Chapter 1

Introduction to Electronics

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Electronics: Principles, Concepts and Practices

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Intro

Electronics

1. Understanding the atom is a crucial starting point when delving into the story of modern electronics.
2. The study of atoms and their behavior provides the foundation for comprehending the behavior of materials and their electrical properties.
3. The story of the atom begins in the early 20th century with groundbreaking discoveries in the field of quantum mechanics.
4. Scientists such as Max Planck, Albert Einstein, Niels Bohr, and Erwin Schrödinger made significant contributions to our understanding of the atom's structure and behavior.

The Atom

Atom

The atom is the smallest unit of matter that retains the complete property of an element. Atoms are made up of three basic particles namely; protons, electrons and neutrons.

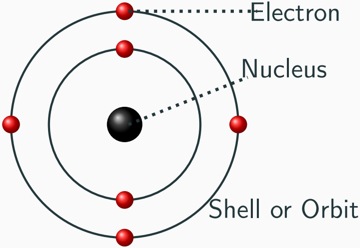


Figure 1: Atomic Structure

Atoms continued . . .

- Electrons are negatively charged.
- The outer region of the atom consists of electron orbits.
- These orbits contain electrons.
- The outermost orbit can only have a maximum of 8 electrons.
- The electrons in the outermost orbits are known as valency electrons.

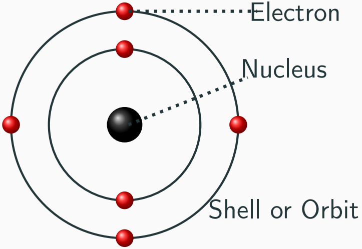


Figure 2: Atomic Structure

The valence electrons determined the physical, chemical and most essential for us, the electrical properties of materials. As a rough role:

1. When the number of valence electrons is less than 4, the material is usually a metaland a conductor. Examples are sodium, magnesium and aluminium which have 1, 2 and 3 valence electrons respectively
2. When the number of valence electrons is greater than 4, the material is usually a non-metal and an insulator. Examples are nitrogen, sulphur and neon, which have 5, 6 and 8 valence electrons respectively.
3. When the number of valence electrons equal 4, the material has both metal and non-metal properties and is usually a semi-conductor. Examples are carbon, silicon and germanium.

Periodic Table
The periodic table is an organised array of elements in order of increasing atomic number, which is the total number of protons in the atomic nucleus.

1	2	3	4	5	6	7	8
1 H							2 He
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ag
19 K	20 Ca	31 Ga	32 Ge	33 As			
		49 In		51 Sb			

Figure 3: Periodic Table

Energy Levels and Bands

Energy Level
A discrete value from a set of quantize values of total energy for a subatomic particle confined by a force to a limited space.

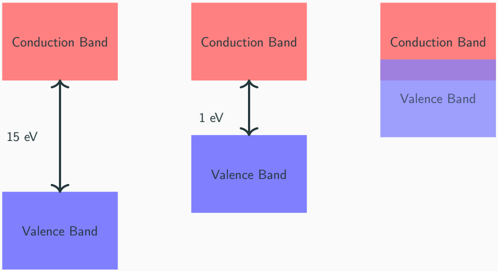
Energy Band
Energy bands consisting of a large number of closely spaced energy levels. This arises from the closely packed atoms of typical crystalline materials.

There are three (3) crucial energy bands in solid materials.

1. The **valence band** is the range of energies possessed by the valence electrons.
2. The **conduction band** refer to the range of energies possessed by free electrons which have been excited and detached from their loose bonds to become conducting electrons
3. **Forbidden energy gap** refers to the spatial separation between conduction and valency band. As the name implies, no electron stays in the forbidden energy gap.
   For different materials, the forbidden gap varies. The more the forbidden energy gap, the tighter the valence electrons are bond to the nucleus.

Material Classification based on Energy Band

The classification includes, insulators, semi-conductors and conductors as shown in fig.4.



a: Insulators

b: Semi-Conductors

c: Conductors

Figure 4: Energy Band

Insulators
Insulators or dielectrics do not readily conduct an electric current when external sources are applied. From the energy bands perspective, we may explain that for insulators, the valence band is full while the conduction band is empty. The energy gap (forbidden energy band) is large.

Semi-Conductors
Materials that have conductivity between that of an insulator and that of most metals. From the energy bands perspective, the energy gap between the conduction and valence band is relatively small.

Conductors
Conductors are materials that permit electrons to flow freely from particle to particle. From the energy gap perspective, conductors have overlapping conduction and valence band.

Ref. to fig. slide **??**, the magnitude of the E field is

$$\vec{E} = \frac{V}{L} \tag{1}$$

The electric field will exert a force $\vec{F}$ on the movable charges which will accelerate a,

$$\vec{F} = q\vec{E} \tag{2}$$

$$\vec{F} = m\vec{a} = m\frac{d}{dt}v(t) \tag{3}$$

Combining equation 2 and 3, and integrating w.r.t, then velocity is

$$v(t) = \frac{q\vec{E}t}{m} \tag{4}$$

We can only speak in terms of the average velocity Ψ for specified time interval τ, given as

$$\Psi(t) = \frac{q\vec{E}\tau}{m} \tag{5}$$

Current flow I, is

$$I = \frac{Q}{\Delta t} = \frac{qN}{\Delta t} \tag{6}$$

$$= \frac{q^2 n\tau \vec{E} A}{m} \tag{7}$$

From a field point of view, we speak in terms of current density J for the cross-sectional area A

$$J = \frac{I}{A} = (\frac{q^2 n\tau}{m})\vec{E} = \sigma \vec{E} \tag{8}$$

here σ is the conductivity of the material. Equation 8 may be expressed in voltage and current as

$$I = AJ = A\sigma \vec{E} = A\sigma \frac{V}{L} \tag{9}$$

Equation 9 reminds you of __________?

Equation 9 reminds you of **Ohms Law!**

Let us rewrite equation 9 in a more familiar way

$$V = I\left(\frac{L}{\sigma A}\right) = IR \tag{10}$$

where R is the resistance of the conductor sample.

Homework:
Check with the class rep for the weekly numerical task!

Interestingly, we have shown the derivation of ohm's law. We bring the discussion on conductors to an end here. Note that the model used here is based on an assumption of two charged particles wherein one is fixed and the other is mobile. This is entirely not the case when we discuss semi-conductors in the next chapter. The focus onward shall be semi-conductors.

Thévenin method

In this method, the voltage-divider circuit is redrawn using the Thévenin technique. Fig. 5 represents the Thévenin equivalent circuit.
Apply KVL to Théveninized circuit to obtain

$$I_{B_Q} = \frac{V_{Th} - V_{BE}}{R_{Th} + (\beta + 1) R_E} \tag{11}$$

Similarly, applying KVL to the output loop of Figure **??**.

$$V_{CE_Q} = V_{CC} - I_{C_Q}(R_C + R_E) \tag{12}$$

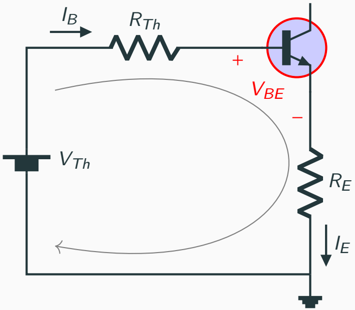


Figure 5: The Thévenin equivalent circuit

Approximation method

This method relies on the assumption that $(\beta+1)R_E >> R_2$. Thus, I_B is negligible. The network equations become:

$$V_B = \frac{R_2 V_{CC}}{R_1 + R_2} \tag{13}$$

$$V_E = V_B - V_{BE} \tag{14}$$

$$I_E = \frac{V_E}{R_E} \tag{15}$$

$$I_C \approx I_E \tag{16}$$

From the output loop we can obtain

$$V_{CE} = V_{CC} - I_C (R_C + R_E) \tag{17}$$

Fig. 6 illustrates the approximation method

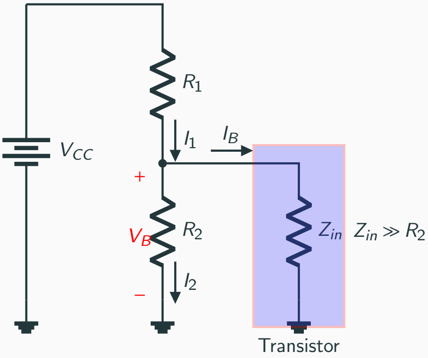


Figure 6: Approximation method

Fig. 7 is the collector feedback circuit.

As with the previous biasing circuit, apply KVL to the base-emitter loop. The network equations become:

$$I_{B_Q} = \frac{V_{CC} - V_{BE}}{R_B + \beta(R_C + R_E)} \tag{18}$$

Applying KVL to the output loop of Fig. 7.

$$V_{CE_Q} \approx V_{CC} - I_C\,(R_C + R_E) \tag{19}$$

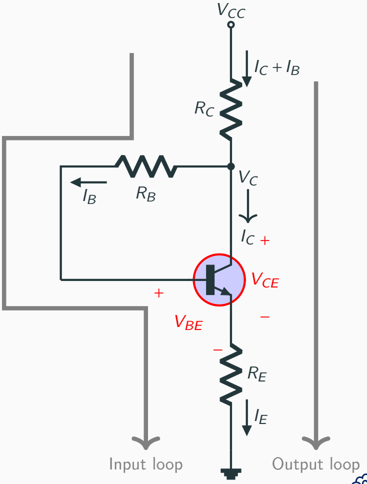


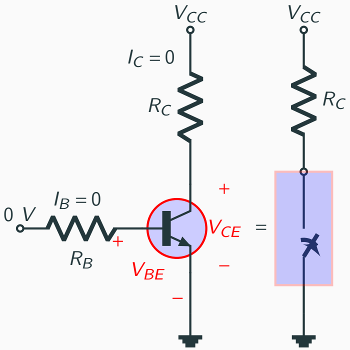
Figure 7: Collector-feedback bias circuit

Circuit Biasing for Switching

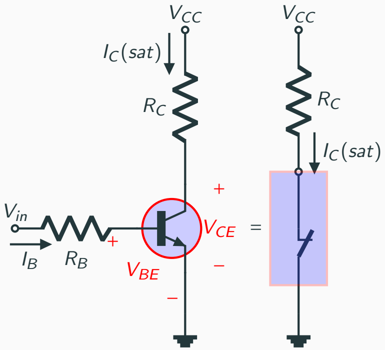
Circuit Biasing for Switching

In the cutoff region, the collector current $I_C \approx 0$.

In the saturation region, the collector-emitter voltage $V_{CE} \approx 0$.



(a) Cutoff open-circuit



(b) Saturation closed-circuit

Figure 8: Illustration of the switching action of a BJT circuit

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