# Characterization of On-Chip Spiral Inductors

ECE 6450

Michael Washington

November 25, 2002

# Why On-Chip Inductors?

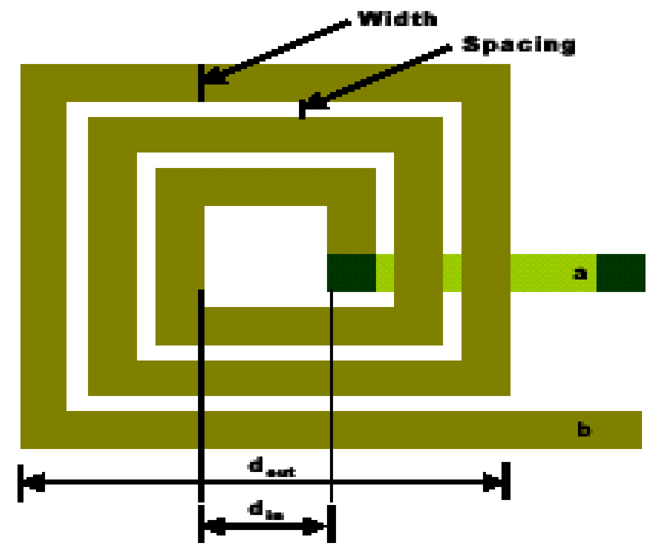
- RF designs require many passive components in discrete form
- Reduce Cost & Area of RF integrated circuits
- Key element in amplifiers, mixers, and oscillators

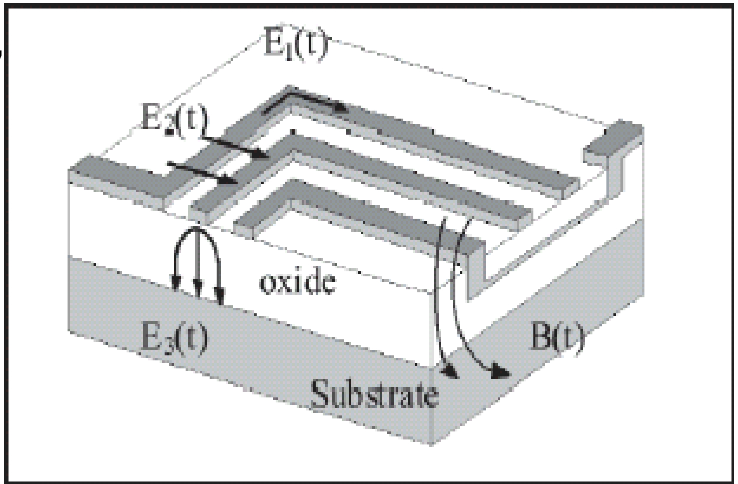
# Key Inductor Parameters

- Quality Factor(Q)
- Inductance(L)
- Self-resonant frequency($F_{srf}$)

# Inductor Geometry

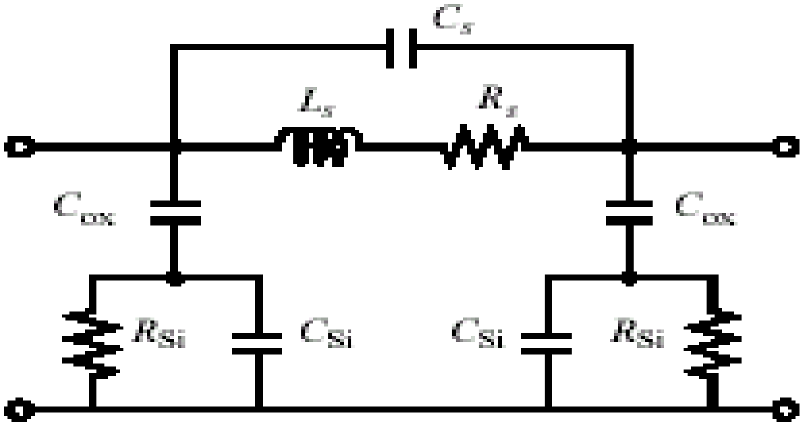
- Square, circular, or octagonal structures are used
- Silicon technology is being investigated as an alternative to GaAs.
- Silicon substrate is cheaper, but has low resistivity
- 3D coils may also be used

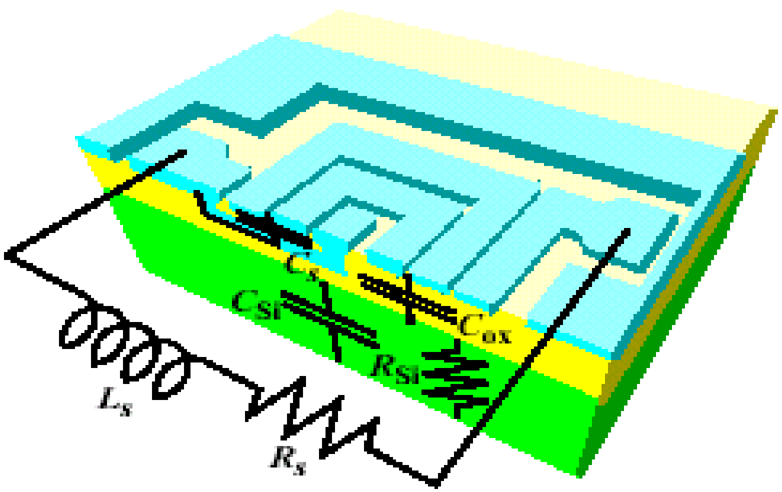


# Inductor Model

- Series inductance and resistance ($L_s$ and $R_s$)
- Series Capacitance ($C_s$)
- Substrate parasitics ($C_{ox}$, $C_{si}$, and $R_{si}$)



# Series Inductance($L_s$)

- Comprised of self($L_{self}$) and mutual(M) inductances.

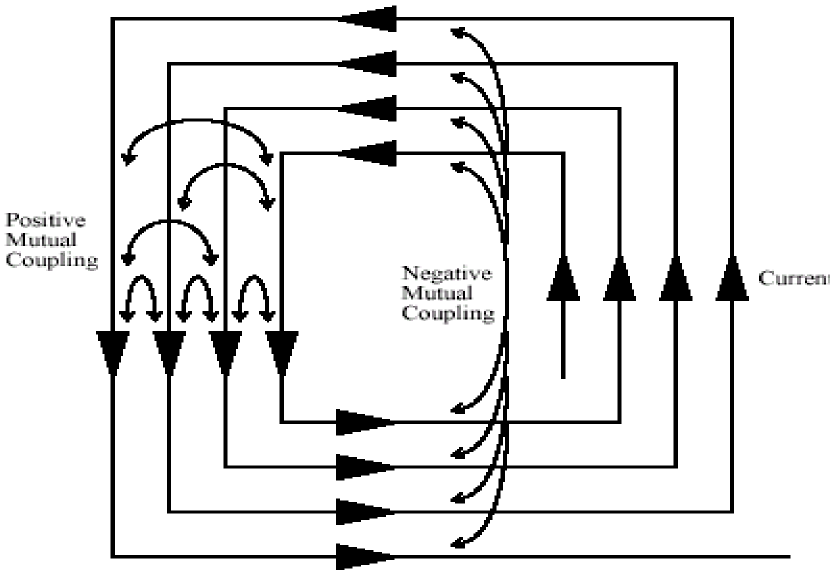
$$L_{self} = 2l[\ln(2l/(w+t)) + 0.5 + (w+t)/3l]$$

l = wire length; w = width; t = thickness

$$M = k*SQRT(L_1L_2) = kL$$

# Series Inductance($L_s$)

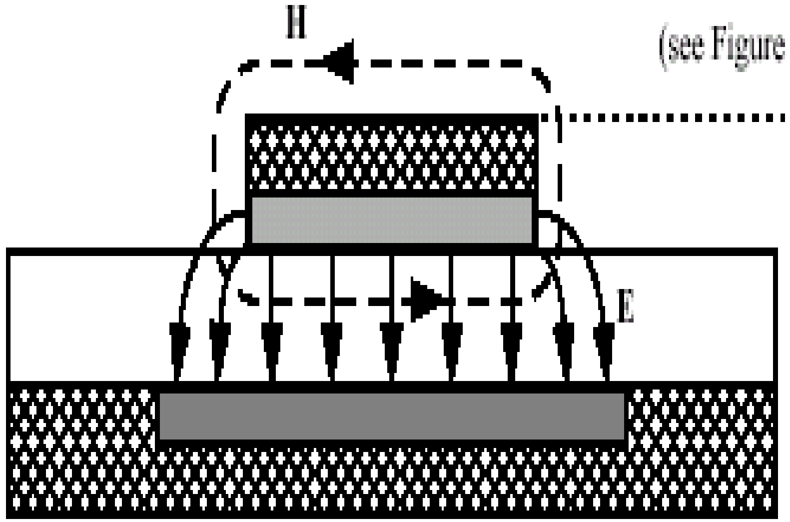
- Greenhouse Method – $L_{total}$ can be computed by summing $L_{self}$ of each wire segment and the positive and negative mutual inductance between all possible wire segment pairs.



# Series Resistance($R_s$)

- Eddy currents reduce the net current flow in the inductor and hence increase the resistance

$R(f)=V/(J(f)*A)$



# Series Resistance($R_s$)

$R = p*l/(w*t_{eff})$

$p$ = resistivity of wire

$l$ = length of wire

$w$ = width of wire

$t_{eff}$ = effective thickness of wire

# Series Capacitance(Cs)

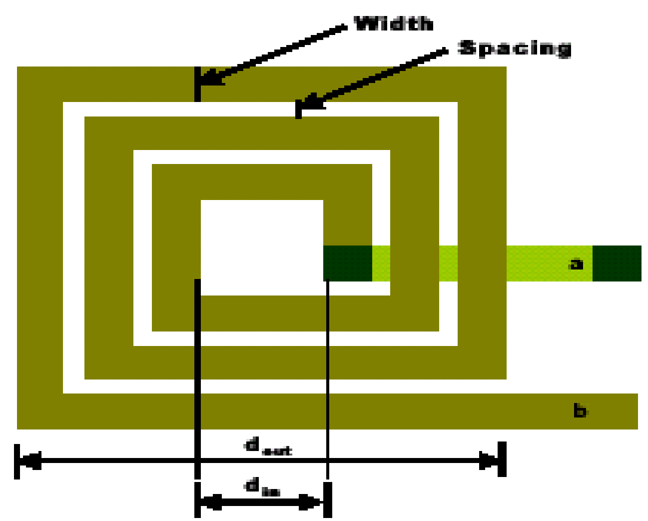
- Models the parasitic capacitive coupling between input and output ports
- Sum of all overlap capacitances of the spiral and the underpass

$$C_s = n \cdot w^2 \cdot \frac{\varepsilon_{ox}}{t_{oxM1\text{-}M2}}$$

N=# of overlap

w= spiral line width

$t_{oxM1\text{-}M2}$=oxide thickness btwn spiral & underpass



# Substrate Parasitics($C_{ox}$, $C_{si}$, $R_{si}$)

$C_{ox}$ = oxide capacitance

$C_{si}$ and $R_{si}$ represent the substrate capacitance and resistance respectively.

Assumed to be distributed equally at both ends of the inductor.

$C_{si}$ and $R_{si}$ are proportional to the area occupied by the inductor.

# Substrate Parasitics($C_{ox}$, $C_{si}$, $R_{si}$)

$C_{ox} = 0.5 * L * w * e_{ox}/t_{ox}$
$C_{ox} = 0.5 * L * w * C_{sub}$
$R_{si} = 2/(L * w * G_{sub})$

$e_{ox}$ = dielectric constant
$t_{ox}$ = oxide thickness

L = spiral length
w = width

$C_{sub}$ and $G_{sub}$ are capacitance and conductance per unit area for the substrates, and they are functions of the substrate doping.

# Quality Factor(Q)

- Measure of how ‘pure’ an inductor is.
- Impedance(Z) of inductor = R +jX
- High Q is critical

    - higher the Q, the fewer the losses

    Q = X/R

# Conclusion

- Ways to improve Q?
  - place inductor far from substrate
  - use metal with low resistance
  - ground shield
  - MEMS technology