Introduction to Basic Electronic Devices

EN1014 Electronic Engineering

Department of Electronic and Telecommunication Engineering
University of Moratuwa

Semester 2

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What You will learn

This unit introduces;

- Concept of abstraction which is a powerful engineering tool
- A brief review of some historical aspects of electronics
- An overview of the circuit design process.

At the end, you will be able to;

- Use the concept of abstraction.
- Recall some historical aspects related to electronics.
- Explain the circuit design process.

Introduction

Engineering

'Engineering is the purposeful use of science.'

~ Dr. Stephen Senturia, MIT ~

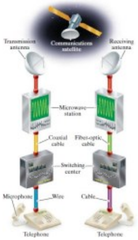
Electrical Engineering in perspective

The profession
concerned with the
design, development, construction and application of
systems
that generate, convert, gather, transport, store, and process
electrical energy
and
signals.

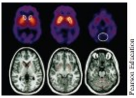
Electrical Engineering in perspective

- Generate, convert and distribute electrical signals has revolutionized the world
- Storage and processing of electrical signals (information)
    - Computers and other devices with microprocessors.
    - Control systems to control physical systems such as airplanes, automobiles, and many others.
- Processing of electrical signals (i.e. signal processing) is seen in many applications.
    - Examples include biomedical (MRI, ECG, ultrasound, etc), audio and speech signals and images/video, remote sensing and array processing, communications, etc.
- Transport of electrical signals and energy has been significant for society.

Some Examples…



A Communication system.



A computerized tomography (CT) scan is an example of an image-processing system.

Figure: A good example of the interaction among systems is a commercial airplane.

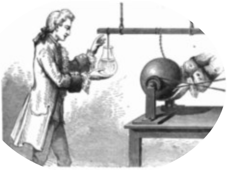
Some Major areas of Electrical Engineering

- Power Systems
- Microelectronics and Fabrication
- Control Systems
- Digital Systems and Computers
- Signal Processing
- Telecommunications
- Electronics
- Photonics
- Biomedical Engineering
- Mechatronics

Electrical Engineering – An Alternative Perspective

Lets look at some of the major discoveries…

Discovery of the Layden Jar - 1745



- Ewald Georg von Kleist and Pieter van Musschenbroek accidentally discovered the Layden Jar in 1745.
- It was the first electrical capacitor; a storage mechanism for an electrical charge.

Watch: https://youtu.be/spuXN0ccRQ8

Benjamin Franklin


Ben Franklin


Franklin Electrostatic Generator

- Flew kites to demonstrate that lightning is a form of Static Electricity.
- He attached a wire to the kite and produce sparks at the ground and charge a Leyden jar.
- This led Franklin to invent the lightning rod.

- Watch: https://youtu.be/RGK6nlE6hw0

Charles Augustus Coulomb (1736-1806)

- Coulomb showed electrical attraction and repulsion follow an inverse square law.
- The unit of charge (Coulomb) is named after him.

Watch: https://youtu.be/rwg5DvyhjYs

Alessandro Volta (1745-1827)

- Invented the battery.
- The unit of voltage is named after him.

Watch: https://youtu.be/Is8wAeoTqHQ

Andr´e Marie Amp`ere (1775-1836)

- Gave a formalized understanding of the relationships between electricity and magnetism using algebra.
- The unit for current (Ampere) is named after him.
- Watch: https://youtu.be/RJb0r8dHzAo

Hans Christian Oersted (1777-1851)

- Demonstrated that electricity affected magnetism.
- Initiated the study of Electromagnetism.
- Discovered Aluminum.

Watch: https://youtu.be/RwilgsQ9xaM

George Simon Ohm (1789-

- Presented the "Ohm's Law".
- Invented the Solenoid.
- The unit for resistance (Ohms) is named after him.

Watch: https://youtu.be/mB1z_x7J5Aw

Michael Faraday (1791-1867)

- Demonstrated electromagnetic induction.
- The unit of capacitance (Farad) is named after him.

Watch: https://youtu.be/mxwVIOHEG4I

Joseph Henry (1797-

- He aided and discovered several important principles of electricity, including self-induction, a phenomenon of primary importance in electronic circuitry.
- The unit of induction (Henry) is named after him.

Samuel Finley Breese Morse (1791-1872)

- Developed the electric telegraph (1832–35).
- In 1838 he and his friend Alfred Vail developed the Morse Code.

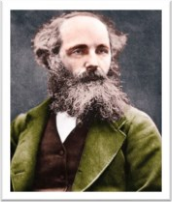
Watch: https://youtu.be/iI7q1xGExcA

Gustav Robert Kirchhoff (1824-

- In 1845 Kirchhoff first announced Kirchhoff's laws.
- In further studies, he demonstrated that current flows through a conductor at the speed of light.

Watch: https://youtu.be/YMNZ2oYu-qI

James Clerk Maxwell (1831-



- The concept of electromagnetic radiation originated with Maxwell, and his field equations, based on Michael Faraday's observations of the electric and magnetic lines of force.

Watch: https://youtu.be/SS4tcajTsW8

Electrical Engineering - An Alternative Perspective

'Electrical engineering is the purposeful use of Maxwell's Equations (or their abstractions) for electromagnetic phenomena.'

- A. Agarwal, J. Lang, MIT -

Maxwell's Equations

- A set of four fundamental equations describing electro-magnetism
  i.e the behaviour of electric and magnetic fields
- Used to model electromagnetism.
- Developed from experimental observations
- Models of reality

Maxwell's Equations

Name	Equation	
	Integral form	Differential form
Faraday's law of induction	$\oint_c \vec{E}\cdot d\vec{l} = -\iint_S \frac{\partial \vec{B}}{\partial t}\cdot d\vec{S}$	$\nabla\times\vec{E} = -\frac{\partial \vec{B}}{\partial t}$
Ampère-Maxwell law	$\oint_c \vec{H}\cdot d\vec{l} = \iint_S \vec{J}\cdot d\vec{S} + \iint_S \frac{\partial \vec{D}}{\partial t}\cdot d\vec{S}$	$\nabla\times\vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$
Gauss' electric law	$\oiint_S \vec{D}\cdot d\vec{S} = \iiint_V \rho\, dV$	$\nabla\cdot\vec{D} = \rho$
Gauss' magnetic law	$\oiint_S \vec{B}\cdot d\vec{S} = 0$	$\nabla\cdot\vec{B} = 0$

What is meant by a 'Model'?

A model in science is a
physical, mathematical, or logical
representation of a system
of entities, phenomena, or processes.
It is a simplified abstract view of the complex reality.

~ Wikipedia ~

Model

A simplified abstract view
of
the complex reality.

Why Model?

- Simplify complex physical realities so that we can make sense of it. (e.g. an atom)
- Simplify our thinking
- Can have varying levels of depth and complexity.
    - we can even make simpler models from models to practically solve problems.

Models from Models

- Way of simplifying our thoughts only to the essential details required for a purpose.
    - Maxwell's equations are an example of this need.
- As a set of partial differential equations over surfaces and volumes, it is very hard to apply them in every practical electromagnetic system.

Concept of Abstraction

- We use the concept of abstraction to simplify Maxwell's equations in order to meet our practical needs.
- Example: Consider a light bulb connected to a battery. What if we want to know the power dissipated by a light bulb. How can we compute this?

Complicated Equations

Name	Equation	
	Integral form	Differential form
Faraday's law of induction	$\oint_c \overline{E}\cdot d\overline{l} = -\iint_S \frac{\partial \overline{B}}{\partial t}\cdot d\overline{S}$	$\nabla\times\overline{E} = -\frac{\partial \overline{B}}{\partial t}$
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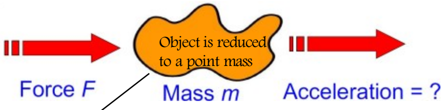
Abstraction

The process of generalizing
by reducing the information content
of a concept or an observable phenomenon
in order to
retain only the relevant information for the purpose.

Abstraction



We ignore shape, temperature, point of force application, and other attributes of the object

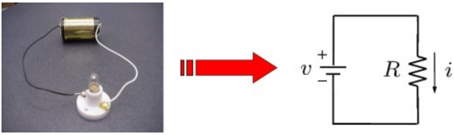
$$F = m.a$$

$$a = \frac{F}{m}$$

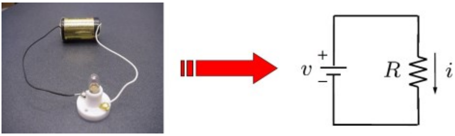
We can do the same with the light bulb in order to find the power dissipated when connected to a battery

Abstraction

- Ignore how current flows through the filament
- Ignore its shape, size, temperature, orientation, etc.
- Model the light bulb with a discrete resistor.



Abstraction



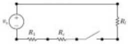
- The three-dimensional object (battery) is ‘lumped’ into a source with voltage V.
- Light bulb has been lumped into an element with resistance *R*.
- The bulb’s resistance is the property of interest needed to compute power.
- Using Ohm’s Law (a model in itself) the current through the light bulb can be found.
- Power can then be computed to be $P = v.i$ (Watts).

Abstraction

- Abstraction is widely used in engineering to simplify science into tractable models.
- Understand the abstractions that have gone into these models and realize their limitations.
- Real-life systems do not always behave as predicted by models. It's important to be able to figure out why.
    - In the light bulb example, we neglected any resistance in the connecting wires. Batteries can have internal resistances as well. This can affect my model's accuracy.

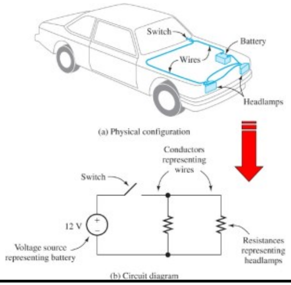
Basic Modeling

The arrangement of flashlight components.



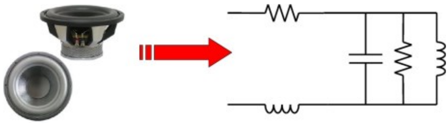
A circuit model for a flashlight.

Basic Modeling

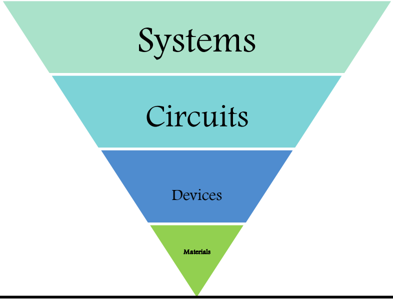


Advanced Modeling

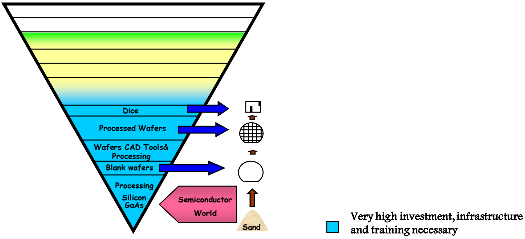
- A speaker is an electro-mechanical device.
- To help compute its output power, frequency response, or other properties, a speaker can be modelled as



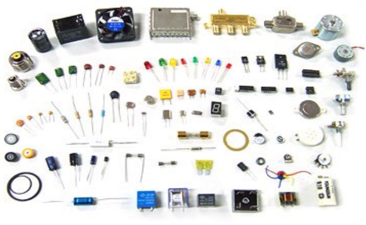
Layers of Abstraction



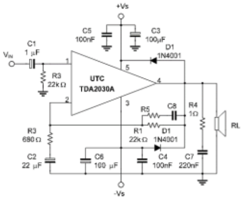
Materials Layer



Lumped Circuit Elements Layer

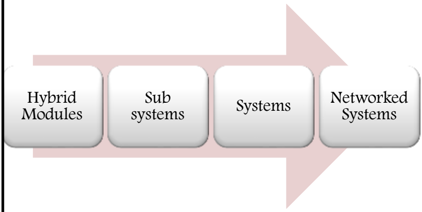


Lumped Circuit Layer

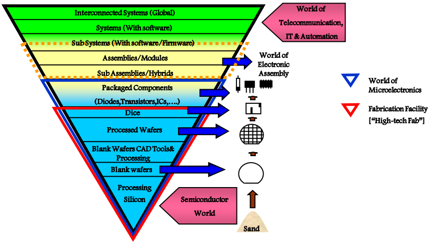


Lumped Hybrid Module Layer

Upper Layers of Abstraction



Systems Layer



The Systems Level : Application sectors

- Audio / Video
- Automotive Electronics
- Robotics
- Industrial Control & Automation
- Personal Electronics
- Mobile/Wireless Communications
- Satellite Systems
- Fiber Optic Communication Systems
- Biomedical Engineering
- Networking – Wired/Wireless
- Home(Domestic) Automation
- Etc…

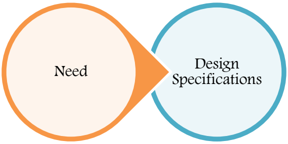
Engineering Design: An Overview

Design of Electrical/Electronic Circuits

NEED

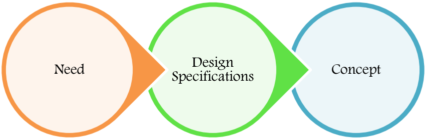
- All engineering designs begin with a need.
- The need may come from the desire to improve on an existing design, or it may be something brand-new.

Design of Electrical/Electronic Circuits



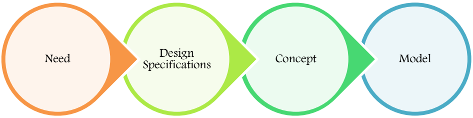
- A careful assessment of the need results in design specifications.
- Design Specifications are measurable characteristics of a proposed design.
- Design specifications allow us to assess whether or not the design actually meets the need.

Design of Electrical/Electronic Circuits



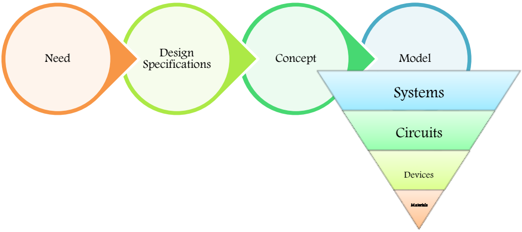
- The concept may be developed as a sketch, as a written description, or in some other form.
- It derives from education and experience.

Design of Electrical/Electronic Circuits

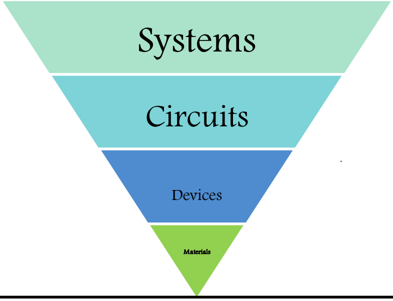


- Translate the concept into a model.

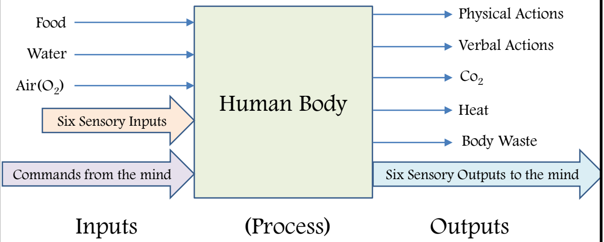
Design of Electrical/Electronic Circuits



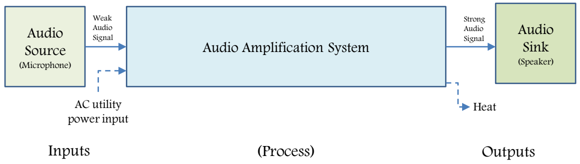
Layers of Abstraction



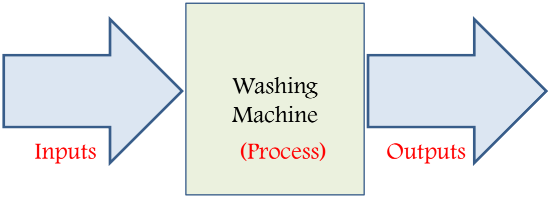
1) Human Body – A System Level Abstraction



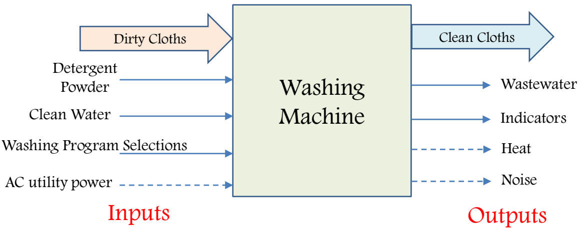
2) Simple Audio System – A System Level



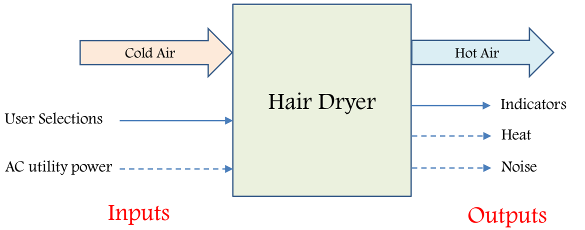
3) A washing Machine – A System Level



A washing Machine – A System Level Abstraction



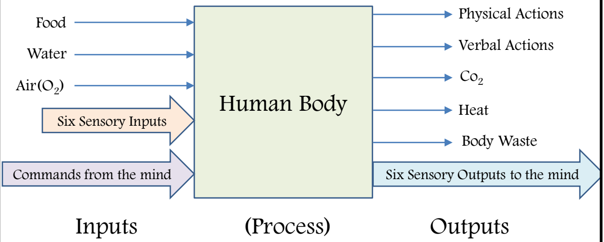
A Hair Dryer – A System Level Abstraction

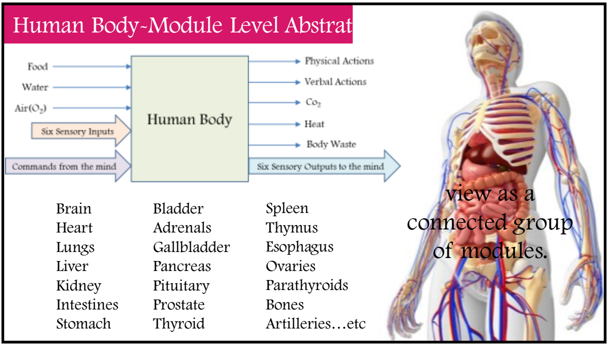


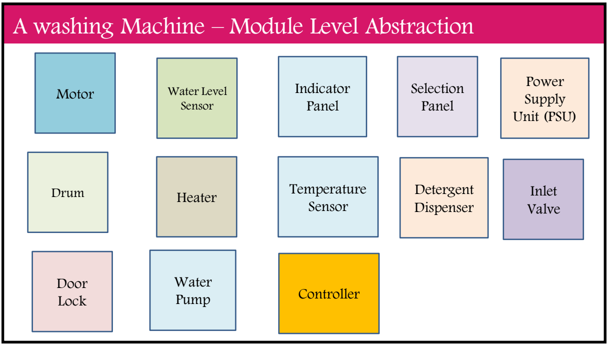
Recap

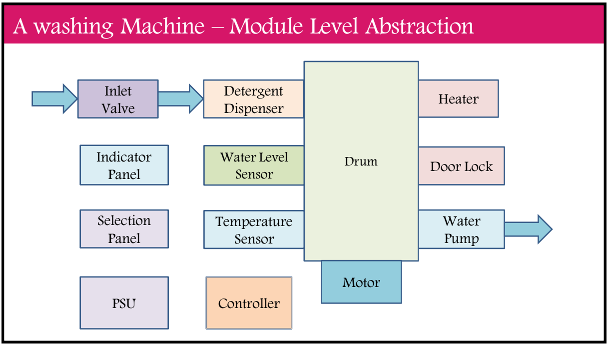
- We abstracted three example systems to retain only the relevant information for the purpose.
- In the external view inputs and outputs are clearly identified. Internal details are not considered.
- System is viewed as a whole.
- In the next level of abstraction, view the system as a connected group of sub-systems/modules.

Human Body – A System Level Abstraction




Human Body-Module Level Abstrat
Food
Water
Air(O_2)
Six Sensory Inputs
Commands from the mind
Human Body
Physical Actions
Verbal Actions
Co_2
Heat
Body Waste
Six Sensory Outputs to the mind
Brain
Heart
Lungs
Liver
Kidney
Intestines
Stomach
Bladder
Adrenals
Gallbladder
Pancreas
Pituitary
Prostate
Thyroid
Spleen
Thymus
Esophagus
Ovaries
Parathyroids
Bones
Artilleries…etc
view as a connected group of modules.


A washing Machine – Module Level Abstraction
Motor
Water Level Sensor
Indicator Panel
Selection Panel
Power Supply Unit (PSU)
Drum
Heater
Temperature Sensor
Detergent Dispenser
Inlet Valve
Door Lock
Water Pump
Controller


A washing Machine – Module Level Abstraction
Inlet Valve
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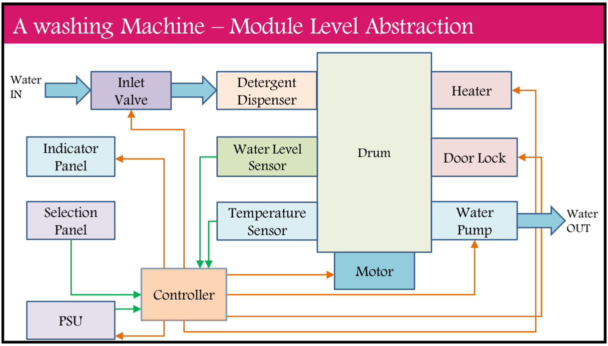
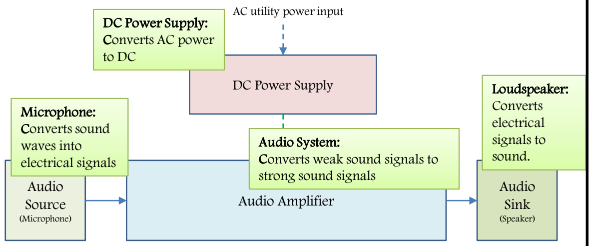
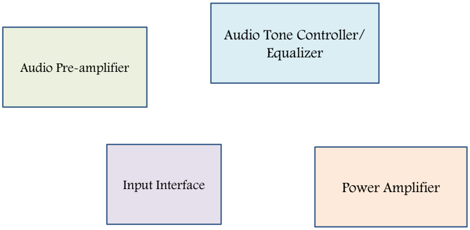
Temperature Sensor
Water Pump
PSU
Controller
Motor


A washing Machine – Module Level Abstraction
Water IN
Inlet Valve
Detergent Dispenser
Drum
Heater
Indicator Panel
Water Level Sensor
Door Lock
Selection Panel
Temperature Sensor
Water Pump
Water OUT
Motor
Controller
PSU

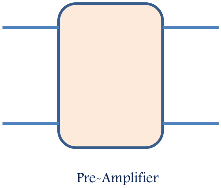
A simple Audio System – A System Level Abstraction



A simple Audio System – Module Level Abstraction

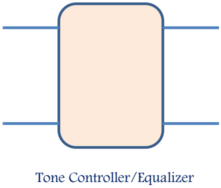


Lumped Module Abstraction of the Pre-Amplifier



Pre-Amplifier
increases the low level (voltage) signal from the microphone into a higher level.

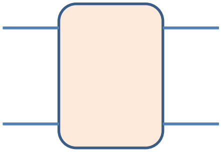
Lumped Module Abstraction of the Tone Controller



Tone Controller
Adjust the balance between different frequency components in the audio signal.
E.g. high frequency(Treble) and low frequency (Bass).

Volume control adjusts level loudness of sound.

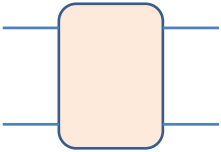
Lumped Module Abstraction of the Power Amplifier



Power Amplifier

Power Amplifier
Increases the audio signal power upto a level suitable to drive the Loudspeaker.

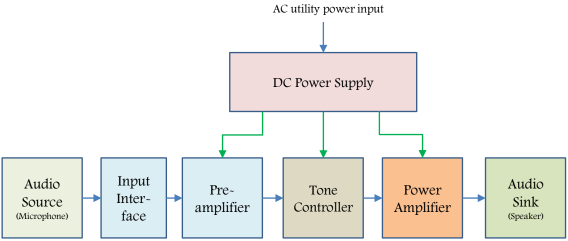
Lumped Module Abstraction of the Input Interface



Input Interface

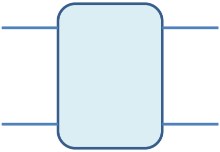
Input Interface
Input Impedance Matching/ Level Adjustment.
Supports multiple input types.
Also minimize input noise.

Simple Audio System – Module Level Abstraction



Lumped Module Abstraction

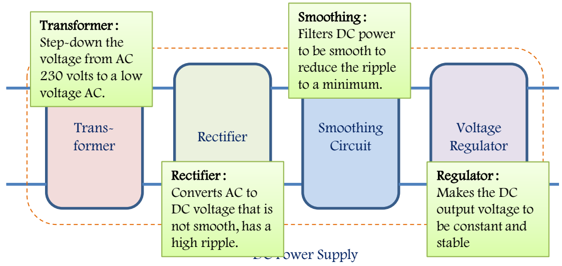
- Converts AC power to DC



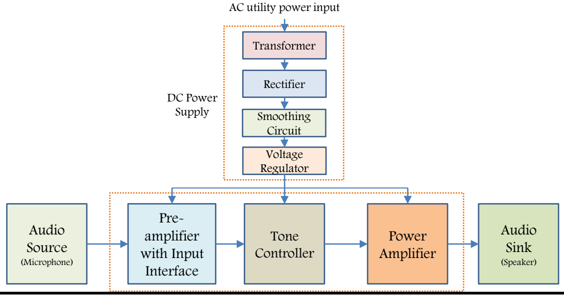
DC Power Supply

72/ 48

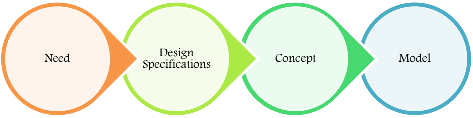
Lumped Circuit Abstraction of DC Power Supply Module



Simple Audio System – Module Level Abstraction



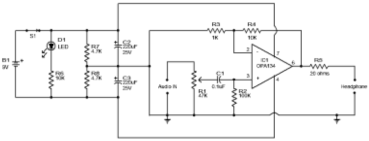
Design of Electrical/Electronic Circuits



- Finally translate the concept into a mathematical model.
- A commonly used mathematical model for electrical systems is a circuit model.

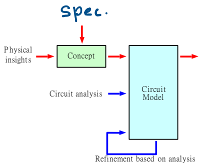
Design of Electrical/Electronic Circuits

- A commonly used mathematical model for electrical systems is a circuit model.

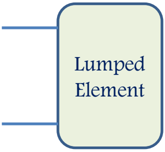


Design of Electrical/Electronic Circuits

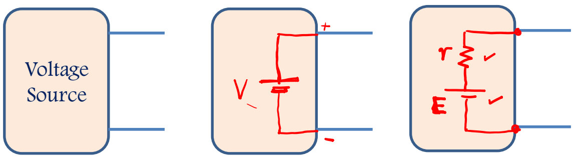
- Each element in the circuit model is a mathematical model of an actual component.
- It is required to represent the behaviour of the actual electrical component to an acceptable degree of accuracy.



One-port Lumped Element Models



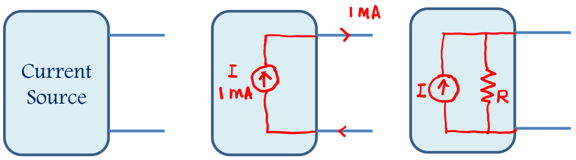
One-port Lumped Source Element Models



Ideal Voltage Source

Non-ideal Voltage Source

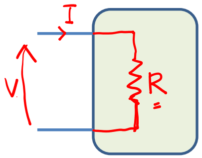
One-port Lumped Source Element Models



Ideal Currrent Source

Non-ideal Current Source

One-port Lumped Circuit Element Models

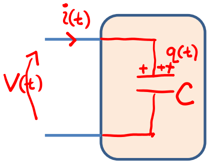


Resistor

$V = I.R$

Math Model

One-port Lumped Circuit Element Models



Capacitor

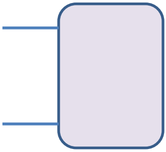
$q(t) = C\, v(t)$

$$\frac{dq(t)}{dt} = \frac{d}{dt}\left[C \cdot v(t)\right]$$

$$\boxed{i(t) = C\,\frac{dv(t)}{dt}}$$

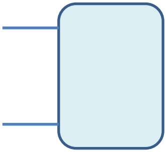
$v(t) =$

One-port Lumped Circuit Element Models



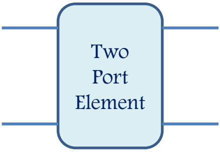
Inductor

One-port Lumped Circuit Element Models

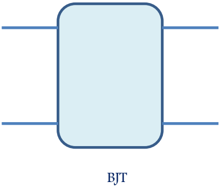


Diode

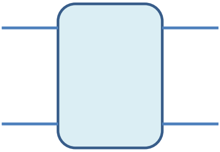
Two-port Lumped Circuit Element Models



Two-port Lumped Circuit Element Models

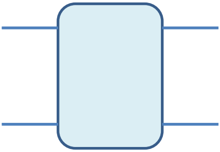


Two-port Lumped Circuit Element Models



FET

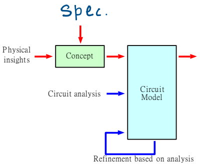
Two-port Lumped Circuit Element Models



Operational
Amplifier
(OPAMP)

Design of Electrical/Electronic Circuits

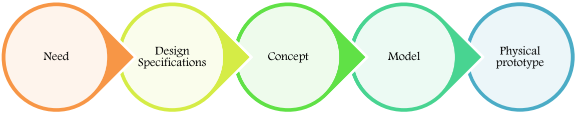
- The tools of circuit analysis are then applied to the circuit.
- Circuit analysis is based on mathematical techniques and is used to predict the behaviour of the circuit model and its circuit components.



Design of Electrical/Electronic Circuits

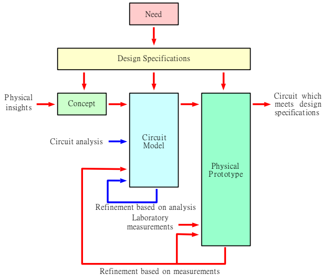
- Desired behaviour is from the design specifications.
- Predicted behaviour comes from circuit analysis.
- A comparison between these two normally leads to refinements in the circuit model and its ideal circuit elements.

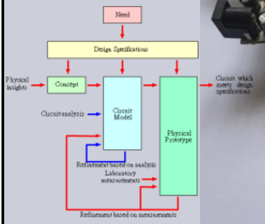
Design of Electrical/Electronic Circuits

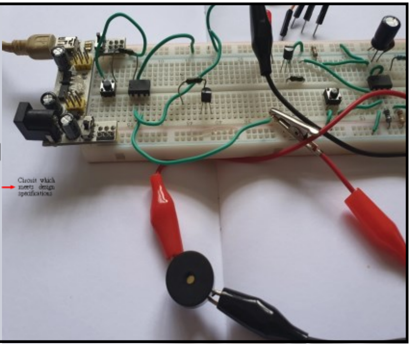


- Once the desired and predicted behaviour are in agreement, a physical prototype can be constructed.

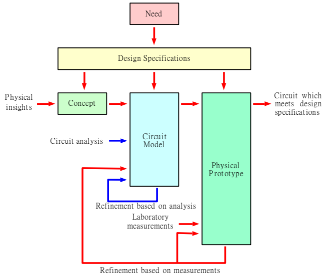
Design of Electrical/Electronic Circuits







Audio Amplifier Circuits



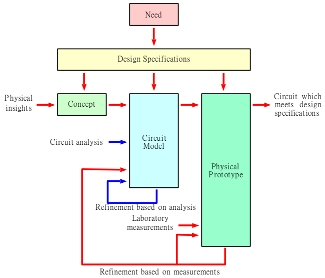
Design of Electrical/Electronic Circuits

- The physical prototype is an actual electrical system, constructed from actual electrical components.
- Measurement techniques are used to determine the actual, quantitative behaviour of the physical system.
- This actual behaviour is compared with the desired behaviour from the design specifications and the predicted behaviour from circuit analysis.

Design of Electrical/Electronic Circuits

- The comparisons may result in refinements to the physical prototype, the circuit model, or both.
- This is an iterative process, in which models, components, and systems are continually refined
- Eventually it produces a design that accurately match the design specifications and meet the need.

Design of Electrical/Electronic Circuits



References

1. Electric Circuits, 10th Edition, James W. Nilsson and Susan A. Riedel.
2. Electrical Engineering, 6th Edition, Allan R. Hambley.
3. Fundamentals of Electrical Networks Lecture Notes, Brian Krongold.
4. Foundations of Analog and Digital Electronic Circuits, 1st Edition, Anant Agarwal and Jeffrey Lang.
5. History of Electronics, http://www.electronicsandyou.com/blog/history-of-electronics.html

The End