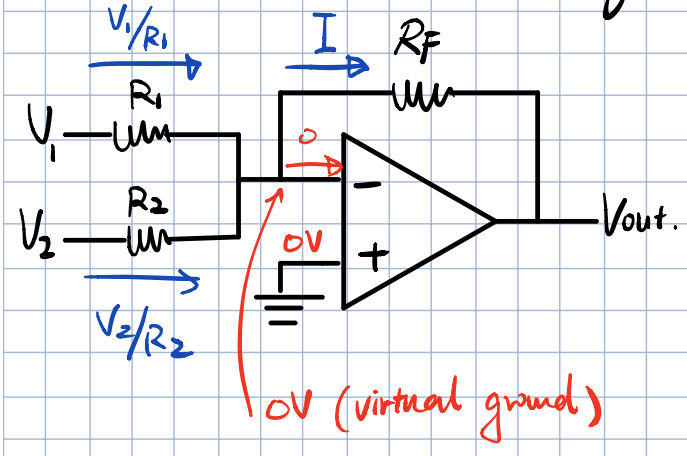
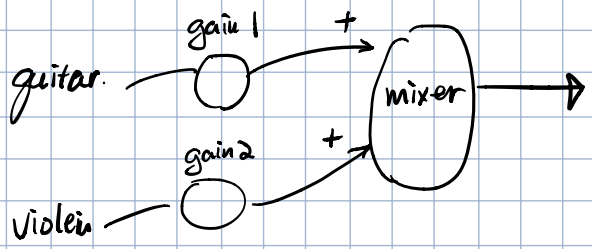
② Adder circuit. (voltage weighted sum)





$$I = \frac{V_1}{R_1} + \frac{V_2}{R_2}$$

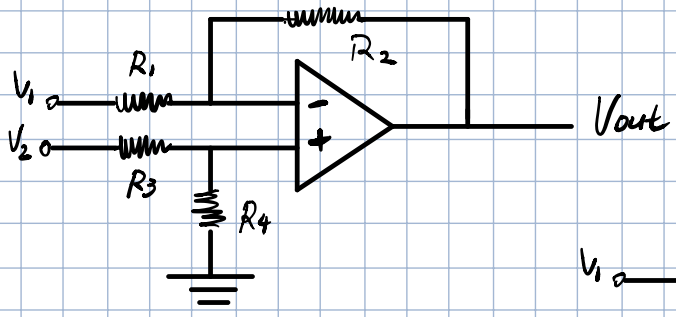
$$V_{out} = 0 - IR_F$$

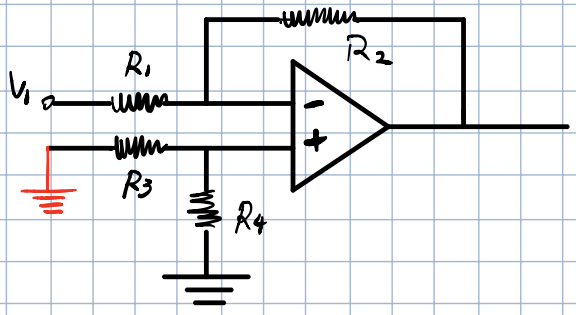
$$V_{out} = -\left(\frac{R_F}{R_1}V_1 + \frac{R_F}{R_2}V_2\right) //$$

③ Difference Amplifier.

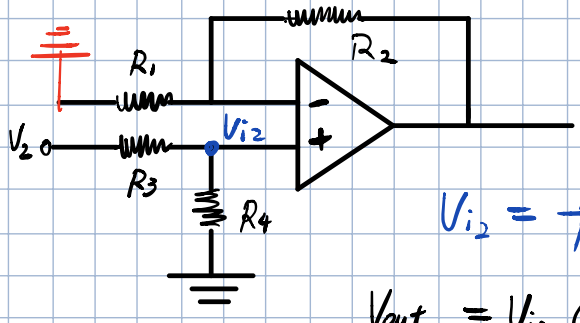
By Superposition.:

one source @ a time + sum up results.





$$V_{out_1} = -\frac{R_2}{R_1}V_1$$



$$V_{i2} = \frac{R_4}{R_3+R_4}V_2$$

$$V_{out_2} = V_{i2}\left(1+\frac{R_2}{R_1}\right)$$

$$= \frac{R_4}{R_3+R_4}\left(1+\frac{R_2}{R_1}\right)V_2$$

$$V_{out} = V_{out_1} + V_{out_2}$$

$$= \frac{-R_2}{R_1}V_1 + \left(1+\frac{R_2}{R_1}\right)\frac{R_4}{R_3+R_4}V_2 //$$

if $\frac{R_3}{R_4} = \frac{R_1}{R_2}$,

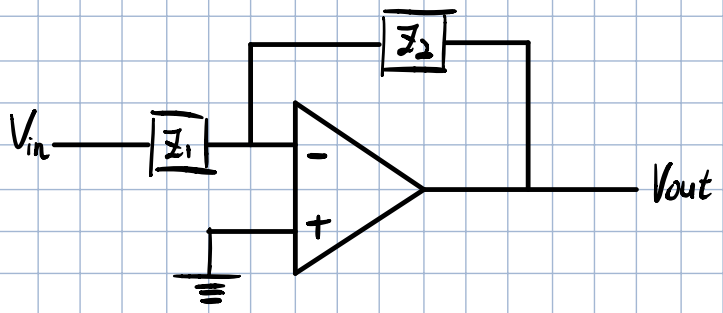
then $V_{out} = \frac{R_2}{R_1}(V_2 - V_1)$ //

→ drawbacks, very difficult to match.

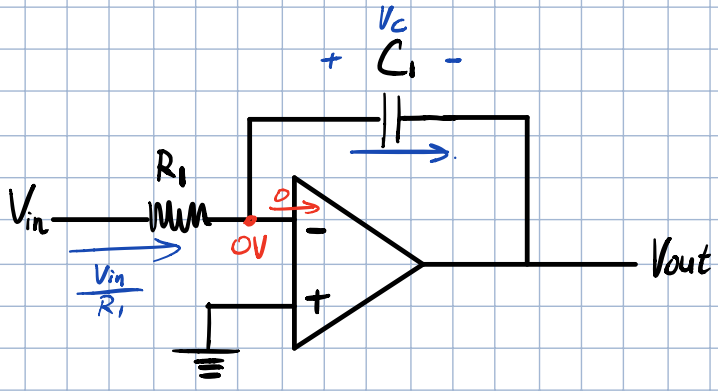
Resistor value has tolerance.

(mismatch → lower input resistance.

Integrator + Differentiator.

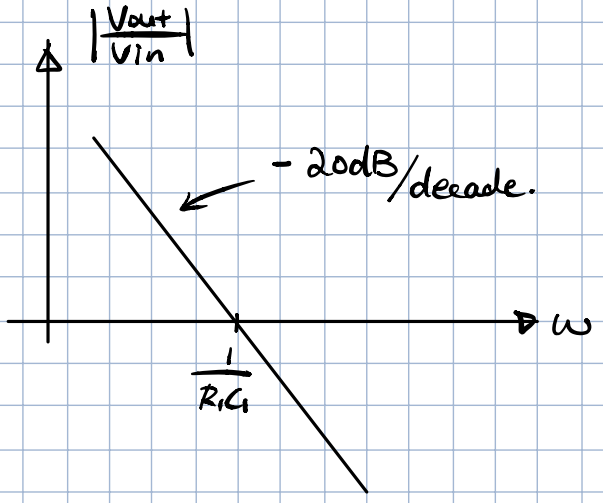


$$\frac{V_{out}}{V_{in}} \approx -\frac{Z_2}{Z_1}$$



$$\frac{V_{out}}{V_{in}} = -\frac{\frac{1}{sC_1}}{R_1} = -\frac{1}{R_1C_1s}$$

$$s=j\omega, \quad \frac{V_{out}}{V_{in}}(\omega) = -\frac{1}{j\omega R_1C_1}$$

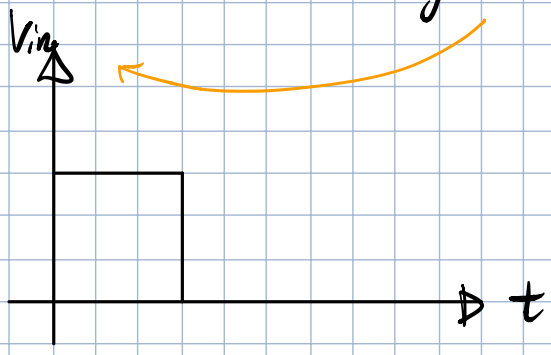


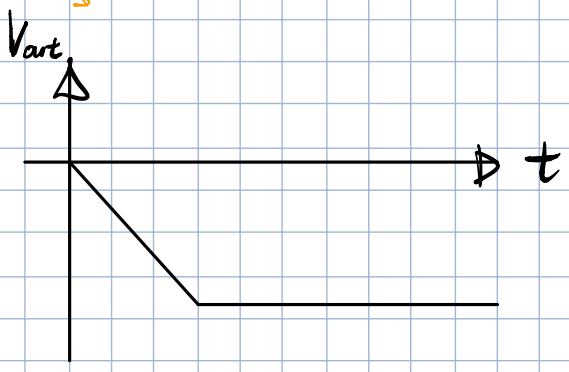
current through the capacitor.

$$\frac{V_{in}}{R_1} = C\frac{dV_c}{dt}, \quad V_c = 0 - V_{out}$$

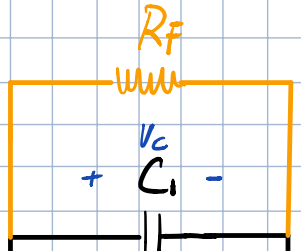
$$C\frac{d(-V_{out})}{dt} = \frac{V_{in}}{R_1}$$

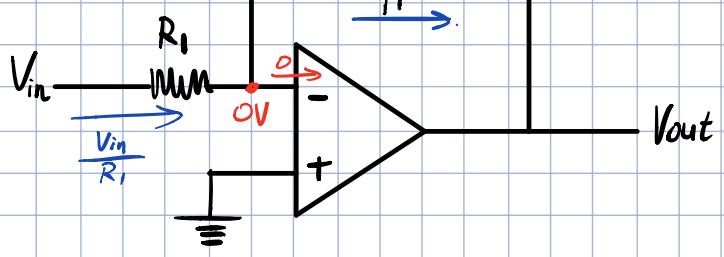
$$V_{out} = -\frac{1}{R_1C_1}\int V_{in}\,dt$$





Not working in real circuit, b/c the gain is too high at DC, causing saturation fin.




R_1
V_{in}
0
0V
$\frac{V_{in}}{R_1}$
−
+
V_{out}