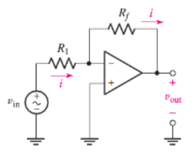
# BLM1612 - Circuit Theory

# Examples

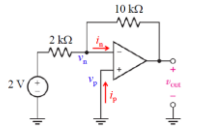
1

# Example 27



- Determine $v_{out}$ if $v_{in}$ = 2 V, $R_f$ = 10 kΩ, and $R_1$ = 2 kΩ.

$v_n = v_p$ $\quad$ $i_n = i_p = 0$



KCL @ $v_n$: $\frac{v_{out} - v_n}{10} + \frac{2 - v_n}{2} - i_n = 0$

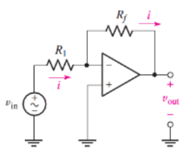
$v_p = 0$

$v_{out} = -10\text{ V}$

(inverting amplifier)

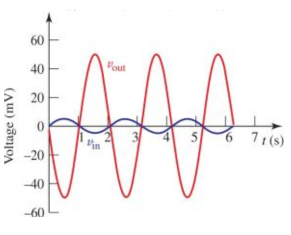
2

# Example 28



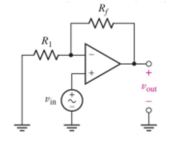
- Plot $v_{out}$ if $v_{in}$ = 5 sin3t mV, $R_f$ = 47 kΩ, and $R_1$ = 4.7 kΩ.

$$v_{out} = -\frac{R_f}{R_1} v_{in}$$



3

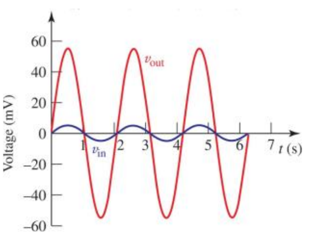
# Example 29



- Plot $v_{out}$ if $v_{in}$ = 5 sin3t mV, $R_f$ = 47 kΩ, and $R_1$ = 4.7 kΩ.

$$v_{out} = \left(\frac{R_f}{R_1} + 1\right) v_{in}$$

non-inverting amplifier



4

# Example 30…

- Design a circuit to achieve: $v_{out} = 2v_1 - 3v_2 + 4v_3 - 6v_4$

$v_{out} = \left(\frac{R_y}{R_x} + 1\right) v_{in}$ — **non-inverting amp**

$v_{out} = \left(\frac{R_y}{R_x} + 1\right) v_{in}$ — **non-inverting amp**

$v_{out} = -\left(\frac{R_f}{R_1} v_1 + \frac{R_f}{R_2} v_2 + \dots\right)$ — **inverting sum**

$v_{out} = v_2 - v_1$ — **difference**

$$v_{out} = -\left\{\frac{R_f}{R_1}\underbrace{\left(-\frac{R_b}{R_a} v_1\right)}_{\text{invert}} + \frac{R_f}{R_2} v_2 + \frac{R_f}{R_3}\underbrace{\left(-\frac{R_d}{R_c} v_3\right)}_{\text{invert}} + \frac{R_f}{R_4} v_4\right\}$$

inverting sum

$$v_{out} = \frac{R_f R_b}{R_1 R_a} v_1 - \frac{R_f}{R_2} v_2 + \frac{R_f R_d}{R_3 R_c} v_3 - \frac{R_f}{R_4} v_4$$

5

# …Example 30…

$$v_{out} = \frac{R_f R_b}{R_1 R_a} v_1 - \frac{R_f}{R_2} v_2 + \frac{R_f R_d}{R_3 R_c} v_3 - \frac{R_f}{R_4} v_4$$

Choose $R_a = R_b = R_c = R_d = 2$ kΩ …

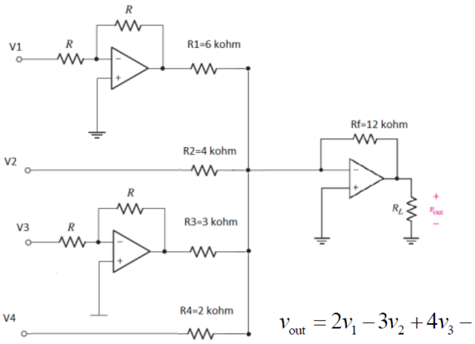
$$v_{out} = \frac{R_f}{R_1} v_1 - \frac{R_f}{R_2} v_2 + \frac{R_f}{R_3} v_3 - \frac{R_f}{R_4} v_4$$

Choose $R_f$ = 12 kΩ → $R_1$ = 6 kΩ, $R_2$ = 4 kΩ, $R_3$ = 3 kΩ, $R_4$ = 2 kΩ …

$$v_{out} = \frac{12}{6} v_1 - \frac{12}{4} v_2 + \frac{12}{3} v_3 - \frac{12}{2} v_4$$

6

## …Example 30

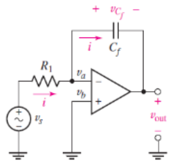



$$v_{\text{out}} = 2v_1 - 3v_2 + 4v_3 - 6v_4$$



## Example 31

- An integrator circuit:




Performing nodal analysis at the inverting input,

$$0 = \frac{v_a - v_s}{R_1} + i$$

We can relate the current $i$ to the voltage across the capacitor,

$$i = C_f \frac{dv_{C_f}}{dt}$$

resulting in

$$0 = \frac{v_a - v_s}{R_1} + C_f \frac{dv_{C_f}}{dt}$$

Invoking ideal op amp rule 2, we know that $v_a = v_b = 0$, so

$$0 = \frac{-v_s}{R_1} + C_f \frac{dv_{C_f}}{dt}$$

Integrating and solving for $v_{\text{out}}$, we obtain

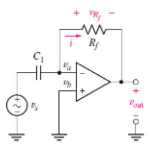
$$v_{C_f} = v_a - v_{\text{out}} = 0 - v_{\text{out}} = \frac{1}{R_1 C_f}\int_0^t v_s\, dt' + v_{C_f}(0)$$

$$v_{\text{out}} = -\frac{1}{R_1 C_f}\int_0^t v_s\, dt' - v_{C_f}(0)$$



## Example 32

- An differentiator circuit




We begin by writing a nodal equation at the inverting input pin, with $v_{C_1} \triangleq v_a - v_s$:

$$0 = C_1 \frac{dv_{C_1}}{dt} + \frac{v_a - v_{\text{out}}}{R_f}$$

Invoking ideal op amp rule 2, $v_a = v_b = 0$. Thus,

$$C_1 \frac{dv_{C_1}}{dt} = \frac{v_{\text{out}}}{R_f}$$

Solving for $v_{\text{out}}$,

$$v_{\text{out}} = R_f C_1 \frac{dv_{C_1}}{dt}$$

Since $v_{C_1} = v_a - v_s = -v_s$,

$$v_{\text{out}} = -R_f\, C_1 \frac{dv_s}{dt}$$

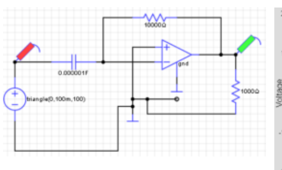


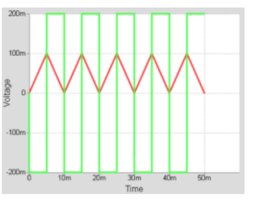
## Example 33

- A real Implementation:

  C = 1 μF, R = 10 KΩ, RC = 0.01 (sec)

  dv/dt = 100 mV/5 msec = 20 V/sec

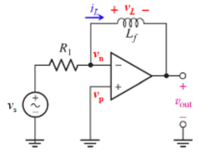







## Example 34

- Derive an expression for $v_{out}$ in terms of $v_s$ for the circuit.




$$v_n = v_p \quad , \quad i_n = i_p = 0$$

$$\frac{v_s - v_n}{R_1} - i_L = 0$$

$$\frac{v_s - v_n}{R_1} - \frac{1}{L_f}\int_{t_0}^{t} v_L \cdot dt' + i_n(t_0) = 0$$

$$\frac{v_s - v_n}{R_1} - \frac{1}{L_f}\int_{t_0}^{t} (v_n - v_{\text{out}}) \cdot dt' + i_n(t_0) = 0$$

$$\int_{t_0}^{t} v_{\text{out}} \cdot dt' + L_f \cdot i_n(t_0) = -\frac{L_f}{R_1} v_s$$

$$v_{\text{out}} = \frac{d}{dt}\left( -\frac{L_f}{R_1} v_s \right) =$$