Thevenin Voltage Sources		
Find Vth	Set load between A and B to open and find V_A - V_B	$V_L = \frac{R_L}{R_{th} + R_L} V_{th}$
Find Rth	Set voltage sources to shorts and find combined resistance between A and B.	

Harmonic Oscillation		
UnDamped	**Damped**	**Cantilever Beam**
$\frac{d^2V}{dt^2} + \omega_0^2 V = 0$ $v(t) = A\cos(\omega_0 t + \phi)$ $\omega_0 = \frac{1}{\sqrt{LC}}$	$\frac{d^2V}{dt^2} + 2\alpha\frac{dV}{dt} + \omega_0^2 V = 0$ $v(t) = Ae^{-\alpha t}\cos(\omega_0 t + \phi)$ $v_1 = v_0 e^{-\alpha(t_1 - t_0)}$ $\alpha = \frac{R}{2L}$	$\frac{Ewt^3}{4l^3} = (m + m_n)(2\pi f_n)^2$ $m = 0.23 m_{beam}$

Op-Amp Circuits

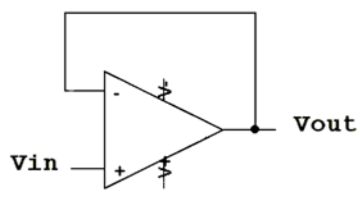
Op Amp Analysis Rules

1. $V_+ = V_-$
2. $I_+ = I_- = 0$

Op-Amp Analysis

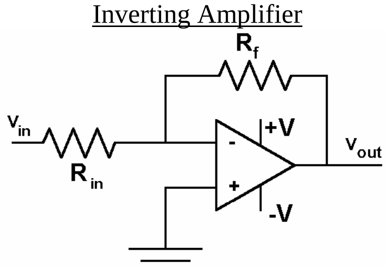
1. Remove Op-Amp
2. Draw a circuit at each input to the op-amp
3. Solve for Vout in terms of the input voltage(s).

Voltage Follower



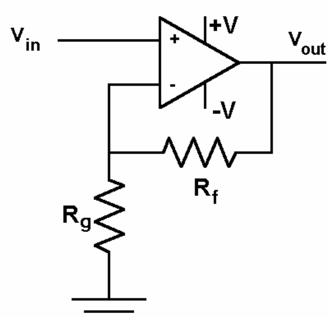
$$A_V = \frac{V_{out}}{V_{in}} = 1$$

Inverting Amplifier



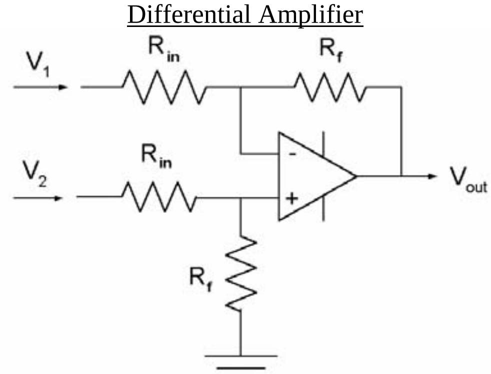
$$A_V = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$$

Non-Inverting Amplifier



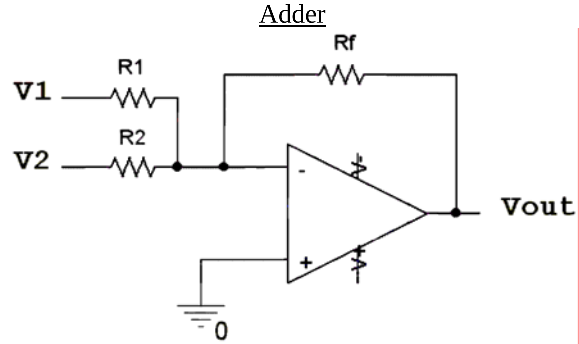
$$A_V = \frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_g}$$

Differential Amplifier



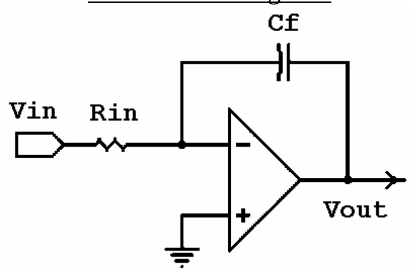
$$V_{out} = \frac{R_f}{R_{in}}(V_2 - V_1)$$

Adder



$$V_{out} = -\frac{R_f}{R_1}V_1 - \frac{R_f}{R_2}V_2$$

Ideal Active Integrator

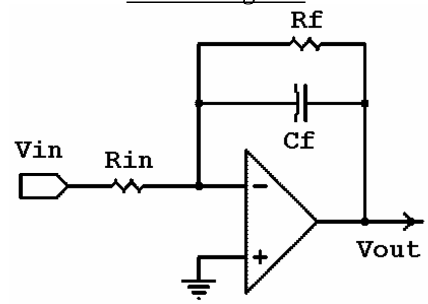


$$H(j\omega)=\frac{V_{out}}{V_{in}}=-\frac{1}{j\omega R_{in}C_f}$$

$$v_{out}(t)=-\frac{1}{R_{in}C_f}\int v_{in}(t)dt$$

$$\int \sin(\omega t)dt=\frac{-1}{\omega}\cos(\omega t)+K$$

Miller Integrator

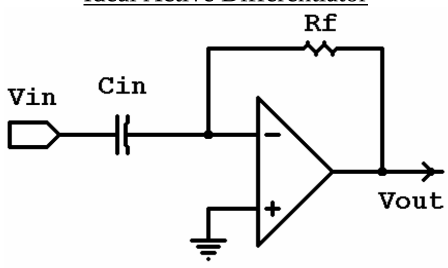


$$H(j\omega)=\frac{V_{out}}{V_{in}}=-\frac{R_f}{R_{in}(1+j\omega R_f C_f)}$$

$$\omega >> \frac{1}{R_f C_f} \Rightarrow H(j\omega)\approx -\frac{1}{j\omega R_{in}C_f}$$

$$\omega >> \frac{1}{R_f C_f} \Rightarrow v_{out}(t)\approx -\frac{1}{R_{in}C_f}\int v_{in}(t)dt$$

Ideal Active Differentiator

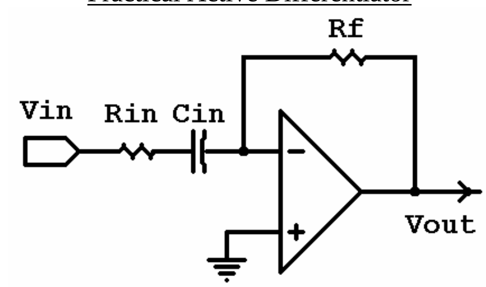


$$H(j\omega)=\frac{V_{out}}{V_{in}}=-j\omega R_f C_{in}$$

$$v_{out}(t)=-R_f C_{in}\frac{dv_{in}(t)}{dt}$$

$$\frac{d\sin(\omega t)}{dt}=\omega\cos(\omega t)$$

Practical Active Differentiator

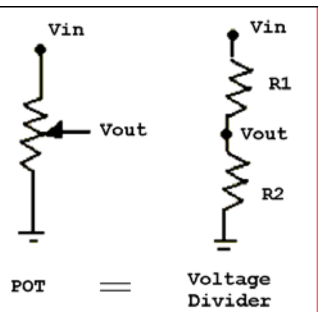


$$H(j\omega)=\frac{V_{out}}{V_{in}}=-\frac{j\omega R_f C_{in}}{1+j\omega R_{in}C_{in}}$$

$$\omega << \frac{1}{R_{in}C_{in}} \Rightarrow H(j\omega)\approx -j\omega R_f C_{in}$$

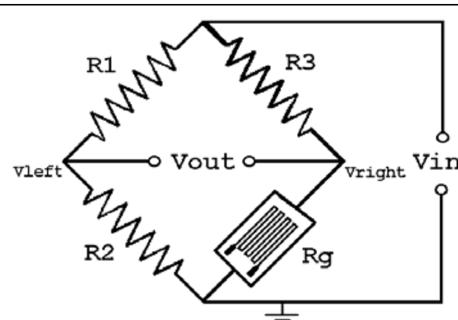
$$\omega << \frac{1}{R_{in}C_{in}} \Rightarrow v_{out}(t)=-R_f C_{in}\frac{dv_{in}(t)}{dt}$$

Potentiometers



$$RT = R1+R2 \quad Vout=\frac{R2}{RT}Vin$$

Strain Gauge Bridge



$$Vout = dV = Vleft - Vright = Vin\left[\frac{R2}{R1+R2}-\frac{Rg}{R3+Rg}\right]$$