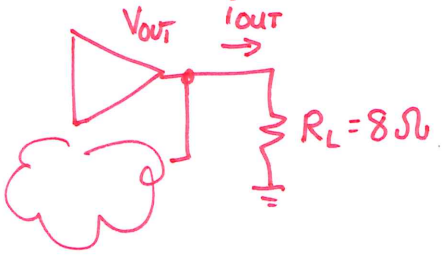
Output Limits:
- Voltage LIMITED BY SUPPLY VOLTAGES (WITHIN 0.1V TO 2V)
- Current ★
- Slew Rate Limiting

Active Lowpass filter
Integrator

★ CURRENT LIMIT

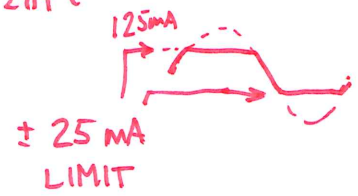


$i_{OUT} = \frac{V_{OUT}}{R_L}$ } COMPARE TO LIMIT

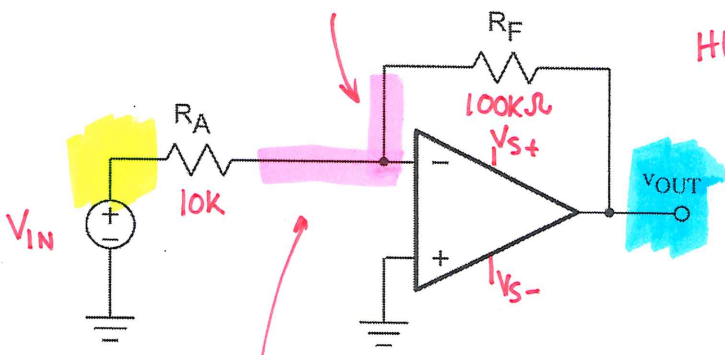
$V_{OUT} = 1V \sin 2\pi f t$

$i_{OUT} = \frac{1V}{8\Omega} \sin 2\pi f t$

$\frac{1V}{8\Omega} = 125mA$



SHOULD BE EQUAL TO V_+ (0V) IF A (OPEN LOOP GAIN) HIGH ENOUGH



$= -10\ V_{IN}$

VIRTUAL GROUND 0V NOT MAINTAINED

WHEN OUTPUT IS LIMITED

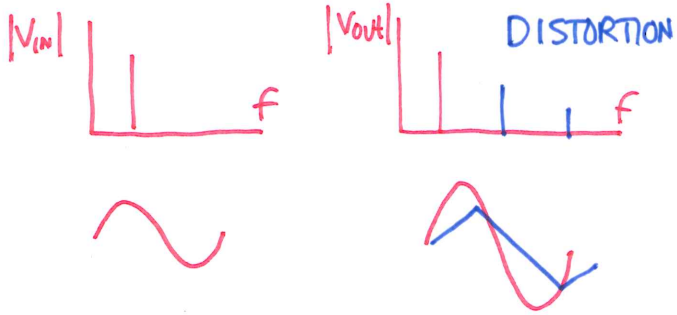
$V_{OUT}(MAX)$

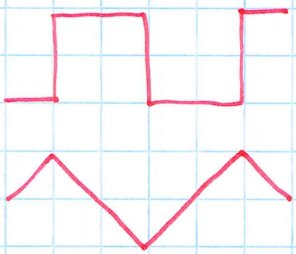
$I_{OUT}(MAX)$

dV_{OUT}/dT (SLEW)

NOT LINEAR SYSTEM BEHAVIOR

~~H(f)~~ sin ωt IN → sin ωt OUT

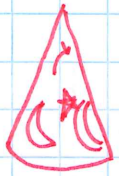




SQUARE WAVE

↓

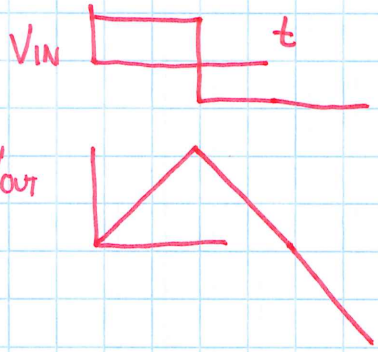
TRIANGLE WAVE?



☐ MAGIC

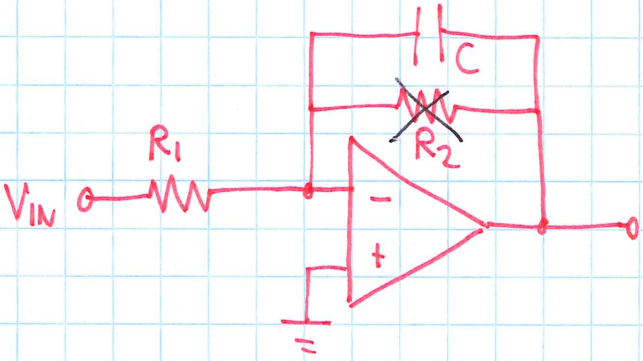
☐ ANALOG MAGIC

$V_{OUT} = \int V_{IN}\, dt$



MAKE AN INTEGRATOR?

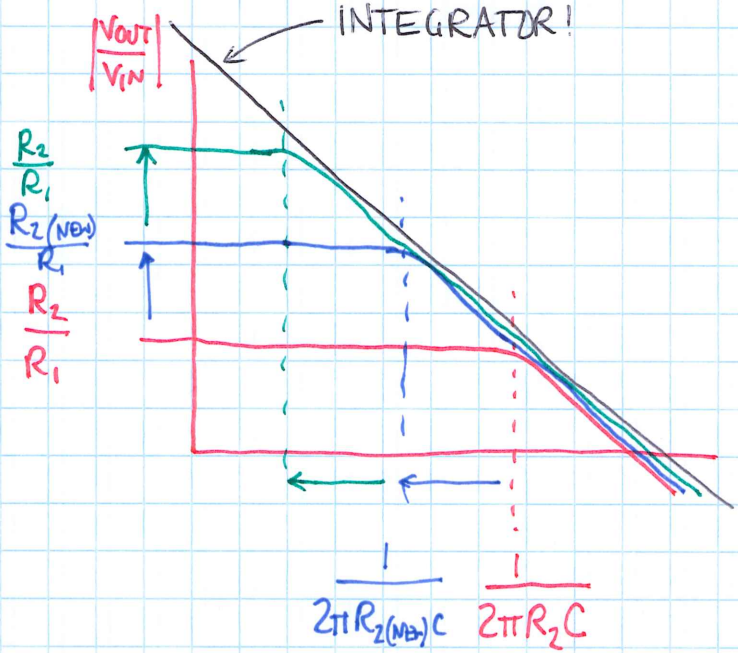
RC ACTIVE LOWPASS FILTER



} ADDED C TO GO FROM $R_F \rightarrow Z_F$

$$Z_F = \frac{R_2}{1+j\omega R_2 C}$$

$$\frac{V_{OUT}}{V_{IN}} = \frac{-R_2/R_1}{1+j\omega R_2 C}$$

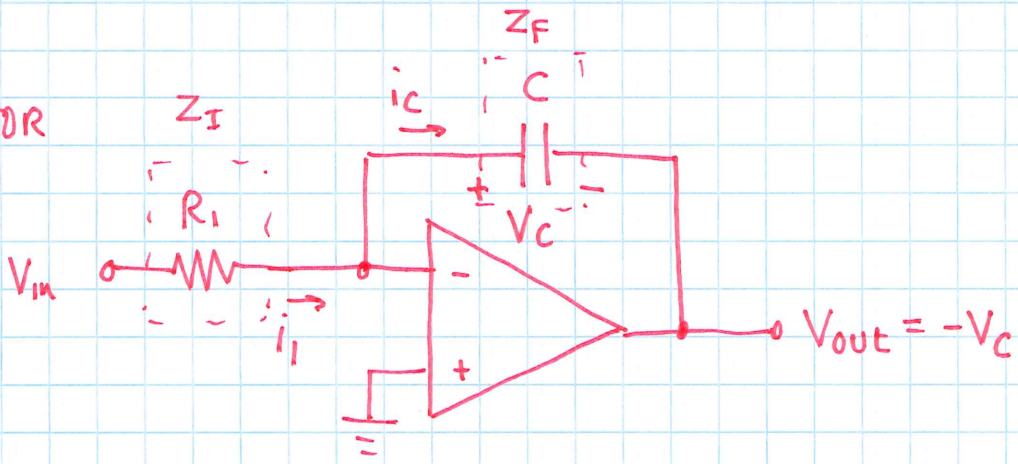


$R_2 = \infty$

R_2 - 10X higher

R_2 ANOTHER 10X higher

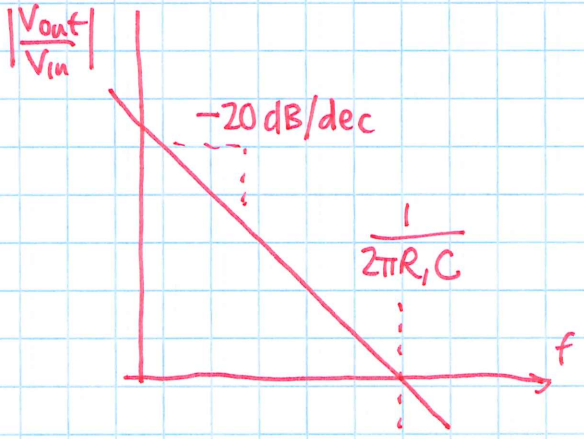
INTEGRATOR



FREQUENCY DOMAIN:

$$\frac{V_{out}}{V_{in}} = \frac{-Z_F}{Z_I} = \frac{\frac{-1}{j\omega C}}{R_1}$$

$$\boxed{\frac{V_{out}}{V_{in}} = \frac{-1}{j\omega R_1 C}}$$



TIME DOMAIN

FOR CAPACITOR:

$$i_C = C\frac{dV_c}{dt}$$

$$i_C\,dt = C\,dV_c$$

INTEGRATE BOTH SIDES FROM t_0 TO t

$$\int_{t_0}^{t} i_C\,dt = C\int_{t_0}^{t} dV_c$$

$$\int_{t_0}^{t} \frac{V_{IN}}{R_1}\,dt = C\left[V_c(t) - V_c(t_0)\right]$$

SOLVE FOR $V_c(t)$

$$V_c(t) = \frac{1}{R_1 C}\int_{t_0}^{t} V_{IN}(t)\,dt + V_c(t_0)$$

$V_o = -V_c$

$$\boxed{V_o(t) = \frac{-1}{R_1 C}\int_{t_0}^{t} V_{IN}(t)\,dt + \underbrace{V_o(t_0)}_{\text{INIT COND}}}$$