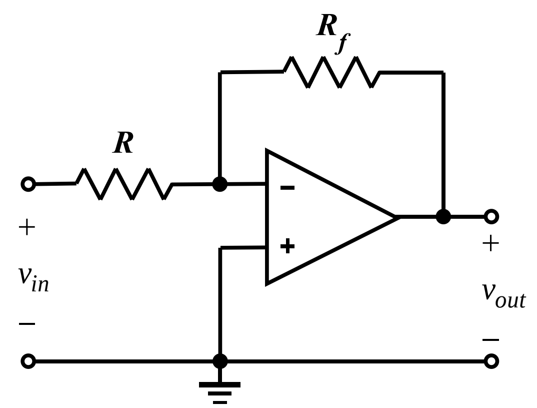
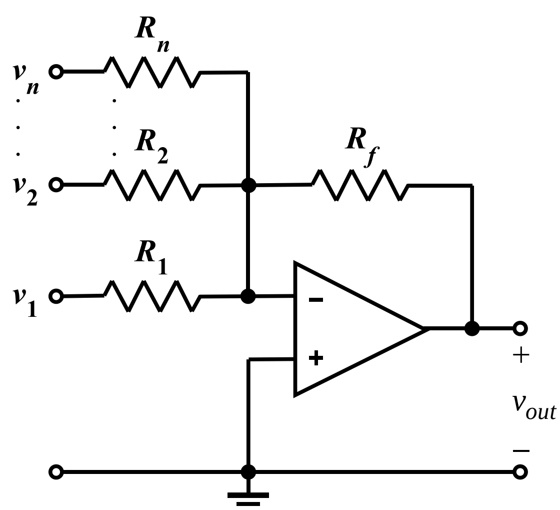
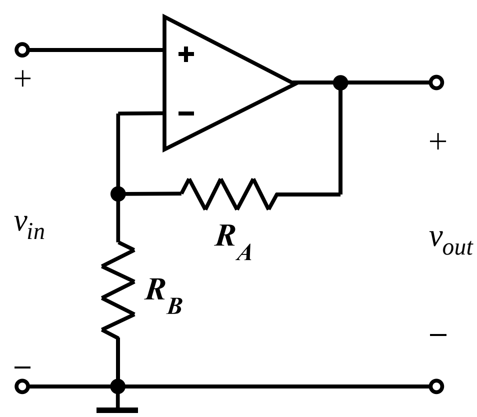
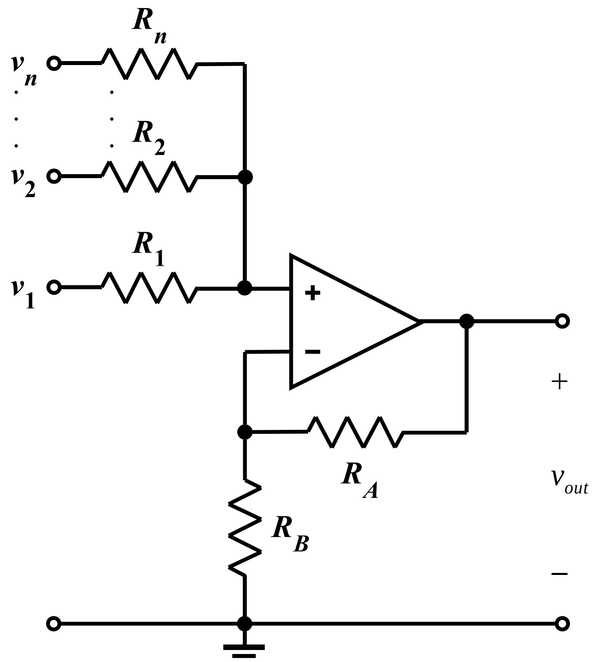
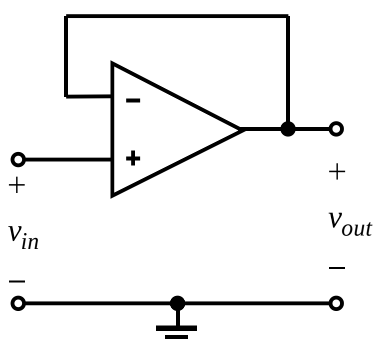
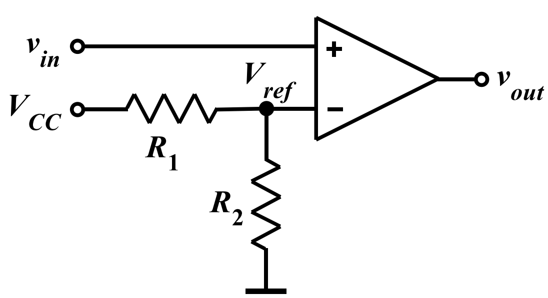
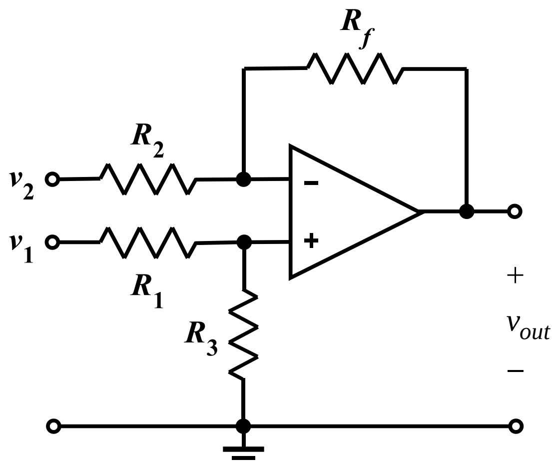
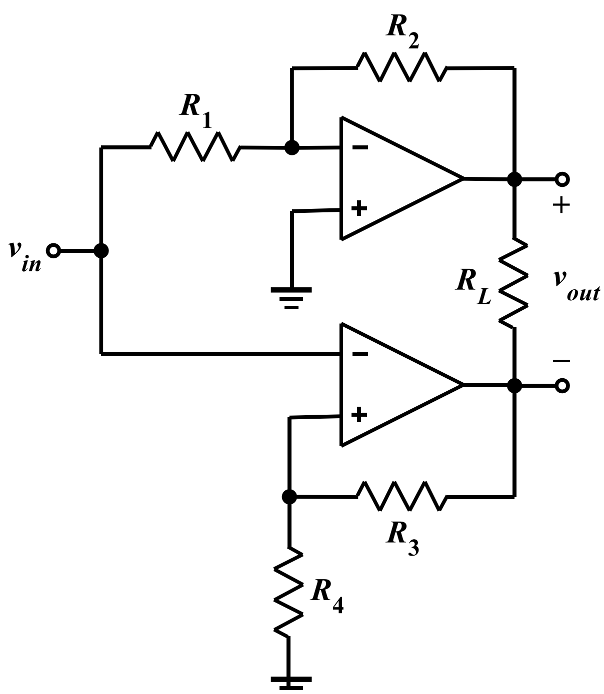
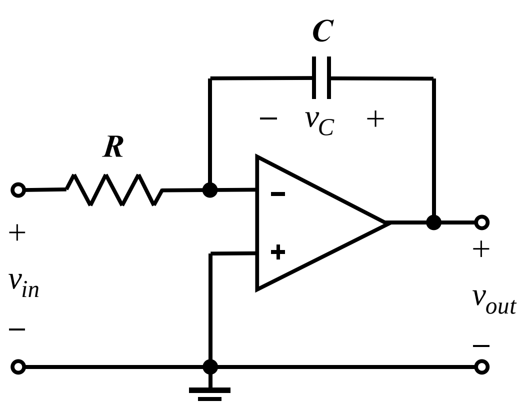
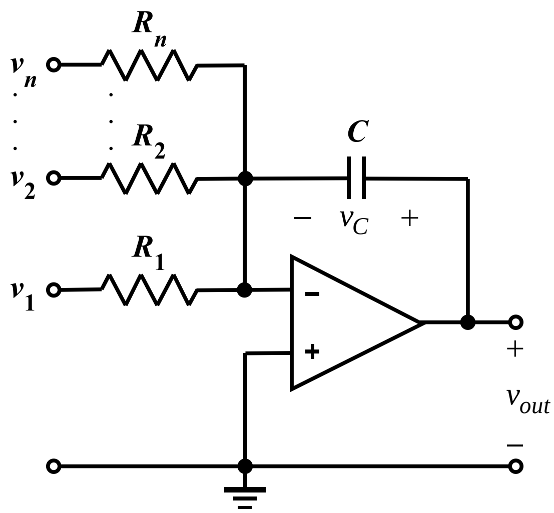
OpAmp Building Blocks

	Circuit	I/O Relationship
Inverting Amplifier		$v_{out} = -\left(\frac{R_f}{R}\right) v_{in}$
Summing Amplifier, Summing Inverter, or Adder		$v_{out} = -\left(\frac{R_f}{R_1}\right)v_1 - \left(\frac{R_f}{R_2}\right)v_2 \cdots - \left(\frac{R_f}{R_n}\right)v_n$ If $R_f = R_1 = R_2 = \cdots = R_3$, then $v_{out} = -\left(v_1 + v_2 + \cdots + v_n\right)$
Non-Inverting Amplifier		$v_{out} = \left(1 + \frac{R_A}{R_B}\right) v_{in}$

Non-Inverting Summing Amplifier		$v_{out} = \left(1+\frac{R_A}{R_B}\right)\frac{\left(\frac{1}{R_1}v_1+\frac{1}{R_2}v_2+\cdots+\frac{1}{R_n}v_n\right)}{\left(\frac{1}{R_1}+\frac{1}{R_2}+\cdots+\frac{1}{R_n}\right)}$ If $R_1 = R_2 = \cdots = R_n$, then $v_{out} = \left(1+\frac{R_A}{R_B}\right)\left(\frac{v_1+v_2+\cdots v_n}{n}\right)$ a) Then, note that if $R_B \to \infty$, $\lim_{R_B\to\infty} v_{out} = \frac{1}{n}(v_1+v_2+\cdots v_n)$, the average of the inputs. b) Or, if $\frac{R_A}{R_B} = n-1$, then $v_{out} = v_1+v_2+\cdots v_n$, the sum of the inputs.
Isolation Amplifier, Buffer, or Voltage Follower		$v_{out} = v_{in}$
Comparator		$V_{ref} = \frac{R_2}{R_1+R_2}V_{CC}$ $v_{in} > V_{ref} \Rightarrow v_{out} > 0$ $v_{in} < V_{ref} \Rightarrow v_{out} < 0$

Difference Amplifier or Subtractor		$$v_{out} = \frac{\left(1+\frac{R_f}{R_2}\right)}{\left(1+\frac{R_1}{R_3}\right)} v_1 - \left(\frac{R_f}{R_2}\right) v_2$$ If $R_f = R_2$ and $R_1 = R_3$, then $$v_{out} = v_1 - v_2$$
Bridge Amplifier		$$v_{out} = -\frac{R_2}{R_1} v_{in} - \left(1+\frac{R_3}{R_4}\right) v_{in}$$ Neither end of v_{out} is grounded. Also, if $\frac{R_2}{R_1} = 1+\frac{R_3}{R_4} \triangleq A_v$, then $$v_{out} = -2A_v v_{in}$$
Integrator		$$v_{out} = -\frac{1}{RC}\int_{-\infty}^{t} v_{in}\, dt$$ $$= v_{out}(0) - \frac{1}{RC}\int_{0}^{t} v_{in}\, dt$$ The initial condition is determined by the initial capacitor voltage since $v_{out} = v_C$.

<table>
<tr>
<td>Summing Integrator</td>
<td>
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$$v_{out} = -\frac{1}{R_1C}\int_{-\infty}^{t} v_1\,dt - \frac{1}{R_2C}\int_{-\infty}^{t} v_2\,dt \cdots - \frac{1}{R_nC}\int_{-\infty}^{t} v_n\,dt = v_{out}(0) - \frac{1}{R_1C}\int_{0}^{t} v_1\,dt - \frac{1}{R_2C}\int_{0}^{t} v_2\,dt \cdots - \frac{1}{R_nC}\int_{0}^{t} v_n\,dt$$

The initial condition is determined by the initial capacitor voltage since $v_{out} = v_C$.</td>
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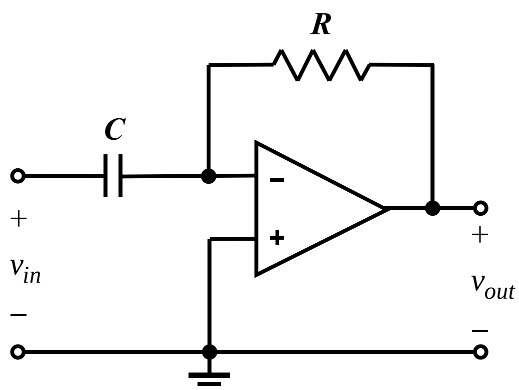
<tr>
<td>Differentiator</td>
<td>
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$$v_{out} = -RC\frac{dv_{in}}{dt}$$

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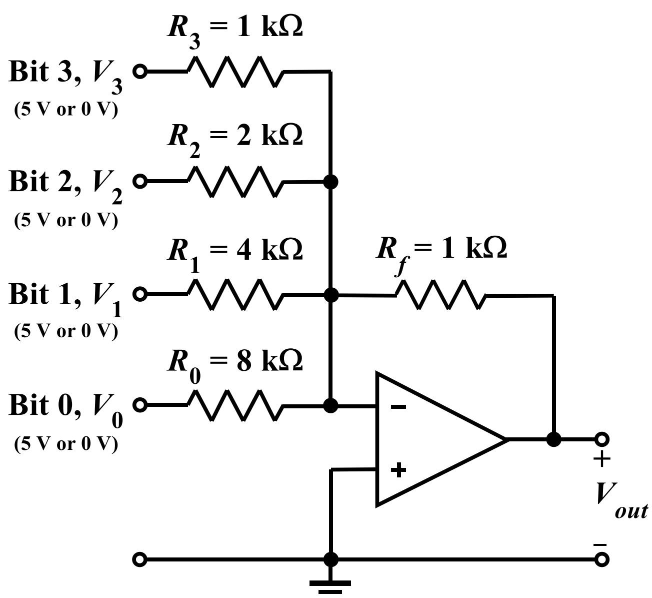
<td>4-Bit Digital to Analog Converter (Special case of the Summing Amplifier)</td>
<td>
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$$V_{out} = -\left(V_3 + \frac{V_2}{2} + \frac{V_1}{4} + \frac{V_0}{8}\right)$$

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