UNIT 3
Embedded Hardware Design

Outline

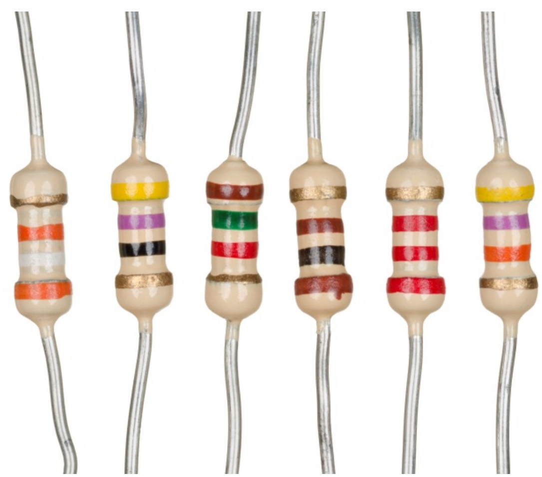
- Analog and digital electronic components
- Serial & parallel communication devices
- Wireless devices
- Timers and counting devices
- The PCB layout design.

Analog and digital electronic components

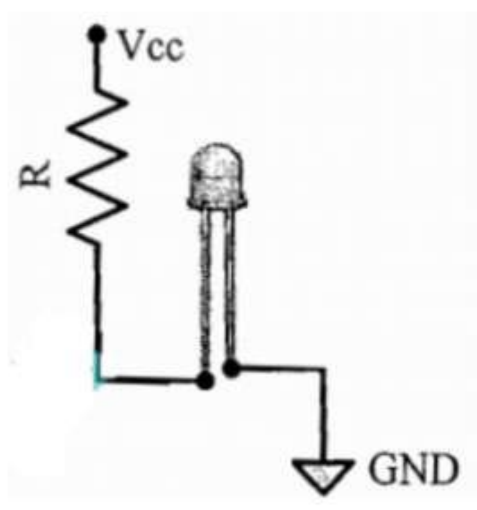
- Basic Analog Electronic components and circuits – Resistor, Capacitor, Diode, Inductor, Transistor etc.
- Basic Digital Electronic components and circuits – Logic Gates, Buffer ICs, Latch ICs, Decoder and Encoder ICs, Multiplexer (MUX) and De-multiplexer (D-MUX), Combinational and Sequential Circuits

Analog Electronic Components

- Resistors, capacitors, diodes, inductors, operational amplifiers (OpAmps), transistors, etc. are the commonly used analog electronic components in embedded Hardware design.
- **Resistor**



- A resistor limits the current flowing through a circuit.
- Interfacing of LEDs, buzzer, etc. with the port pins of microcontroller through current limiting resistors is a typical example for the usage of resistors in embedded application.



Capacitors & Inductors

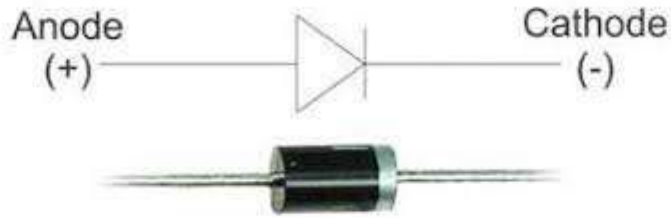
- Capacitors and inductors are used in signal filtering and resonating circuits.
- Reset circuit implementation, matching circuits for RF designs, power supply decoupling, etc. are examples for the usage of capacitors in embedded hardware circuit.

- Electrolytic capacitors, ceramic capacitors, tantalum capacitors, etc. are the commonly used capacitors in embedded hardware design.
- Inductors are widely used for filtering the power supply from ripples and noise signals.
- Inductors with inductance value in the microhenry (μH) range are commonly used in embedded applications for filter and matching circuit implementation

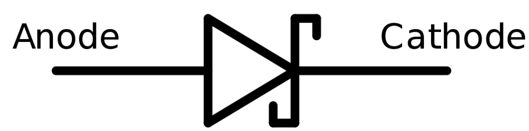
Diodes

- P-N Junction diode, Schottky diode, Zener diode, etc. are the commonly used diodes in embedded hardware circuits.
- A schottky diode is same as a P-N Junction diode except that its forward voltage drop (voltage drop across diode when conducting) is very low (of the order of 0.15V to 0.45) when compared to ordinary P-N junction diode (of the order of 0.7V to 1.7V).
- Also the current switching time of schottky diode is very small compared to the ordinary P-N junction diode.

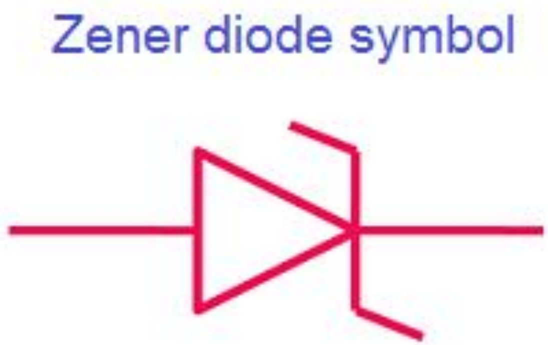
- A zener diode acts as normal P-N junction diode when forward biased.
- It also permits current flow in the reverse direction, if the voltage is greater than the junction breakdown voltage.
- It is normally used for voltage clamping applications.
- Reverse polarity protection, voltage rectification (AC-DC converters), freewheeling of current produced in inductive circuits, clamping of voltages to a desired level (e.g., Brownout protection circuit implementation using zener diode), etc. are examples for the usage of diodes in embedded applications.



P-N JUNCTION DIODE



SCHOTTKY DIODE

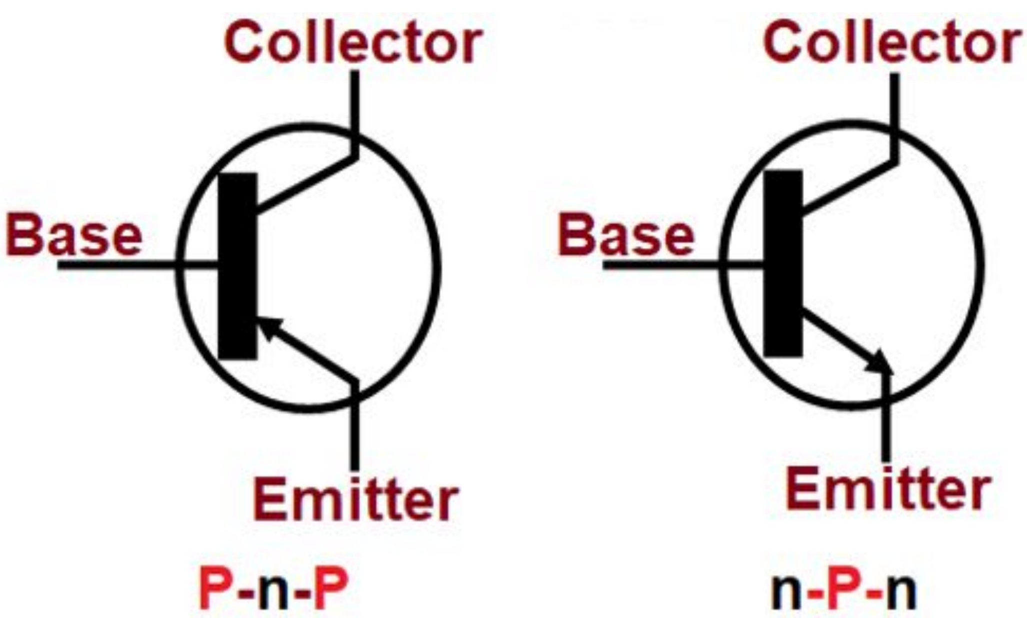


ZENER DIODE

Transistors

- Transistors in embedded applications are used for either switching or amplification purpose.
- In switching application, the transistor is in either ON or OFF state.
- In amplification operation, the transistor is always in the ON state (partially ON).

- The common emitter configuration of NPN transistor is widely used in switching and driving circuits in embedded applications.
- Relay, buzzer and stepper motor driving circuits are examples for common emitter configuration based driver circuit implementation using transistor.



Digital Electronic Components

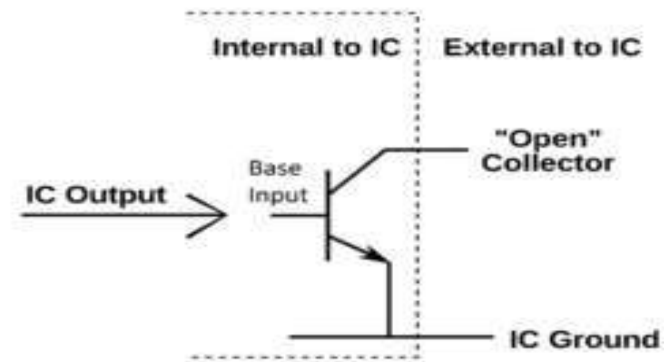
- Digital electronics deal with digital or discrete signals.
- Microprocessors, microcontrollers and system on chips (SoCs) work on digital principles.
- Embedded systems employ various digital electronic circuits for ‘Glue logic’ implementation.
- ‘Glue logic’ is the custom digital electronic circuitry required to achieve compatible interface between two different integrated circuit chips.
- Address decoders, latches, encoders/decoders, etc. are examples for glue logic circuits.
- Transistor Transistor Logic (TTL), Complementary Metal Oxide Semiconductor (CMOS) logic etc. are some of the standards describing the electrical characteristics of digital signals in a digital system.

Open Collector and Tri-State Output

Open Collector

- Open collector is an I/O interface standard in digital systemdesign and a common type of output found on many IntegratedCircuit (IC) chip which behaves like a switch that is either connected to ground or disconnected.
- Instead of outputting a signal

of a specific voltage or current, the output signal is applied to the**base of an internal NPN transistor** whose collector is externalized (open) on a pin of the IC.



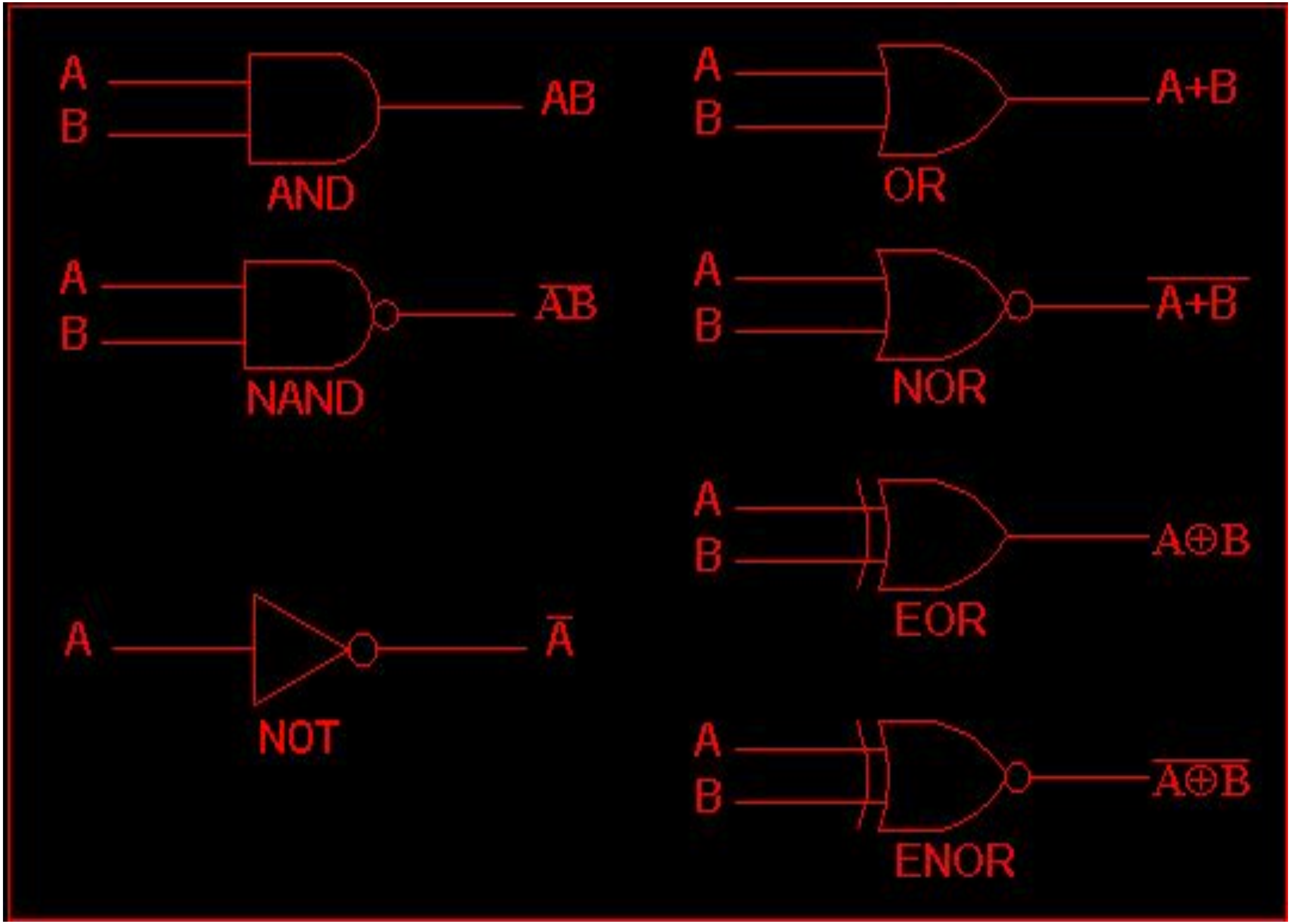
- The **emitter of the transistor is connected internally to the ground** pin.
- figure illustrates an open collector output configuration.

Tri-State Output

- The output of a standard logic device has two states, namely ‘Logic 0 (LOW)’ and ‘Logic 1 (HIGH)’ whereas tri-state devices have three states for the output, namely, ‘Logic 0 (LOW)’, ‘Logic 1 (HIGH)’, and the ‘High Impedance (FLOAT)’.
- A tri-state logic device contains a device activation line called ‘Device Enable’.
- When the ‘Device Enable’ line is activated (set at ‘Logic 1’ for an active ‘HIGH’ enable input and at ‘Logic 0’ for an active ‘LOW’ enable input), the device acts like a normal logic device and the output will be in any one of the logic conditions, ‘Logic 0 (LOW)’ or ‘Logic 1 (HIGH)’.
- When the ‘Device Enable’ line is de-activated (set at ‘Logic 0’ for an active ‘HIGH’ enable input and at ‘Logic 1’ for an active ‘LOW’ enable input), the output of the logic device enters in a high impedance state and the device is said to be in the floating state.

Logic Gates

- Logic gates are the building blocks of digital circuits.
- Logic gates control the flow of digital information by performing a logical operation of the input signals.
- Depending on the logical operation, the logic gates used in digital design are classified into-AND, OR, XOR, NOT, NAND, NOR and XNOR.
- The logical relationship between the output signal and the input signals for a logic gate is represented using a truth table.
- Figure illustrates the truth table and symbolic representation of each logic gate.



A
B
AB
AND
A
B
A+B
OR
A
B
$\overline{AB}$
NAND
A
B
$\overline{A+B}$
NOR
A
B
$A \oplus B$
EOR
A
$\bar{A}$
NOT
A
B
$\overline{A \oplus B}$
ENOR

INPUTS		OUTPUTS					
A	B	AND	NAND	OR	NOR	EXOR	EXNOR
0	0	0	1	0	1	0	1
0	1	0	1	1	0	1	0
1	0	0	1	1	0	1	0
1	1	1	0	1	0	0	1

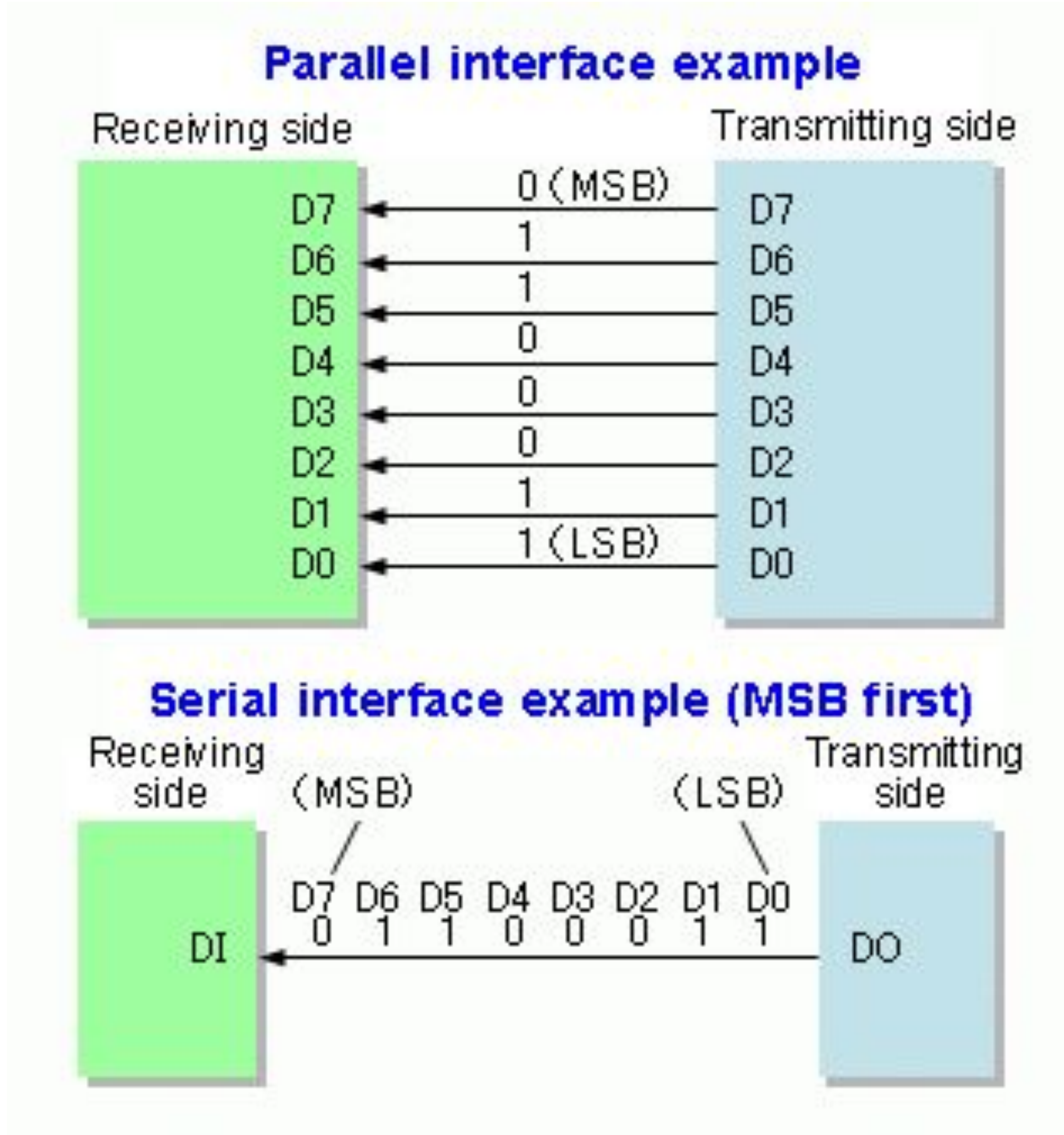
NOT gate	
A	$\overline{A}$
0	1
1	0

Parallel communication

- Multiple data, control, and possibly power wires
  - One bit per wire
- High data throughput with short distances
- Typically used when connecting devices on same IC or same circuit board
  - Bus must be kept short
    - long parallel wires result in high capacitance values which requires more time to charge/discharge
    - Data misalignment between wires increases as length increases
- Higher cost, bulky

Serial communication

- Single data wire, possibly also control and power wires
- Words transmitted one bit at a time
- Higher data throughput with long distances
  – Less average capacitance, so more bits per unit of time
- Cheaper, less bulky
- More complex interfacing logic and communication protocol
  – Sender needs to decompose word into bits
  – Receiver needs to recompose bits into word
  – Control signals often sent on same wire as data increasing protocol complexity



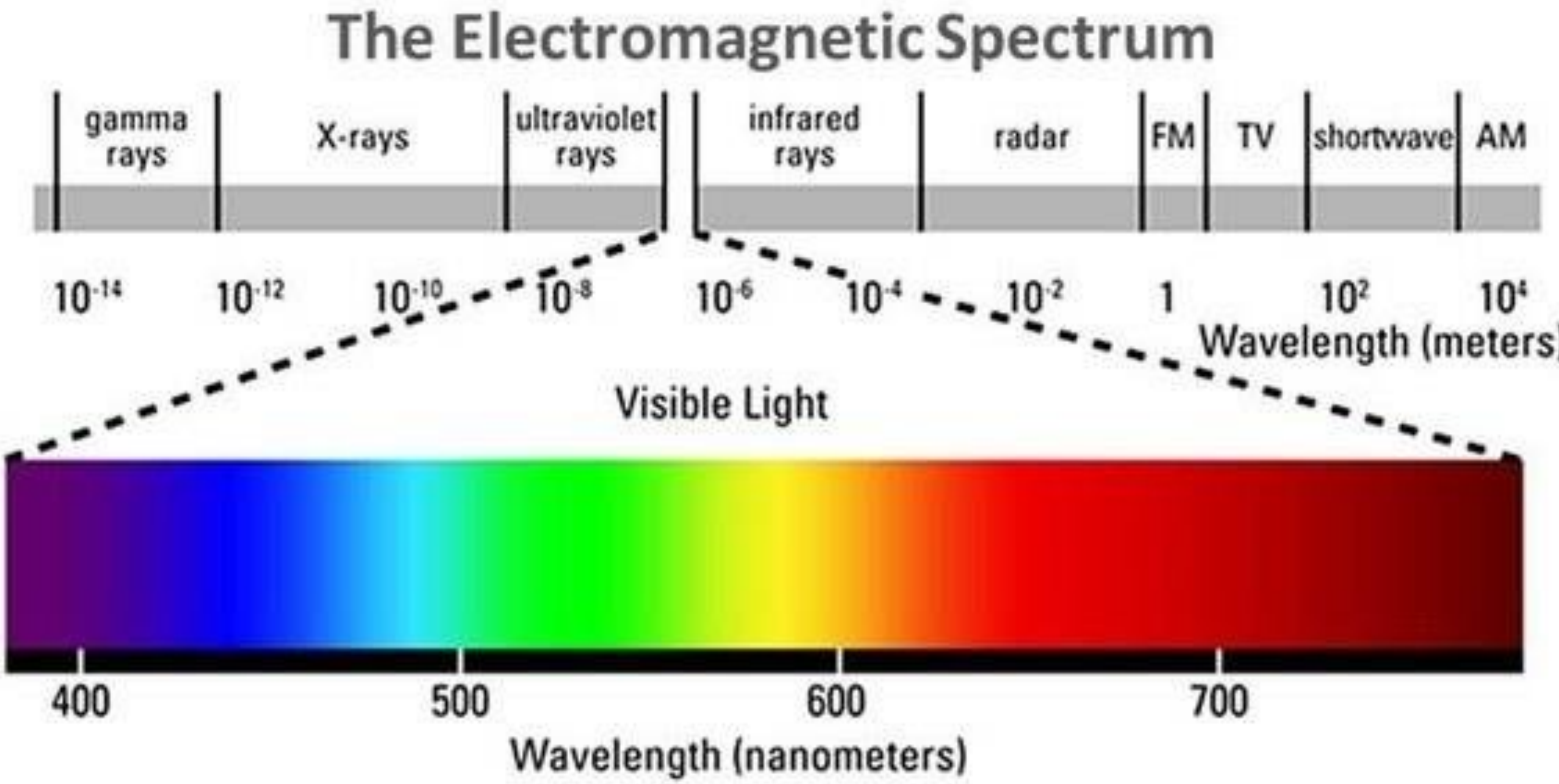
Parallel interface example
Receiving side
Transmitting side
D7 D6 D5 D4 D3 D2 D1 D0
0 (MSB)
1
1
0
0
0
1
1 (LSB)
D7 D6 D5 D4 D3 D2 D1 D0
Serial interface example (MSB first)
Receiving side
Transmitting side
(MSB)
(LSB)
D7 D6 D5 D4 D3 D2 D1 D0
0 1 1 0 0 0 1 1
DI
DO

Difference between Serial and Parallel Transmission

S.NO	SERIAL TRANSMISSION	PARALLEL TRANSMISSION
1	In serial transmission, data(bit) flows in bi-direction.	In Parallel Transmission, data flows in multiple lines.
2	Serial Transmission is cost efficient.	Parallel Transmission is not cost efficient.
3	In serial transmission, one bit transferred at one clock pulse.	In Parallel Transmission, eight bits transferred at one clock pulse.
4	Serial Transmission is slow in comparison of Parallel Transmission.	Parallel Transmission is fast in comparison of Serial Transmission.
5	Generally, Serial Transmission is used for long distance.	Generally, Parallel Transmission is used for short distance.
6	The circuit used in Serial Transmission is simple.	The circuit used in Parallel Transmission is relatively complex.

Wireless communication

- Infrared (IR)
  - Electronic wave frequencies just below visible light spectrum
  - Diode emits infrared light to generate signal
  - Infrared transistor detects signal, conducts when exposed to infrared light
  - Cheap to build
  - Need line of sight, limited range
- Radio frequency (RF)
  - Electromagnetic wave frequencies in radio spectrum
  - Analog circuitry and antenna needed on both sides of transmission
  - Line of sight not needed, transmitter power determines range



The Electromagnetic Spectrum
gamma rays
X-rays
ultraviolet rays
infrared rays
radar
FM
TV
shortwave
AM
10⁻¹⁴
10⁻¹²
10⁻¹⁰
10⁻⁸
10⁻⁶
10⁻⁴
10⁻²
1
10²
10⁴
Wavelength (meters)
Visible Light
400
500
600
700
Wavelength (nanometers)

Printed Circuit Board (PCB)

- A PCB or (Printed Circuit Board) is a board that contains several electrical components that areconnected using conductive electrical tracks.
- A PCB provides physical support for mounting the electronic components and also the electrical connections between them.
- Students, hobbyists and beginners in electronics often start working on electronic circuits using breadboards.
- They are suitable for small projects which involve a limited number of components (throughhole components) and connections.

Why do we need PCBs?

- If you want to make your design more appealing, then PCBs are the next step.
- With the help of PCBs, we can avoid common problems like noise, distortion, imperfect contact, etc.
- Moreover, if you want to go commercial with your design, you have to use a proper circuit board.

- Printed circuit board (PCB) assemblies are a vital part of embedded systems, which vary in their function, size and complexity so dramatically that careful planning and design is required to meet the exact requirements. These requirements are becoming ever more complex, as embedded systems are used to serve increasingly complex roles as internet connectivity becomes a prerequisite and the demand for smaller devices grows.

- Here is a step-by-step to what goes into planning and designing a PCB assembly for an embedded system:

1. **Defining the requirements**

Every design project begins with a set of requirements. The most obvious place to start is prescribing what it is that the PCB assembly will be required to do but that isn’t all. Size matters, as does how it connects to other parts of the embedded system, where it needs to be placed and what kind of environmental conditions it will be subjected to. All of these factors will affect the complexity of the printed circuit board assembly and, thus, how many layers it will need, the type and number of components and connections.

2 . **Creating a schematic**

Once the designers have established all the requirements and developed a concept to meet them all, they draw up a detailed schematic – a diagram showing which components are required, where they need to be placed and how they need to be connected. They will also draw up a bill of materials to establish exactly which parts they're going to need based on what the operating voltages and current levels are of each component as well as their size, price and availability.

3. Electronic Design Automation Software

Having created the schematic, these details are then entered into an electronic design automation software package, which creates and collates a set of documents, called a Gerber or CAD file, that can then be used as, essentially, a set of instructions to fabricate the PCB assembly.

4. Selecting the fabrication method

- The fabrication method chosen for any PCB assembly will depend on the original requirements, the resources available, the timeframe and the budget. At MPE, we often train our staff, buy in resources and create processes to meet our customers' requirements, giving us huge flexibility when it comes to design and we are constantly adding to our capabilities, processes and staff.

5. Testing

- The final phase is to prescribe which tests the PCB assemblies will undergo to ensure the design fulfils the requirements. We employ a number of different testing techniques and recently extended our capabilities by investing in a new environmental testing machine to ensure our PCB assemblies can withstand the environmental conditions they will be required to operate in.