EE 505
Lecture 13

Capacitor Matching Issues
Example:

\[ A_v = f \left( \frac{c_1}{c_2} \right) \]

\[ f \left( \frac{c_1}{c_2} \right) \bigg|_{c_1 = c_2} = 2 \]

Important that \( A_v \) be accurately controlled in many applications.
Caparitor types

a) Parallel Plate
b) Fringe (MIM)
c) Depletion

Applications

a) Matching critical applications (must be highly linear)
b) Filtering (spectral shaping)
c) Filtering (noise/ripple)
d) Varicaps
Parallel Plate

Top View

If $C_{dn}$ is the nominal capacitance density, then ideally

$$C = (C_{dn}) A_1$$
When building parallel plate capacitors, total capacitance density of conductors – often correct several conductors in parallel cross section.

\[ C_{eq} = \sum_{i=1}^{n} C_i \]
MOS Capacitor

Observation: \( C_{ox} \) is often much larger than the capacitive density for any layer to layer caps besides poly to channel.

Note: One plate always connected to diffusion, \( C \) is quite nonlinear.
- must have a dc bias to form inversion layer

\[ \text{MIM} \quad \text{Top level metal often very thick} \quad (d_k \gg d_1) \]

\[ d_k \]

\[ d_1 \]
In some processes, the "fringe" capacitance density is larger than the vertical plate density.

- Very linear
  - Matching properties are comparable (or better)
Multiple layers are often comded in parallel to increase the capacitance density.

**Ideal capacitor**

\[ C \text{ not a function of the voltage across it} \]

\[ i = C \frac{d\phi}{dt} \]

- Varactors or Varicaps
- Highly nonlinear
\[
\begin{align*}
(V_1) \left( \frac{1}{1 + RCs} \right) &= V_2 \\
V_2 \left( \frac{1}{1 + RCs} \right) &= V_3 \\
V_3 \left( \frac{1}{1 + RCs} \right) \cdot k &= V_1
\end{align*}
\]

\[
V_1 = k \left( \frac{1}{1 + RCs} \right) \left( \frac{1}{1 + RCs} \right) \left( \frac{1}{1 + RCs} \right) V_1
\]

\[
V_1 (1 + RCs)^3 = k V_1
\]

\[
V_1 \left[ (1 + RCs)^3 - k \right] = 0
\]

\[
D(s) = (1 + RCs)^3 - k = 0
\]

\[
\therefore 1 + RCs = k^{\frac{1}{3}} \Rightarrow s = k^{\frac{1}{3}} - 1
\]
Parallel Plate Capacitor Issues

1) $C_0$ is not constant with position $(C_0(x, y))$
   
   i) Random components are uncorrelated from point to point
   
   ii) Gradients in $C_0$ generally present

2) Edge of defining plate is a random variable

3) Fringe capacitors are created between desired plates & everything else in a layout.

4) Corners tend to not be sharp & vary somewhat from corner to corner.
For matching, it is important to ratio match the total capacitance, not just $C_0A_1$.

If $C_2 = 2C_1$

For ratio matching, use a unit cell and multiply instances of that cell.
\[ C = C_d (A_1 - \Delta P + \Delta_{\text{out}} + 2\Delta_{\text{in}}) \]

\[ + C_{sw} (P - 2 \Delta_{\text{out}}) \]

\[ + C_{\text{out}} N_{\text{out}} \]

\[ + C_{\text{in}} (N_{\text{in}}) \]

\[ \text{Cd : normal cap density} \]

\[ \text{C}_{\text{sw}} : \text{cap density in sw} \]

\[ \text{C}_{\text{out}} : \text{value for each outside corner cap} \]

\[ \text{C}_{\text{in}} : \text{value for each inside corner cap} \]