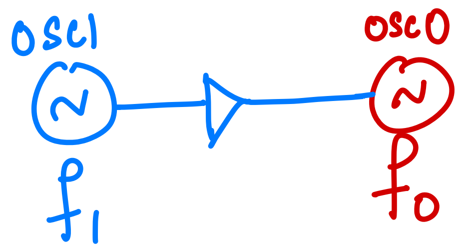
Injection Locking - Introduction

What is injection locking?



If $|f_1 - f_0| \leq \Delta f$, then osc0 spontaneously oscillates at f_1 & has a well defined phase relationship with osc1.

aka "Entrainment"

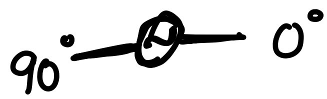
What if $|f_1 - f_0| > \Delta f$?

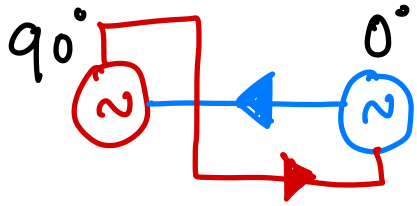
Then you get *Injection Pulling*, where osc-0 tries to lock but fails
⇒ Spectrum gets spread out or "corrupted"

Why do we care?

1) One clean signal (PLL), it can be easily duplicated. ⇒ Better phase noise performance & freq. stability.

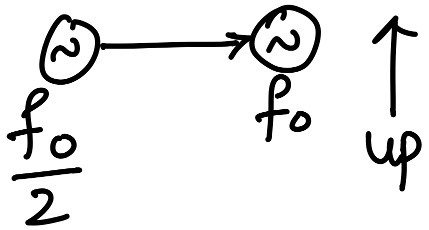
2) Quadrature signal generation.

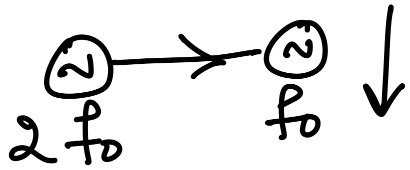




"anti-phase" coupling.

3) Sub-harmonic & Super-harmonic locking.





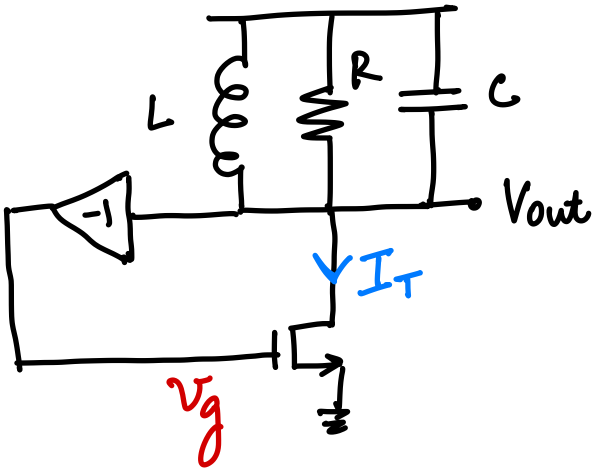
*4) > Large scale phase arrays at MM-wave & for wireless power transfer.

> Ising machines for NP-Hard combinatorial problems.

5) Pulling is generally considered bad!
(So we want to avoid it)

Intuition - (From a circuit design perspespective)

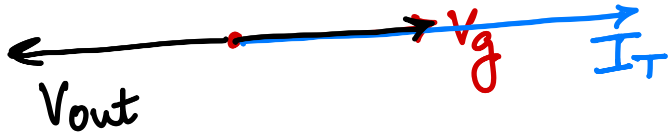
Concept #1



(Assume Barkhausen to be true)

- If the loop gain is 1 ⇒ oscillates!

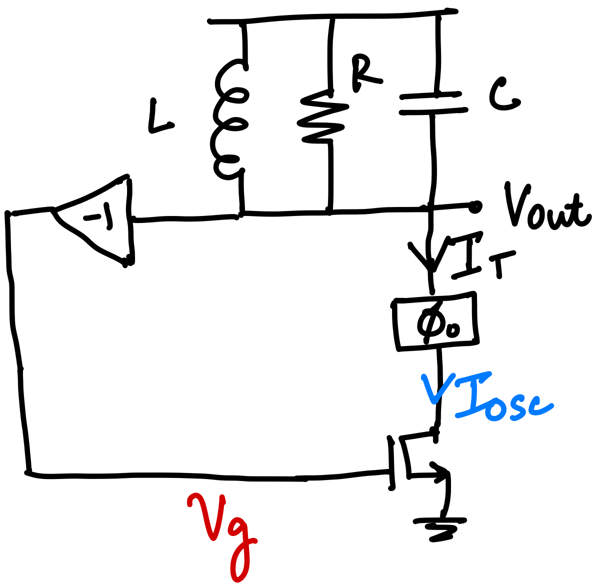
$$\angle \frac{V_{out}}{I_T} = 180^\circ \quad \Big| \quad \frac{V_{DD} - V_{out}}{I_T} = R$$

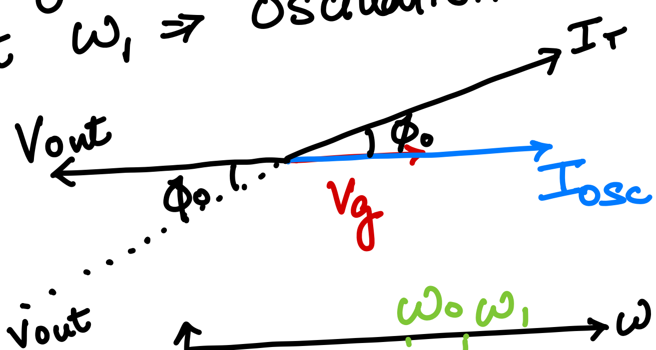


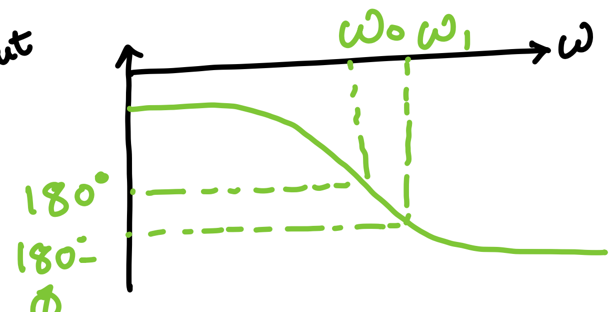
⇒ circuit oscillates at ω_0 → resonance freq. of the tank $= \frac{1}{\sqrt{LC}}$

Concept #2

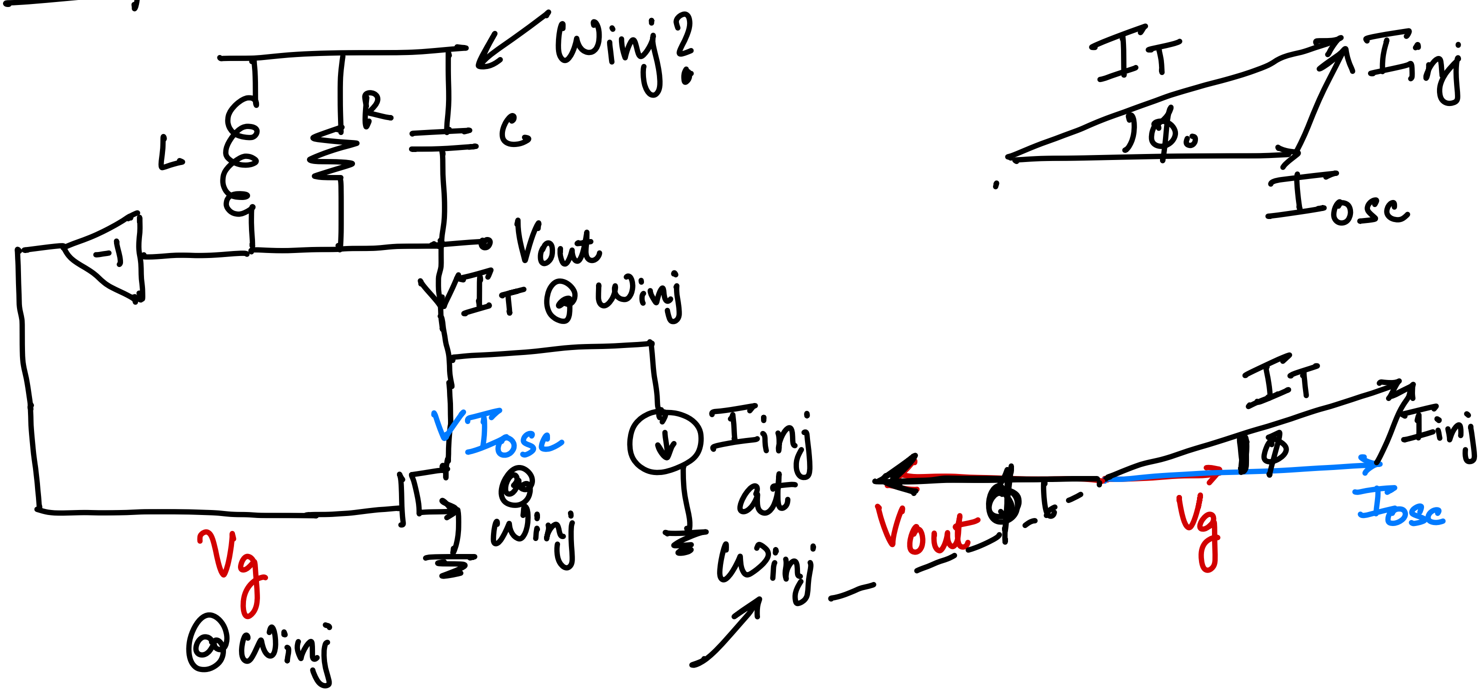
"Loop gain condition is satisfied at ω_1 ⇒ oscillation occurs at ω_1".







Concept #3



Mechanism

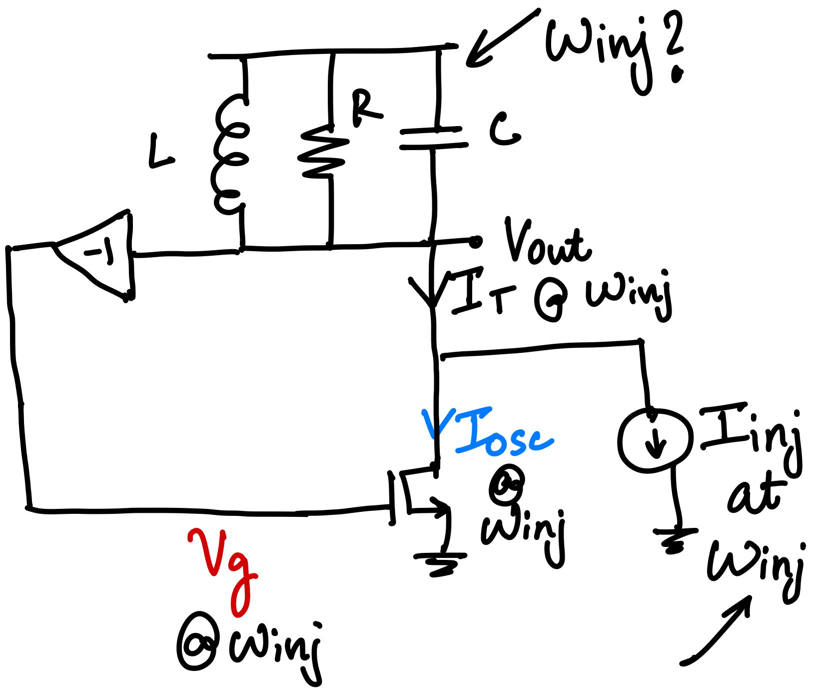
> Winj is injected into oscillator

> At Winj, the tank phase is offset by ϕ_0

> The oscillator "locks" onto Winj with a phase that cancels ϕ_0 to restore the loop phase condition at Winj!

"I_{osc} adjusts it's phase w.r.t the injection to satisfy loop phase condition at Winj"

Winj ⟷ (Ader's Equation) I_{osc} phase when locked!



Loop Phase = 360°