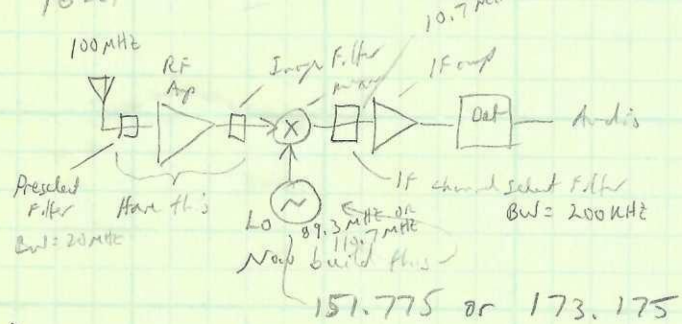
10/8

(Intentional) Oscillator Design

Recall

Semester Product

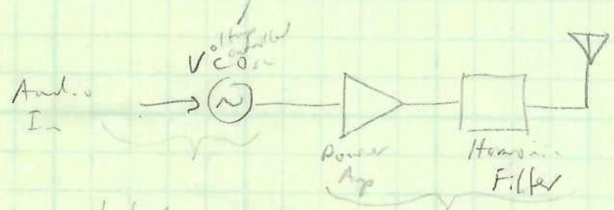
162.475 MHz



Now build this

151.775 or 173.175

"Midterm" FM TX Block Diagram



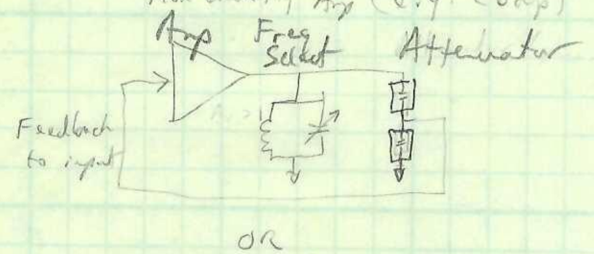
Add freq control to osc

Connect to amp & get complete TX (midterm "Exam")

(INTENTIONAL) OSCILLATOR DESIGN

Draw CB amp 1st

Non Inverting Amp (e.g. CB amp)

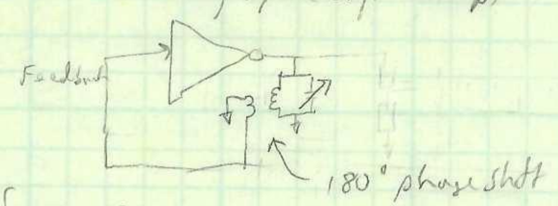


"Colpitts"

OR

Inverting Amp (e.g. CE amp)

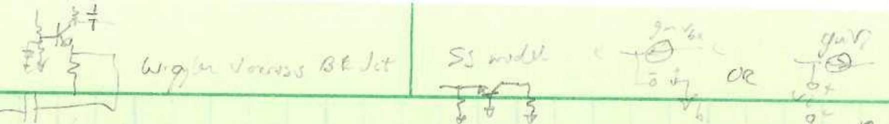
"Hartley"



Condition for osc:

1. "Loop gain" (either $|A_V|$ or G_p) ≥ 1
2. Phase shift around loop $= 0°$ or $\pm n(360°)$

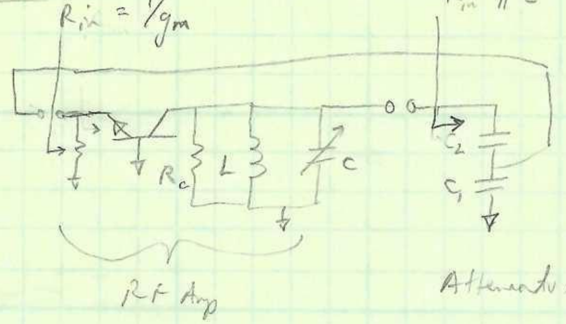
1. Determines osc "start time" (together with ckt Q)
2. Determines frequency of osc

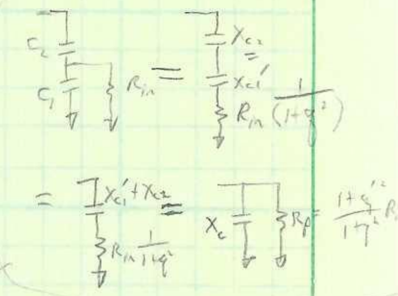


CB Colpitts Oscillator

AC ckt

$R_{in} = 1/g_m$ $\qquad$ $R_{in}' \parallel C'$





NOTES:

- [Use C_1, C_2 for "voltage divider" (attenuator) instead of R_s because a) R's or not R's at HF, b) R's load tank ckt]
- ~~Effect of (C_1 series C_2) must be considered in determining f_0~~
- C_1, C_2 acts as a simple V divider iff $X_{c_1} << R_{in}$
- ~~Otherwise~~ R_{in} is transformed to $R_{in}' \parallel C'$ and is in $\parallel$ w/ R_c $\Rightarrow$ loop gain is decreased, tank freq changed

$\Rightarrow$ [Effect of C' must be considered in calculation of f_0

Simplified analysis:

Let $\boxed{X_{c_1} << R_{in}}$

Then

$$Att_n \approx \frac{-jX_{c1}}{-jX_{c1} + -jX_{c2}} \approx \frac{C_2}{C_1 + C_2}$$

NOT C1!

$$C' \approx C_1 -- C_2 = \frac{C_1 C_2}{C_1 + C_2}$$

$$R_{in}' \approx \left(\frac{X_{c1}+X_{c2}}{X_{c1}}\right)^2 R_{in}$$

☆ Loop Gain $= g_m (R_c \parallel R_{in}'') \dfrac{X_{c1}}{X_{c1}+X_{c2}}$

☆ Remove physical R

Loop Gain $\approx g_m R_{in}'' \dfrac{X_{c1}}{X_{c1}+X_{c2}}$

$$\approx g_m R_{in}\left(\frac{X_{c1}+X_{c2}}{X_{c1}}\right)^2 \left(\frac{X_{c1}}{X_{c1}+X_{c2}}\right)$$

from power conservation

$$= g_m R_{in} \frac{X_{c2}+X_{c1}}{X_{c1}}$$

$$\approx g_m \frac{1}{g_m} \frac{X_{c2}+X_{c1}}{X_{c1}}$$

$$= 1 + \frac{X_{c2}}{X_{c1}}$$

Flipped

$$= 1 + \frac{C1}{C2}$$

Pwr Conservation

$$\frac{V_2^2}{R_{in}'} = \frac{V_1^2}{R_{in}}$$

$$\Rightarrow \frac{R_{in}'}{R_{in}} = \left(\frac{V_2}{V_1}\right)^2$$

Set loop gain = 2 to 4 for robustness

$\Rightarrow$ [C1 = 1 to 3 times C2]

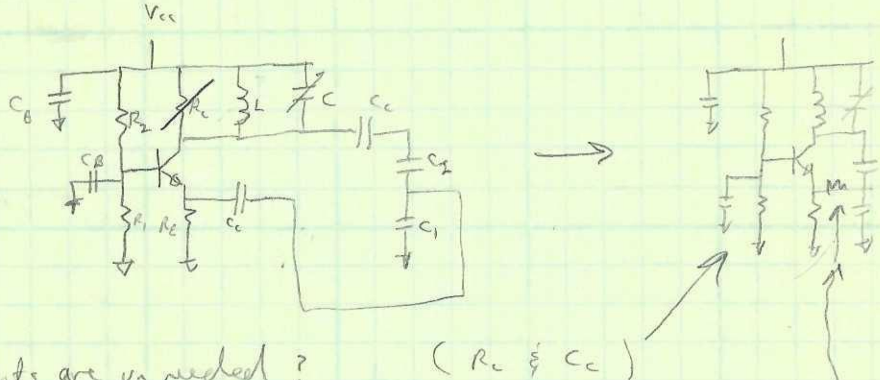
(.04)(480)

$g_m R_{in}'' \left(\frac{C_2}{C_1+C_2}\right) = 10$

$g_m \frac{1}{g_m}$

$\left(\frac{X_2+X_1}{X_1}\right)^2$

Colpitts Ckt



Which components are unneeded?

Show Example

Design Procedure

1) Start with tuned load RF amp config (w/o R_C)

2) Choose $C_1 \ni X_{C_1} \lesssim \frac{1}{2}\frac{1}{r_e} = \frac{1}{2 g_m}$

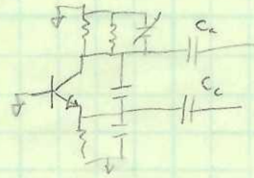
3) Pick C_2 as 1 to 3 times C_1

4) Pick C & L to give desired freq / tuning range (Influence [illegible] change step...)

5) Consider using Emitter input resistor to raise R_{in}

Osc Output

Can take output from E or C nodes



Constraints

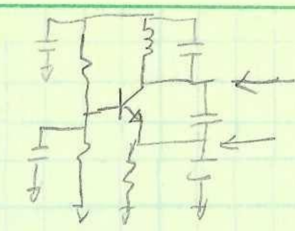
Pick C_c to

Introduce minimal loading (gain change)
Cause minimal freq shift
Get desired signal V, P to load.

Amplitude

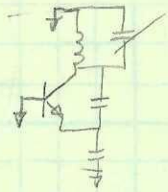
At emitter: $v_E \approx$ 50 to 200mV RMS   why?

Recall CB osc



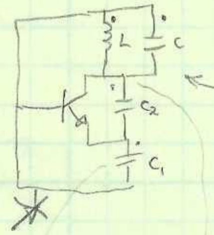
CC Colpitts Osc

AC ckt for CB Colpitts osc is

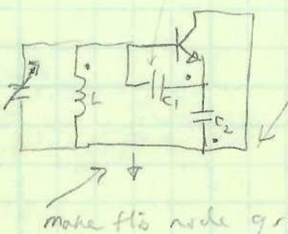


what is ckt gnd? Just a reference point for other voltages

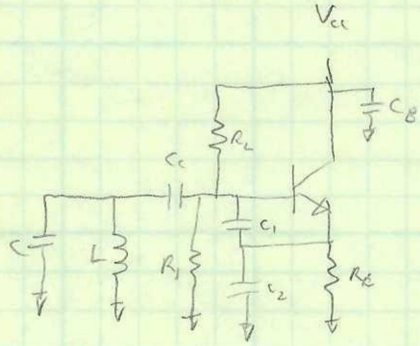
Connect, then Remove ground:



Redraw:



Ckt with Bias included:



☆ Can also view as CC amp with C_2, C_1 forming V stepup feeding back to base

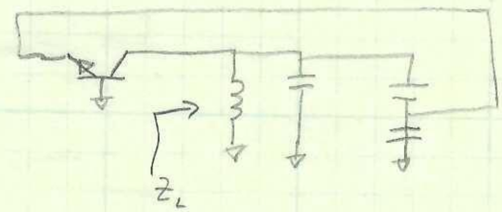
$V_B = \frac{X_{C2}+X_{C1}}{X_{C2}} V_i$

☆ Show Example (from μW journal)

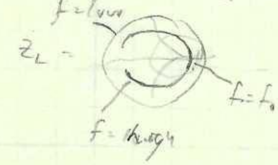
☆ Discuss CC buffering

Voltage Controlled Oscillators (VCO)

Recall
Osc Freq determined by phase shift around loop



$A_{V_{loop}} = g_m Z_L \frac{X_{c1}}{X_{c1} + X_{c2}}$



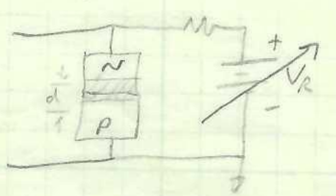
@ $f_0 = \frac{1}{2\pi\sqrt{LC_{tot}}}$, $\angle Z_L = 0$ ⇒ oscillation

To vary f_0, use  or 

Voltage controlled capacitors

$C \sim \frac{\epsilon A}{d}$

$d = f(V_R)$

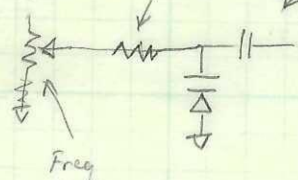


Varactor Diode:

Provides high cap change per volt

☆ Show Data Sheet MMBV609L

Practical Ckt for voltage controlled tuning



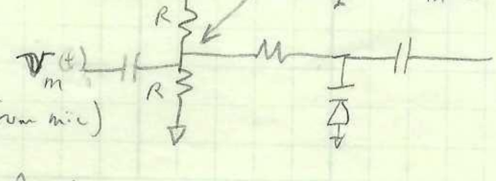
☆ Show pot & mounting.

☆ Show mic

Skip

FM modulation:

$V_R = \frac{V_{cc}}{2} + v_m(t)$



☆ SHOW Examples: RS cell Phone

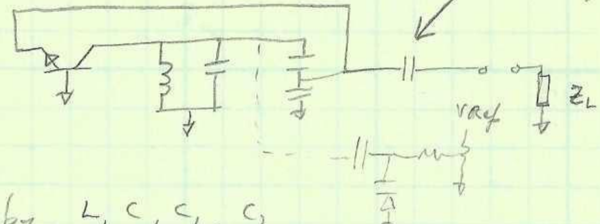
10/10

Additional OSC Topics

Freq Stability

Consider CB colpitts OSC

"Lightly couple"



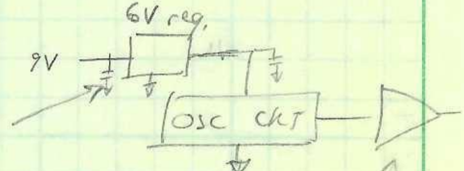
f_0 primarily determined by L, C, C_1, C_2

Also affected by:

- Changes in C_{cb}, C_{be} with supply voltage, temperature
- Changes in L, C values w/ temperature (≥ 50 ppm/°C)
- Changes in load resistance/reactance!
- Changes in varactor reference voltage

Solns:

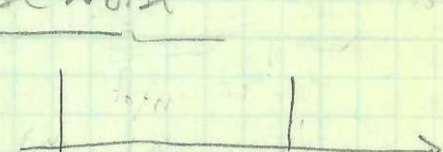
☆ Show data sheet.



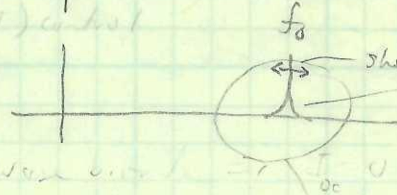
- Use filtered/regulated pwr supply
- Add buffer amp at output (or [illegible] w/ stable load Z)
- Use temperature stable components [illegible] (NPO capacitors)
- And/or Use crystal controlled PLLs! (discussed later)

Short Term Stability & Phase Noise

Ideal OSC Spectrum

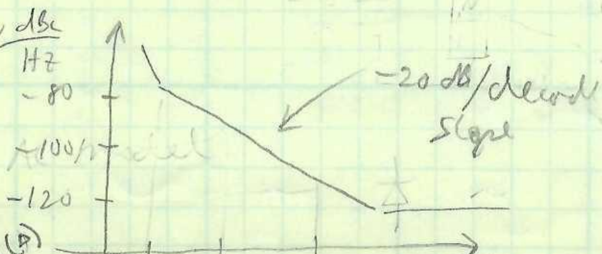


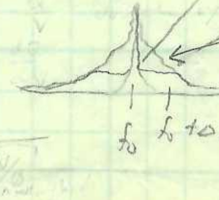
Actual Spectrum



Bring Example (8650 + speaker)

phase modulation / functions $\frac{dBc}{Hz}$





$V_{osc} = Ae^{j\omega_0 t}$ [illegible]

$\approx Ae^{j\omega_0 t}(1 + j\theta(\Delta) \dots)$

$f \propto d\theta/dt$

Modeling Phase Noise and measuring in "dBc/Hz"

Ideal Oscillator

$$v_{osc}(t) = A\cos(\omega_0 t)$$

or

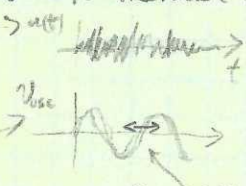
$$v_{osc} = Re\left\{A e^{j\omega_0 t}\right\}$$

Oscillator w/ phase noise (Re{ } implied)

$$v_{osc}(t) = A e^{j(\omega_0 t + n(t))}$$

$$= A e^{j\omega_0 t} e^{jn(t)}$$

← random phase variations due to thermal noise/etc

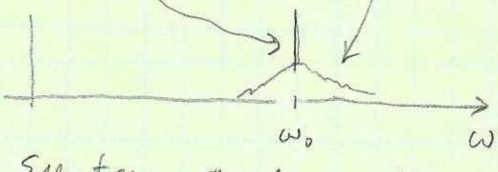


By Taylor Series Expansion (for $n(t) \ll 1$)

$$v_{osc}(t) \approx A e^{j\omega_0 t}(1 + jn(t))$$

Taking Fourier Transform

$$V(\omega) = A\left[2\pi\delta(\omega-\omega_0) + jN(\omega-\omega_0)\right]$$



PN is measured using spectrum analyzer as ratio of power in noise sidebands to the total osc power

(ratio ↑ difference in dB units)

$$PN\Big|_{dBc/Hz} \triangleq P_{osc}\Big|_{dBm} - P_n(\Delta\omega)\Big|_{dBm\ \text{in 1 Hz bandwidth}}$$

☆ Show / draw a spectrum w/ spec an measurement

Phase Noise Measurement

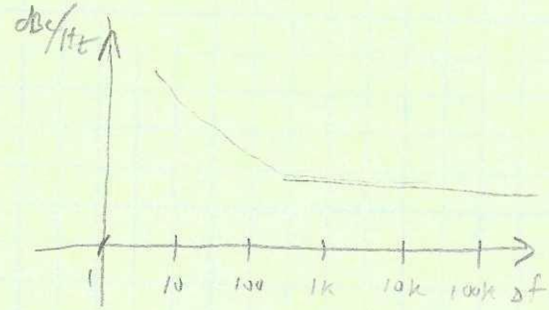
Measure total P_{osc} in dBm

Measure $P_n(\Delta f)$ in dBm

Normalize by RBW $\quad P_{n_{1Hz}}(\Delta f)\Big|_{dBm} = P_n(\Delta f)\Big|_{dBm} - 10\log(RBW)$

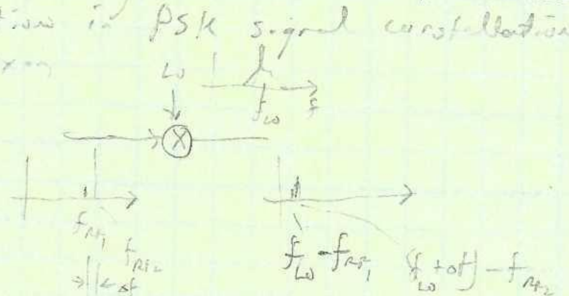
Compute/Plot $PN(\Delta f)\Big|_{dBc/Hz} = P_{osc}\Big|_{dBm} - P_{n_{1Hz}}(\Delta f)\Big|_{dBm}$

Δf	$P_n(\Delta f)$	$P_{n_{1Hz}}(\Delta f)$	$PN_{dBc/Hz}$
1k			
3k			
10k			
30k			
100k			
300k			



PN Effects on Systems

- FM noise in analog modulation – limits audio SNR
- Phase variation in PSK signal constellation
- Reciprocal mixing



PN Reduction

- Use higher Q in oscillators
- Use PLL with high quality reference oscillator
- Other – BJTs better than CMOS, etc.