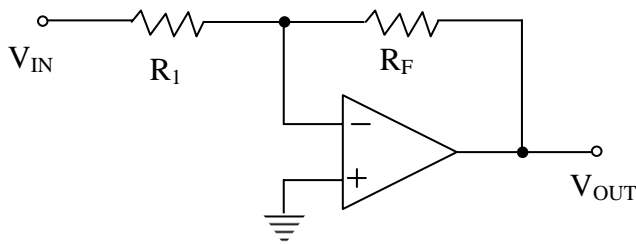


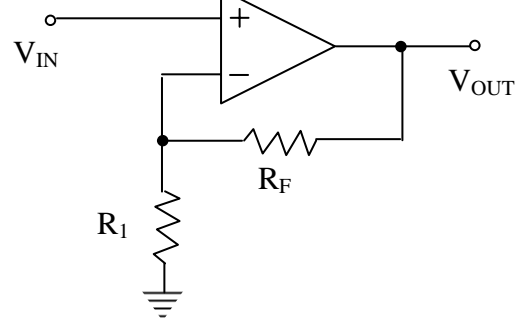
## Summary of Op Amps

### 1. Common inverting op amp



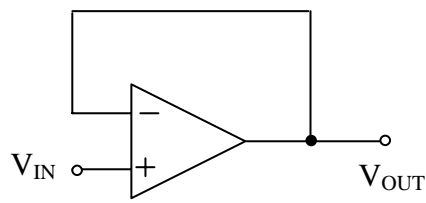
$$V_{OUT} = -\frac{R_F}{R_1} V_{IN}$$

### Non-inverting op amp



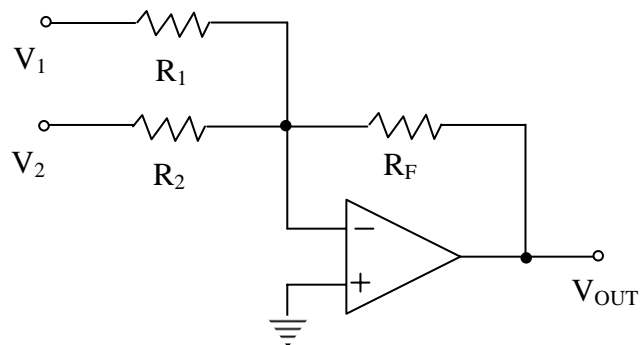
$$V_{OUT} = \left(1 + \frac{R_F}{R_1}\right) V_{IN}$$

### 2. Voltage Follower (Buffer)



$$V_{OUT} = V_{IN}$$

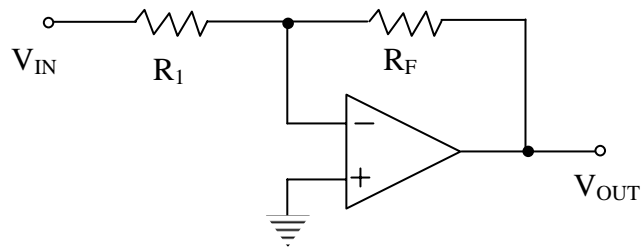
### 3. Addition



$$R_1 = R_2 = R_F; V_{OUT} = -(V_1 + V_2)$$

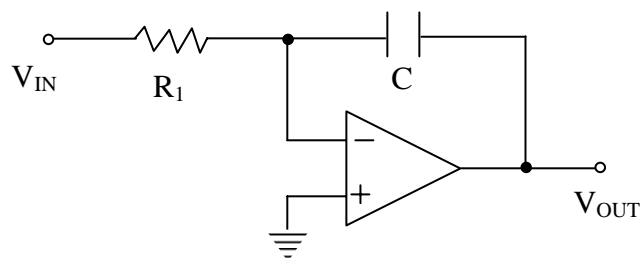
$$V_{OUT} = -\left(\frac{R_F}{R_1} V_1 + \frac{R_F}{R_2} V_2\right)$$

#### 4. Multiplication Circuit (Proportional)



$$V_{OUT} = -\frac{R_F}{R_1} V_{IN} \text{ (the minus sign indicates reverse polarity)}$$

#### 5. Integrator (I)

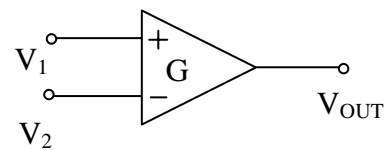
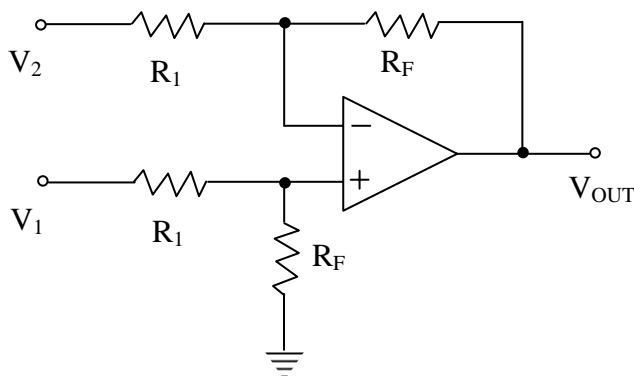


$$V_{OUT} = -\frac{1}{RC} \int V_{IN} dt \text{ (Output is integration of input voltage)}$$

If  $V_{IN} = K$  we have:

$$V_{OUT} = -\frac{K}{RC} t \text{ (a linear ramp)}$$

#### 6. Differential Amplifier Circuit (Comparator – Error Detecting Circuit)



Simplified circuit

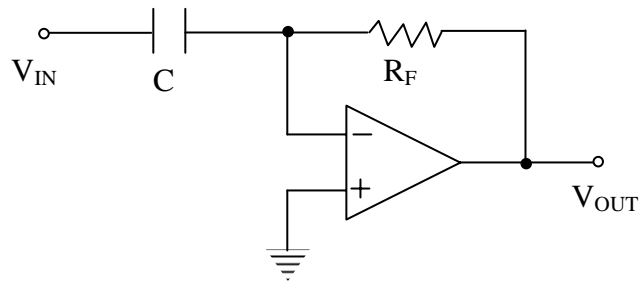
$$V_{OUT} = \frac{R_F}{R_1} (V_2 - V_1) = G \times (V_2 - V_1) \text{ (G is the differential voltage gain)}$$

If  $R_F = R_1$ , we have

$$V_{OUT} = V_2 - V_1$$

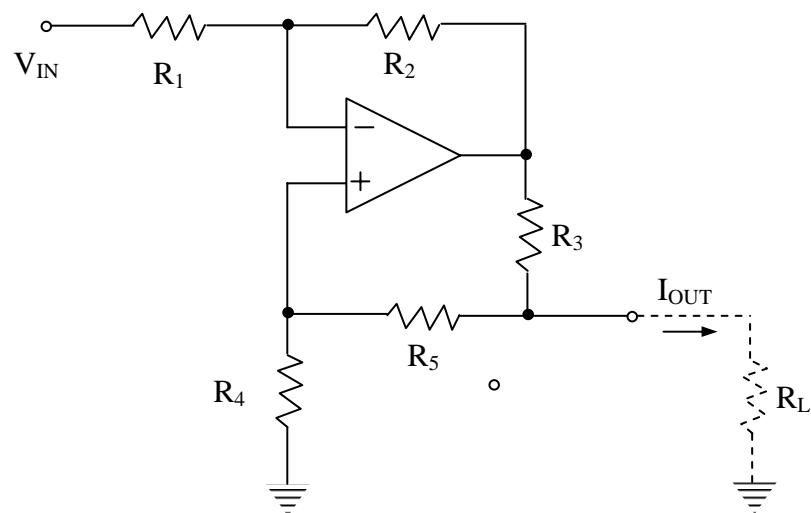
Note: Voltage followers can be used for input isolation.

### 7. Differentiator (D)



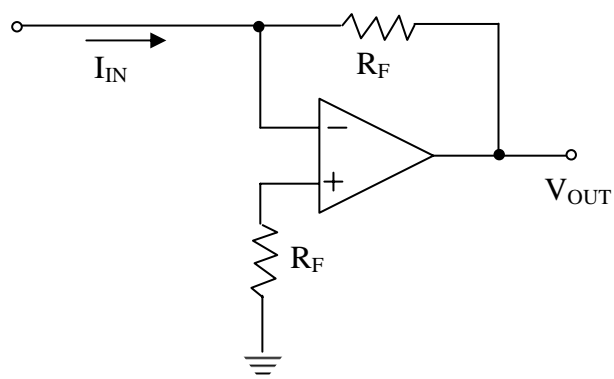
$$V_{OUT} = -R_F C \frac{dV_{IN}}{dt}$$

### 8. Voltage-to-Current Converter



$$\text{If } R_1(R_3 + R_5) = R_2R_4 \quad I_{OUT} = -\frac{R_2}{R_1R_3} V_{IN}$$

### 9. Current-to-Voltage Converter



$$V_{OUT} = IR_F$$