Resistors
T.P. 1.9
EE4345- Semiconductor Electronics Design
The Heisenburg Uncertainty Group

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Base Resistors (1/2)

In General:
- Available in standard bipolar and analog BiCMOS
- Base sheets in standard bipolar range from 100-200 ohms/sq and BiCMOS from 300-600
Base Resistors (2/2)

Advantages:
- Base sheet is relatively precise & base resistors are doped heavily enough to minimize tank modulation
- Probably the best general purpose resistor available in bipolar form

Disadvantages:
- Capacitive coupling if not careful when routing signals
- Must be placed in a suitable tank of either an N-epi region in standard bipolar or an N-well in analog BiCMOS
Emitter Resistors (1/2)

In General:
Emitter R’s used in standard bipolar to ballast power transistors and serve as current resistors. Also used in as tunnels in single level metal processes.
Emitter Resistors (2/2)

Advantages:
- No difficulty directly contacting the emitter diffusion
- Probably the best general purpose resistor available in bipolar form

Disadvantages:
- Due to low sheet, it is only suitable for small resistors <100 ohms)
- Must be placed in a suitable tank
- If biased more than 6 V, the emitter-base junction will avalanche
Base Pinch (1/2)

In General:
- Effective sheet resistance from 2-10 kohms/sq allowing compact layouts
- Used to make high value resistors that can’t be economically made using other diffusions
- Also used to construct compact high-value resistors
Base Pinch (2/2)

Advantages:
- Can withstand larger differential voltages if they are constructed in multiple segments

Disadvantages:
- Can only be matched if they are identical in dimensions and if they see the same relative tank biasing
- Must be placed in a suitable tank
- If biased more than 6 V, the emitter-base junction will avalanche
High Sheet Resistors (1/2)

In General:
- Sheet Resistances of 1-10 kΩ/square are possible
- Consist of shallow boron implants into the N-epi tank
- Heads consist of base diffusion for good ohmic contact
- Junction depth typically = .5 microns
- Should always have NBL underneath [prevents tank debiasing and acts as a barrier to minority carrier injection if resistor momentarily forward biases into tank]
High Sheet Resistors (2/2)

Advantages:
- Optimal sheet resistances around 2kΩ/square
- Useful for packing large amounts of resistance into limited die areas
- Less variable than pinch resistors
- Higher sheet resistance than base resistors
- Generally used in std bipolar designs with supply currents <1mA

Disadvantages:
- High V HSR resistors prone to spread charging
- Vulnerable to V modulation effects
- Affected by conductivity modulation
- Avalanche V limited by shallowness of the HSR implants
Epi Pinch Resistors

In General:
- Sheet resistances of 5-10 kohms/square
- Consists of N-epi pinched between substrate and overlaying base diffusion, also called an epi-FET
- Pinch off V depends on epi thickness, doping, & base junction depth
- Typical pinch off V 20-40 V
- Often laid out in serpentine pattern
Epi Pinch Resistors (2/2)

Advantages:
- Almost exclusively used in startup applications where they provide a trickle of current
- Not used in large numbers due to inherent variability and nonlinearity

Disadvantages:
- Suffers from severe voltage considerations
Metal Resistors (1/2)

In General:
- Sheet Resistances of 20-40 mohms/square due to metal thickness of 10-15 kAngstroms
- Used for sense circuits and ballasting large power bipolar transistors
- Al metal layer over field oxide
- Can use double metal layer process
Metal Resistors (2/2)

Disadvantages:
- Requires special techniques to provide accurate voltage sensing across resistors
- Can expect +/- 20% variation in metal sheet resistance due to thickness variations
Poly Resistors (1/2)

In General:
- Used in CMOS and BiCMOS processes
- Also for constructing MOS gates which are heavily doped to improve conductivity
- Sheet resistance of 25-50 ohms/sq
- Resistivity not only depends on the doping, but also the grain structure
Poly Resistors (2/2)

Advantages:
- Better type of R on most processes due to results in smaller layouts
- No tank modulation
- Little conductivity modulation if sheer resistance < 1 kohm

Disadvantages:
- Variability
- Moderate parasitic capacitance if not on top of the oxide field
- Do not tolerate transient overloading
Resistors

- Resistor Design Considerations
- NSD and PSD Resistors
- N-Well Resistors
- Thin Film Resistors
  - What is Thin Film?
  - How is Thin Film Created?
- Adjusting Resistor Values
  - Tweaking and Trimming Resistors
Resistor Design Considerations

- Resistor value
- Its change over time
- Its change in value with temperature
- Its power handling capacity
  - Choice of resistor material
  - Sheet Resistivity
NSD and PSD Resistors

\[ R = Rs \left[ \frac{Ld}{(Wd+Wb)} \right] + 2Rh \left[ \frac{Lh}{(Wd+Wb)} \right] \]

- **Rs** = Sheet resistance
- **Rh** = Sheet resistance of material used to construct the head
- **Lh** = Overlap of implant over the contact
N-Well Resistors
What Is Thin-Film?

- Depositing passive and non-passive circuit elements on an insulating substrate
Thin-Film Resistors: Equipment

High-Vacuum Deposition System
Thin-Film Resistors: Equipment

Basket          Vacuum Control Unit
Thin-Film Resistors: Equipment

Pirani Gauge

Cold Cathode Gauge
Thin-Film Resistors: Equipment

Heater                       Quartz Crystal Oscillator
Thin-Film: Cleaning The Substrate

IPC Plasma Cleaner       Cleaner Trays
Thin-Film: Cleaning The Substrate

Vacuum Gauge

RF Power
Thin-Film Resistors

\[ R = \frac{Rs \cdot (L / W)}{(\Omega)} \]

- \( R \) = Total Resistance \((\Omega)\)
- \( Rs \) = Sheet Resistance \((\Omega/t)\)
  - \( ? \) = Bulk Resistivity of resistor material
  - \( t \) = Resistor Thickness \((\text{cm})\)
- \( L \) = Resistor Length \((\text{cm})\)
- \( W \) = Resistor Width \((\text{cm})\)
Thin-Film Resistors

![Diagram of a thin-film resistor structure with labeled parts: Deposited oxide passivation layer, Aluminum contact, Tantalum thin-film layer, Silicon substrate, Tantalum resistor, Aluminum contact, SiO2.]

**Figure 2.51** Typical thin-film resistor structure.
Tweaking Resistors

- Sliding Contact
- Trombone Slide

- Each technique involves a different mask, and no one method can adjust all types of resistor.
Tweaking Resistors: Sliding Contacts

(A) Range of slide

(B) Range of slide
Tweaking Resistors: Trombone Slides

Alternate position of resistor after trombone slide
Trimming Resistors: Fuses and Zener Zaps
Trimming Resistors: Laser Trims

(A)

(B)

(C)

(D)
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References

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