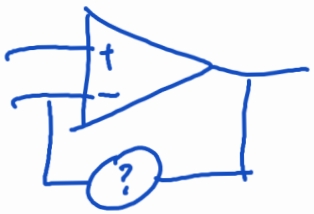
Opamps & 1st order

$i_c = C v_c'$

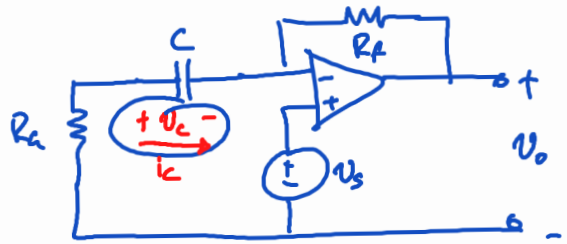


Rules
- $v^+ = v^-$ if neg fdbk
- $i^+ = 0$, $i^- = 0$

Analysis Method
- KCL @ Inputs
- never KCL @ output

Steps 1st order

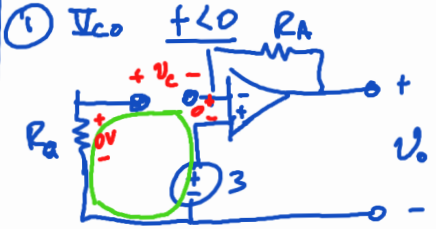
① V_{c0}, I_{L0} $t<0$ DC steady state
② τ $t>0$
③ $V_{c\infty}$, $I_{L\infty}$ $t=\infty$ DC steady state
④ $v_c = V_{c\infty} + (V_0 - V_{c\infty})e^{-t/\tau}$
i_L I I I
⑤ Find asked to find



$R_a = 20k$ $C = 5\mu F$
$R_f = 80k$ $v_s = 3u(t) + 3$

Find v_o

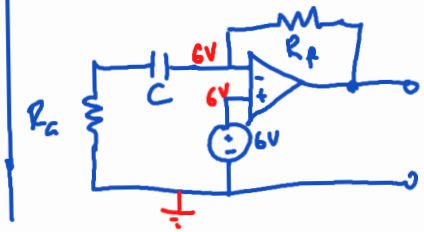
① V_{c0} $t<0$



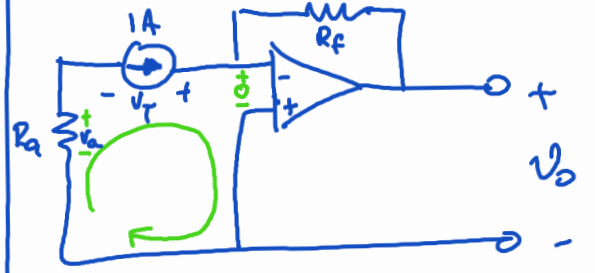
KVL: $-0 + v_c + 0 + 3 = 0$

$v_c = -3V$

② τ $t>0$ $\tau = R_{eq} \cdot C$



When find R_{eq} ($\tau = R_{eq} \cdot C$) for opamps
① zero all sources
② Replace C w/ $I_T = 1A$
③ V_T is across I_T $\Rightarrow R_{eq} = \frac{V_T}{I_T} \Rightarrow \tau = R_{eq} \cdot C$



KVL: $-V_a - V_T + 0 = 0$

$V_a = (-1A)R_a$

KVL $-R_a - V_T = 0$

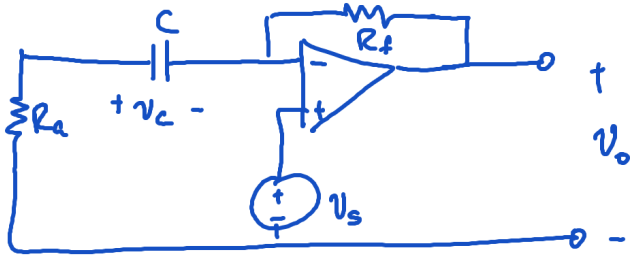
$V_T = R_a$

$R_{eq} = \frac{V_T}{I_T} = \frac{R_a}{1} = R_a$

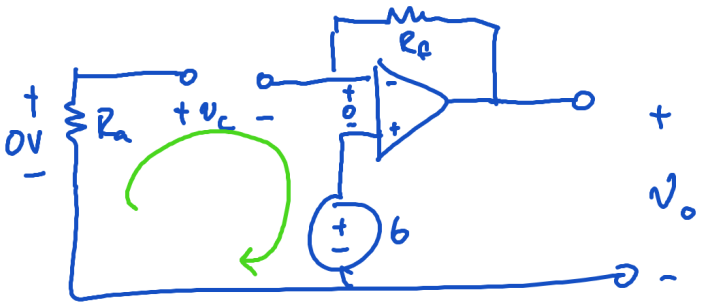
$\tau = R_{eq} \cdot C$
$= R_a \cdot C$
$= (20k)(5\mu)$
$= 100m = 0.1$

$\tau = 1/10$

$+1\tau$
$+1/100m$
$+1/(1/10) = 10t$

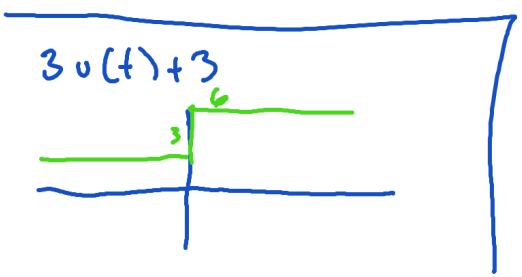


③ Find $V_{c\infty}$ $t=\infty$ DC steady state



KVL green: $-0 + v_c + 0 + 6 = 0$

$$V_{c\infty} = -6V$$

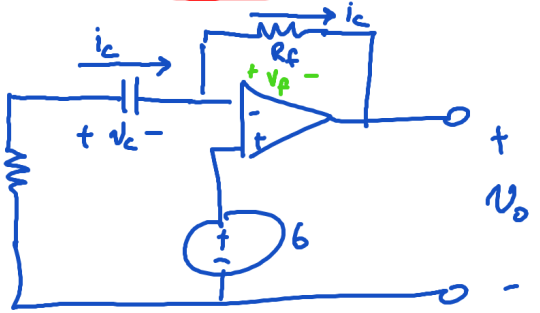


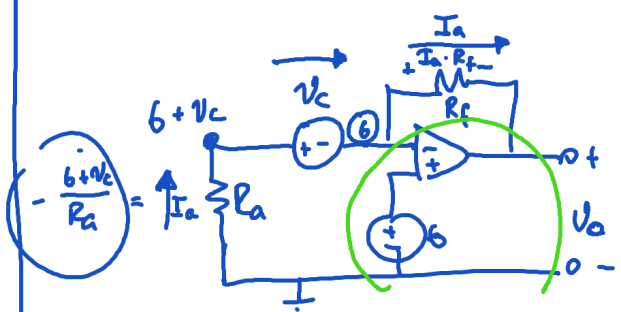
④ $v_c(t) = V_\infty + (V_0 - V_\infty)e^{-t/\tau}$

$= -6 + (-3 - -6)e^{-t/(4/10)}$

$= \boxed{-6 + 3e^{-10t} \; V, \; t \geq 0}$

⑤





$V_f = I_a \cdot R_f$

KVL: $-6 + 0 + V_f + V_0 = 0$

$V_0 = 6 - V_f$

$= 6 - I_a R_f$

$V_0 = 6 - \left(-\frac{6+v_c}{R_a}\right) R_f$

$= 6 + \frac{R_f}{R_a}(6 + v_c)$

$\doteq 6 + 4(3e^{-10t})$

$= \boxed{6 + 12e^{-10t} \; V}$

$i_c = C v_c'$

$= (5\mu)(-30e^{-10t}) A$

$= -150\mu e^{-10t} A$

$= \underline{-150 e^{-10t} \mu A}$

$V_f = R_f \cdot i_c$

$= (80k)(-150e^{-10t})\mu$

$-12\,00e^{-10t} m$

$= -12e^{-10t} V$

$V_0 =$

$-6 + 0 + V_f + V_0 = 0$

$-6 - 12e^{-10t} + V_0 = 0$

$\boxed{V_0 = 6 + 12e^{-10t} \; V}$