IC Engineering I

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2025-01-08

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Preface

This is a Quarto book.

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1 Introduction

This book covers basic topics in circuits and devices for Integrated Circuit (IC) engineers.

This is a book created from markdown and executable code.

This is an exmaple of reference citation: Thomas, Rosa, and Toussaint (2016)

2 Passive IC devices

This chapter covers basics principle behind passive IC devices: Resistors, Capacitors and Inductors.

2.1 Resistance

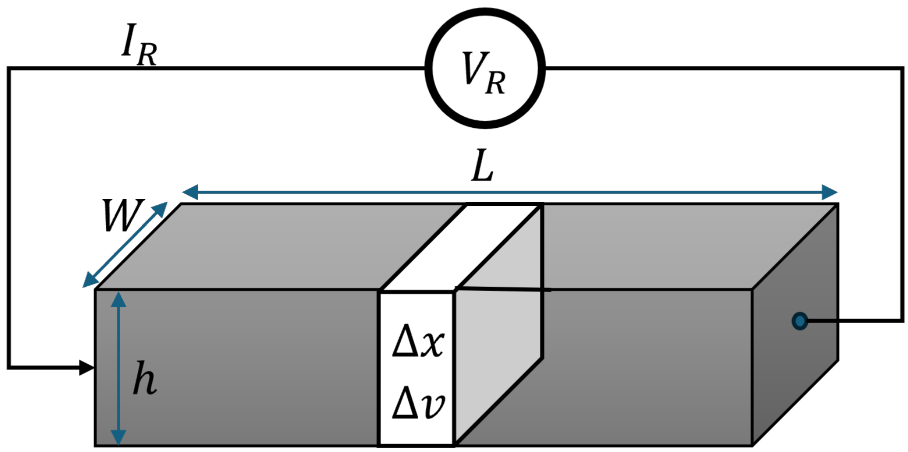

Figure 2.1: Setup for resistance calculation

Resistance calculation of metal or semiconductor material is fundamental to IC engineering. Consider a block of metal or semiconductor material with dimensions L, W and h as shown in Figure 2.1. Let n be the charge per unit volume. To calculate the current I_R for an applied voltage V_R across the length of the material, we will consider an incremental cross section of the material with length Δx. The current can be written as the total charge in the incremental volume in time Δt:

$I_R = \frac{\Delta Q}{\Delta t} = \frac{Q_S \Delta x}{\Delta t} = Q_S v_d$

$I_R = SheetCharge \times AverageVelocity$ or,

where, $Q_S = nWh$ is the sheet-charge or the charge per unit length,

v_d is the average velocity of the electrons:

$v_d = \frac{\Delta x}{\Delta t} = \mu E$, and

where, $E = \frac{\Delta v}{\Delta x}$, and μ is the *mobility* of the material.

Therefore, $I_R = \mu Q_S \frac{\Delta v}{\Delta x}$

The incremental resistance can be expressed as

$\Delta R = \Delta v / I_R = \rho \frac{\Delta x}{Wh}$

where, $\rho = 1/(n\mu)$ is the *Specific resistivity* (ρ) is a property of the material that can be defined as the resistance per unit volume expressed in SI units of Ωm but more conveniently as Ωcm.

The total resistance of the volume can be found by summing up all incremental resistances ΔR:

$R = \rho \frac{L}{A}$

where, L is the length and A is the cross-sectional areai (Wh).

In integrated circuit design, the height of the metal routing is fixed and is typically in the range of 0.1 to 5 micrometers ($\mu m, 10^{-6} m$) and the resistance is measured in square units as *ohms per square* or $\Omega/\square$.

$R = (\rho/h)(L/W)$

Where, ρ/h is typically called sheet-rho (ρ_{sheet})

The specific resistance (in Ωcm) and unit resistance (in $\Omega/\square$) of typical metals used in integrated circuits such as aluminum (Al), copper (Cu) and gold (Au) are tabulated:

	$\mu - \Omega$ cm	$m\Omega/\square$
Al	2.65	26.5
Cu	1.68	16.8
Au	2.44	24.4

References

Thomas, Roland E., Albert J. Rosa, and Gregory J. Toussaint. 2016. *The Analysis and Design of Linear Circuits*. John Wiley & Sons. https://www.dropbox.com/scl/fi/83ygnyynx2sfex1h7tdhg/Thomas-AnalysisDesignOfLinearCkts-Wiley-2023.pdf?rlkey=4xzk0an1z7r3fcj936o0enjg4&dl=0.