Integrated Circuits, MOSFETs, OP-Amps and their Applications

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Lecture - 01
Introduction to Integrated Circuits (IC) Technology

Hello. So, this is the first class on our subject integrated circuits MOSFETS, op-amps and their applications. Now I recall a very famous saying by Henry Ford. He said that coming together is beginning. So, using the NPTEL platform, we have come together to understand, how this indicator circuits and MOSFET and op-amps can be used for various applications then he says staying together is a progress.

So, I hope that my lectures are interesting to you. You find new things in those lectures and we stay together, we learn and that will be our progress while working together is a success. So, when I give you some assignments, when I give you some homework, right and you ask me questions if you have any doubts. So, you are working together, I am trying to teach you something, you are learning something, the same time, we are trying to exchange information in the form of assignments and home works and questions and answers, right.

So, this is my goal that at the end of this particular series you are able to understand, how the indicator circuits op-amps as well as MOSFETS are fabricated at the same time, what are their applications. Now to start with, I have very interesting demo for you to start with this particular series, I have a tea in my hand.

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So, if you guys can see, of course, this mug you can see coffee written, but inside the mug, there is tea, alright and let me sip it and it is really delicious.

So, the point is I know how to make a tea, right and you probably would know how to make a tea as well, those who do not know let us see right, what we need, we need milk, right, of course, some amount of water we need, some cardamoms, here are some cardamoms, alright or we say.

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[FL] then we have tea, and finally, we have some sugar, these are the ingredients used to make this delicious tea. So, you will be confused why and how come this op-amps integrated circuits and MOSFETS and application has regarding something to do with tea, right.

So, the point that I am making today is a teacher will show you the ingredients, he will tell you, for example, let us talk about tea, right, what is this called, this is called milk, cool, what is this called, this is called cardamom, nice tea, alright, sugar, what to do with this. So, one time teacher will show you, how to mix these things together to form a delicious cup of tea and then you have to do it by yourself.

Every time, if you ask give me the cup of tea, it is called spoon feeding, is it not; every time you want everything to be ready is not a correct approach in learning, right. So, whatever teachers tells us, whoever he is or whoever she is, right, listen the ingredients, understand the topics, right, he will tell you this topics or this ingredient or this circuits or this components are used for this particular applications.

Now, learn by yourself, spend time, not only understanding what this lectures are all about, but also to understand how you can utilize this knowledge for different applications, right and do not rely on spoon feeding, you should not rely on spoon feeding, you should be independent, alright and you can be get independent when you acquire knowledge.

So, using this beautiful NPTEL platform, we start our first lecture and the lecture is on integrated circuit technology, its introduction right. So, you can see on the screen IC technology or introduction to IC technology. Now before we start this particular presentation, I am sure that in your undergrad or in your twelfth physics or in your in your masters, right.

Those who have studied electronics instrumentation applied physics, electrical engineering mechanical engineering, have came across discrete components. So, what are discrete components? Discrete component are a resistor.

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If you can please zoom in, this is a resistor in my hand, let us see if you can see it. So, this is a resistor, alright and everybody knows it, everyone knows it, this is what is a resistor ok.

Now, let us see another component, this is a capacitor.

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Right; capacitor, alright. Now we he have another component; we have diode.

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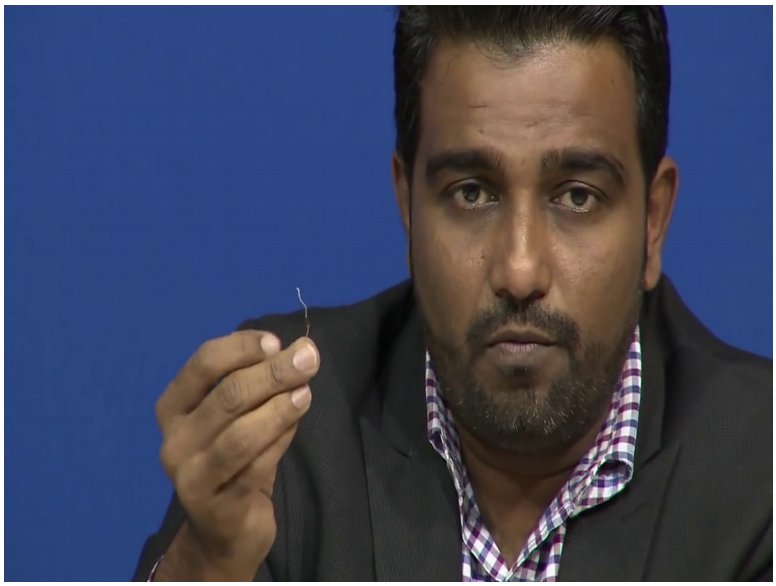

We have a diode. Diode is anode and cathode, right. Now finally, to show you, we have here integrated circuit or IC, right.

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This is what is an integrated circuit what do you mean by integrated circuit now.

So, when you integrate these components, passive devices-active devices; that is transistors are active devices, passive device is resistors right, capacitors right, inductors; these are passive devices. So, a device that does not require external power passive devices requires external power to drive active devices.

This devices active and passive integrated together on a small silicone chip and packaged, this forms yours integrated circuit alright this is your IC. So, let us see; what is an integrated circuit, what is the use of this particular integrated circuit and what are the kind of integrated circuit technology that are available?

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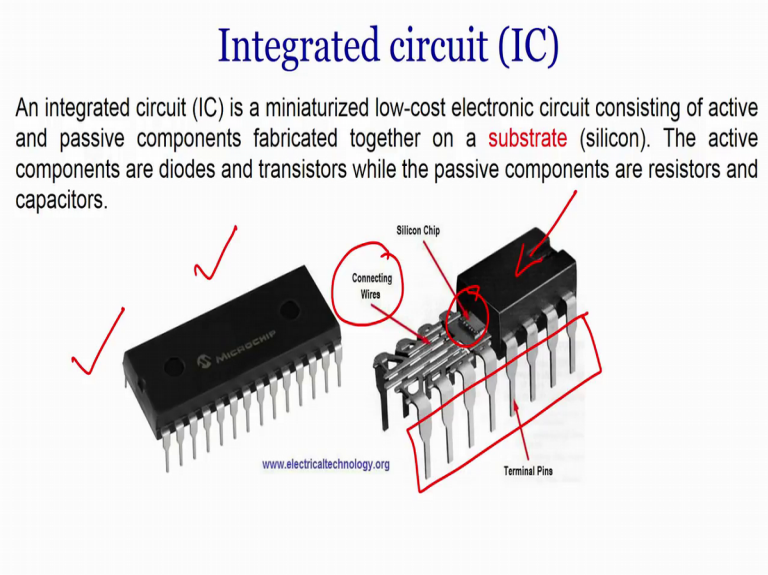

An integrated circuit; as you can see here, right this particular section, this one is your IC; that is what I have shown you, right, this is your integrated circuit and what is it? An integrated circuit is a miniaturized low cost electronic circuit consisting of active and passive components fabricated together on a substrate.

So, what exactly substrate means; we will learn in the series; what are the kind of substrates that are available, what are the kind of substrates that are used and one of the substrate that is used in IC technology is silicone that is why here in the definition, I have written substrate in the bracket silicone the active components like we discussed are nothing, but diodes and transistors while the passive components are resistors and capacitors. Now what you see here is very interesting, you will see this arrow; this one goes right to this particular chip, right.

And this chip which is extremely small, this is a small chip of silicone and within this chip; there are thousands and thousands of transistors integrated with each other to form different kind of circuits; so, this particular chip; this silicone chip right; how it is fabricated and once it is fabricated; right.

Once it is fabricated how it is connected to these external terminals you see this; these are eternal external terminals how it is connected. So, here there is a connecting wires, if you see here, there are connecting wires, this connecting wires right, they are connected to this silicone chip and there are several techniques to take connection one of the technique is called wire bonding other technique is soldering another technique is called metallization and so on and so forth.

So, when you make a silicon or when you fabricate lot of transistors lot of devices lot of active and passive components integrated together on a small silicon chip similar to this and then connect it to external world using this integrated circuit technology where there are some connecting pins, where some connecting wires and finally, you use this casing for pack packaging the entire circuit this whole thing will get us, this particular device and that is nothing, but your integrated circuit right. So, let us see the next slide.

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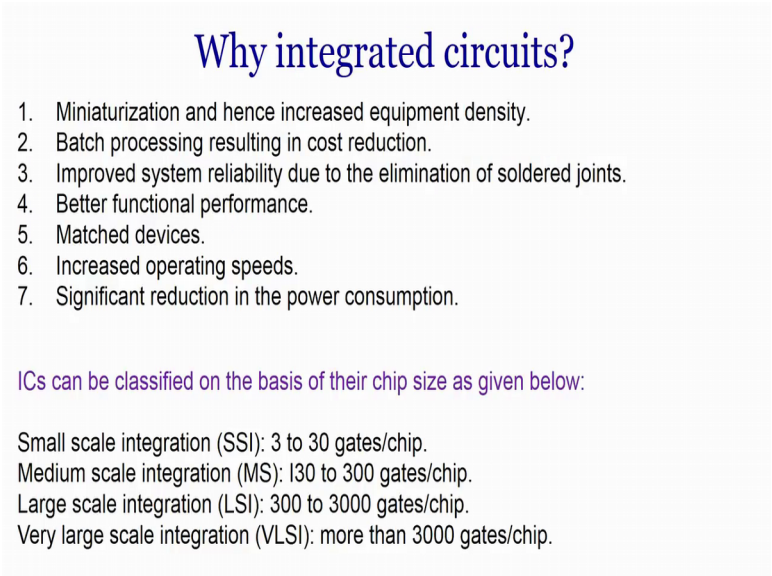

So, the first question that comes to our mind is why we need this integrated circuit? What is the use of indicator circuit? We have discrete components, we can make different circuits, we can make PCBs, right, why to go for integrated circuit and is it really useful.

So, let us see indicator circuits have several advantages, first is its miniaturization; that means, it can be made extremely small and when you make something really small; that means, you can increase the equipment density what does that mean if I show you a silicon wafer, right and within the silicon wafer, if I can make 12 devices or if I can make

56 devices or if I make 108 devices or if I make one million devices, right which will give you a better aspect, what is good for you to have lot of components within a single chip and that kind of having lot of components lot of devices transistors, diodes, resistors, capacitors on a single chip is possible using IC technology and that is why it is extremely useful because it can be miniaturized and hence because of this miniaturization, your equipment density would increase, alright, there is the main advantage of using IC technology .

Now, what is the second advantage of using IC technology? Second advantage is batch processing resulting in cost reduction, what does that mean? That mean that if I fabricate one resistor, alright and I will show you in detail, how you can fabricate a resistor, how you can fabricate a heater, how you can fabricate a MOSFET, right and what are technologies behind used for this particular fabricating this devices, we will discuss in detail.

But before we go to that particular set of lectures, let us understand, what will happen when we fabricate 1 resistor or if you fabricate 10 resistors. So, it is obvious that increasing the number of resistors fabrication registers at one time will decrease the cost; that means, that batch processing number of devices produced in one batch is increased why increased because of his miniaturization you can have millions of transistors on one silicon substrate.

So, you can do batch processing; that means, cost will come down, right that is the second point that we discussed which is batch processing resulting in cost reduction. Let us see the third advantage. Third advantages are improved system reliability due to elimination of soldered joints as you see in the first slide; what we have shown there are no solder joints. So, when that then there are no solder joints; that means, what; that means, that your reliability would be better how is it possible that without having solder joints or not having solder joints will improve reliability.

Now, all of us has done basic electronics project in our undergrad studies where we have done soldering is not it everyone knows soldering and if you have if you are not good in soldering or even if you are good you see that the solder. Once you do it, it will come off, it is not reliable again, it is not that soldering is not used it is used, but for this particular application we do not require soldering at all and if you remove soldering from the

picture, then your reliability comes up because you do not have to rely on this wires that we are soldering because soldering has less reliability.

So, we will see; what kind of how we can take the context from the indicator circuit sometime later, but right now you understand that using the integrated circuits or why integrated circuits are important because it has improved system reliability to due to the elimination of solder joints what is our fourth point the fourth point is better functional performance of course, it is better because you have millions of transistors on one device you can have lot of circuits you know you can play with it, you can have op-amps, you we will see op-amps; op-amps itself has a huge circuits made up of MOSFETS and we will see that is why we have to understand MOSFETS, right.

When we understand op-amps, we understand MOSFETS, when we understand MOSFETS, we understand integrated circuit that is why everything is interrelated, right, but the point is where this indicator circuit will have a better performance or functional performance.

Next is it has match devices, next is it is increase or the devices with that is integrated circuits have increased operating speeds now of course, it is important right, what do you mean by operating speeds, how fast your device is right would you go to the market and buy a phone that takes 2 minutes to start or will you buy a phone that takes five seconds to start or will you buy a phone that takes even smaller time to start.

So, how a device works? How it can start or it can restart or reset and restart, right, this everything depends on the circuit within it and within a transistor how fast this transistor works right that depends on how we fabricate the transistor, there is a totally a separate series of lectures that are required to understand, how we can change the switching speed how can change the drain to source the length between drain and source right how we can change the gate and how we can move from the traditional MOSFET to FINFETS and so on.

So, let us not worry about it what we understand is that if you use integrated circuits then your operating speeds can be higher right. Now final point; it may not be final that is what I started with giving you an example of a tea, right that these the things that I am telling you are the ingredients, you have to find oh maybe [FL] is not there in the tea is not it, same way, there can be more advantage other than 7 listed on the screen.

So, reading is on the way to gain more and more and more knowledge, right and we should never stop learning, we should never stop learning and you when you never stop learning, when you learn something when you read something, you understand put more things in your brain you understand new topics and the topics other than what is taught through a lectures through or from the professors.

So, it is very important to read other points other than what I will give it to you in this lecture. So, the point 7 is the significant reduction in the power consumption. So, when you see an integrated circuit it will be it can be operated at way low power compared to the other circuits. So, what we had discussed today right now we have discussed.

Why indicator circuits and we have seen what is inside the integrated circuit when I show you this IC, see, now you know that within this packaged device there is a silicon chip and within the silicon chip there are transistors and through and there are connections that comes out to this external pins. So, now, you know it is not so much difficult to understand; what is within it.

But this is just a crude way of understanding. So, what if there is a silicon chip. So, what if there is a transistor how we can fabricate those transistors that is what we had to learn right. So, anyway let us let us go to the next topic and that is based on this size right chip size the ICs can be classified or indicator circuits can be classified if it is between three to thirty gates per chip it is called small scale integration or SSI.

If it is 130 to 300, it is medium scale integration or MSI, if it is 300 to 3000 gates per chip, it is called large scale integration or LSI and finally, if it is more than 3000, then we call it very large scale integration now these are basic, then there are ultra large scale more.

But let us not get confused we see basic things which are repeating low scale integration rather, it is small scale integration, it is medium scale integration, it is large scale integration and it is very large scale integration.

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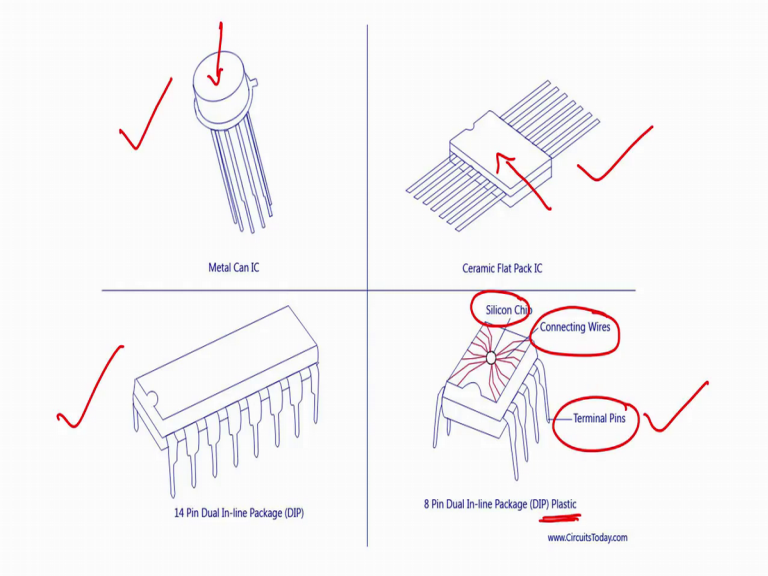

So, these are some of the ICs or a schematic that I have used in circuits today dot com this is a website from which I got this schematic.

The idea is to use it and to into show students what are the kind of ICs that that you generally come across the first IC on the left corner that is this particular IC is nothing, but a metal can IC. So, when you see this particular thing this is nothing, but a metal cap all right. So, this is called metal can IC or metal can integrated circuits then there is another one which is this one this is ceramic flat pack integrated circuit you can see it is a flat pack and it is a ceramic.

So, now ceramic silicon glass flexible substrate; so, this silicon or glass or ceramic or plastic right and you will come across lot of lot of things that people use to fabricate several kind of devices. So, what are these? What is the base material that is used is called the base material that is used to fabricate this devices is called substrate alright. So, when you see the screen it is written ceramic flat pack IC; that means, ceramic is used for fabricating used in fabricating this flat pack IC.

Now, next one is your 14 pin dual inline package it is also called DIP, why 14 pin because there are 7 on one side, there are 7 on other side, we will see operational amplifier and then we will see more; how this pins are related to what kind of functionality finally, on my the fourth chip on the screen, right the bottom right is 8 pin

dual inline package and again you see what is that plastic right the plastic now dual inline package plastic.

So, what does that mean and again you see here, it is similar to what we have seen in the first slide. There is a silicon chip, there are connecting wires and there are terminal pins, right. So, when you come across this kind of different indicator circuit do not get confused, they are all integrated circuits its only way they are fabricated or packaged, it can be metal package, it can be ceramic flat, it can be 14 pin, it can be more number of pins, it can be DIP it can be DIP plastic, right. So, do not get confused with those terminologies it is all integrated circuits.

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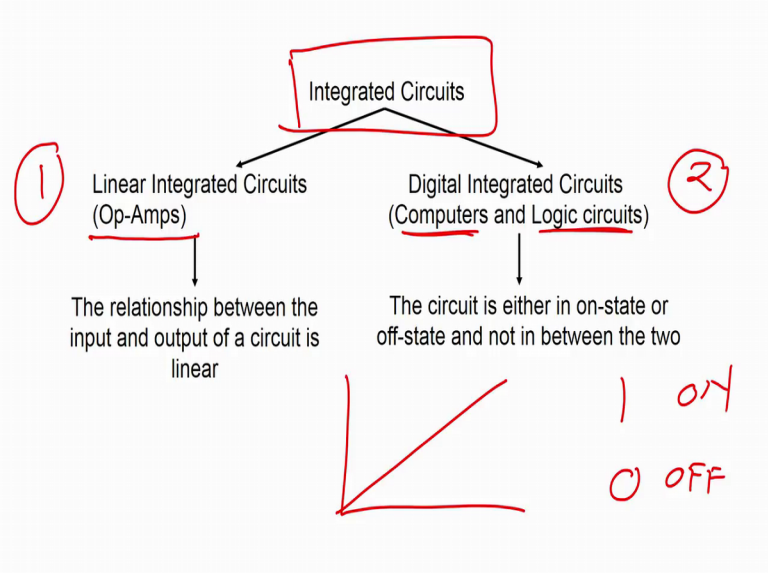

So, let us move to the next slide, what does this integrated circuit? So, basically integrated circuits; we can divide into 2 parts integrated circuits, right we are dividing into 2 parts part; number one, it is linear integrated circuits part second or the second part is digital integrated circuits what are linear indicator circuits.

Examples are operational amplifiers or op-amps and that we will study right what is linearity linear like this linear. Now digital integrated circuits computer and logic circuits this computers and logic circuits uses digital integrated circuits computers and logic circuits, it uses digital integrated circuits. Now as we see here, the relation between the input and output of a circuit is linear of course, because that is wow that is why it is called linear indicator circuit is it not.

So, the relation should be linear relation between what between the input and the output while the second one the circuit is either in on state or off state and not in between the 2; that means, that either it can be 1 or it can be 0. Either it is on or it is off that is what your digital circuit means; either it is on that is 1 it is off it is 0, very easy; very easy to remember, you see when we understand the concept, it is extremely easy to remember the things ok.

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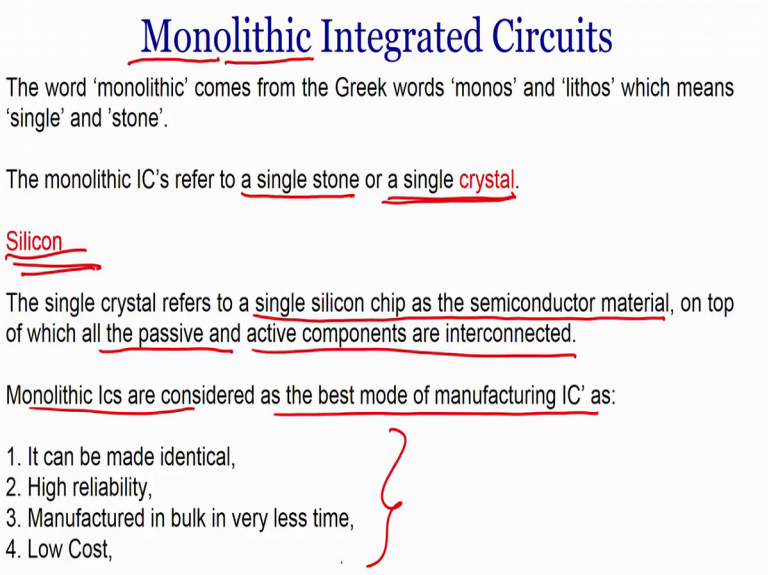

So, let us go to the next slide. Now we will see few techniques, right or technologies that are use to fabricate this integrated circuit, the first one is monolithic integrated circuits. What is monolithic integrated circuits, yeah, very interesting, you see we divided this monolithic into 2 parts, alright.

One is mono means single one, all right and lithic comes from the Lithos. So, how we got this word? The word comes from Greek, alright monolithic comes from the Greek words one is monos and second is lithos; that means, single and stone; that means, that if you carve a single stone to a sculpture it is monolithic, alright.

So, what do you think? Why it is monolithic integrated circuit; that means, that we are using a single structure, right, all single crystal to fabricate our integrated circuit, right. So, we have to use this silicon and we had to do lithography to form your integrated circuit that is why mono and lithos; right monos, lithos, monolitho, monolithography or mono lithic integrated circuit, alright. So, the monolithic ICs refer to a single stone or a

single crystal. Now again confusing word crystal, what does crystal mean? The crystal is nothing, right crystal means just a silicon, you see here silicon do not worry, it is very very easy ok.

So, or a single crystal or single silicon single crystal silicon the single crystal here refers to a single chill the silicon chip as the semiconductor material now I am hundred percent sure that you guys know what is semiconductor what is conductor what is insulator thus there may be few and you see do not worry, if you do not know that is why you have to attend the lectures.

So, it is nothing wrong if you do not recall; what is conductor, what is semiconductor, what is metal; all right, I will give you an example conductor will conduct electricity very well billions of electrons, it is a ocean of electrons, if you have studied somewhere right very easy to pass electricity to conduct electricity conductor.

Semi conductor; semi is half, right or you say final; semi final, right semi conductor; that means, it is possible to conduct electron with a particular parameters, right, we have to give some energy. So, that the electron will start conducting in semiconductor what are examples of metal, let us say any metal or conductor what are examples of conductor any metal right aluminum gold platinum, right.

So, if you talk about the semi conductors, what are examples silicon germanium very easy right then you talk about intrinsic extrinsic that we will see do not worry about it what is intrinsic; what are your extrinsic; again you see the idea is not only to help you guys or to help you to understand; how the indicator circuits are fabricated or how the op-amps are used or how the MOSFETS are used, but also to help you to refresh; what you know and that is very important always keep on refreshing what you know what you have studied very important it is because it will be used in certain phase of your life directly or indirectly, alright.

So, where are we? We are on this semi conductor and semi conductor; we give example silicon and germanium nice very good. Now we have insulator what is insulator that will not conduct that will not conduct what is an insulator wood is an insulator you see wood. So, my friends I do not know from which phase of life or from which area you are you are watching this particular series, but I can give you an example which is kind of common.

If you really think of you may have seen a person; you know getting shock because of the open wire and people hitting that person with a wood; is it not, why they are hitting with a wood because wood is an insulator, wood will not conduct electricity. So simple, right, they do not know that it is an insulator, they know it will not conduct electricity, right and we know it is called insulator amazing.

So, that is that semiconductor devices electronics is very very easy, right always take a real life examples, alright, metal, what you see right how the current comes or how the power comes to your home through some wires right what are the wires made up of are they made up of copper if copper, then it is a metal; that means, it will conduct electricity very easy, right.

So, the point I am making here is that the single crystal in this monolithic integrated circuit is nothing, but a silicon chip as a semiconductor material and on top of this semiconductor material, we are using all the passive and active components which are interconnected right here see what we have read the single crystal refers to a single silicon chip as the semiconductor material on which passive and active components are interconnected nice.

Now, what is the advantage right or why a monolithic ICs are considered as the best mode of manufacturing IC, it is the best mode alright. So, why they are considered best what is there that they are considered best? So, let us see, what is that that they make it best first is it can be made identical that is that is really good right it is highly reliable it can manufacture in bulk in very less time and when these manufacture in bulk in very less time it will result in low cost.

So, because of this parameter it is considered or monolithic ICs are considered as best more for or more of manufacturing right, let us see once again, it can be made identical high reliability it is manufactured in bulk in very less time and finally, it is low cost. So, this parameter together will build together helps to make monolithic ICs to be the best mode of manufacturing. Now let us go to the next slide.

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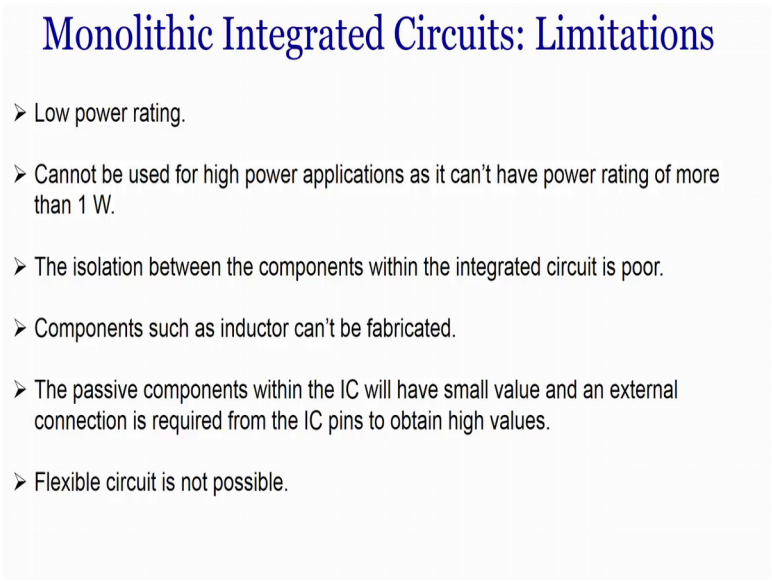

Everything that has advantages would also have some limitations right no one is spared no one is spared in this world.

So, if you have good qualities there would be some bad qualities work on your good qualities work on your better qualities to reduce your bad qualities right, but there are certain limitations that you cannot work on and what are the limitations for monolithic integrated circuits one low power rating; that means, it cannot be used for high power applications and it cannot have power or it cannot have power rating of more than 1 watt, it cannot be used for high power applications.

What is the next limitation isolation between components within the indicator circuit is poor; what is the next one component such as inductor cannot be fabricated what is next one passive components with the ICs will have a small value; an external connection is required what is next one flexible circuit is not possible. So, there are certain limitations associated with monolithic integrated circuits.

So, what to do, right and if there are some limitations, there are some solutions to work on these limitations, right. So, we have to see another technology, right which will overcome in some aspect these limitations right.

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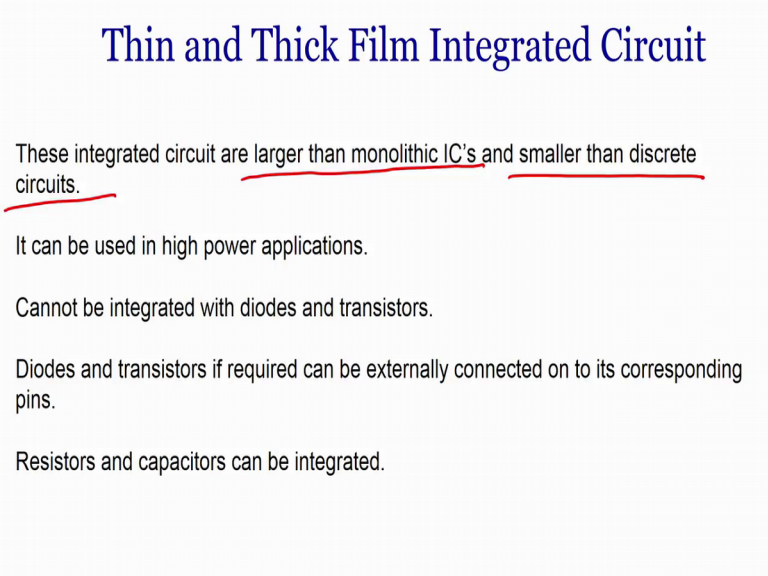

And this technology is nothing but thick or thin and thick film integrated circuit you can call thick and thin; you can call thin and thick; does not matter. So, what are thin and thick film integrated circuits? These integrated circuits are larger than monolithic integrated circuits; first point that you have to remember is these integrated circuits are larger than monolithic integrated circuits, but at the same time they are smaller than the discrete circuits, alright.

So, thin and thick film integrated circuits larger then monolithic ICs smaller than discrete circuits second point it can be used in higher power applications. So, high power application can be used you see the limitations of monolithic ICs were they cannot be used for high power applications while this circuits can be used cannot be indicated with diodes and transistors right this are the limitations, right.

So, first 2 are the advantages other things are the limitations cannot be integrated with diodes and transistors diodes and transistors if required can be externally connected on to its corresponding pins finally; resistors and capacitors can be integrated.

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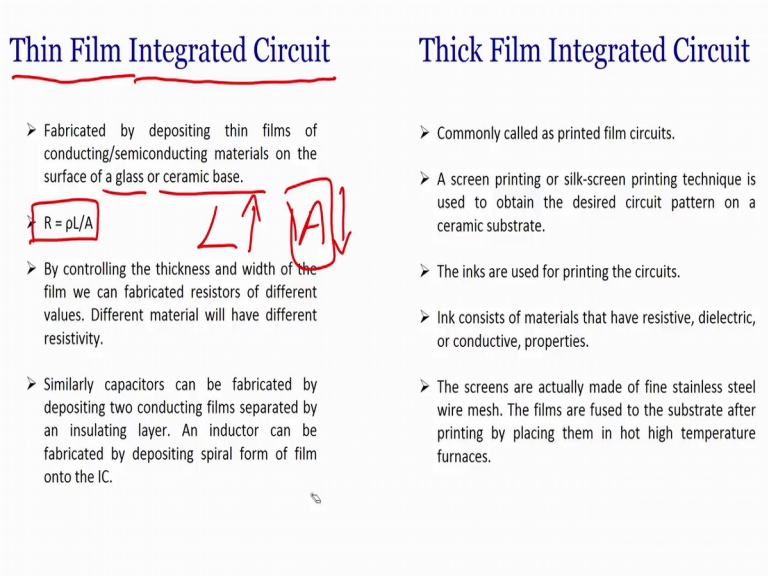

So, let us see what is thin film what is thick film and I will give you an example of both thin film and thick film integrated circuits. First let us see the left side of the screen and that is written; we have written thin film integrated circuit, right.

So, fabricated by depositing thin films of conducting or semiconducting materials on the surface of glass or ceramic base that does not mean that we cannot deposit film on silicon, we can deposit film on silicon, we can deposit film on silicon, we can film deposit film on oxidized silicon, we can deposit thin films on class, we can deposit thin films on ceramic base, we can deposit thin films on flexible substrates that is what is called thin film integrated circuit. How the deposition is done? You will see there are several techniques to deposit a metal film or a semi conductor film or insulating film, alright.

So, the point that I am making right now is that the thin film why it is all thin film because the thickness of the film is extremely small. So, here we have taken one example what is an example R equals to rho L by A. What is this? Very easy right; what is our resistance? What is rho; resistivity. What is L; length, what is A? Area; now we all know this equation is it not.

So, can we make a resistor using thin film technology and if yes how can we change the resistivity, it is very easy which is the material, right, but if you want to change the resistance right assuming that the material is same then what you can do you can either

increase the length or you can decrease the area is it not because your equation is R equals to rho L by A. So, what does that mean by controlling the thickness and width thickness and width comes when there is an area.

So, by the controlling the thickness and width of the film, we can fabricate resistors of different values different material will have different resistivity. Similarly capacitors; what does capacitor means? A simple definition of a capacitor is 2 plates separated by a dielectric or air right dielectric is a simple insulator ok.

So, if I want to fabricate a capacitor, I can fabricate a capacitor by depositing an insulating film between 2 metal films or in another way it is it is same thing what is written capacitor can fabricated by depositing 2 conductive film separated by an insulating layer or insulating layer between 2 conducting films same thing, right. So, this is how we can fabricate a capacitor we can also fabricate a inductor using thin film integrated circuit. So, these are some of this is how the thin film integrated circuit ca can be fabricated.

Now, let us see let us see the thick film technology and I will try to show you the actual device using the thin film technology that I have fabricated. So, that you understand how it looks like. So, we move to this next section which is our thick film integrated circuit.

So, commonly this is also new you known as printed film circuits or screen printing or silk screen printing right it is obtained to it is used to obtain desired patterns right on the substrate it can be ceramic substrate it can be paper as well right. So, I will give you an example.

If you see what I have in my hand, what is this?

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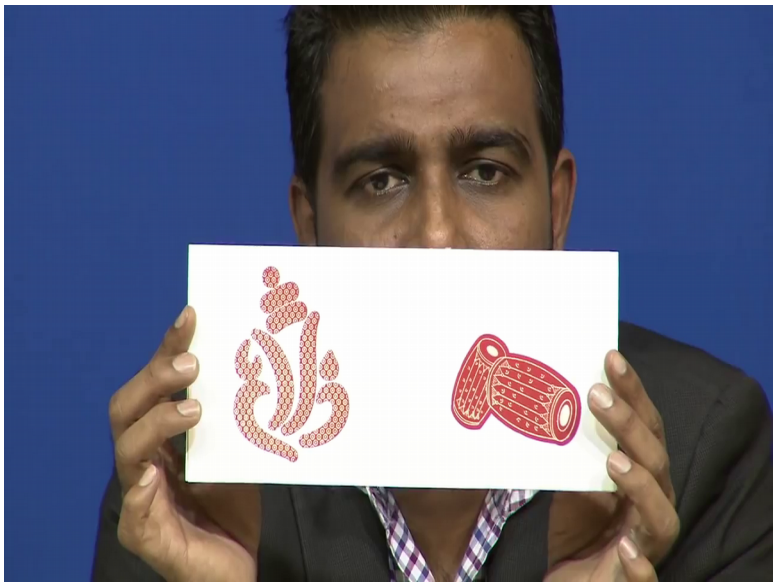

These are the patterns of course, there is a wedding invitation, let us not consider this. So, let us see this one all right what do you see there is a instrument right here right and there is a Ganesha pattern which is here right is it not; you can see it instrument and a pattern now how can you make this patterns do you know have you ever went to a screen printing shop right this is wedding card right similarly we kind of print lot of things using the screen printing technology and this is thick film.

Because you can see even if you touch, right, you will see the difference between the white paper and the pattern there is some kind of a step right step is there because the film thickness is very large compared to thick thin film. So, what I am showing here is nothing, but thick film technology and now here the material is nothing, but it can be insulator we do not need a conducting material here is not it.

But in case of integrated circuit technology it can be resistive material it can be a dielectric material it can be a conductive material with different properties right. So, in this if you have seen there is a screen that is used right with this pattern and there is there is a ink that you can put and there is a squeeze that you just splash it or just squeeze it or across the silk screen and below is your substrate.

So, what will happen whatever the pattern is there through that the ink will come down and it will stick on the substrate you take it, you hit the substrate and the pattern is there on your substrate, right, many times, I have used this word substrate what is it? It is

silicon, it is glass, it is ceramic, it is plastic, it is a material on which you fabricate devices right that is your substrate.

Now, you have seen this. So, what is the use of this screen printing screen printing you can make quick sensors if you have seen gas sensors they are used using screen printing because very easy to fabricate you see there is a manual screen printing there is a semi automatic screen printing there is a automatic screen printing where you just keep one printing the patterns in bulk, right.

When you keep on making the things in bulk the cost will go down alright. So, screen printing thick film technology uses the screen printing. Now let us go to the advantage of thick film and thin frame ICs right over the compared to monolithic ICs.

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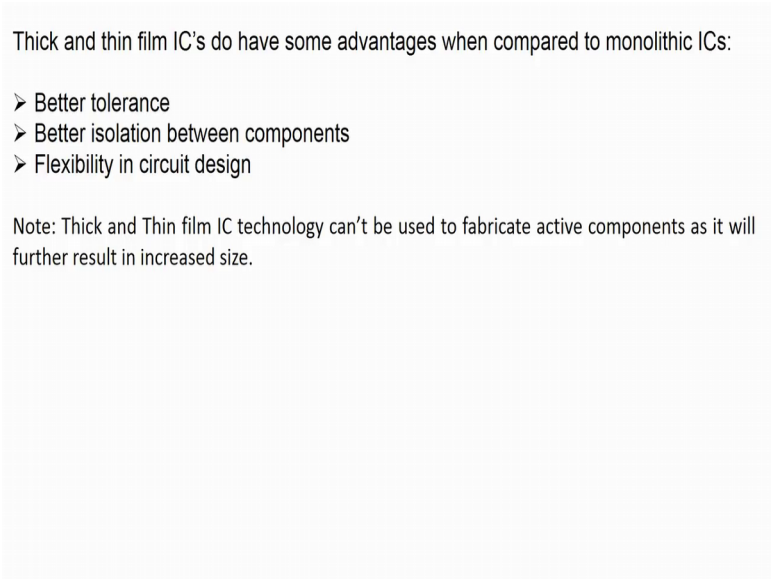

First is it has better tolerance you can you can you can control you can control the thickness write better isolation between components flexibility in circuit design right; however, thin film or thick film can be used to fabricate active components and it will further result in increased size it is not that it cannot be used, but it will result in increase in size right because there are a lot of research papers that you may found.

If you are interested in reading papers that people use the thin film technology to fabricate transistors, but if you want to fabricate millions and millions of transistors, you

have to have lot of masks, right because we will see what are mask again, right and that will be in this; in the following series that you will understand how the IC is fabricated.

The today's lecture is focused on what are ICs what are IC technologies. So, do not worry about it, right when the time comes you will know right and I will show it to you. So, let us go to the next slide the next slide is hybrid.

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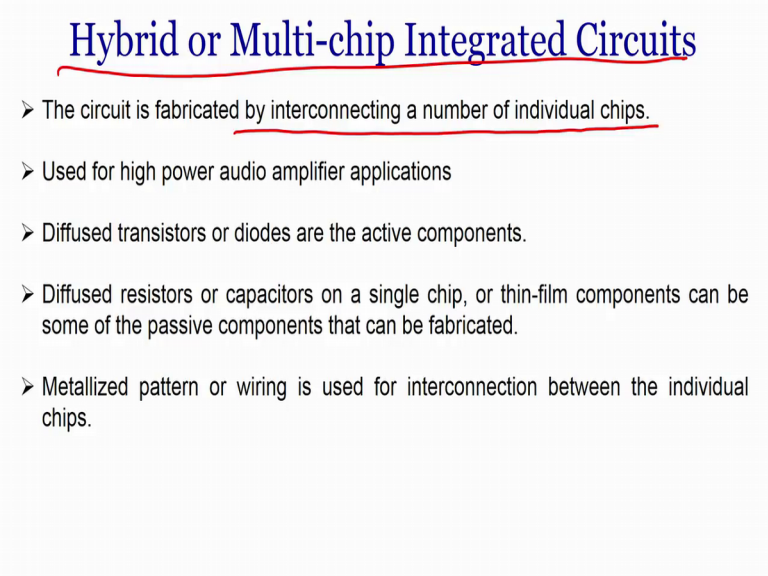

Or multi chip integrated circuits. So, the integrated circuit is fabricated by interconnecting a number of individual chips right as you can see, this circuit is fabricated by interconnecting number of chips why and this is the advantage actually this is the circuit the interconnection of number of individual chip is a advantage of multi chip indicator chips or circuits.

This is used for high power audio amplifier applications it is used for high power audio amplifier application. So, you see remember this points, it is very important because sub some suddenly if somebody ask you or question you that what is the advantage of hybrid or multi chip indicator circuits over monolithics over thin frame and thick frame IC technology.

You can quickly say, first advantage is interconnecting number of individual chip second advantage is high power audio amplifier application right third advantage is you can diffuse the transistor or diodes as the active components.

Now diffuse transistors or diodes can be made you on this integrated circuit diffuse resistor capacitor on single chip or thin film components can be of some of the passive components that can be fabricated right and finally the metalized pattern or wiring is used for interconnection between the individual chip; that means, that there are several advantages when you talk about hybrid multi chip integrated circuits. So, b j t fat how they are fabricated how b j t is fabricated, how fat is fabricated, how MOSFETS are fabricated we will see in the next class, alright.

So, let us quickly recall what we learnt today first we learn what is integrated circuit why integrated circuit is important right how integrated circuits are divided into 2 main group one is linear indicator circuits second is digital integrated circuits linear integrated circuits example is operational amplifier digital indicator circuit example is computers or logic circuits linear integrated circuits works on linearity between input and output digital works on 1 and 0.

Then we saw monolithic integrated circuit right then we saw. So, what is monolithic again carving from a single stone right making a fabricating a device on a single silicon crystal, alright, then we saw the advantages and disadvantages of monolithic integrated circuit technology.

Then we saw thin film technology and thick film technology and we understood that thin films can be used to the different materials can be used to deposit thin film on the different substrate. It can be glass, it can be ceramic, it can be plastic, it can be silicon, it can be oxidized silicon, it can be insulator on silicon, right, there is word called SOI; silicon on insulator. So, we will see about that also.

Then we saw thick film technology, we saw an example of a pattern, right and now if you go somewhere may be in market, right and you see; there is a screen printing shop just stop by there talk with that guy right and you will see, he has a lot of time to talk with you, right, we do not go and talk people have time to talk.

So, try go listen right discuss discussing with any person always somehow you will learn something does not matter from whether he is an engineer as a scientist or a common man who has no degree, but he may have lot of experience a guy working in his screen printing shop may have huge amount of experience then you will get sitting in a laboratory and doing a thick film technology right. So, always remember discuss

discussion talking with people understanding sharing of ideas will improve your knowledge, alright.

So, thick film whenever you go to market if you come across a screen printing shop step stop by discuss by him a tea right now finally, we saw hybrid or multi chip integrated circuit technology and then we saw advantages and disadvantages of all the technologies in the next class we will see the silicon I will bring a wafer for you.

So, you can see how silicon substrate looks like, we will also see several techniques that are used to fabricate this indicator circuits extremely interesting, I will give an example at the end of this particular course like I said technically theoretically, you will have idea how things works and when you go to a laboratory which is a facility to fabricate those devices you will not get confused you will not be blank right you know this is how it works oh equipment is like this is the equipment used for depositing thin film this are the equipment used for fabricating a MOSFET right, but here you have to understand how it is fabricated right theoretically alright.

So, I hope I see you in the next class and we keep our journey on and we learn with every class right. So, the last slide for this particular class, I will thank you all for attending this particular lecture.

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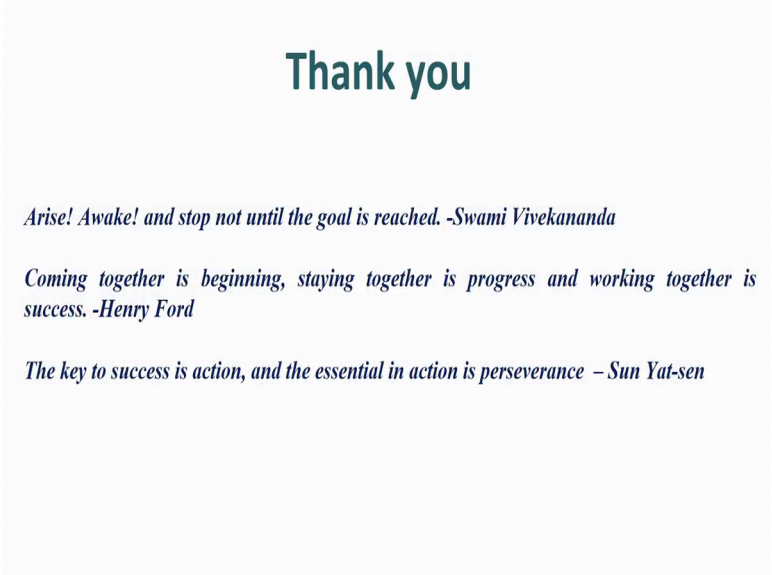

And it is a very very famous saying by Swami Vivekanand [FL], Arise, Awake and Stop not, until your goal is reached, right, do not give up right life is hard, but you should not give up and of course the second line, we already discussed and the final one the key to success is action and essence and the essential in action is perseverance. So, it is always good to read other things apart from engineering, right, try to read something right, try to watch. In fact, I will tell you a cool example, you see science fiction movies there is lot of friction right, but there is lot of science.

So, get the science part and enjoy the movie right see what they are showing whether they are showing a thermal sensors right where you can see a person in night, how this thermal sensor would work. So, learn something from everything, right when you see around you have lot of things to learn alright guys. So, I will see you in the next class, till then you take care of yourself, bye.