# EE 240B – Spring 2018

## Advanced Analog Integrated Circuits
## Lecture 20: Passive Devices and Layout

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# Passives: Resistors

## Resistors

- **Resistance is bad for digital circuits**
  - But, often want large-valued, well-controlled R for analog
  - E.g., a 1kOhm resistor made out of copper interconnect (~200mΩ/□) would require 5000 □'s

- **Fortunately, most processes include explicit provisions for large resistors**
  - Up to ~20nm, typically unsilicided poly or n-well
  - Typically get ~1kΩ/□
  - Even with explicit resistors, still need to watch out for a few things however



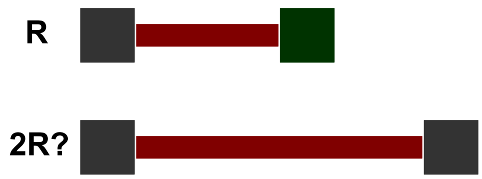
## Resistor Variations

- **Almost always temperature dependent:**

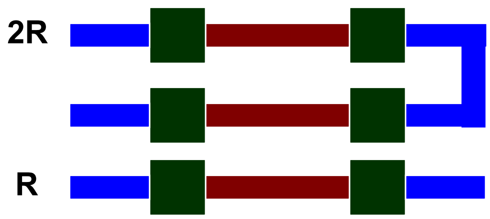
- **Also often voltage dependent:**

## Systematic Variations from Layout

- **Example:**




- **Use unit element instead:**



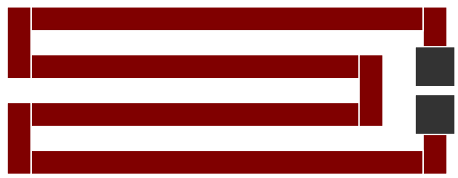



## Better Unit Element

## Resistor Layout (cont.)

Serpentine layout for large values:

Better layout (mitigates offset due to thermoelectric effects):



See Hastings, “The art of analog layout,” Prentice Hall, 2001.



## Electromigration and Parasitics

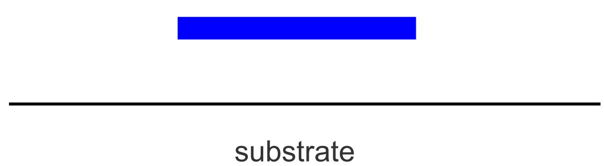
- **Electromigration rules limit maximum current density**
  - Same value resistance must be physically larger to carry more current
  - Hence, more current → larger capacitive parasitcs

# Passives: Capacitors



# Capacitors

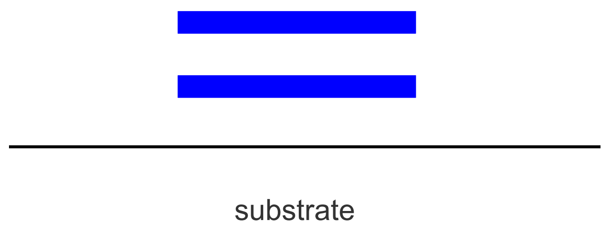
- **Simplest capacitor:**




- **What's the problem with this?**

# Capacitors

- “Improved” capacitor:



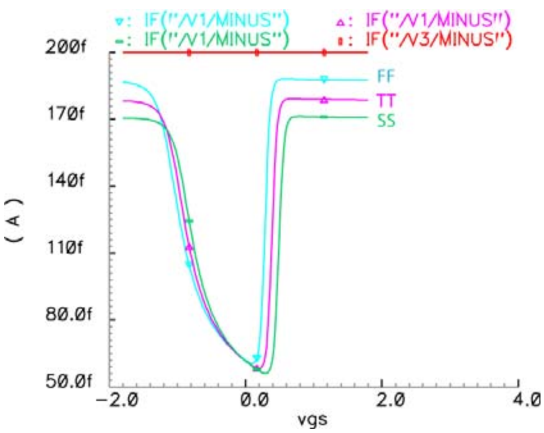

- Is this only 1 capacitor?



# Capacitor Options

| Type | C [aF/μm²] | $V_C$ [ppm/V] | $T_C$ [ppm/°C] |
|---|---|---|---|
| Gate | 10,000 | Huge | Big |
| Poly-poly (option) | 1000 | 10 | 25 |
| Metal-metal | 50 | 20 | 30 |
| Metal-substrate | 30 | | |
| Metal-poly | 50 | | |
| Poly-substrate | 120 | | |
| Junction caps | ~ 1000 | Big | Big |

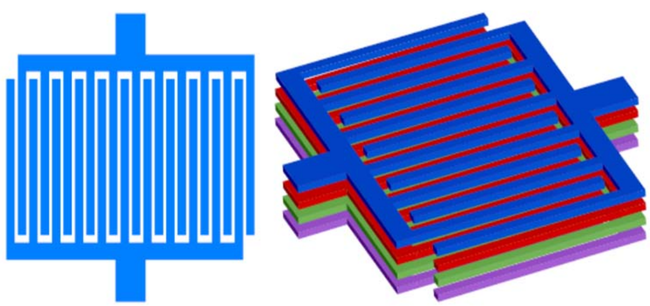
# MOS Capacitor




- **High non-linearity, temperature coefficient**
- **But, still useful in many applications, e.g.:**
  - **(Miller) compensation capacitor**
  - **Bypass capacitor (supply, bias)**



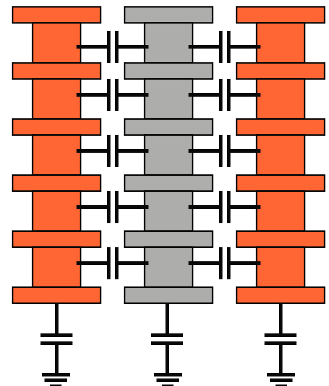
# “MOM” Capacitors



- **Metal-Oxide-Metal capacitor. Free and most common in modern CMOS.**
- **Use lateral flux (~$L_{min}$) and multiple metal layers to realize high capacitance values**

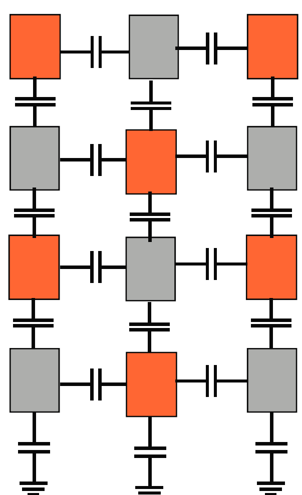
## MOM Capacitor Cross Section

- **Use a wall of metal and vias to realize high density**
- **More layers – higher density**
  - May want to chop off lower layers to reduce $C_{bot}$
- **Reasonably good matching and accuracy**





## Another MOM Option



## Capacitor Parasitics

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## Passives: Inductors

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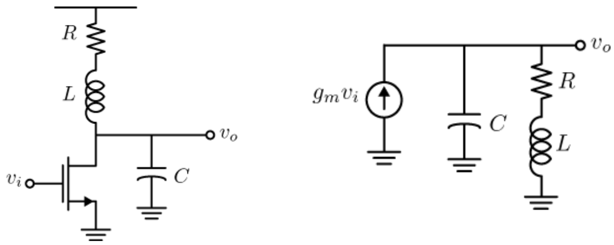
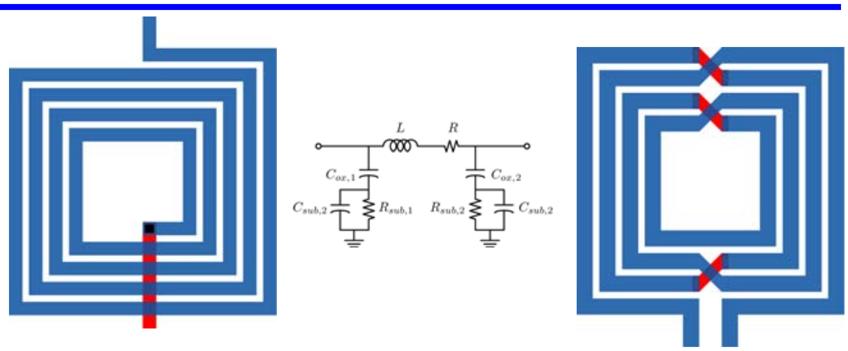
# What About Inductors?




- **Mostly not used in analog/mixed-signal design**
  - Usually too big
  - More of a pain to model than R's and C's
  - But they do occasionally get used
- **Example inductor app.: shunt peaking**
  - Can boost bandwidth by up to 85%!
  - Q not that important (L in series with R)
  - But frequency response may not be flat



# Spiral Inductors




- **Used widely in RF circuits for small L (~1-10nH).**
- **Use top metal for Q and high self resonance frequencies.**
  - Very good matching and accuracy – if you model them right