EECS16A DIS 5C

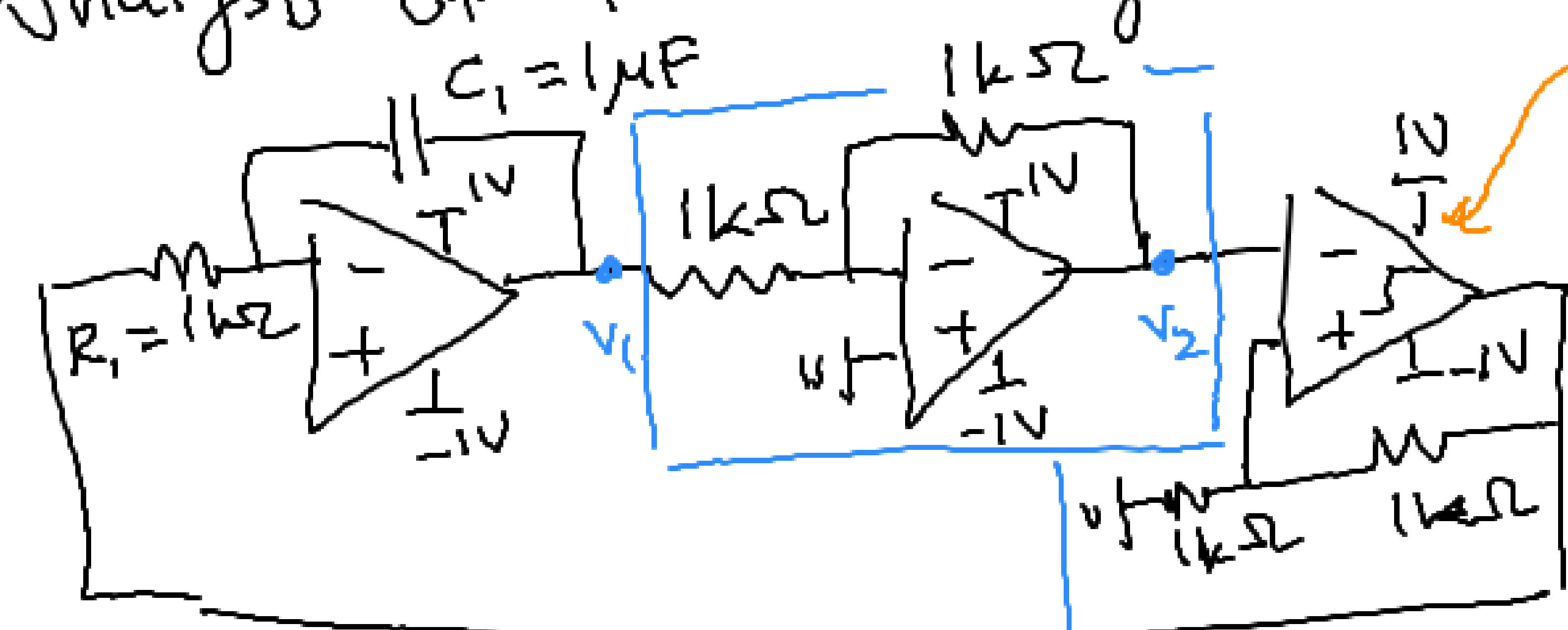
Interesting new circuit → Timer circuit / oscillator
Use op amps to produce a square wave

① More analysis of op amp circuits (identify topologies)

② Two new topologies
- → Integrator – integrate voltages
- → Schmitt trigger – make a better, noise resistant comparator

↑ out of scope (because of a DE)

Today: Analysis of the following ckt



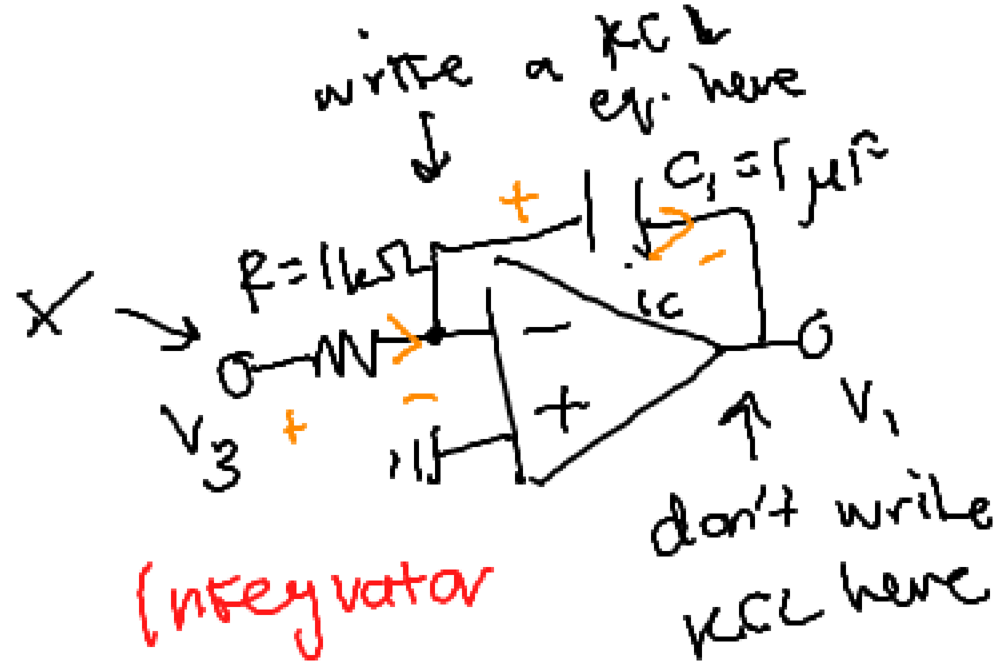
comparator
- not an op amp
- not in NFB

← this circuit is analyzable with the techniques you know

Any recognizable blocks?

inverting amp

$V_2 = -V_1$



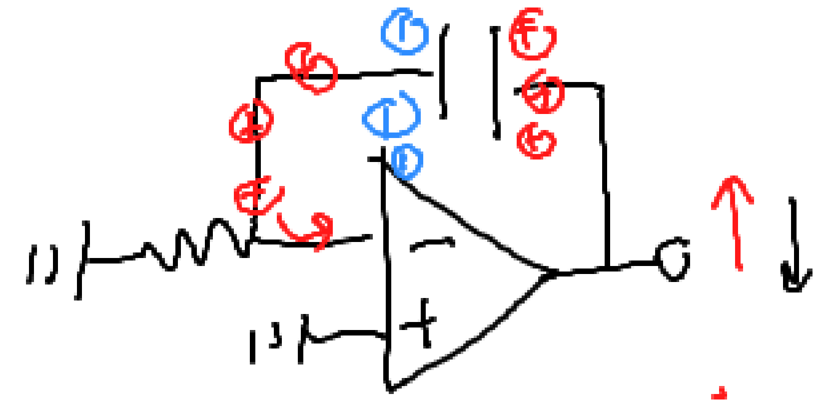
GR#2 if NFB → $U^+ = U^-$

$U^- = 0V$

KCL @ U^-

$$\frac{V_3 - 0V}{R} = i_C = C\frac{d}{dt}V_C$$
$$= C\frac{d}{dt}(0 - V_1)$$
$$\frac{V_3}{R} = -C\frac{d}{dt}V_1$$
$$\frac{dV_1}{dt} = -\frac{1}{RC}V_3$$
$$V_1(t) = -\frac{1}{RC}\int_0^t V_3(t)\,dt + V_1(0)$$

← reflection of initial charge that might be on C

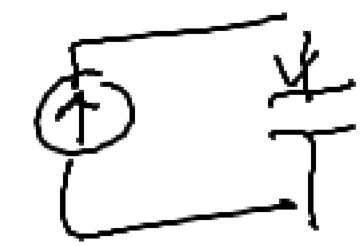


U^- @ beginning is 0V
output goes up
⇒ positive charge on U^-
U^- ↑ $V_{out} = A(U^+ - U^-)$ ↑ ↓

$$\int_{V_1(0)}^{V_1(t)} dV_1 = \int_0^t -\frac{1}{RC}V_3\,dt$$
$$V_1(t) - V_1(0) = -\frac{1}{RC}\int_0^t V_3(t)\,dt$$
$$V_1(t) = V_1(0) + -\frac{1}{RC}\int_0^t V_3(t)\,dt$$

Error: put = instead of +

$V_3 \sim I$



$V_{out} = \frac{I}{C}t$

This op amp circuit calculates an integral! Integrator op amp

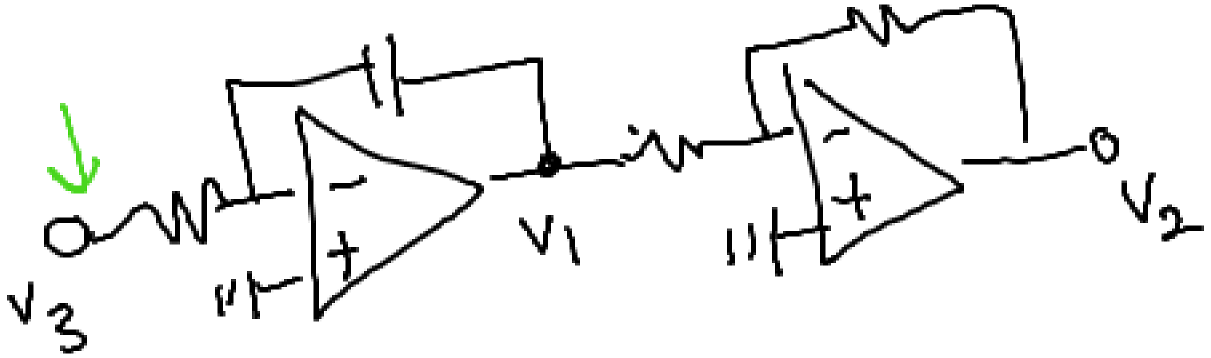
V_3 is constant for this problem

→ V_1 is linear with time

$$V_1 = \frac{-V_3 t}{RC}$$

$[\Omega][F]$
$\left[\frac{V}{A}\right]\left[\frac{C}{V}\right] = \left[\frac{1}{C/s}\right]\left[\frac{C}{1}\right]$ = seconds

$Q = CV$
$\frac{Q}{V} = C$



$$V_1 = -\frac{V_3}{RC}t + V_1(0)$$

(assuming V_3 is constant)

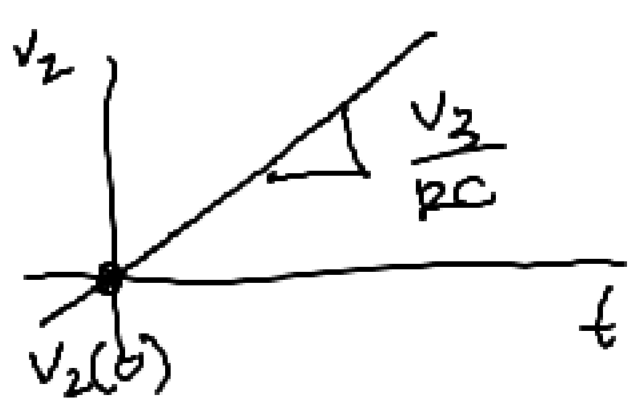
$$V_2 = -V_1$$

$$V_2 = \frac{V_3}{RC}t - V_1(0)$$

$$V_2 = \frac{V_3}{RC}t + V_2(0)$$

$$V_2(0) = \frac{V_3}{RC}\cdot 0 - V_1(0)$$

$$V_2(0) = -V_1(0)$$



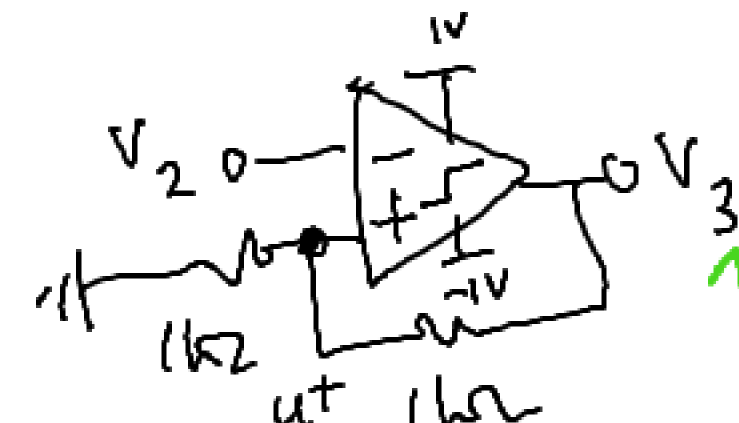
$R = 1k\Omega$

$C = 1\mu F$

$RC = 1msec$

$\Omega \cdot F = sec$

every one ms, increase V_2 by V_3 volts



Schmitt trigger

Comparator

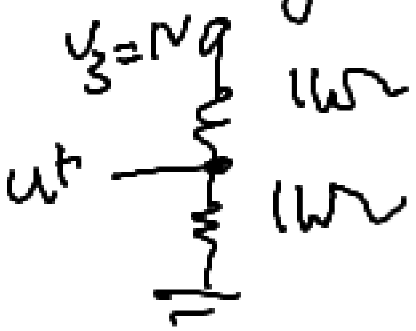
output: only Vdd/Vss

1V or -1V

If $V_3 = 1V$ what is u^+?

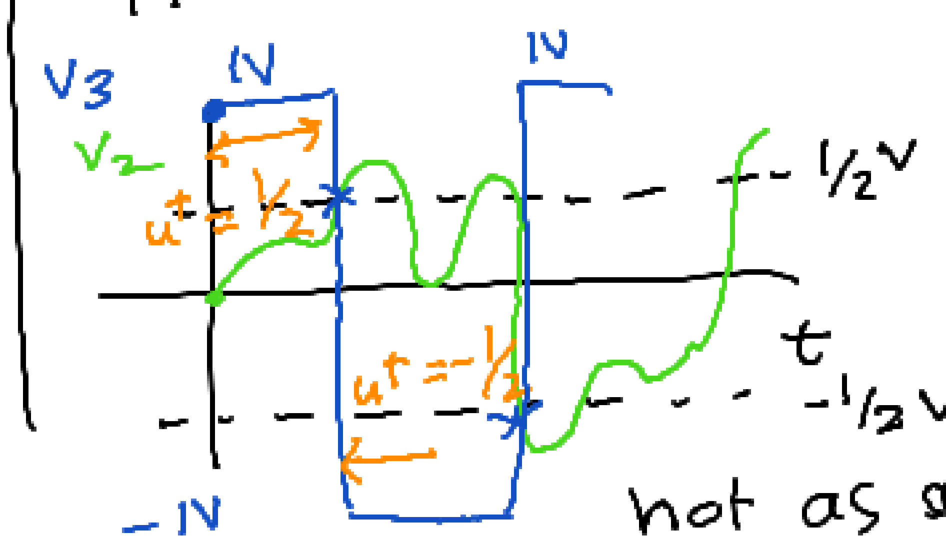
A: $u^+ = \frac{1}{2}V$ Why?: Voltage divider

$$u^+ = \frac{1k\Omega}{1k\Omega + 1k\Omega} \cdot 1V = \frac{1}{2}V$$



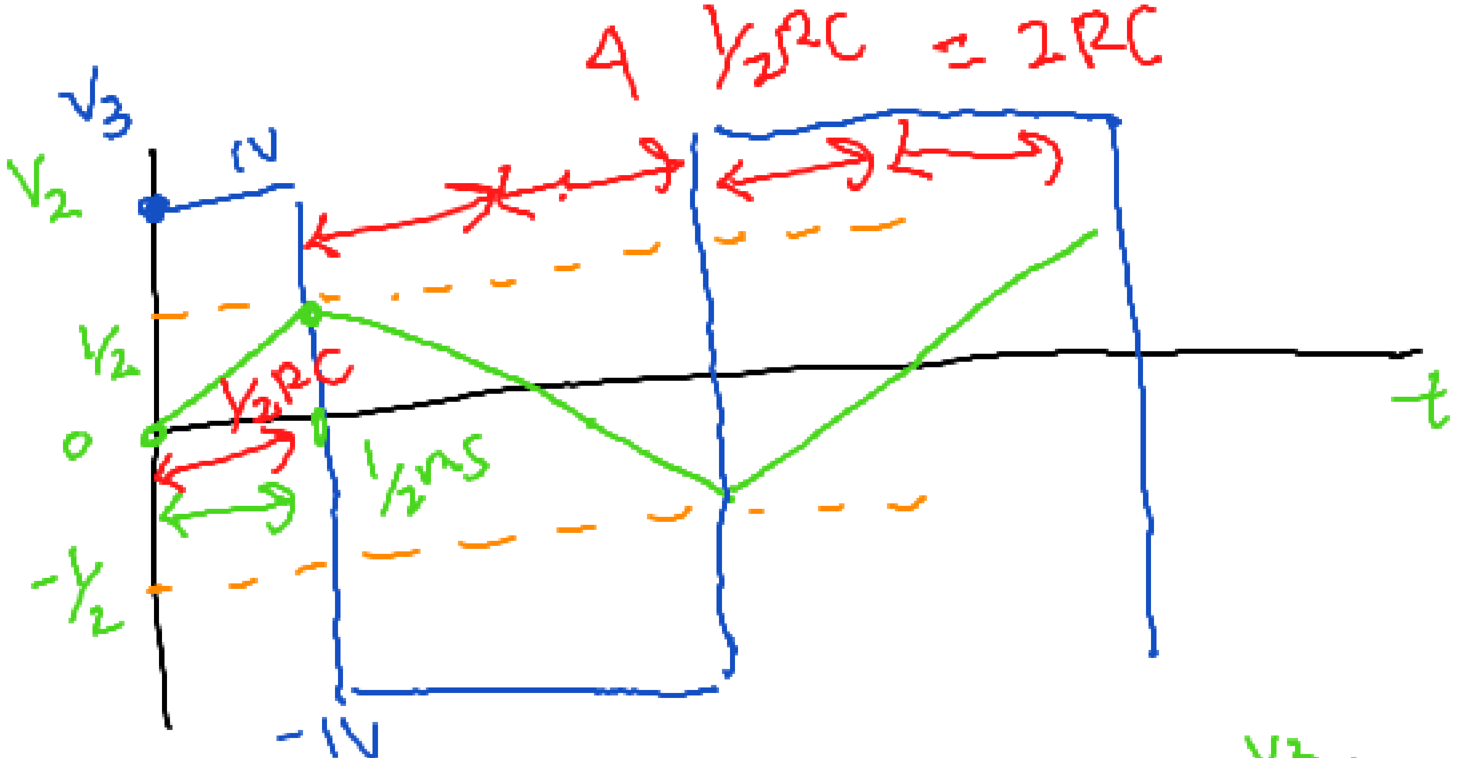
If $V_3 = -1V$ what is u^+? $u^+ = -\frac{1}{2}V$

How does V_2 affect V_3?



we only switch output when we exceed $\frac{1}{2}$ / $-\frac{1}{2}$

not as sensitive as a comp.



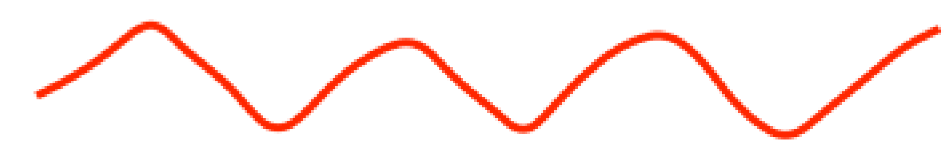
Conclusion: can get a square wave

⇓

a triangle wave ~~(sawtooth)~~

Error correction: sawtooth is:

This is a triangle wave:



$V_2(0) = 0V$

$V_3(0) = 1V$

$$V_2(t) = \frac{V_3}{RC}t + V_2(0)$$
$$= \frac{1V}{1ms}t + 0$$

$V_2(t) = \frac{1}{2}V$

$t = ?$

$$\frac{1}{2}V = \frac{1V}{1ms}t \ni t = \frac{1}{2}ms$$

$$V_2(t) = \frac{V_3}{RC}t + \frac{1}{2}V$$

time from 1/2ms

$$V_2(t) = \frac{-1V}{1ms}t + \frac{1}{2}V$$

Period of the waves is determined by RC