MMIC Design and Technology
Oscillator Design

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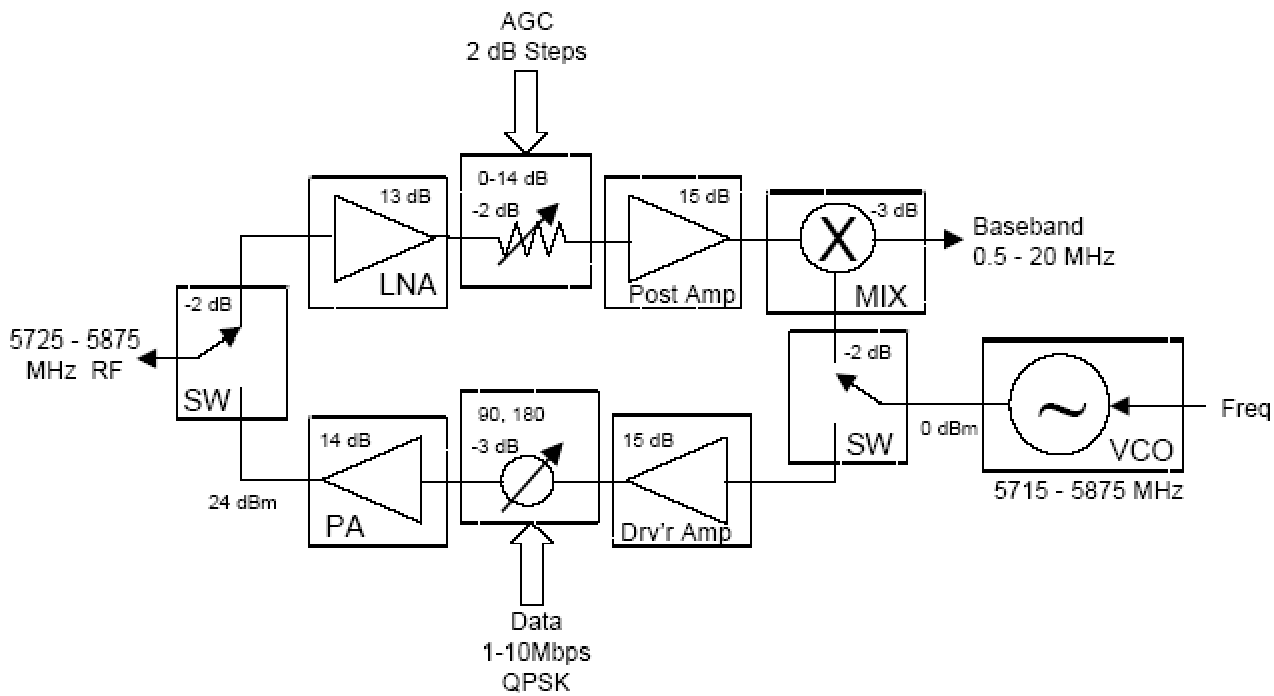
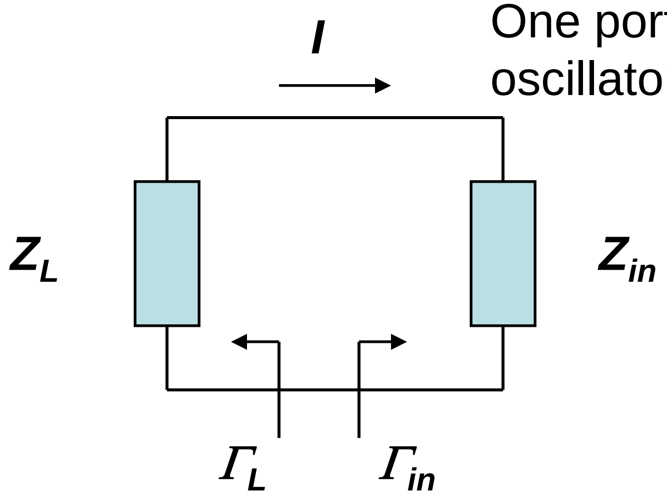
Transceiver Example



We now know amplifier design
And techniques for low noise amplifier design

Oscillator



One port negative resistance oscillator circuit

Kirchoff $$(Z_L + Z_{in})I = 0$$

For I >0 $$Z_L = -Z_{in}$$

$$\Gamma_L = \frac{Z_L - Z_0}{Z_L + Z_0} = \frac{-Z_{in} - Z_0}{-Z_{in} + Z_0} = \frac{Z_{in} + Z_0}{Z_{in} - Z_0} = \frac{1}{\Gamma_{in}}$$

$$\Gamma_L \Gamma_{in} = 1$$

$$\Gamma_{in} > 1$$

Oscillation

$$Z_L = -Z_{in}$$

$$Z_L = R_L + jX_L$$

$$Z_{in} = R_{in} + jX_{in}$$

$$R_L + R_{in} = 0$$

$$X_L + X_{in} = 0$$

$$X_L(j\omega_0) = -X_{in}(I, j\omega_0)$$

ω_0 Is the oscillation frequency

Oscillator Stability

For stability the circuit should resist small changes in I or ω and return to its original state.

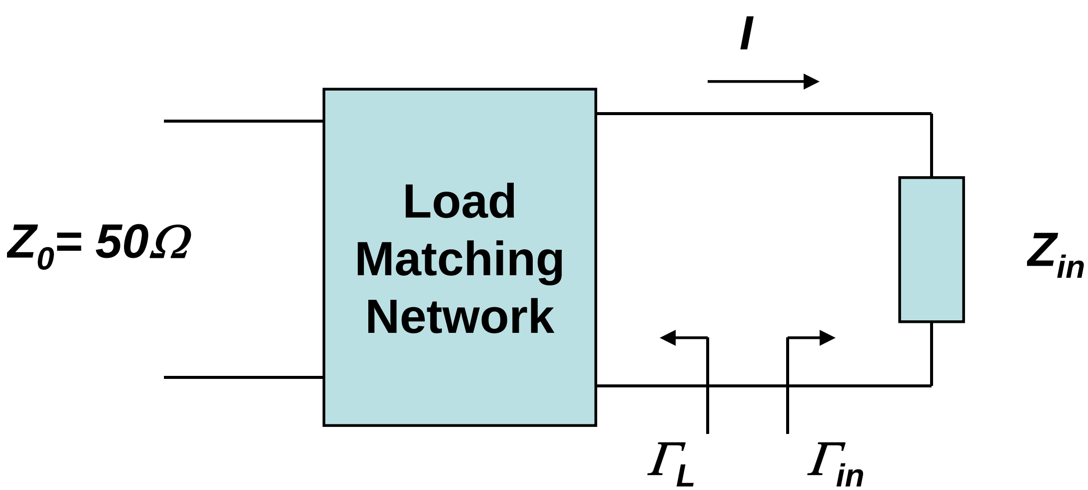
Detailed perturbation analysis results in :

$$\frac{\partial(X_L + X_{in})}{\partial\omega} >> 0$$

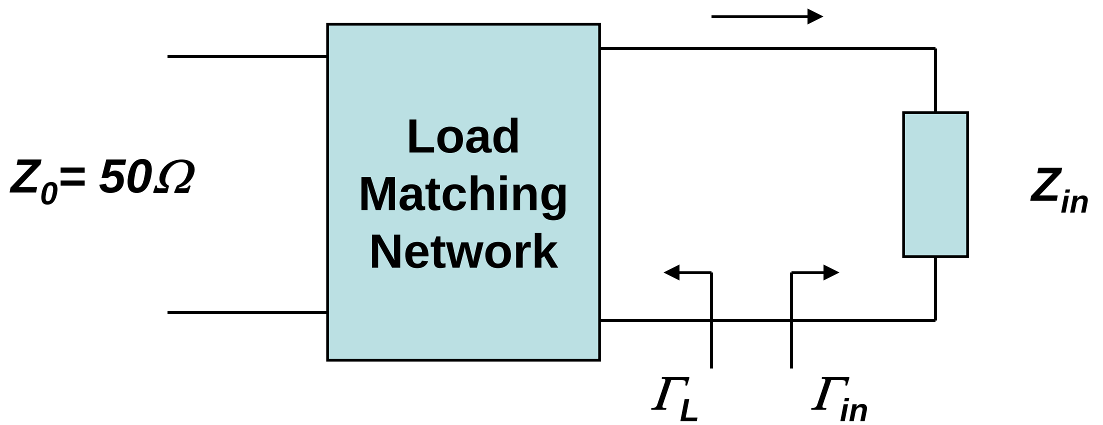
High Q circuit results in maximum oscillator stability

Oscillator Design

- For a given Γ_{in} transform a 50 ohm output to present Γ_L to the oscillator.



Example



Given:

Γ_{in} = 1.25 / 40 degrees when measured at 50Ω

$$\left|\Gamma_{in}\right| > 1$$

$$\Gamma_L = \frac{1}{\Gamma_{in}} = \frac{\mathrm{Re}[\Gamma_{in}] - j\,\mathrm{Im}[\Gamma_{in}]}{\left|\Gamma_{in}\right|^2}$$

Plot on smith chart

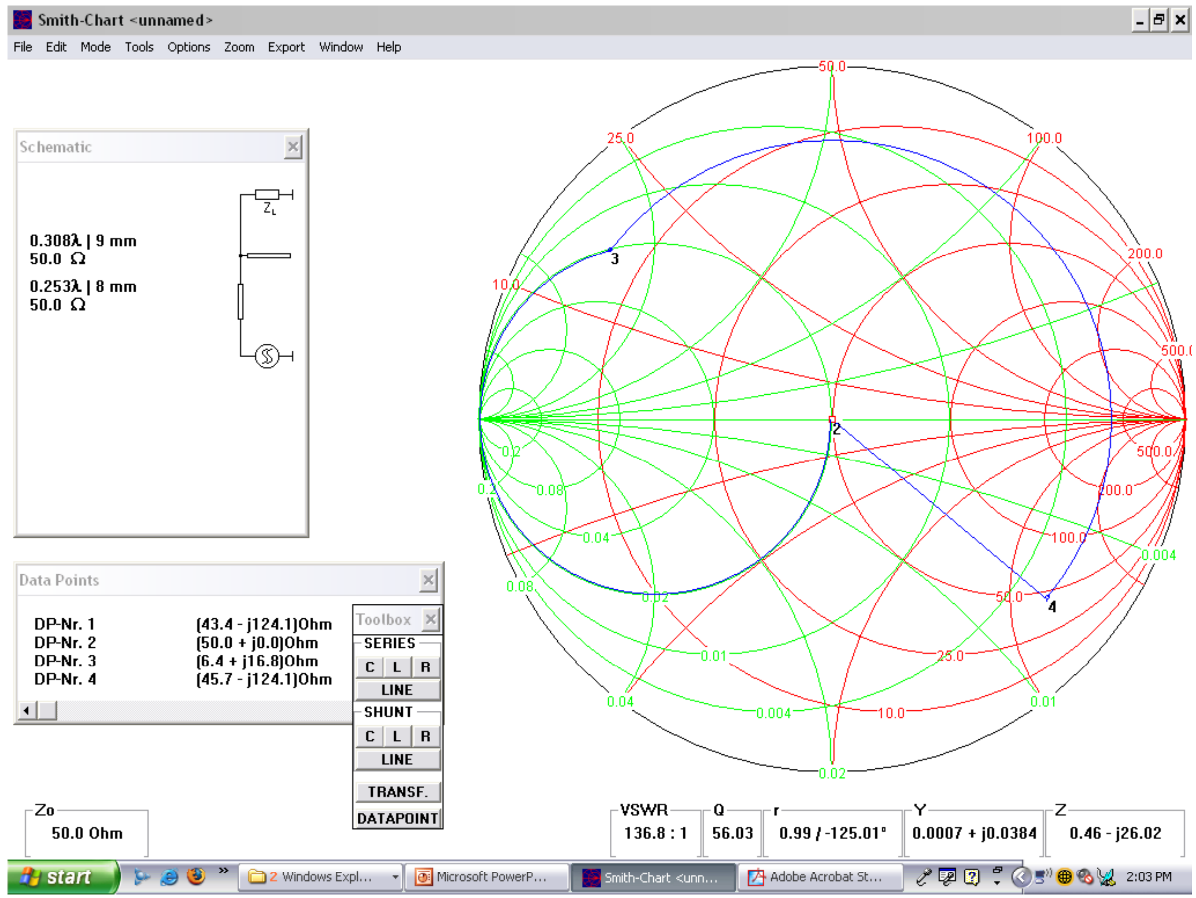
Then transform $\mathbf{Z_0}$ to $\mathbf{Z_L}$

Calculation of example

Γin = 1.25 / 40 degrees when measured at 50Ω

ΓL = 1.25^{-1} / -40 degrees
= 0.8 / -40 degrees

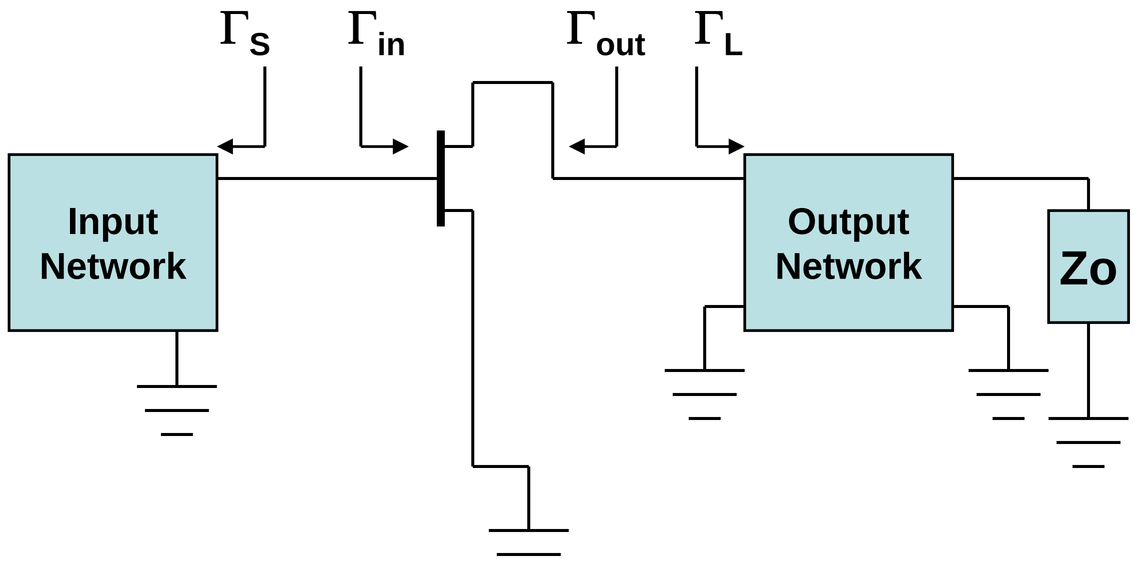
Plot on smith chart
and
transform 50Ω to give **ΓL**



Oscillation Stability

- Analysis is done at small signal
- R_{in} is an increasing function of ***I***
  - *R_{in} becomes less negative as power increases*
- If at small signal $R_L + R_{in} = 0$
  - When power increases $\mathbf{R_L + R_{in} > 0}$ and oscillation will stop
- In practice choose $R_L = -R_{in} / 3$
- X_L is chosen to resonate so $X_L = -X_{in}$

Transistor Oscillators



Choose Γ_L such that Γ_{in} >1

Or

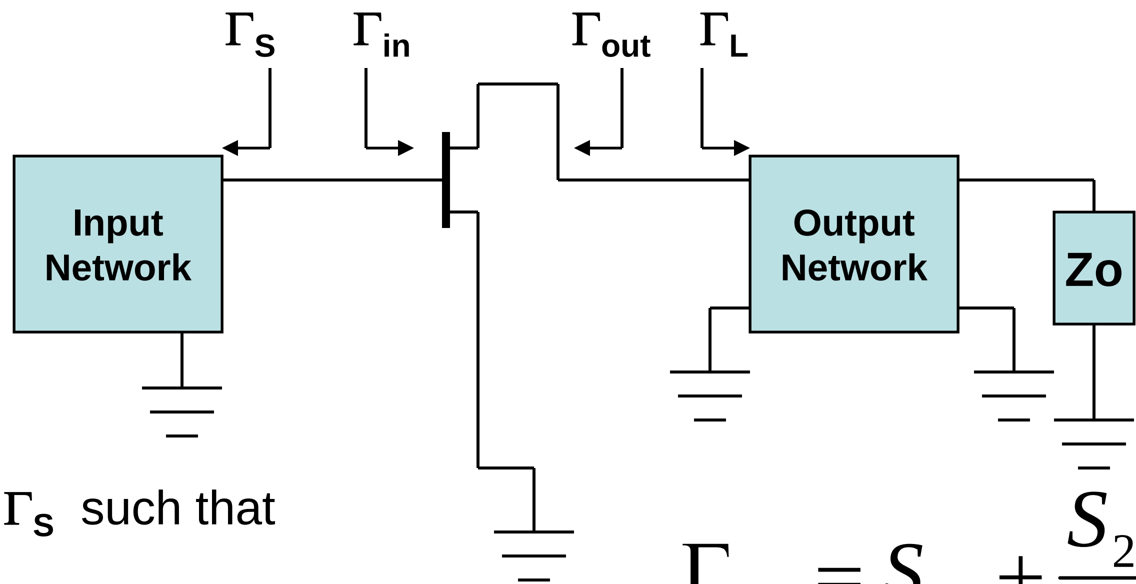
Choose Γ_s such that Γ_{out} >1

Stability

- Transistor is unstable when $|\Gamma_{in}| > 1$

$$\Gamma_{in} = S_{11} + \frac{S_{21} S_{12} \Gamma_L}{1 - S_{22} \Gamma_L}$$

Transistor Oscillator Design



Choose Γ_S such that $\Gamma_{out}>1$

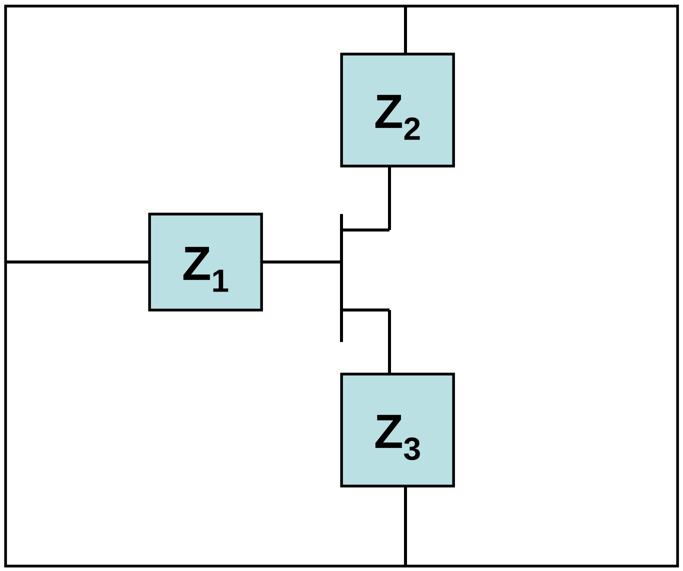
Develop network to provide Zs

$$\Gamma_{out} = S_{22} + \frac{S_{21}S_{12}\Gamma_s}{1 - S_{11}\Gamma_s} > 1$$

$$\Gamma_L = \frac{1}{\Gamma_{out}} = \frac{\mathrm{Re}[\Gamma_{out}] - j\,\mathrm{Im}[\Gamma_{out}]}{|\Gamma_{out}|^2}$$

Develop network to transform **Zo** to Γ_L

FET Oscillator Circuits



Use 3 port S parameters for the FET

3 port parameters can be developed from 2 port

Choose one of the Z_i to give a 2 port With instability.

$$S_{ii}^T > 1$$

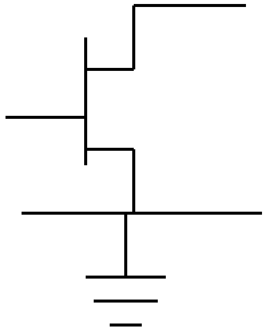
With $\mathbf{Z_1=Z_2=Z_0}$

And

$$\Gamma_3 = \frac{Z_3 - Z_0}{Z_3 + Z_0}$$

$$\left[S^T\right] = \begin{bmatrix} S_{11} + \dfrac{S_{31}S_{13}\Gamma_3}{1 - S_{33}\Gamma_3} & S_{12} + \dfrac{S_{13}S_{32}\Gamma_3}{1 - S_{33}\Gamma_3} \\ S_{21} + \dfrac{S_{31}S_{23}\Gamma_3}{1 - S_{33}\Gamma_3} & S_{22} + \dfrac{S_{23}S_{32}\Gamma_3}{1 - S_{33}\Gamma_3} \end{bmatrix}$$

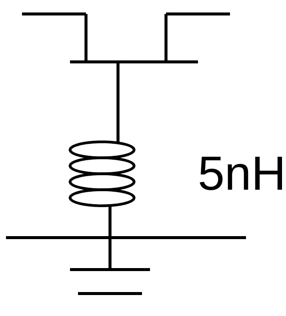
Example



For a particular FET the Common source 50Ω measured S parameters at 4GHz are

$$[S]=\begin{bmatrix} .72/-116^\circ & .03/57^\circ \\ 2.60/76^\circ & .73/-54^\circ \end{bmatrix}$$

The same FET in Common gate with 5nH Has S' parameters



$$[S']=\begin{bmatrix} 2.18/-35^\circ & 1.26/18^\circ \\ 2.75/96^\circ & .52/155^\circ \end{bmatrix}$$

More unstable than Common source
$S'_{11}>1$ and S'_{12} is large

Example

- Design a 10GHz Oscillator using the FET data.

Example continued

$$\Gamma_{in} = S'_{11} + \frac{S'_{12}\, S'_{21}\, \Gamma_T}{1 - S'_{22}\, \Gamma_T}$$

Choose Γ_T = 0.59 / -104deg

Γ_{in} = 3.96 / -2.4 deg

$$Z_{in} = -84 - j1.9\Omega$$

$$Z_L = \frac{-R_{in}}{3} - jX_{in} = 28 + j1.9\Omega$$

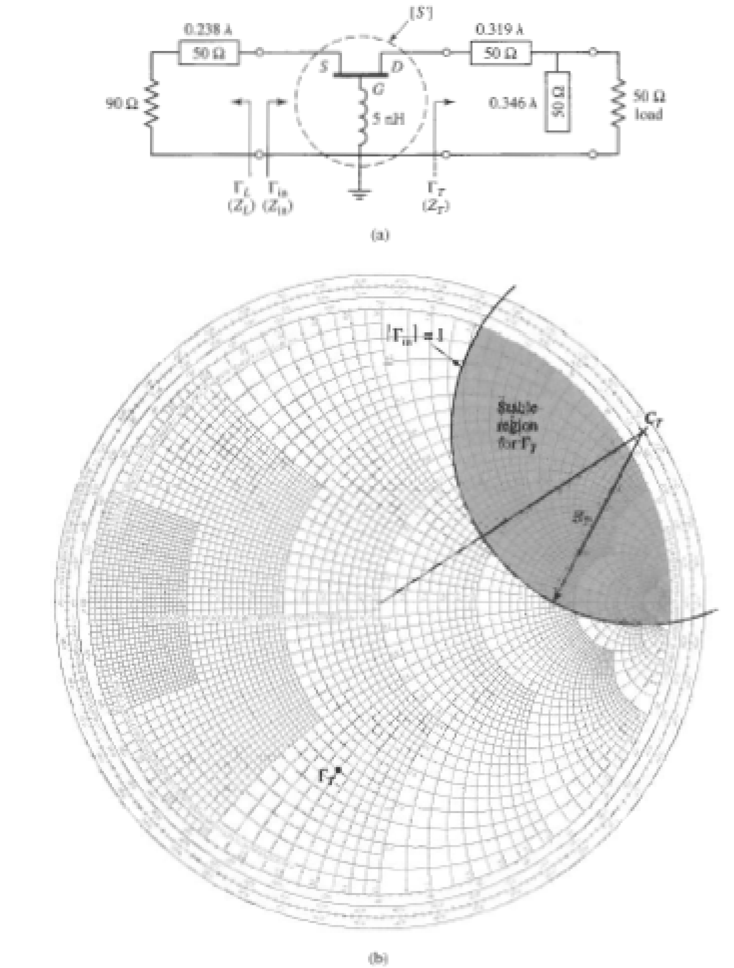


FIGURE 11.25 Circuit design for the transistor oscillator of Example 11.9. (a) Oscillator circuit. (b) Smith chart for determining Γ_T.

Tunable Oscillators

- Choice of Γs determines Γout and therefore determines oscillation frequency
- An adjustable impedance would allow for adjusting the oscillation frequency

Voltage Controlled Oscillator

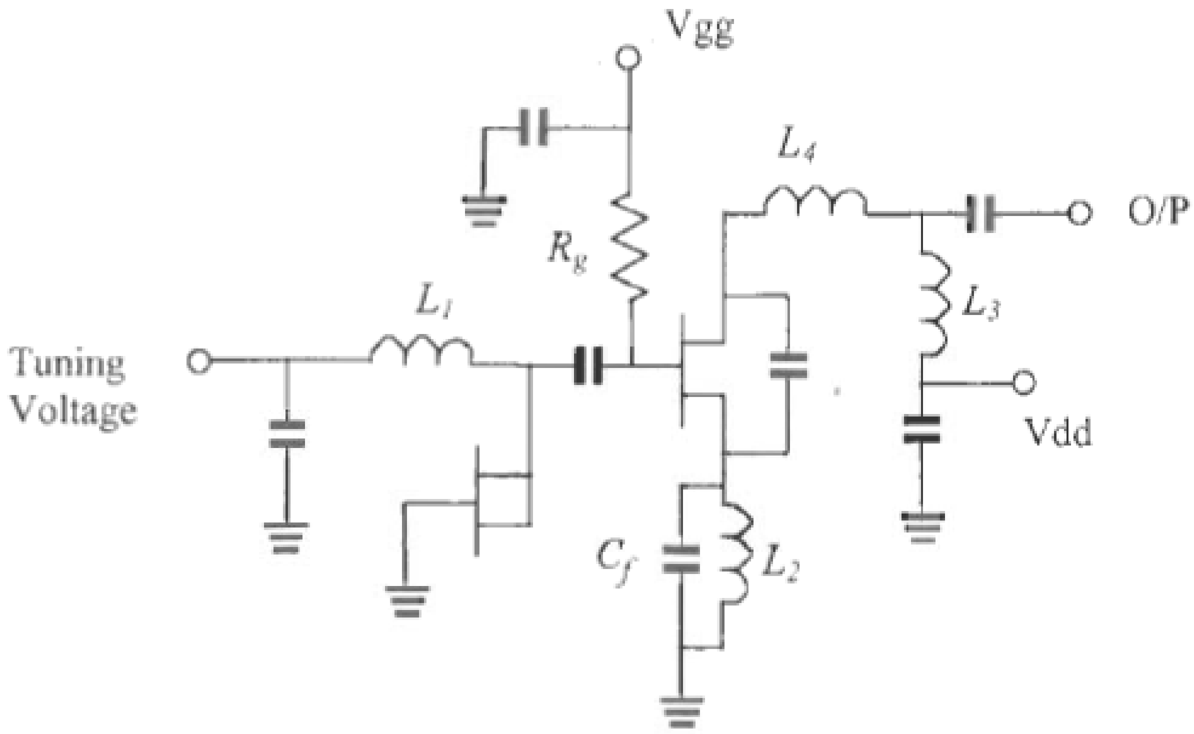


Figure 6.8 VCO circuit diagram