

IC Engineering I

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Table of contents

Preface	3
1 Introduction	4
2 Passive IC devices	5
2.1 Resistance	5
References	7

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

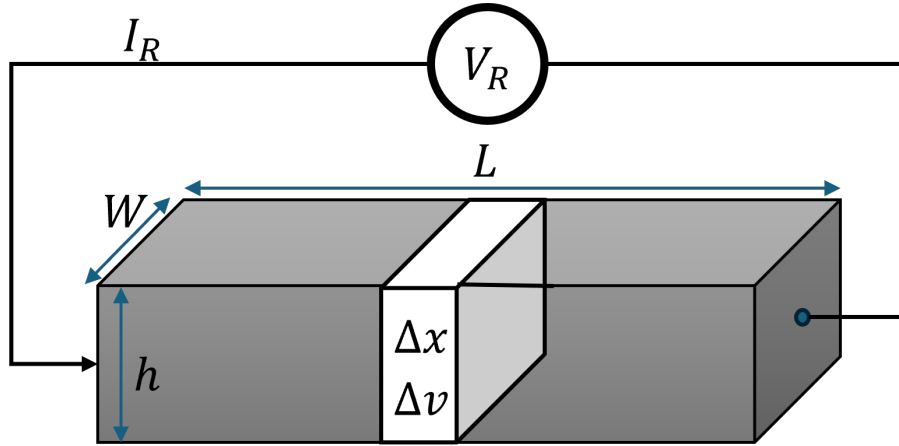


Figure 2.1: Setup for resistance calculation

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 :

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

$$I_R = \text{SheetCharge} \times \text{AverageVelocity} \text{ or,}$$

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 area (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 Ω/\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 Ω/\square) of typical metals used in integrated circuits such as aluminum (Al), copper (Cu) and gold (Au) are tabulated:

	$\mu - \Omega \text{ cm}$	$m\Omega/\square$
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/83ygnyynx2sfe x1h7tdhg/Thomas-AnalysisDesignOfLinearCkts-Wiley-2023.pdf?rlkey=4xzk0an1z7r3fcj936o0enjg4&dl=0>.