Lab 6: Design of a Colpitts oscillator

Objective:
To design, simulate, build and test a Colpitts oscillator.

Theory
The block diagram in figure 6.1 shows the elements of the system for producing sustained oscillations. The input to the amplifier is a portion $\beta$ of the output fed back.

![Block Diagram](image)

Figure 6.1:

We may write:

$$V_{in} = \beta V_{out} \quad (1)$$

The output voltage is written as:

$$V_{out} = AV_{in} \quad (2)$$

Substitute (2) into (1)

$$V_{in} = \beta V_{in} A$$

$$V_{in} (1 - \beta A) = 0 \quad (3)$$

The non-trivial solution for sustained oscillations is:

$$(1 - \beta A) = 0 \Rightarrow \beta A = 1 \quad (5)$$

In general both $A$ and $\beta$ are complex so that may write $A \angle \phi \beta \angle \theta$. The total phase angle $\phi + \theta$ should be 0 degrees (or 360) and the loop gain $\beta A = 1$. These two conditions are called the Barkhausen criterion for sustained oscillation. The two elements of an oscillator should be designed and tested.
separately, if the beta network does not load the input of the amplifier (which it does not in this particular design).

**The amplifier stage**

We may assume that the FET drain-source resistance is much greater than the load, so no loading takes place. The voltage gain of the circuit shown in figure 1 is:

\[
V_{\text{out}} = -g_m V_{gs} R_L \Rightarrow \frac{V_{\text{out}}}{V_{gs}} = A_v = -g_m R_L.
\]

Substitute in the measured value for \(g_m\) (see RF amplifier experiment). For this example let us assume \(g_m\) equals 1 ms.

\[
|A_v| = g_m R = 1 \times 10^{-3} \times 2.7 \times 10^3 = 2.7
\]  \hspace{1cm} (6)

*Figure 6.2*

Measure the gain and you should get waveform similar to that shown in figure 3.

*Figure 6.3*

Note the 180 degree phase shift. Measure the stage gain.
The Beta network

The transfer function for this network is simply written using the potential divider principle as:

\[
\beta = \frac{1}{j\omega C_2} \times \frac{\omega C_2}{j\omega L + 1} = \frac{1}{\omega^2 L C_2 + 1} = \frac{1}{\omega^2 L C_2}
\]  

(7)

But the resonant frequency is obtained by considering the total capacitance.

\[
C_T = \frac{C_1 C_2}{C_1 + C_2}
\]

Substituting for \( \omega^2 = \frac{1}{LC_T} \) into (7)

\[
\beta = \frac{1}{1 - \frac{1}{LC_T} L C_2} = \frac{1}{1 - \frac{C_1 C_2}{C_1 + C_2}} = \frac{1}{1 - \frac{C_1 + C_2}{C_1}} = \frac{C_1}{C_2}
\]

Figure 6.4

Let's assign a loop gain of 1.5 (Greater than one to ensure it oscillates).

\[
|\beta A| = g_m R_f \frac{C_1}{C_2} = 1.5 \Rightarrow 1.5 = 2.7, \frac{C_1}{C_2} \Rightarrow C_1 = C_2 \frac{1.5}{2.7} = 0.555C_2.
\]

This gives a relative value between the two capacitances. If the oscillator is to produce sustained oscillations at 100 kHz, then we must calculate absolute values for the two capacitances (Assume the inductance value is known). Create the circuit shown in figure 5 to test the design of the beta network i.e. the beta value and the resonant frequency.
The JFET current source is simulated using a voltage source in series with a high resistance. Measure the beta value.

Figure 6.5: frequency response of Beta network

Complete the circuit and test for sustained oscillations. Measure the harmonic distortion at either end of the inductance. What is responsible for the different value?

Figure 6.6