ERODE SENGUNTHAR
ENGINEERING COLLEGE
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PERUNDURAI -638 057, TAMILNADU, INDIA.

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

COURSE TITLE: RECENT TRENDS IN ELECTRONIC INSTRUMENTATION AND AUTOMATION

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1. TRANSDUCERS AND MEASUREMENT SYSTEMS

1.a. Types of transducer

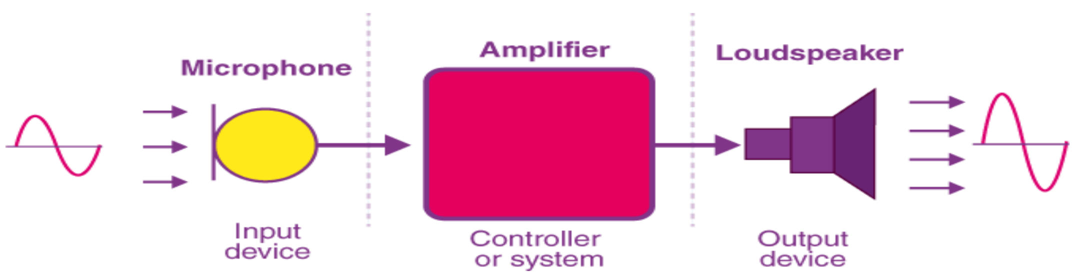
The primary function of transducers is to convert a physical force into an electrical signal so that it can be easily handled and transmitted for measurement.

There are two types of transducers, as follows:

- Input Transducer
- Output Transducer

Input Transducer

An input transducer or a sensor takes in physical energy and converts it into an electrical signal that can be read. A microphone, for example, converts physical sound waves into an electrical signal that can be transferred through wires.



Output Transducer

An output transducer, or an actuator, takes in electrical signals and converts them into other forms of energy. A lamp converts electricity into light and a motor, on the other hand, converts electricity into motion.

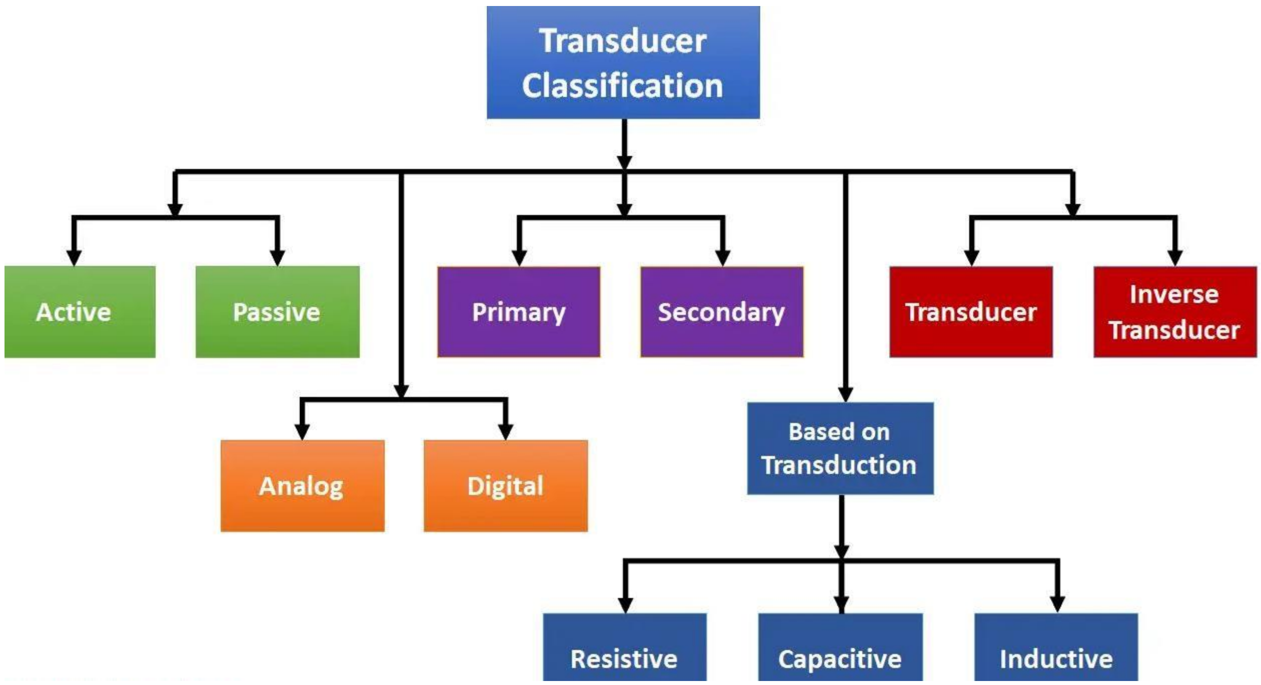
Parts of Transducer

A transducer consists of the following two important parts:

- Sensing element
- Transduction element

Transducers have other vital parts such as signal processing equipment, amplifiers and power supplies.

1.b. Classification of Transducer Types



This classification is based on the principle of transduction as resistive, inductive, capacitive etc. depending upon their conversion into resistance, inductance or capacitance respectively. They can be classified as thermoelectric, piezoelectric, electrokinetic, optical and magneto-restrictive.

Classification as primary and secondary transducers

Primary Transducers

Some transducers contain the mechanical as well as electrical device. The mechanical device converts the physical quantity to be measured into a mechanical signal. Such mechanical device are called as the primary transducers, because they deal with the physical quantity to be measure.

Secondary Transducers

The secondary transducer converts the mechanical signal into an electrical signal. The magnitude of the output signal depends on the input mechanical signal.

1.c. Applications of Transducer

- A transducer measures load on the engines
- They are used to d etect the movement of muscles; this process is known as acceleromyograph.

- Transducers are used in an ultrasound machine.
- The transducers in a speaker convert electrical signals into acoustic sound.
- A transducer is used in the antenna to convert electromagnetic waves into an electrical signal.

Applications of Ultrasonic Transducers

- These transducers have many applications in different fields like industrial, medical, etc. These are having more applications because of ultrasonic waves. This helps finds the targets, measure the distance of the objects to the target, to find the position of the object, to calculate the level also the ultrasonic transducers are helpful.

- In the medical field, the ultrasonic transducer is having the applications in diagnostic testing, surgical devices while treating cancer, internal organ testing, heart checkups, eyes and uterus checkups ultrasonic transducers are useful.

- In the industrial field, ultrasonic transducers have few important applications. By these transducers, they can measure the distance of certain objects to avoid a collision, in production line management, liquid level control, wire break detection, people detection for counting, vehicle detection and many more.

1.d. Transducer Efficiency

Transducer efficiency is defined as the ratio of output power in the desired form to the total power input. Mathematically, the ratio is represented as follows:

$$E=Q/P$$

P represents the input in the above ratio, and Q represents the power output in the desired form. The efficiency of the transducer always falls between 0 and 1.

No transducer is 100% efficient; some power is always lost in the conversion process. This loss is manifested in the form of heat. In incandescent lamps of certain wattage, only a few watts are transformed into visible light. Most of the power is dissipated as heat. Due to this, an incandescent lamp is a bad transducer in terms of efficiency.

1.e.Principle of transduction

The input/output signals (in the form of energy) in a sensor can be divided into six. They are,

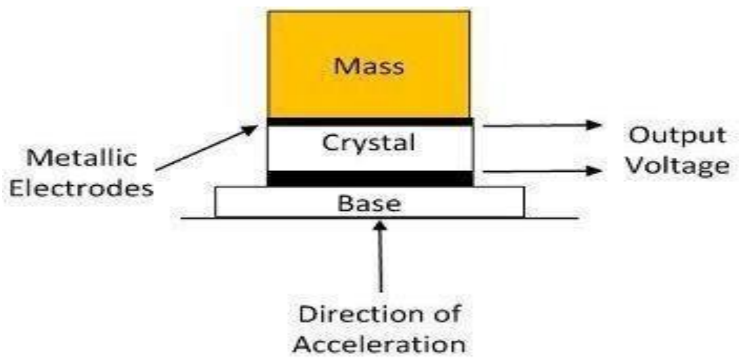
1. Mechanical
2. Thermal
3. Electrical
4. Magnetic
5. Radiant
6. Chemical

Some of the physical and chemical transduction principles can be grouped according to the form of energy in which signals are received and generated.

1.f.Inverse Transducer

The inverse transducer is the transducer which converts the electrical quantity into a non-electrical quantity. In other words, the transducer is a kind of actuator which has an electrical input and the non-electrical output.

Examples: The analogue ammeter and the voltmeter convert the current into a displacement. The oscilloscope is used for converting the electrical signal into a physical displacement.



Piezo-electric Crystal

Difference Between Transducer & Inverse Transducer

Basis For Comparison	**Transducer**	**Inverse Transducer**
Definition	The transducer converts the non-electrical quantity into an electrical quantity.	The inverse transducer converts the electrical quantity into the non-electrical quantity.
Input	Non-electrical quantity	Electrical quantity
Output	Electrical quantity	Non-electrical quantity
Examples	Photoconductive transducer, Thermocouple, Pressure gauge, strain gauge	Piezoelectric Transducer, current carrying conductor placed in an magnetic field.

2. NEURAL NETWORK & FUZZY LOGIC

2.a. Cooperative Fuzzy Neural Network

In the case of cooperative neural fuzzy systems, both artificial neural network and fuzzy system work independently from each other. The ANN tries to learn the parameters from the fuzzy system. This can be either performed offline or online while the fuzzy system is applied. Figure 2 depicts four different kinds of cooperative fuzzy neural networks.

The upper left fuzzy neural network learns fuzzy set from given training data. This is usually performed by fitting membership functions with a neural network. The fuzzy sets are then determined offline. They are then utilized to form the fuzzy system by fuzzy rules that are given (not learned) as well.

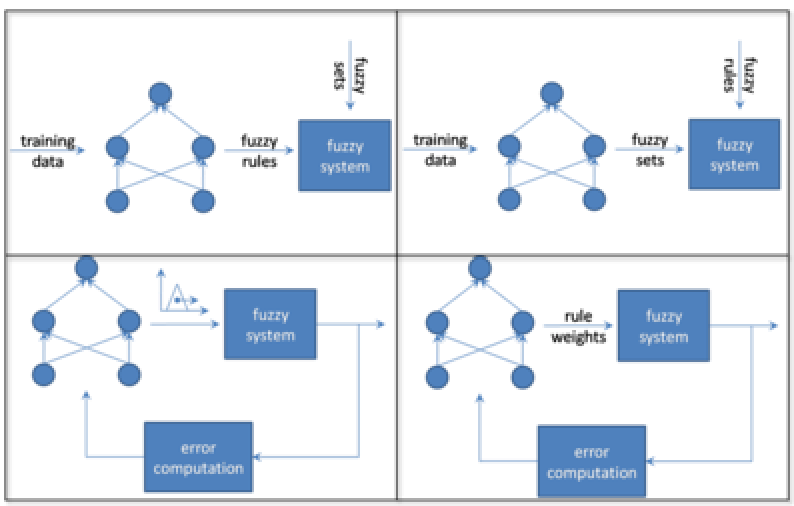


Fig: Different cooperative fuzzy neural networks

The upper right neuro-fuzzy system determines fuzzy rules from training data by a neural network. Here as well, the neural networks learns offline before the fuzzy system is initialized. The rule learning usually done by clustering on self-organizing feature maps (Bezdek et al., 1992; Vuorimaa, 1994). It is also possible to apply fuzzy clustering methods to obtain rules.

In the lower left neuro-fuzzy model, the system learns all membership function parameters online, i.e., while the fuzzy system is applied. Thus initially fuzzy rules and membership functions must be defined beforehand. Moreover, the error has to be measured in order to improve and guide the learning step.

The lower right one determines rule weights for all fuzzy rules by a neural network. This can be done online and offline. A rule weight is interpreted as the influence of a rule (Kosko, 1992). They are multiplied with the rule output. In (Nauck et al., 1997) the authors argue that the semantics of rule weights are not clearly defined. They could be replaced by modified membership functions. However, this could destroy the interpretation of fuzzy sets. Moreover, identical linguistic values might be represented differently in dissimilar rules.

2.b. Hybrid Fuzzy Neural Network

Hybrid neuro-fuzzy systems are homogeneous and usually resemble neural networks. Here, the fuzzy system is interpreted as special kind of neural network. The advantage of such hybrid NFS is its architecture since both fuzzy system and neural network do not have to communicate any more with each other. They are one fully fused entity. These systems can learn online and offline.

The rule base of a fuzzy system is interpreted as a neural network. Fuzzy sets can be regarded as weights whereas the input and output variables and the rules are modeled as neurons. Neurons can be included or deleted in the learning step. Finally, the neurons of the network represent the fuzzy knowledge base. Obviously, the major drawbacks of both underlying systems are thus overcome.

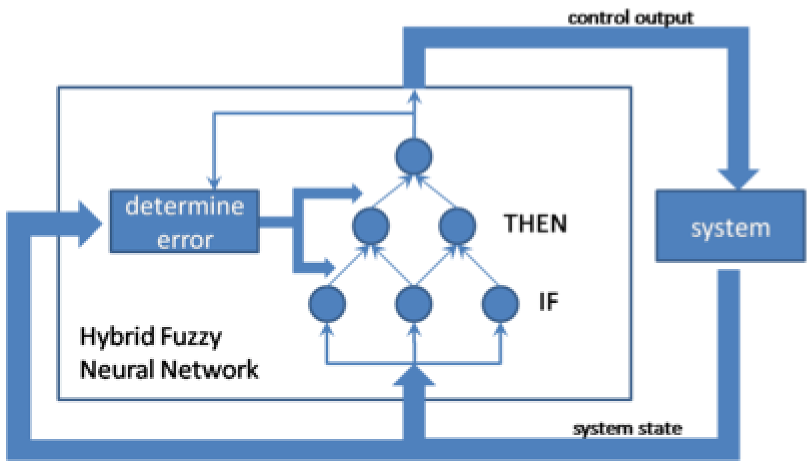


Fig: A hybrid fuzzy neural network

In order to build a fuzzy controller, membership functions which express the linguistic terms of the inference rules have to be defined. In fuzzy set theory, there does not exist any formal approach to define these functions. Any shape (e.g., triangular, Gaussian) can be considered as membership function with an arbitrary set of parameters. Thus the optimization of these functions in terms of generalizing the data is very important for fuzzy systems. Neural networks can be used to solve this problem.

2.c. Classical set theory

- A Set is any well defined collection of objects.
- An object in a set is called an element or member of that set.
- Sets are defined by a simple statement,
- Describing whether a particular element having a certain property belongs to that particular set.

$$A = \{a1 ,a2 ,a3 ,\ldots\ldots,an \}$$

- If the elements ai (i = 1,2,3,….,n) of a set A are subset of universal set X, then set A can be represented for all elements x ϵ X by its characteristics function

$$\mu A (x) = 1 \text{ if } x \in X \text{ otherwise}$$

2.d. Fuzzy Logic - Membership Function

- The membership function fully defines the fuzzy set
- A membership function provides a measure of the degree of similarity of an element to a fuzzy set

Membership functions can

– either be chosen by the user arbitrarily, based on the user's experience (MF chosen by two users could be different depending upon their experiences, perspectives, etc.)

– Or be designed using machine learning methods (e.g., artificial neural networks, genetic algorithms, etc.) Fuzzy Sets (Continue)

There are different shapes of membership functions;

- Triangular,
- Trapezoidal,
- Gaussian, etc,..

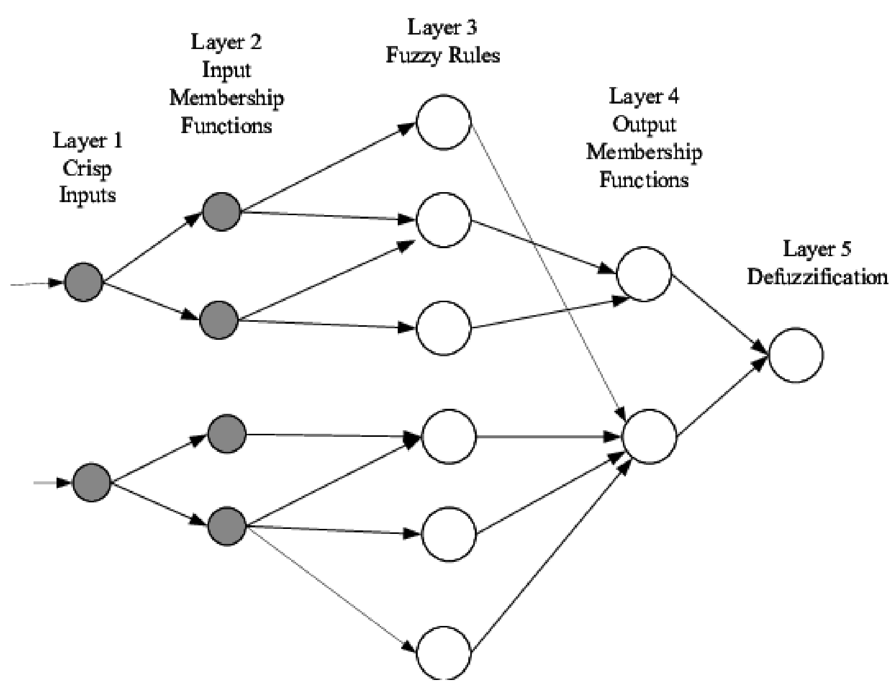
2.e. Defuzzification Methods

Fuzzy rule based systems evaluate linguistic if-then rules using fuzzification, inference and composition procedures. They produce fuzzy results which usually have to be converted into crisp output. To transform the fuzzy results in to crisp, defuzzification is performed.

Defuzzification is the process of converting a fuzzified output into a single crisp value with respect to a fuzzy set. The defuzzified value in FLC (Fuzzy Logic Controller) represents the action to be taken in controlling the process.

2.f. Examples of Neural-Trained Fuzzy system

- The Laboratory for International Fuzzy Engineering Research (LIFE) in Yokohama, Japan has a back-propagation neural network that derives fuzzy rules. ...
- Ford Motor Company has developed trainable fuzzy systems for automobile idle-speed control.
- NeuFuz, software product of National Semiconductor Corporation, supports the generation of fuzzy rules with a neural network for control applications.



3. FIBER OPTICS & OPTOELECTRONICS TESTABILITY

3.a. Fiber-optic gyroscopes

Fiber Optic Gyroscope (FOG) systems use the Sagnac effect to measure the angular velocity or rotation rate on an object (e.g. aircraft).

Two counter-propagating beams traveling through a FOG coil undergo a differential phase shift when subjected to a rotation in the plane of the coil. The magnitude of this phase shift is proportional to the rotation rate and hence it can be used to measure the angular velocity. The FOG offers significant advantages over other IMU technology:

- Size
- Accuracy
- Low maintenance
- Long lifetime

A FOG is not sensitive to acceleration, vibration, or dithering, which means they are capable of very high signal to noise ratios (SNR), as required for the highest performance gyroscopes. They have no moving parts, which reduces the probability of mechanical failure. The technology is also scalable and can be designed into very compact volumes.

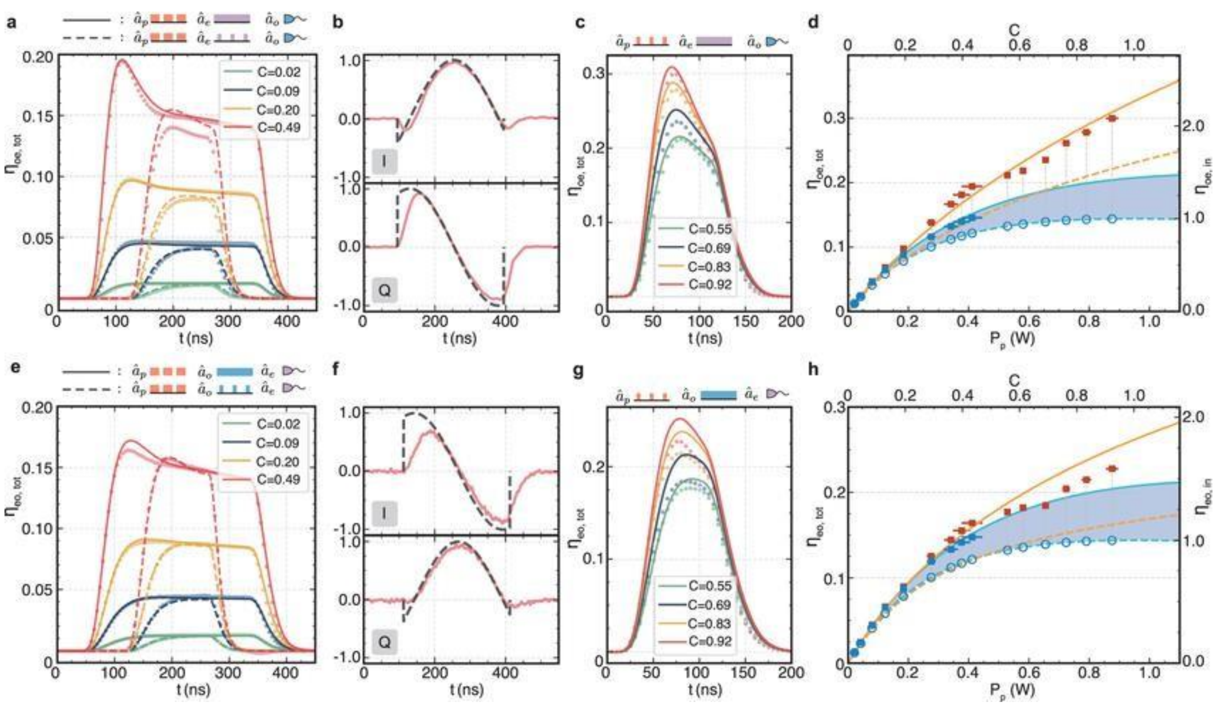
Fibercore has developed a range of optical fibers specifically for use in FOG systems. These include an extensive range of Bow-Tie design, highly birefringent gyroscope (HB-G) fibers for use as the FOG sensor coil fiber, as well as a new range of short beat length (HBG-SB) fibers optimized for the next generation of FOG coil designs. Fibercore also offers a number of supporting products, for use in other components of the FOG system, such as ZingTM polarizing fibers (HB-Z), standard PM fiber (HB), telecoms PM fiber (HB-T) and IsoGainTM erbium doped fiber for broadband ASE source generation.

Fig:Fiber Optic Gyroscope (FOG)

3.b. ONFs as Enablers of High Cooperativity and Optical Depth

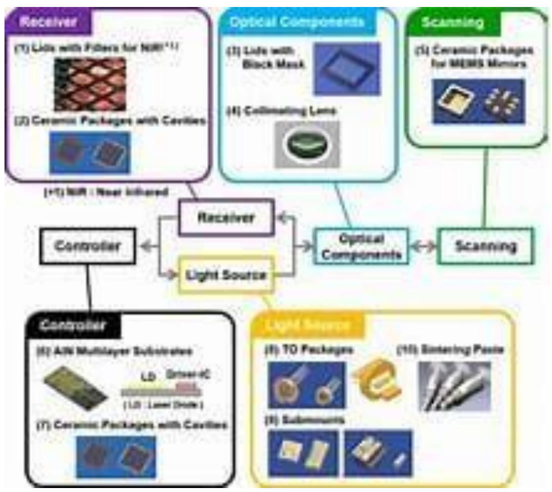
The Nobel Prize-worthy efforts of Serge Haroche focused on decreasing T with microwave cavities possessing finesses greater than 109 while making sure that the cavity-mode cross section significantly overlaps with the properly aligned Rydberg atom cross section. With this system, his group created highly nonclassical states and performed quantum non-demolition measurements of photon jumps Haroche (2013).

Recent advances in superconducting technology have allowed physicists to create nonlinear quantum circuits that behave like "artificial atoms" Makhlin et al. (2001). By coupling these so-called qubits to a high-quality-factor coplanar resonator, scientists have engineered an analog of cavity QED, dubbed circuit QED, that achieves couplings far beyond what have been realized in optical systems Blais et al. (2004); Wallraff et al. (2004). This architecture not only relies on the high finesse of the cavity to increase C, but the area of the artificial atoms (antennae, qubits) has also been increased significantly beyond that of the mode. This limit can not yet be realized with atoms in free space, but may be achievable for atoms near photonic and plasmonic structures, where the field can be confined beyond the diffraction limit.



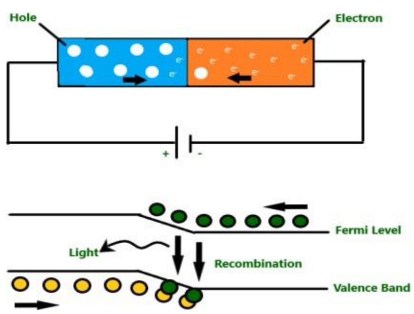
3.c. Electronic-Optoelectronic integration

In order to realize system functions needed for practical applications, optoelectronic devices must be packaged and assembled by coupling them, either optically or electronically, with many other components. It is recognized that such packaging procedures occupy a significant fraction of the manufacturing cost and often produce O. Wada (ed.), Optoelectronic Integration: Physics, Technology and Applications © Kluwer Academic Publishers 1994 2 yield and reliability problems. It is thus natural to expect that these optoelectronic devices are integrated with other optical and electronic components. Integration makes the module compact, while still maintaining the performance and functions even better than they are with discrete devices, and it reduces the number of components required for a system, resulting in higher reliability and lower cost. Such advantages of integration have actually driven the whole Si electronic IC industry for over more than a quarter of a century.



3.d. Optoelectronic Devices

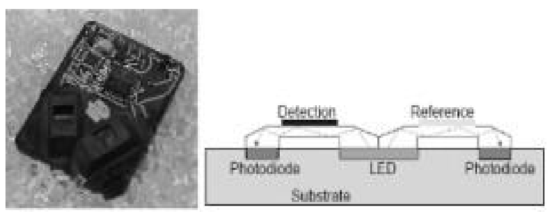
Optoelectronics is the research, design, and production of a hardware device that transforms electrical energy into light and light into energy using semiconductors. It is the connection between optics and electronics. Optoelectronic devices are special types of semiconductor devices that are able to convert light energy to electrical energy or electrical energy to light energy. Solid crystalline minerals, which are heavier than insulators but lighter than metals, are used to make this device. An optoelectronic device is an electrical gadget that uses light. Numerous optoelectronics applications, including those in the military, telecommunications, automatic access control systems, and medical equipment, use this technology.



3.e. Polymer opto-electronic sensors on foil

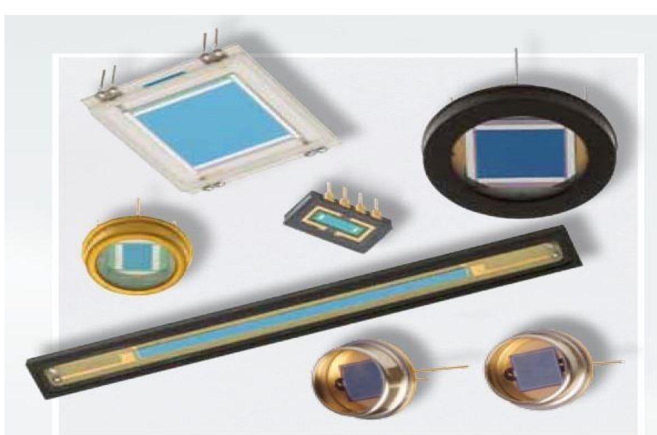
Opto-electronic polymers transfer light into electricity and vice versa. Applications, mostly in the development stage, are e.g. flexible displays based on organic light- emitting diodes (OLEDs) and photo-voltaic cells based on photo-diodes. These are large area applications, which are expected to be manufactured on foil by reel-to-reel technologies. This is of interest for micro-fluidic applications in foil, because OLEDs and photodiodes can also be used as optical sensors when a selective media is positioned in between [9].

Advantages of opto-electronic polymer sensors are the potential (i) to fine tune the spectrum of the LEDs or photodiodes, with regard to the sensor material, (ii) to manufacture these in high volumes with reel-to-reel (embossing, lithographic, jetting, printing and laminating) techniques and (iii) to integrate these in micro-fluidic applications in foil.



This sensor was manufactured by two shot moulding of the polymer waveguides and substrate, selective metal plating of the substrate and thin film applied opto-elelectronic polymers. Waveguide material was COC, substrate material was LCP (Liquid Crystal Polymer) LDS (from Ticona) which was plated by laser direct structuring. The alcohol sensitive coating was organic solvent based and was applied by drop-casting.

The photodiode and LED devices were a stack of (i) a glass layer with a sputtered transparent conductive indium doped tin-oxide (ITO) film, structured by a photo-lithographic process, as anode, (ii) spin coated layers of a transparent conductive polymer (PEDOT) and the actual opto-electronic polymer (derivative of poly(phenylene vinylene)) and (iii) a thermally evaporated metal cathode of barium-aluminium alloy and (iv) an aluminium encapsulation.



4. ELECTRIC POWER UTILIZATION AND ILLUMINATION

4.a. Illumination

- An act or instance of illuminating.
- The fact or condition of being illuminated.
- A decoration of lights, usually colored lights.
- An entertainment, display, or celebration using lights as a major feature or decoration.
- Intellectual or spiritual enlightenment.
- Also called illuminance, intensity of illumination.
- Light that comes into a room, that shines on something, etc.
- A source of light.

4.b. Laws of Illumination

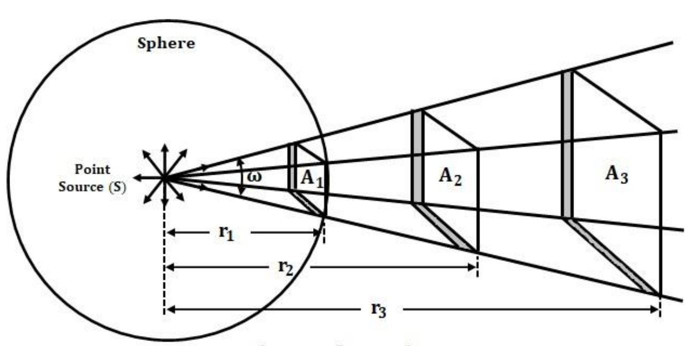
There are two main laws of illumination of a surface, they are,

- Inverse Square Law, and
- Lambert's Cosine Law.

Inverse Square Law :

The inverse square law states that the illumination on the surface is inversely proportional to the square of the distance between the surface and the light source.

But the drawback of inverse square law is that this law is only applicable if the light source is considered as a point source. If a point source that emits an equal amount of light in all directions is placed at the center of the hollow sphere, then the light flux will reach all over the inner surface of the sphere uniformly i.e., an equal amount of light flux will be distributed over every square millimeter of the sphere.



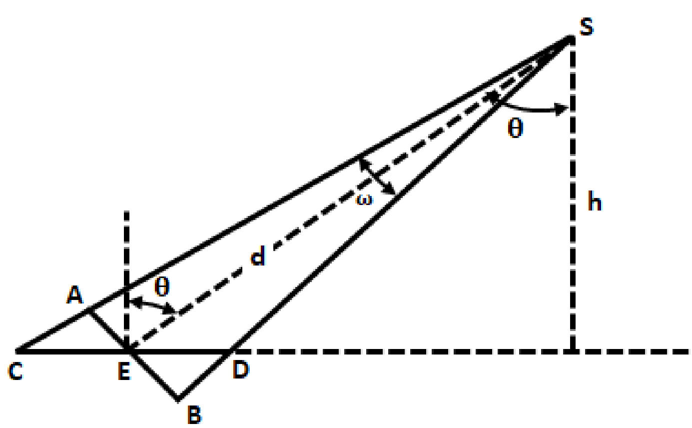
Inverse Square Law

Lambert's Cosine Law :

Lambert's cosine law states that the illumination (E) at any point on the surface is proportional to the cosine of angle which direction of the incident light flux makes with the normal (perpendicular) at that point.

The light flux received by the surface area changes with the change in angle between normal to the surface and the direction of the light flux. The illumination is maximum when the light flux falling is equal to normal to the surface, if the surface is inclined to the light flux falling, then the illumination is reduced.

Let us prove the above discussed Lambert's cosine law mathematically. Consider a point source 'S' at a height 'h' from the surface CD. Assume that surface CD subtends solid angle 'ω' at point source 'S' as shown below. Let AB be the inclined surface area normal to the light flux with E as the center point of the surface.

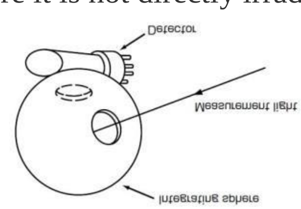


Lambert's Cosine Law

4.c. Integrating spheres

Integrating spheres have a spherical-shaped inner surface and inner wall made of light scattering material, such as barium sulfate, having high reflectance. Integrating spheres are effective in causing a light beam (measurement light) entering the sphere to scatter uniformly.

Integrating spheres have a hole (aperture) at the position irradiated by the measurement light. When measuring the measurement light which passes through the sample and enters the sphere, the sample is placed at this aperture. The detector is installed at an aperture (mainly, at the top or bottom of the integrating sphere) where it is not directly irradiated by the measurement light.



Polar curves

Polar curves Polar curves Polar curves Polar curves are graphs of equations that are defined by polar coordinates. As with regular equations and curves, the polar curve consists of all polar coordinates that satisfy the given equation.

4.d. Comparison between tungsten filament lamps and fluorescent tubes

Tungsten Filament Lamp	Fluorescent Tube
It's light is close to the natural light.	It's light is not close to natural light.
Actual colour can be judged.	Actual colour can not be judged.
Initial cost is low.	Initial cost is high.
Life is about 1000 Hrs.	Life is about 4000 Hrs.
Maintenance cost is more.	Maintenance cost is low.
Brightness is more.	It's light is cool and pleasant.
Light output is reduced with time.	It also reduces but very less.
Heat radiation loss is there.	As the temperature is less, and hence less radiation.
Less Lumen output/watt.	More Lumen output/watt (it is 40 lumen/watt).
Lumen efficiency is poor due to coloured glass etc. in case of coloured light.	The colour of light depends upon the gas.
No stroboscopic effect.	It has stroboscopic effect.

4.e. Basic principles of light control

- Light can travel through vacuum.
- Light can penetrate through transparent materials but cannot pass through opaque objects.
- Light travels in a straight line in an optically homogeneous medium.
- Light bounces back when made to fall on polished surfaces such as mirrors or metal surfaces.
- There are four methods of light control: Reflection, Refraction, Diffusion, and

Absorption.

Depending upon the characteristics of light, discussed above, there are following four method of light control viz −

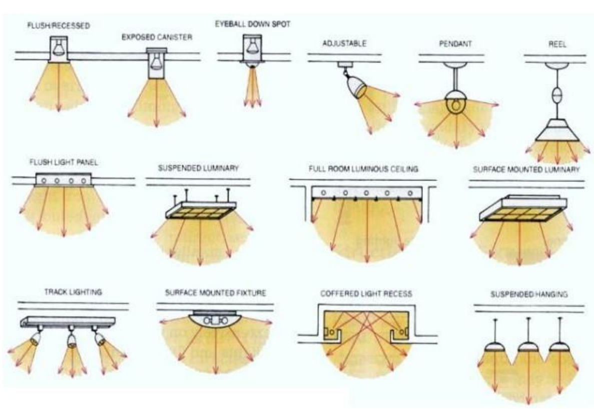
- Reflection
- Refraction
- Diffusion
- Absorption

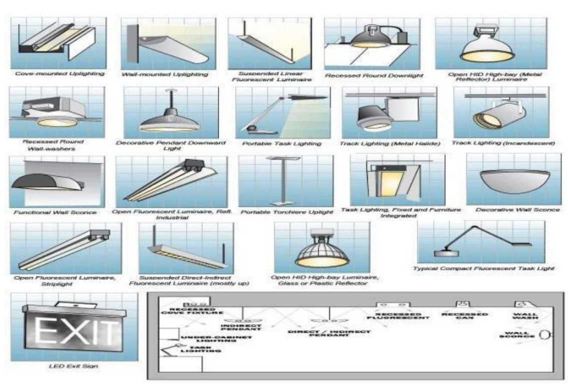
4.f. Types of Flood Lights

- Standard Light Fixture
- Solar Lights
- Multi-Directional Lights
- Security Lights
- Motion Sensor Lights
- Light With Camera
- Landscape Lights
- All In One Light
- Work Lights
- Post Lights

Types of lighting

- Direct Lighting
- Semi-Direct Lighting
- Semi-Indirect Lighting
- Indirect Lighting
- General Lighting

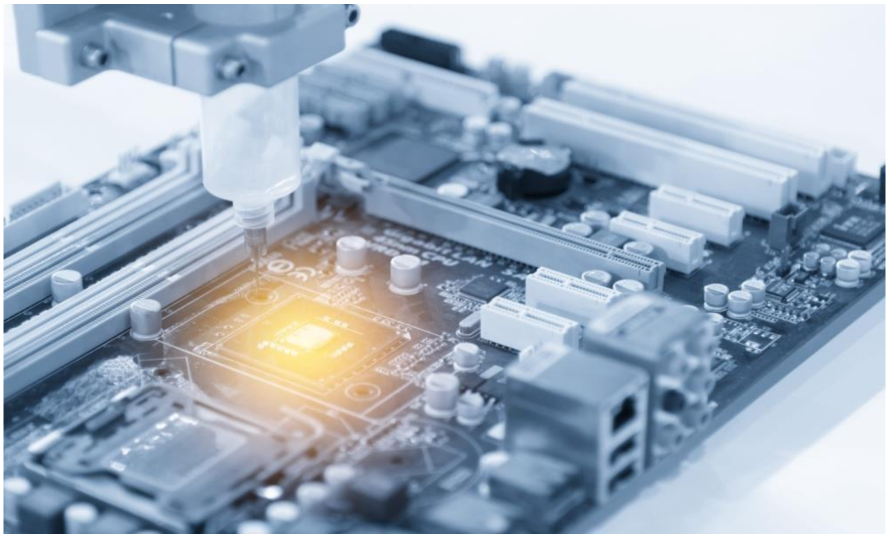




5. EMBEDDED SYSTEM DESIGN

5.a. Targeted firmware rehosting for embedded systems

Executing code in a controlled environment is a fundamental part of modern systems analysis. Unfortunately, embedded systems pose a challenge because their code expects to interact with specialized on-chip and off-chip peripherals, such as general-purpose I/O (GPIO) ports, sensors, and communication interfaces. The execution environment must emulate these devices with sufficient fidelity to ensure that observed behavior accurately mimics the target system running on hardware. However, because of the large variety of peripheral devices, most are not modeled by the execution environment, creating a considerable blind spot for our most powerful analysis techniques. Indeed, there may be no documentation at all about a target system, which makes building a complete emulator for it nearly impossible.



Embedded systems are hard to analyze

- On standard platforms, tools can take advantage of standard I/O interface
- Analysis tools like fuzzing and dynamic RE "just work"
- Embedded systems may have nonstandard (or unique) I/O interfaces

A targeted approach to rehosting

- Key Insight: Firmware implicitly encodes expected hardware behavior
- What values need to be read from the device to read the boot point?
- Goal: Generate HW device that guides firmware towards the boot point A

5.b. Secure Boot

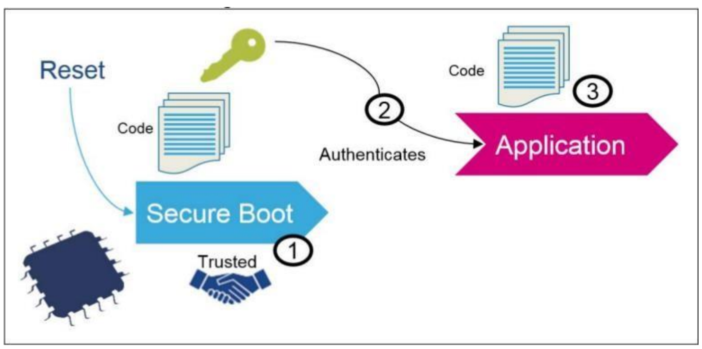
The first step in protecting the operating system is to ensure that it boots securely after the initial hardware and firmware boot sequences have safely finished their early boot sequences. Secure Boot makes a safe and trusted path from the Unified Extensible Firmware Interface (UEFI) through the Windows kernel's Trusted Boot sequence. Malware attacks on the Windows boot sequence are blocked by the signature-enforcement handshakes throughout the boot sequence between the UEFI, bootloader, kernel, and application environments.

As the PC begins the boot process, it will first verify that the firmware is digitally signed, reducing the risk of firmware rootkits. Secure Boot then checks all code that runs before the operating system and checks the OS bootloader's digital signature to ensure that it's trusted by the Secure Boot policy and hasn't been tampered with.

Trusted Boot

Trusted Boot picks up the process that started with Secure Boot. The Windows bootloader verifies the digital signature of the Windows kernel before loading it. The Windows kernel, in turn, verifies every other component of the Windows startup process, including boot drivers, startup files, and your antimalware product's early-launch antimalware (ELAM) driver. If any of these files were tampered, the bootloader detects the problem and refuses to load the corrupted component. Tampering or malware attacks on the Windows boot sequence are blocked by the signature-enforcement handshakes between the UEFI, bootloader, kernel, and application environments.

Windows can automatically repair the corrupted component, restoring the integrity of Windows and allowing the Windows 11 device to start normally.



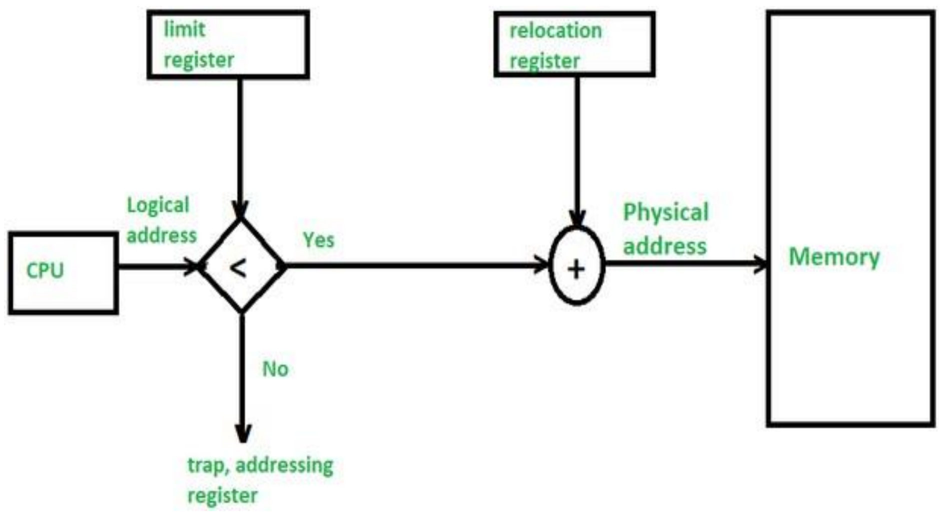
Measured Boot

If a PC in your organization does become infected with a rootkit, you need to know about it. Enterprise anti-malware apps can report malware infections to the IT department, but that doesn't work with rootkits that hide their presence. In other words, you can't trust the client to tell you whether it's healthy.

As a result, PCs infected with rootkits appear to be healthy, even with anti-malware running. Infected PCs continue to connect to the enterprise network, giving the rootkit access to vast amounts of confidential data and potentially allowing the rootkit to spread across the internal network.

5.c. Memory Mapping and Protection

In Memory protection, we have to protect the operating system from user processes and which can be done by using a relocation register with a limit register. Here, the relocation register has the value of the smallest physical address whereas the limit register has the range of the logical addresses. These two registers have some conditions like each logical address must be less than the limit register. The memory management unit is used to translate the logical address with the value in the relocation register dynamically after which the translated (or mapped) address is then sent to memory.

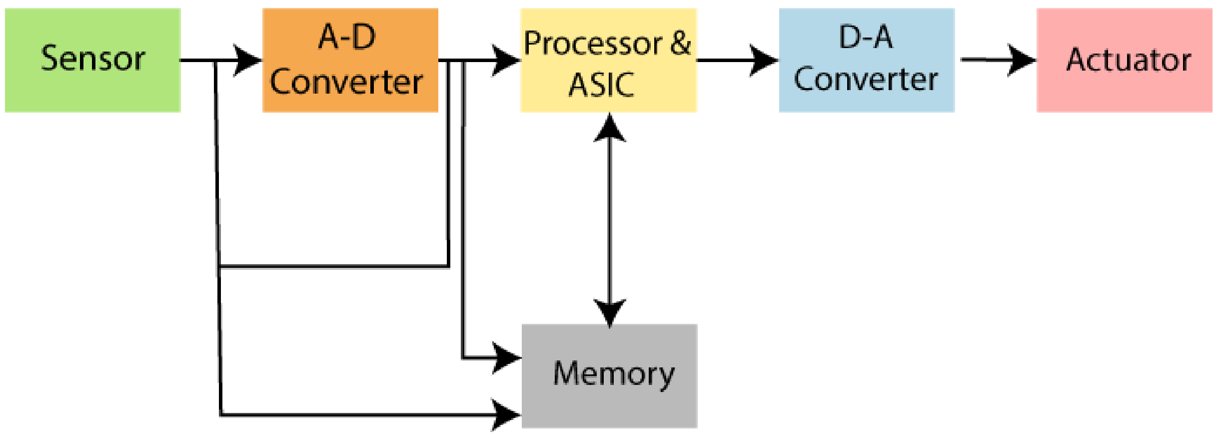


5.d. Some characteristics of embedded systems are:

- They perform a specific task or function
- They have low cost and low power consumption
- They have time and efficiency constraints
- They have minimal or no user interface
- They react to external stimuli
- They are not easily changed or upgraded by the users
- They are connected with peripherals and input/output devices

- They have high availability and reliability

5.e. Basic Structure of an Embedded System



5.f. Processors in a System

In computing and computer science, a **processor** or **processing unit** is an electrical component (digital circuit) that performs operations on an external data source, usually memory or some other data stream. It typically takes the form of a microprocessor, which can be implemented on a single metal–oxide–semiconductor integrated circuit chip. In the past, processors were constructed using multiple individual vacuum tubes,multiple individual transistors or multiple integrated circuits.

5.g. Compilers and Assemblers

Compiler

A Compiler is primarily used for programs that translate source code from a high-level programming language to a machine level language to create an executable program. A compiler will consider the entire program as a whole code and then translates. The main job of the compiler is that it checks all kinds of limits, ranges, errors, etc. Before the compiler can successfully execute the code, the errors must be removed from the source code. Example of compiled languages is C, C++, Java, C#, etc.

Assembler

The Assembler takes as input the assembly code and translates it into relocatable machine code. Assembler checks each instruction for its correctness and generates a diagnostic message.