Common Base Oscillator Design

Detail on 010_Oscillators_and_VCOs.pdf, pp. 2-3

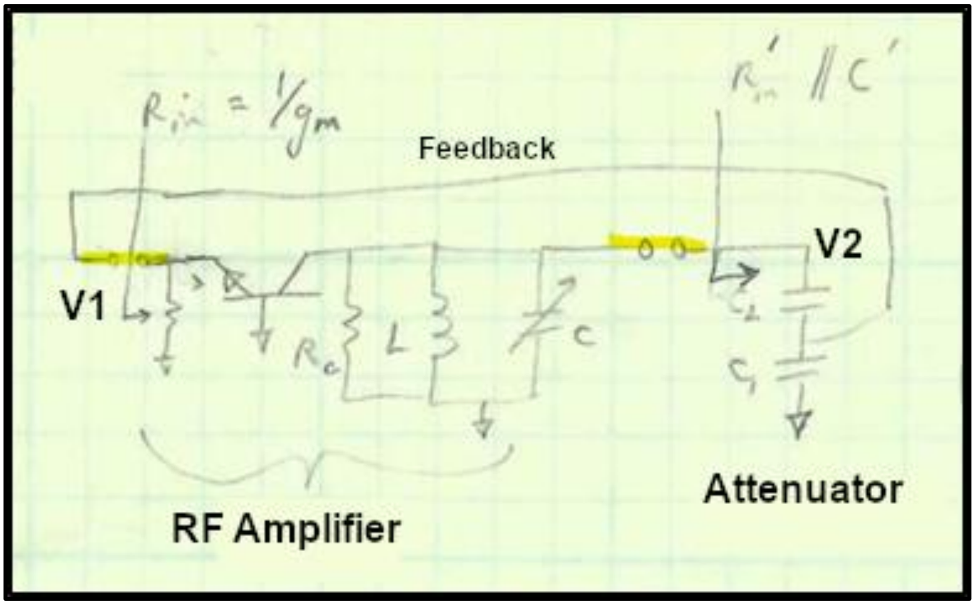

Figure 1 Common Base Colpitts Oscillator

1. Figure 1:
    1. This is a common base Colpitts oscillator. **Not** shown are the transistor biasing details.
    2. The highlighted breaks indicate open-circuit conditions. Both are maintained, i.e., left as open-circuits, when R_{in} and C' (see #8 below) are determined.
    3. The shown impedance, viz., $R'_{in}||\,C'$, is the impedance at the top of C_2 when the breaks are short-circuited.
2. C_1 and C_2 are used for the attenuating voltage divider feedback rather than resistors since:
    1. Resistors may not be "resistors" at radio frequencies.
    2. Resistors will load the completed circuit.
3. C_1 and C_2 form a simple voltage divider iff $|X_{C_1}| \ll R_{in}$.
4. R_{in} is transformed to $R'_{in}\ ||\ C'$ which itself is in parallel with R_c. (See #9 below for the definition of R'_{in}.) This leads to a decrease in the loop gain and a change in the oscillating frequency, f_0. The effect of C' must be considered in designing for a desired f_0.
5. The following represents a simplified analysis.
6. Let $|X_{C_1}| \ll R_{in}$. A value for $|X_{C_1}|$, which is 50%, or less, of R_{in}, will suffice.

7. Then, the voltage attenuation will be,

$$\frac{-j \cdot |X_{C_1}|}{-j \cdot |X_{C_1}| + -j \cdot |X_{C_2}|} \approx \frac{C_2}{C_1 + C_2}$$

   1. Note that C_2 is in the numerator **not** C_1 due to the relationship between capacitors and their reactances.

8. C' is the series combination of C_1 and C_2, viz.,

$$C' = \frac{C_1 \cdot C_2}{C_1 + C_2}$$

9. If the amplifier's input is arbitrarily chosen as the start and end of the loop, the voltage around the loop starts and ends with V_1 while the power starts and ends with V_1^2/R_{in}. That is, loop voltage gain and loop power gain are two sides of the same coin.

   This fact may be used to determine R'_{in} in terms of the other circuit components. R'_{in} is the resistance counterpart of R_{in} for which power is conserved around the loop. Specifically,

$$\frac{V_2^2}{R'_{in}} = \frac{V_1^2}{R_{in}} \quad \rightarrow \quad \frac{R'_{in}}{R_{in}} = \left(\frac{V_2}{V_1}\right)^2$$

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

$$\frac{V_2}{V_1} = \frac{X_{C_1} + X_{C_2}}{X_{C_1}}$$

$$\therefore R'_{in} = R_{in} \cdot \left(\frac{X_{C_1} + X_{C_2}}{X_{C_1}}\right)^2$$

10. Now, the loop voltage gain may be expressed as,

$$\text{Loop voltage gain} = g_m \cdot (R_c \,||\, R'_{in}) \cdot \frac{X_{C_1}}{X_{C_1} + X_{C_2}}$$

11. While R_c serves an important role in an amplifier, it serves no role in an oscillator based on that amplifier and may literally be removed from the circuit. This results in,

$$\text{Loop voltage gain} \approx g_m \cdot R'_{in} \cdot \frac{X_{C_1}}{X_{C_1} + X_{C_2}}$$

$$= g_m \cdot R_{in} \cdot \left(\frac{X_{C_1} + X_{C_2}}{X_{C_1}}\right)^2 \cdot \frac{X_{C_1}}{X_{C_1} + X_{C_2}}$$

$$= g_m \cdot R_{in} \cdot \frac{X_{C_1} + X_{C_2}}{X_{C_1}}$$
$$= g_m \cdot \frac{1}{g_m} \cdot \frac{X_{C_1} + X_{C_2}}{X_{C_1}}$$
$$= 1 + \frac{X_{C_2}}{X_{C_1}}$$
$$= 1 + \frac{C_1}{C_2}$$

12. To **start** the analysis, set the loop gain to be in the range of 2 to 4 for robustness. Thus,

$$\left|X_{C_1}\right| \le {}^{1}\!/_{(2 \cdot g_m)}$$
$${}^{C_1}\!/_{3} \le C_2 \le C_1$$

13. The initial design loop gain choice of 2 to 4 is dictated by the fact that there are unknown energy dissipating parasitics in the oscillator.
    1. **N.B.** Ultimately, *sustained* oscillation will necessarily result in both the loop voltage gain **and** the loop power gain being exactly 1, i.e., power is conserved around the loop. This is necessary to prevent the transistor from saturating.
    2. The initial design loop gain choice of 2 to 4 may have to be altered to allow the circuit to oscillate sustainably.

Example design procedure

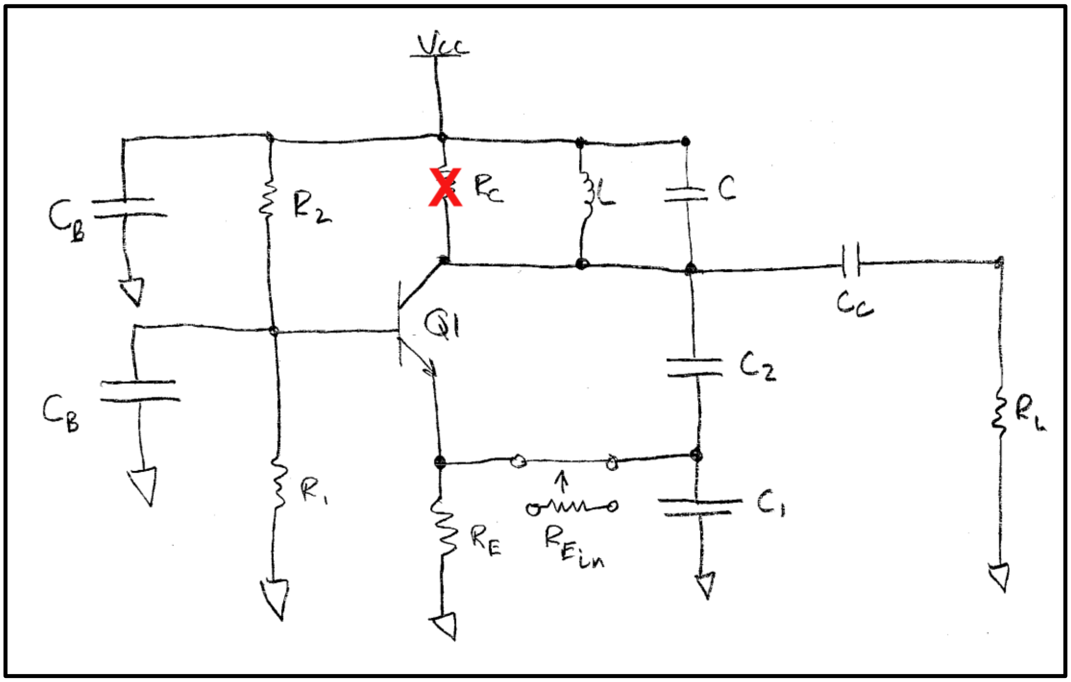

Figure 2 Common Base Colpitts Oscillator with biasing detail

1. Figure 2:
    1. R_c is Xed out since it serves no role in an oscillator, which is based on an RF amplifier circuit. R_c is literally to be removed from the circuit.
    2. The two coupling capacitors, C_c, may be ignored, i.e., short-circuited, until step 9.
    3. Bias the transistor such that the collector current, I_C, is 1 to 2 mA. The relatively low collector current prevents $|X_{C_1}|$ from being too small, less than 10 Ω. Such a low value for $|X_{C_1}|$ could mean that C_1 becomes an inductor at the target frequency.
2. Determine $g_m = {}^{I_C}/_{(\eta \cdot V_T)} = {}^{I_C}/_{0.04} = {}^{1}/_{R_{in}}$.
3. At the desired oscillation frequency, f_0, the value of C_1 is chosen such that $|X_{C_1}| \le {}^{1}/_{(2 \cdot g_m)}$.
4. C_2 is then chosen to be ${}^{C_1}/_{3} \le C_2 \le C_1$.
5. Pick L and C to achieve f_0. Consider the desired tuning range and steps when making the selection.

6. Make fine adjustments to L and / or C to obtain the desired f_0.
7. $R_{E_{in}}$ may be added to raise R_{in} if a higher collector current is desired in step #1.3.[1]
8. The oscillator output may be taken from the top of C_2 or at the junction of C_2 and C_1.

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9. Constraints – choose C_c to,
   1. introduce minimal loading. Loading changes the loop gain.
   2. cause minimal change in f_0.
   3. get the desired voltage and power to the load.
10. Output at the emitter, $v_e \approx 50\ to\ 200\ mV_{RMS}$.

[1] The analysis of so doing is beyond the scope of the current effort.