TFE4188 - Introduction to Lecture 9

Oscillators

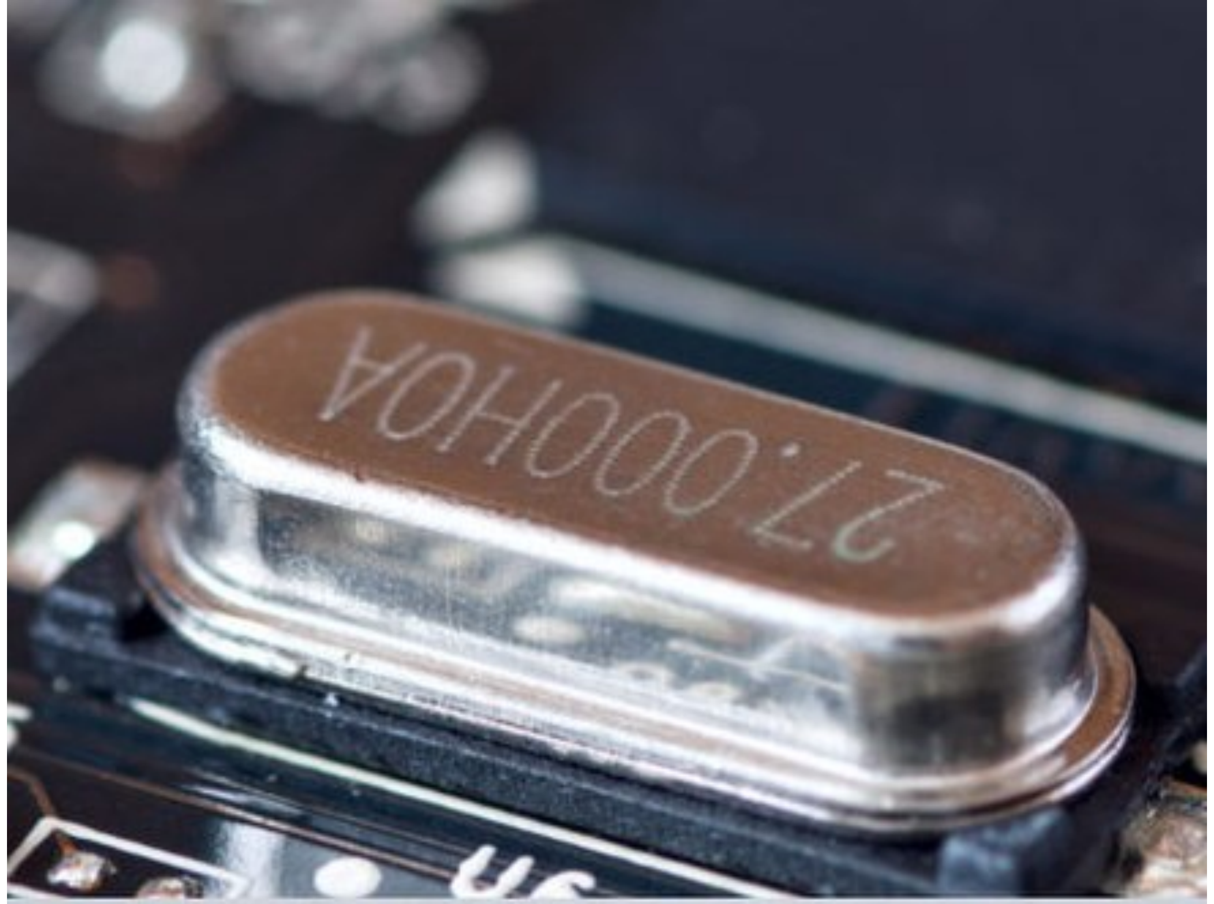
Goal

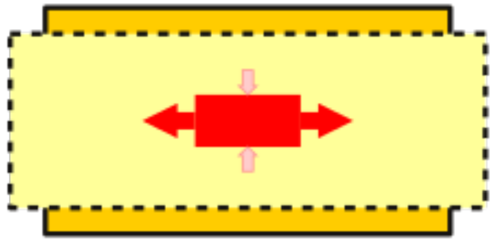
Introduction to **Crystal Oscillators**

Introduction to **VCOs**

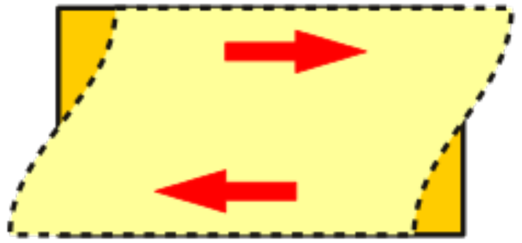
Introduction to **Relaxation-oscillators**

Crystal oscillators

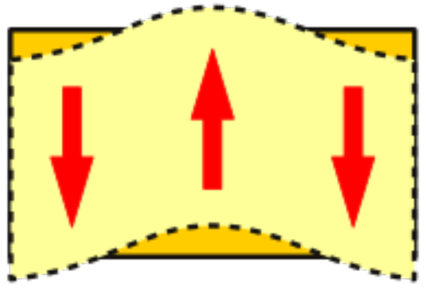

27.000H0A



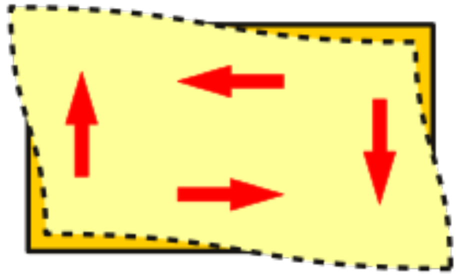
Longitudinal mode



Thickness shear mode

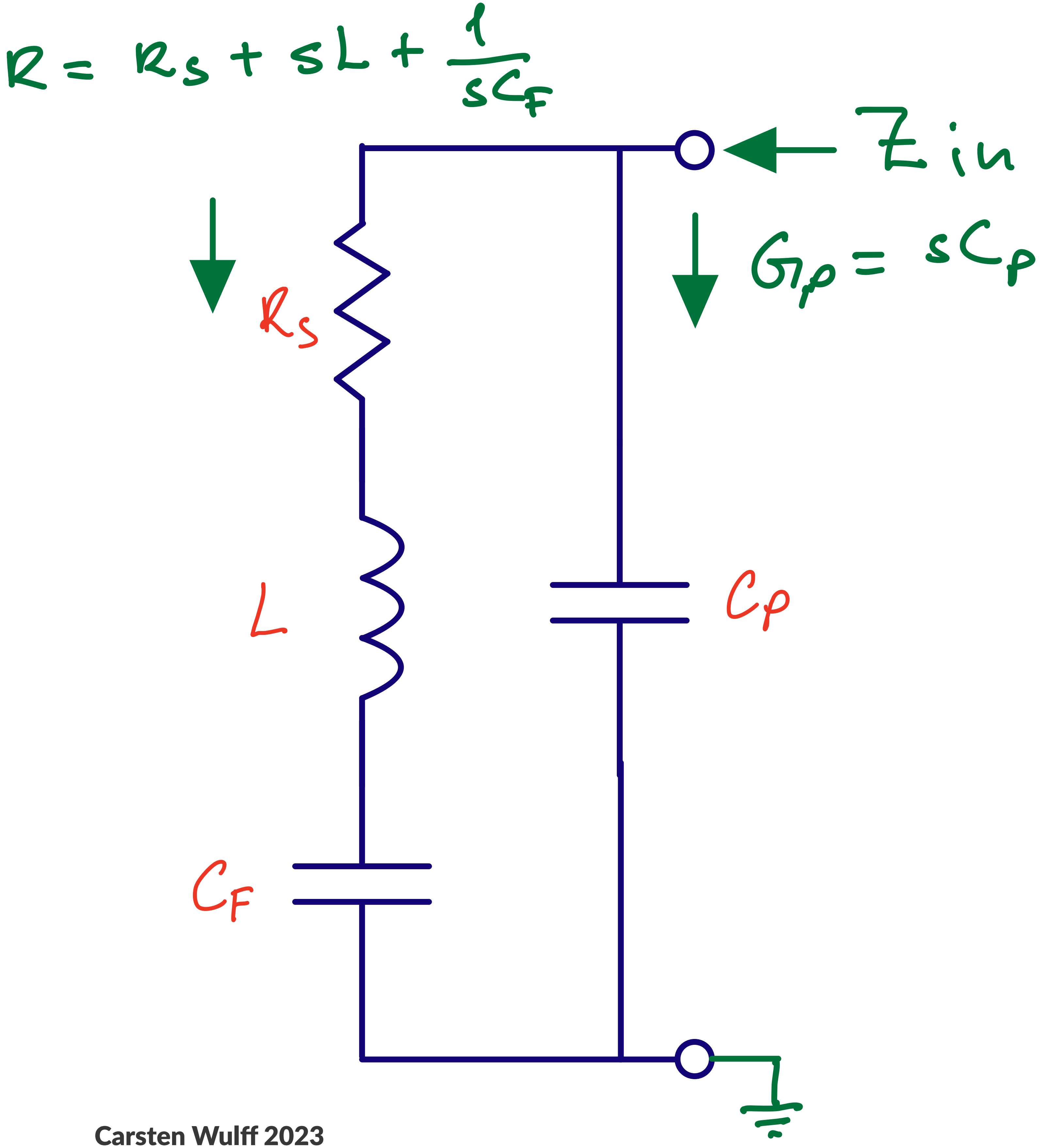


Flexural mode



Face shear mode

Tuning fork



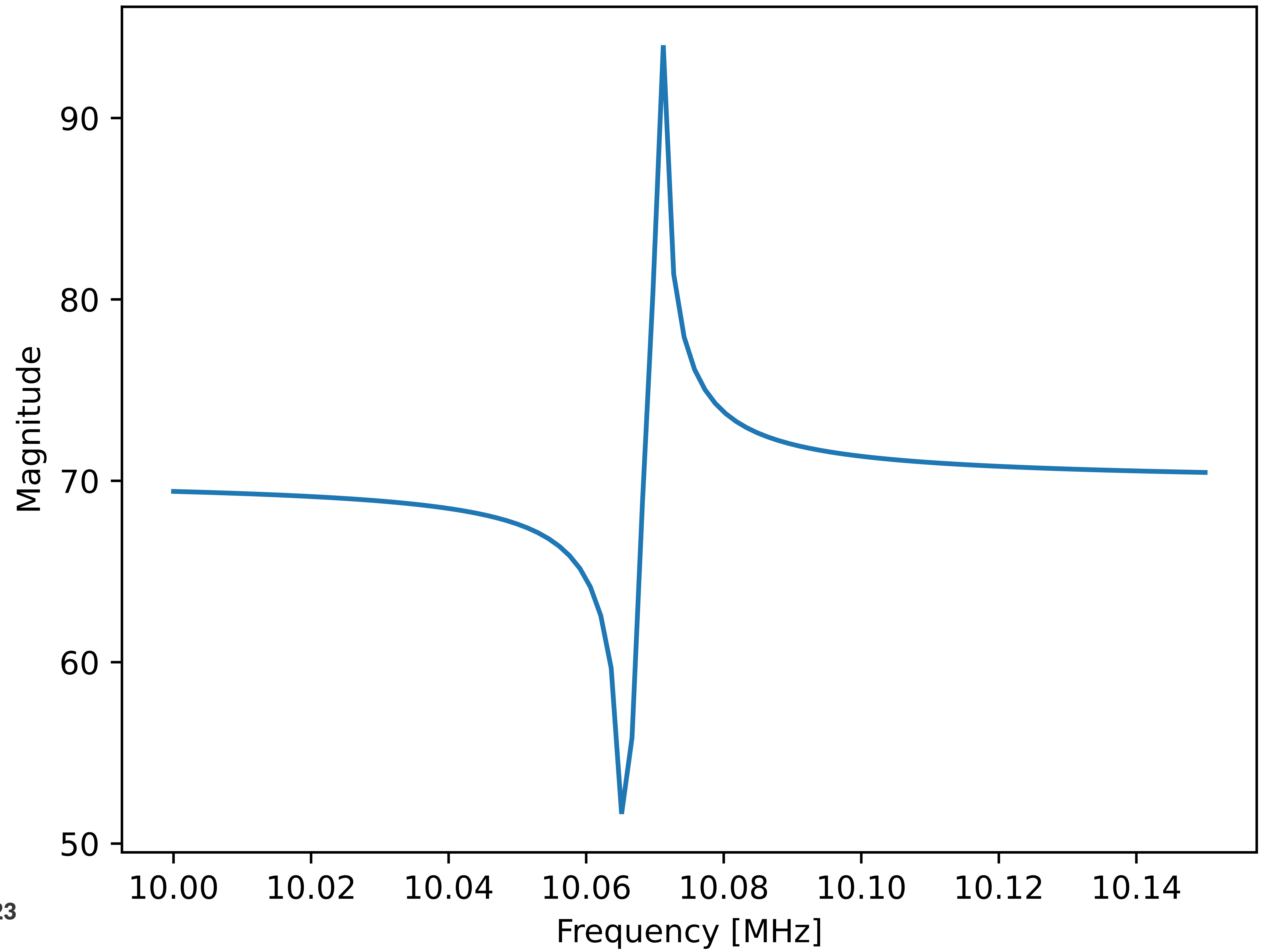
Assuming zero series resistance

$$Z_{in} = \frac{s^2 C_F L + 1}{s^3 C_P L C_F + s C_P + s C_F}$$

Since the 1/(sCp) does not change much at resonance, then

$$Z_{in} \approx \frac{L C_F s^2 + 1}{L C_F C_p s^2 + C_F + C_P}$$

See Crystal oscillator impedance for a detailed explanation.

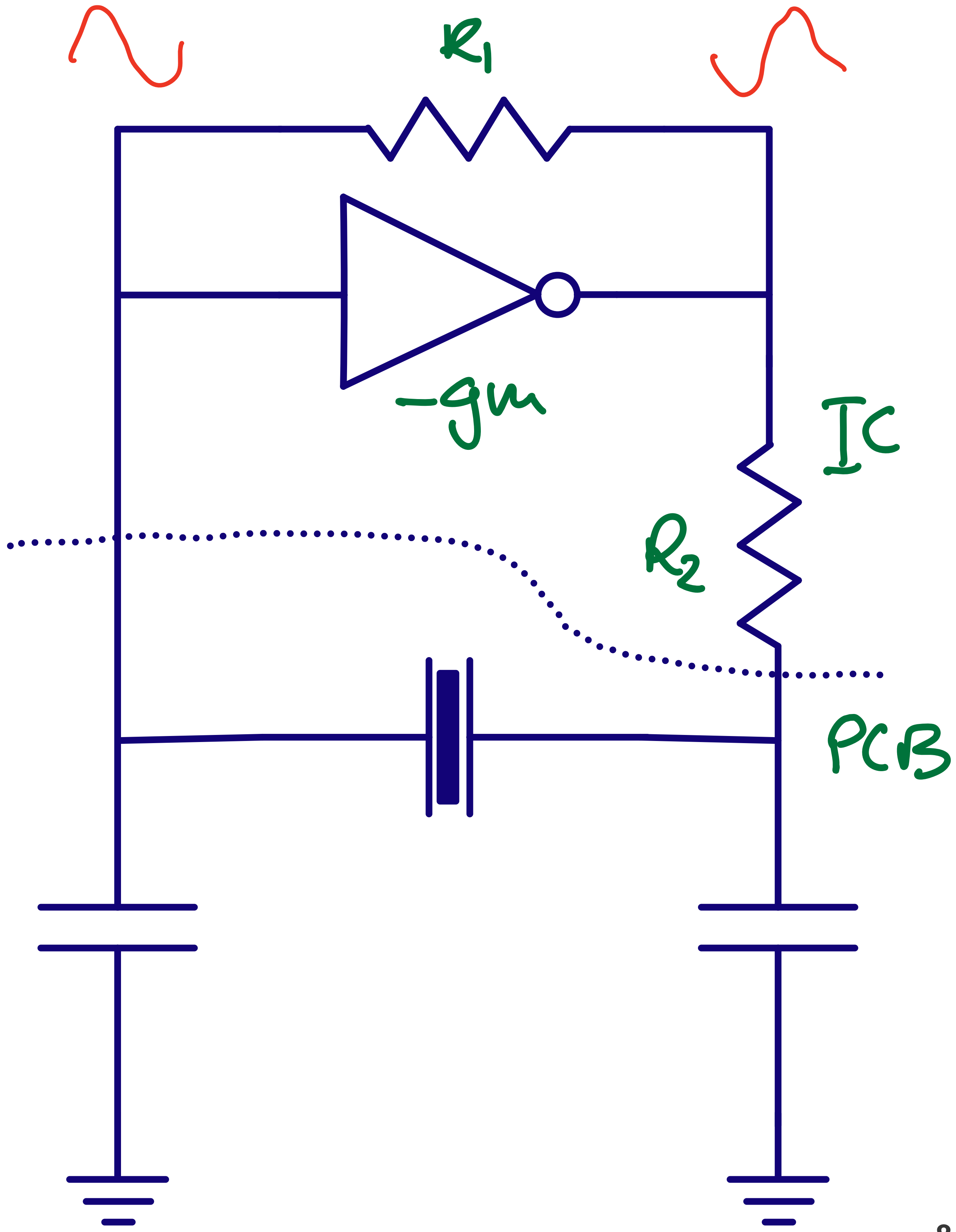


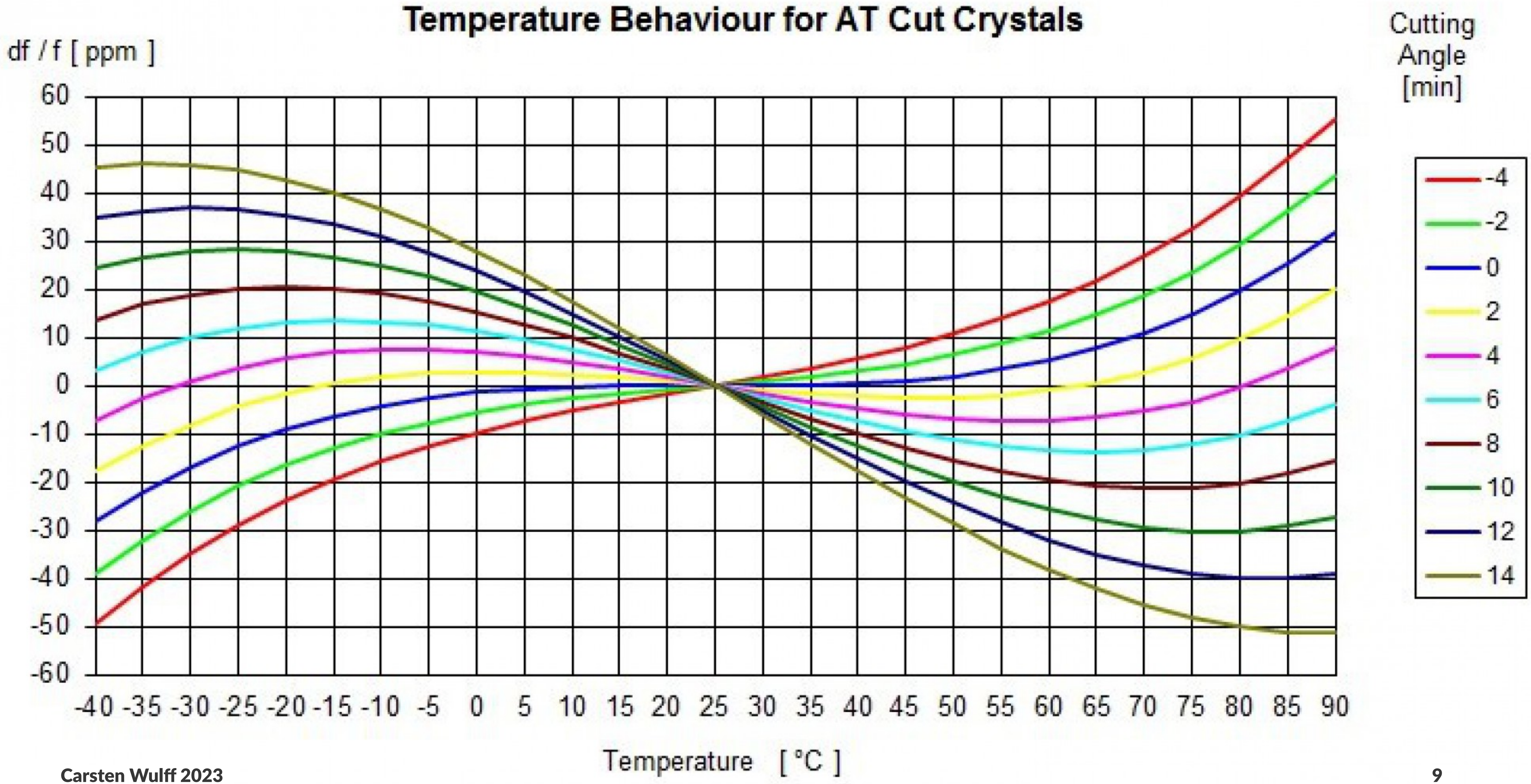
90
80
70
60
50
Magnitude
10.00
10.02
10.04
10.06
10.08
10.10
10.12
10.14
Frequency [MHz]

Negative transconductance compensate crystal series resistance

Long startup time caused by high Q

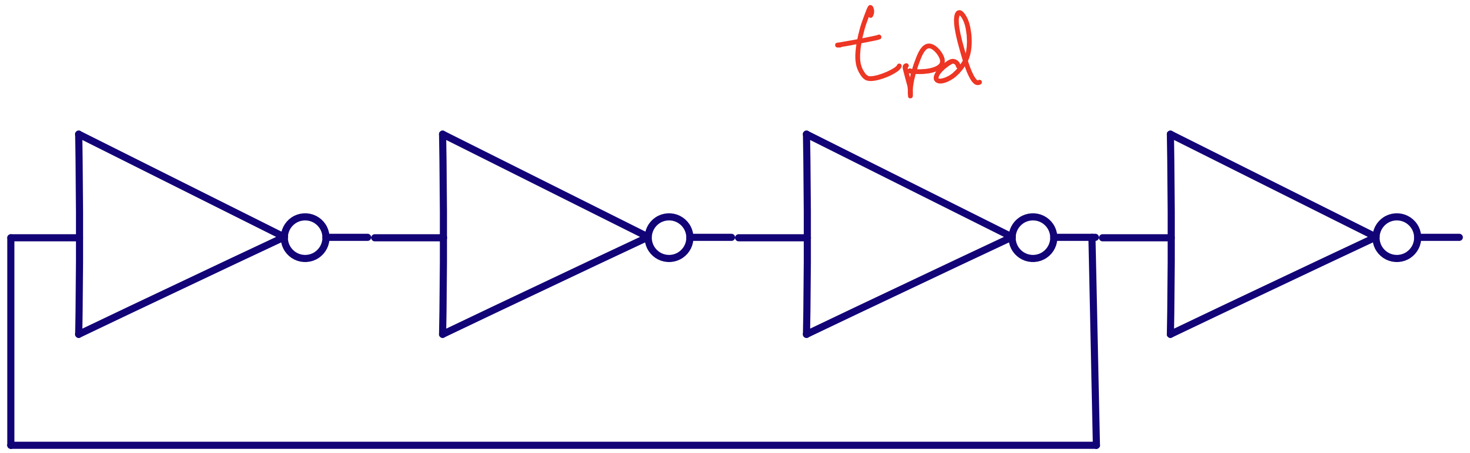
Can fine tune frequency with parasitic capacitance




Temperature Behaviour for AT Cut Crystals
df / f [ppm]
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-40 -35 -30 -25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
Temperature [°C]
Cutting Angle [min]
-4
-2
0
2
4
6
8
10
12
14

Controlled Oscillators

Ring oscillator



$$t_{pd} \approx RC$$

$$R \approx \frac{1}{gm} \approx \frac{1}{\mu_n C_{ox} \frac{W}{L}(VDD - V_{th})}$$

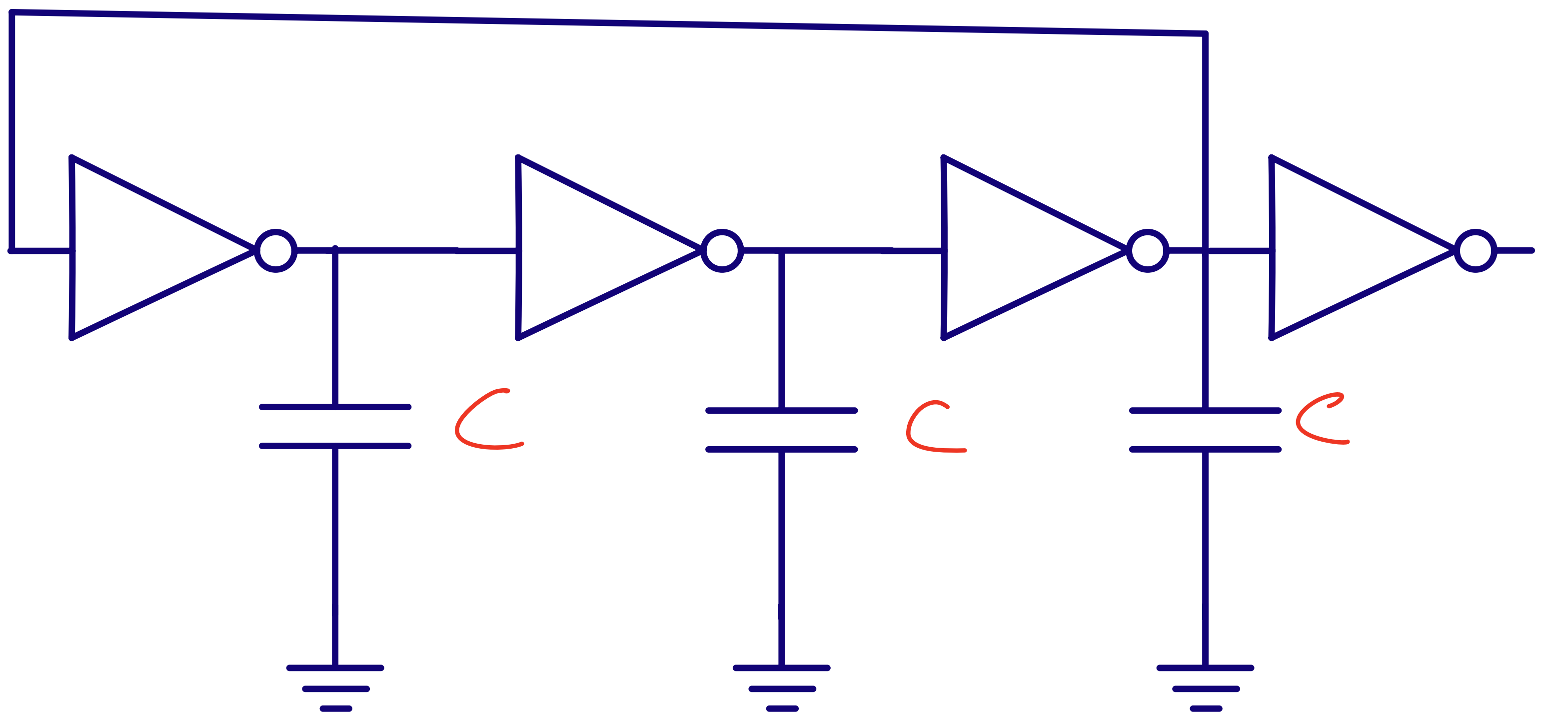
$$C \approx \frac{2}{3} C_{ox} W L$$

$$t_{pd} \approx \frac{2/3 C_{ox} W L}{\frac{W}{L}\mu_n C_{ox}(VDD - V_{th})}$$

$$f = \frac{1}{2 N t_{pd}} = \frac{\mu_n (VDD - V_{th})}{\frac{4}{3} N L^2}$$

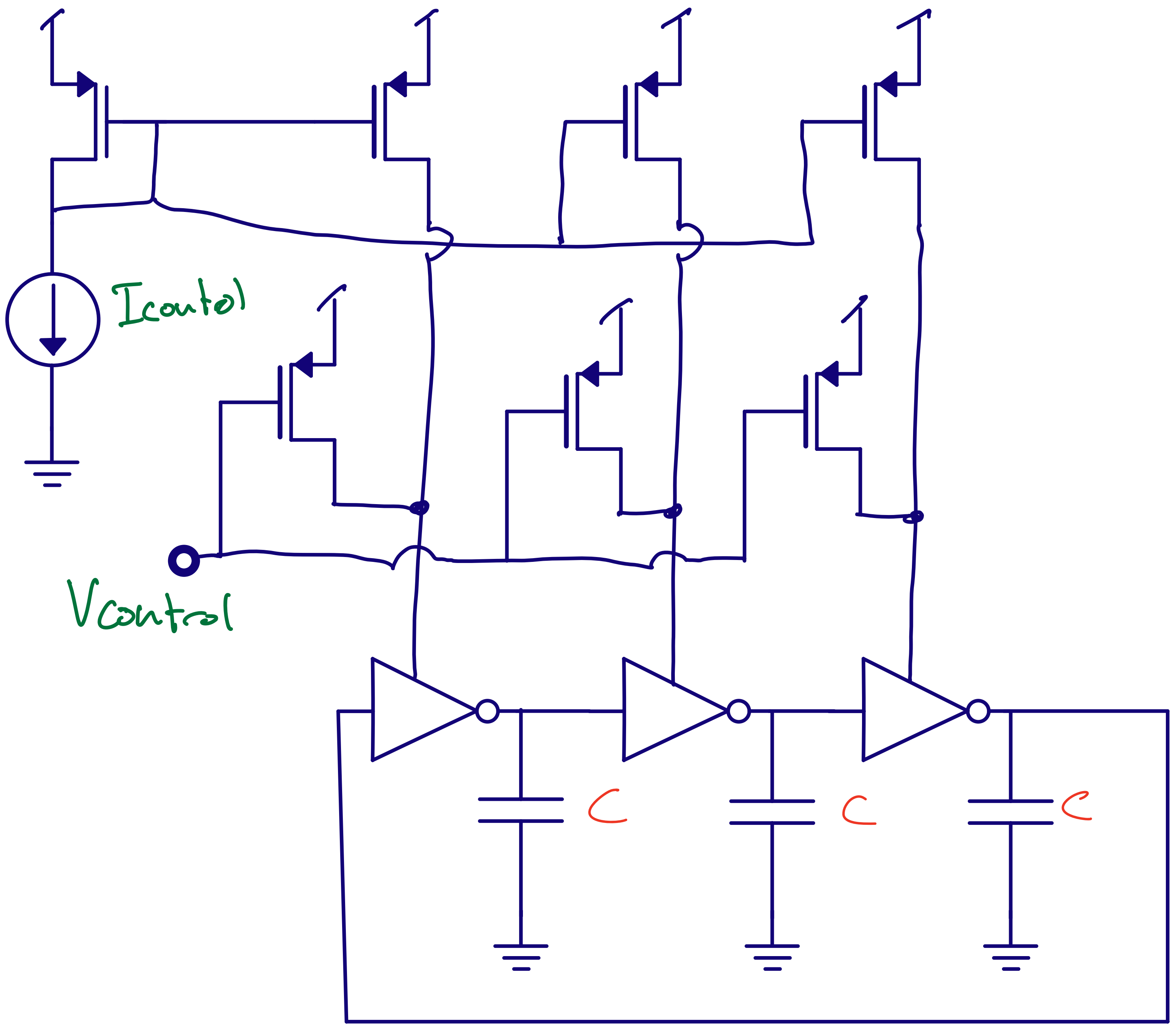
$$K_{vco} = 2\pi \frac{\partial f}{\partial VDD} = \frac{2\pi \mu_n}{\frac{4}{3} N L^2}$$

Capacitive load



$$f = \frac{\mu_n C_{ox} \frac{W}{L} (VDD - V_{th})}{2N\left(\frac{2}{3} C_{ox} WL + C\right)}$$

$$K_{vco} = \frac{2\pi \mu_n C_{ox} \frac{W}{L}}{2N\left(\frac{2}{3} C_{ox} WL + C\right)}$$



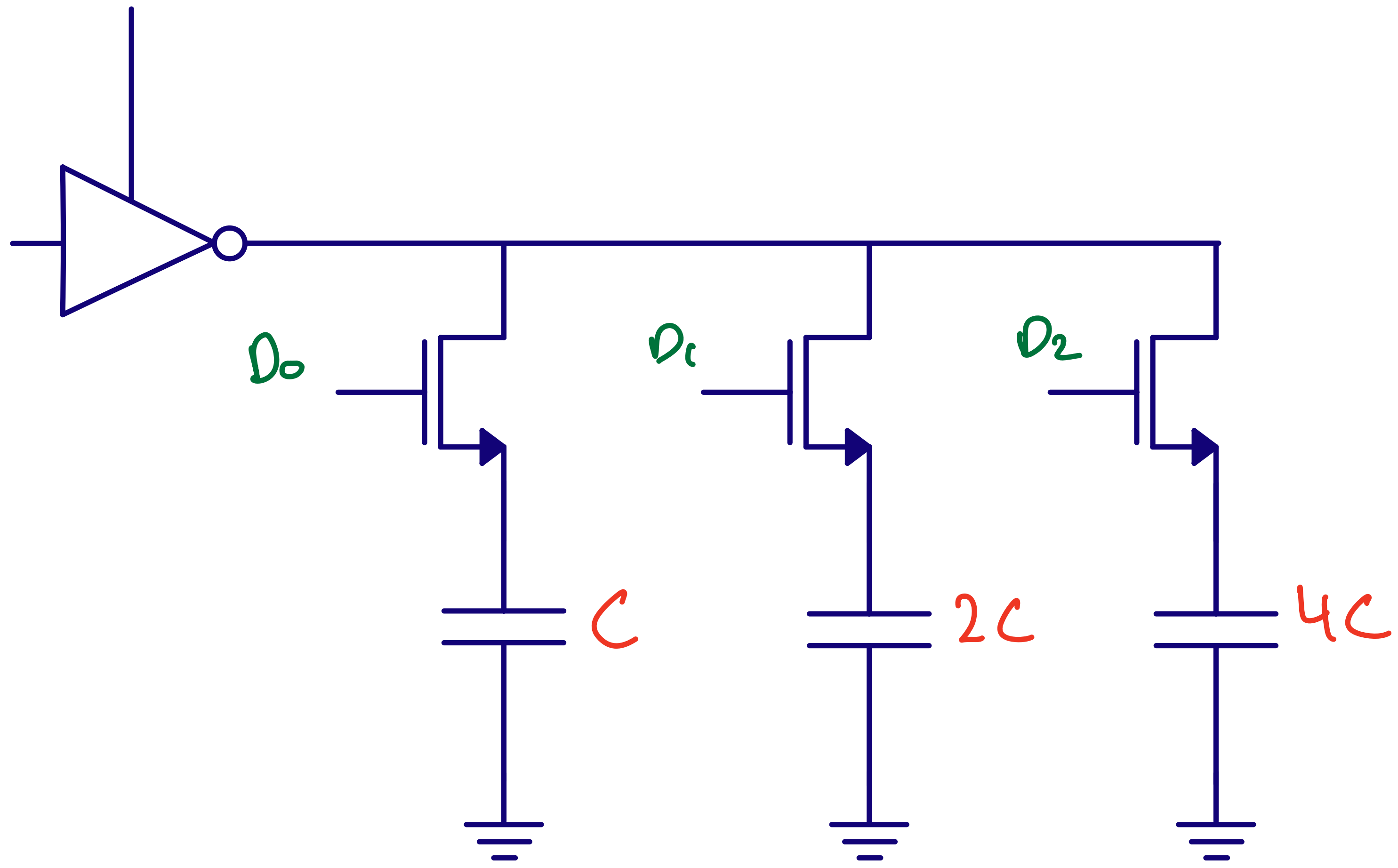
Realistic

$$I = C\frac{dV}{dt}$$

$$f \approx \frac{I_{control} + \frac{1}{2}\mu_p C_{ox}\frac{W}{L}(VDD - V_{control} - V_{th})^2}{C\frac{VDD}{2}N}$$

$$K_{vco} = 2\pi\frac{\partial f}{\partial V_{control}}$$

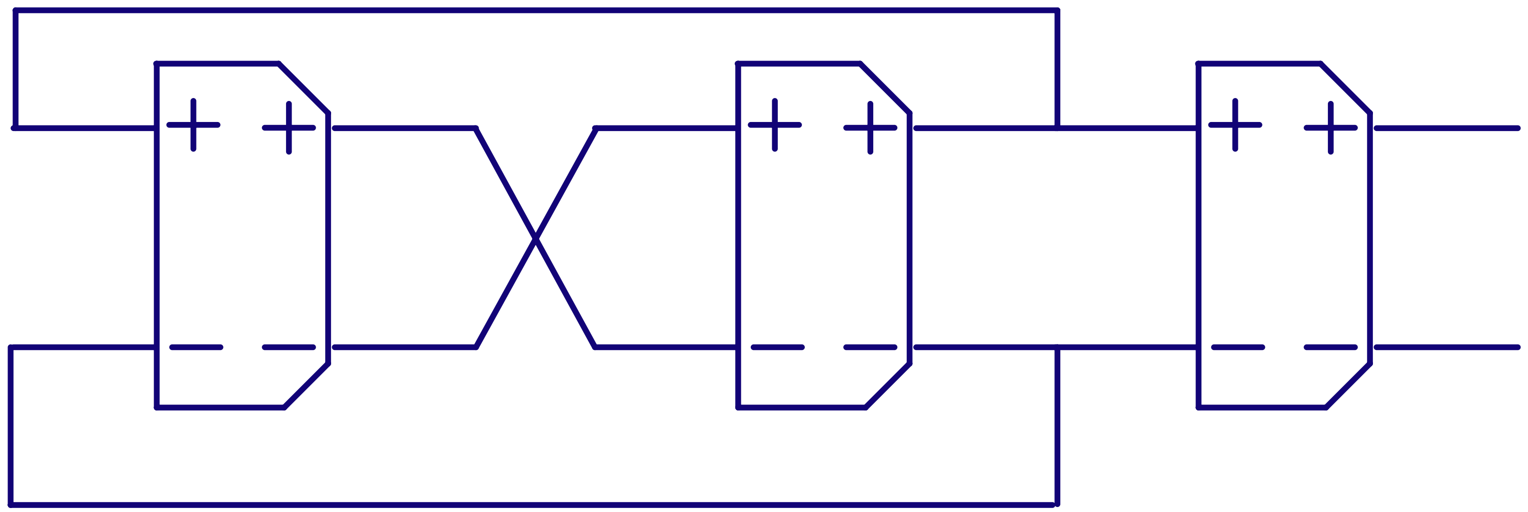
$$K_{vco} = 2\pi\frac{\mu_p C_{ox} W/L}{C\frac{VDD}{2}N}$$

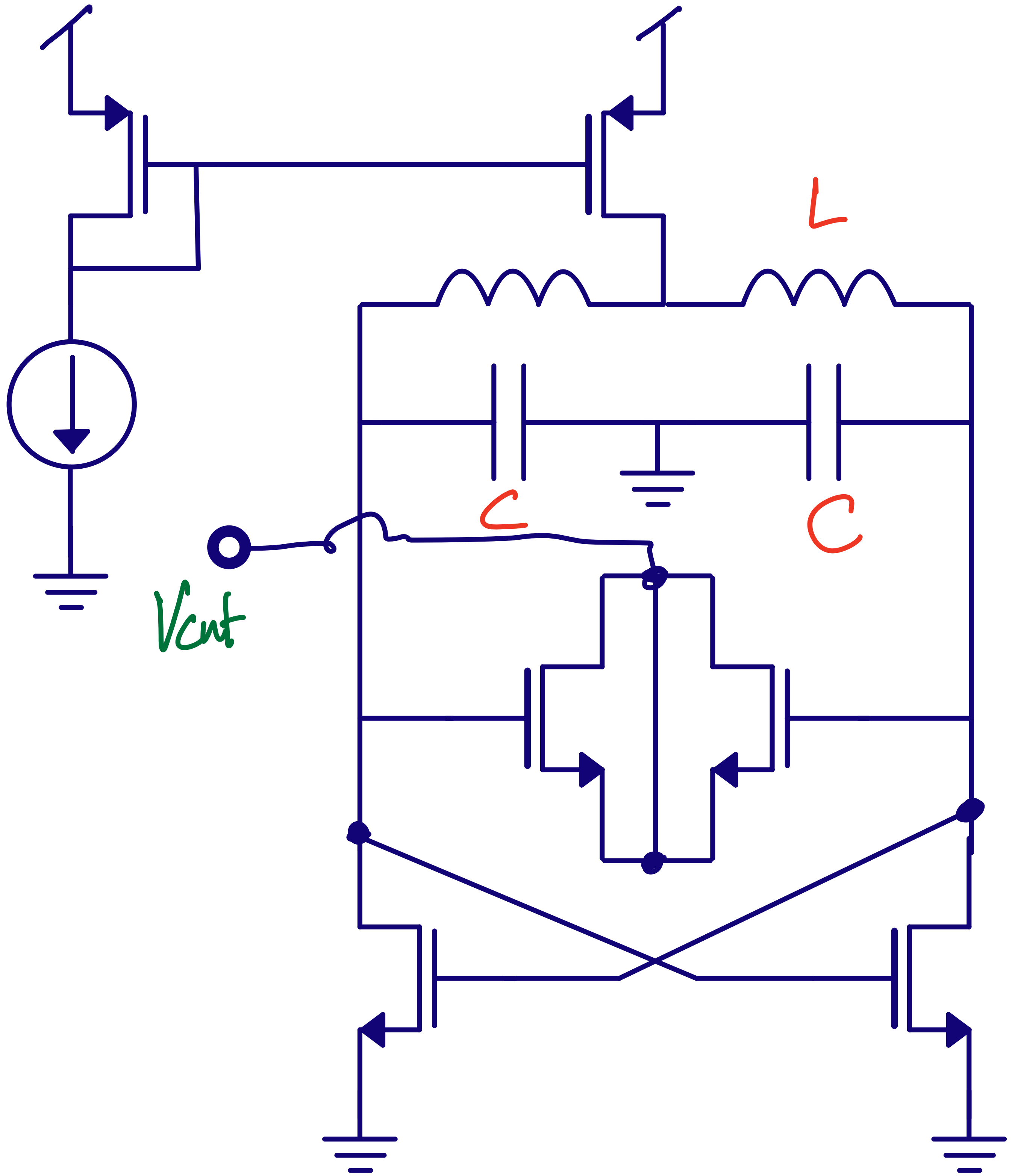


Digitally controlled oscillator

Differential

Potentially less sensitive to supply noise

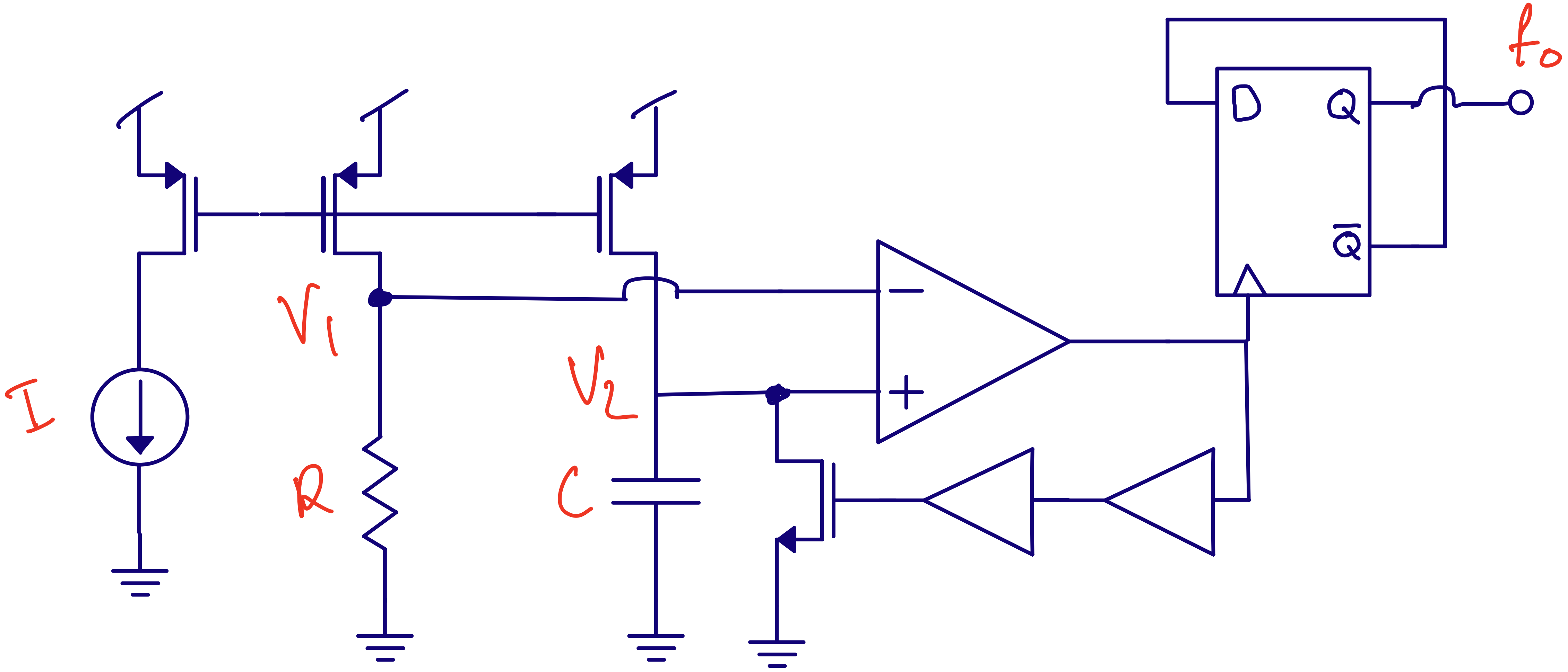




LC oscillator

$$f \propto \frac{1}{\sqrt{LC}}$$

Relaxation oscillators



Q: Show that Fo is 1/(2RC)

Additional material

The Crystal Oscillator - A Circuit for All Seasons

The Delay-Locked Loop - A Circuit for All Seasons

The Ring Oscillator - A Circuit for All Seasons

Thanks!