Integrated Circuits, MOSFETs, OP-Amps and their Applications
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Lecture - 33
Introduction to Noise and its Types

Hi, welcome to this module. And this module is a last model for our class 12, which is oscillators and noise right. So, until now what we have seen, we have seen what are the oscillators. So, let us quickly recall what are the oscillators, and what are the kind of oscillators, and then we will we will move to the noise ok. These second last lecture for this particular course, next lecture we will see the data sheet, and finally, we will have a recall lecture follow followed by some experiments.

So, if you if you recall what are the oscillators, we know that oscillators required two things which is called Barkhausen criteria. The first one is that the small single which is the output which is fed from the output back to the input, you should be in phase with respect to the input signal right that is first thing that is the if the input signal is 0 degree, the output signal which is feedback to the input through the feedback network should also be at 0 degree. The second condition was that the that the mode of mode of a into beta should be greater than or equal to 1. What is a, is your gain; and beta is your feedback network right.

So, using this if we use r and c as a feedback network right then we can use or we can we can design oscillators which can be used for at lower frequency. While if I use l and c that is inductor and capacitance as reactance is or reactive components, then we can design oscillators which can work at higher frequencies right. This is what we have seen. We have then seen what are the crystal oscillators, and how what are kind of crystal oscillators that can be used. We have also seen how this stability factor affects the crystal oscillator. As well as we have if you recall quickly Hartley oscillator this we have seen right, crystal oscillators we have seen, then we have seen ujt oscillators, and its characteristic curve right.

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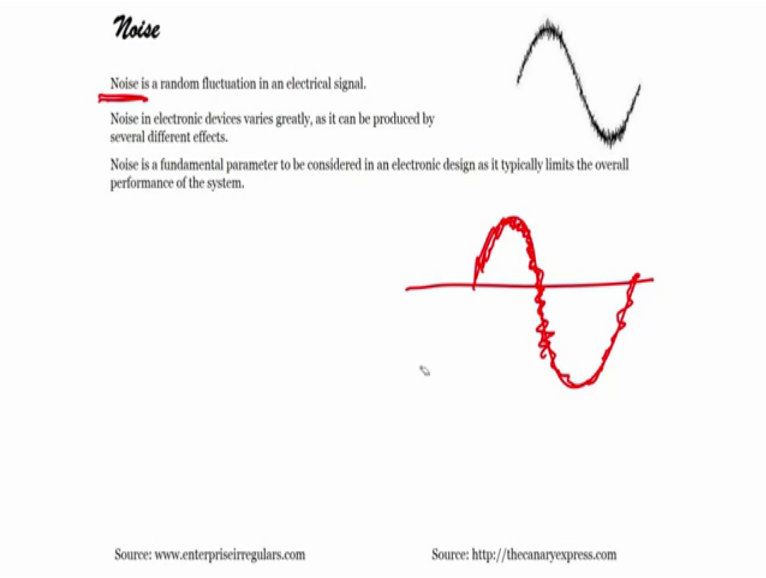

Now, let us see what is noise ok, what is noise? So, noise when you talk about noise it is a random fluctuation in an electrical signal. Noise in electronic devices varies greatly as it can be produced by several different effects. Noise in fundamental parameter to be considered in an electronic design it typically limits the overall performance of the system. So, you see a signal if I want a clean signal right if I have the distortion in the signal right that may be due to the due to the random fluctuation of the electrical signal. And this random fluctuation of the electrical signal is nothing but your called noise all right. This random fluctuation is called noise hm.

And it can be produced by several different effects right we will see in the next slide its what are the several effects or what are kind of noise that can arise in a electronic system. It is a it is a fundamental parameter to be considered, because we have to remove this noise to obtained the pure signal right. We have to remove the unwanted fluctuation in the signal, so that we can retain the wanted signal.

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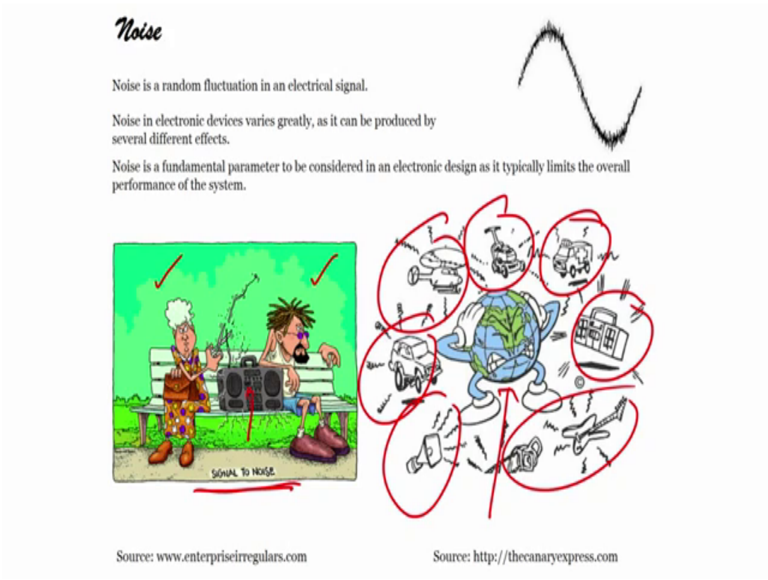

Now, in general the noise is also created by the several components, you see here chopper, noise of a car, siren right, guitar, radio, ambulance, racing car, and what not and what not right. But this is unwanted signal for the for the or this cause noise pollution right, this cause noise pollution. Similarly, a noise for one person cannot be can be a entertainment for other person all right.

If you see this particular images which is very nice image, it was from enterprises in the regulators dot com. And we see that signal to noise the sound that comes out from this particular radio right is a is a music for this guy, while it is a noise for this women right. So, you see and noise in any case can be defined in a in a different way in a in a comic way as well, but when we talk about electronics the we are not talking about just a noise that we can hear, but noise that are present in the electrical signals.

So, this is some not noise which is horn noise or which is a chopper noise or which is some honking right or which is some loudspeaker or very loud music, but these are the noises which are present in the electronic form. And when this is a noise right at let us say if the if there are 100 people around me it all talking then you may not understand what I am talking. You have to understand, what is the signal. Suppose, whatever I am right now teaching you is a signal right. And then there are there are 100 people around me who are talking, so it is it is difficult for you to retrieve the signals from, if I if I say that the 100 people talking is a noise, and what I am teaching you right now is a signal.

Then you have to retrieve this signal from the noise right that means, you have to filter out this noise and retrieve only the signal, so that you can hear it clearly all right. So, this is a just an example. So, if we have if you recall what we have seen earlier we have seen signal to noise ratio, and what is our said topic the topic was C M R R right.

What is CMMR? CMRR is common more rejection ratio right. Higher CMRR better the better the performance signal, higher signal to noise ratio better the performance of electronic circuit all right. So, in theory or quickly if you want to define noise, then you can say that noise is nothing but a random fluctuation in an electrical signal all right. Let us now see what are the kind of electrical signals, what are the kind of noise present in the electrical signal.

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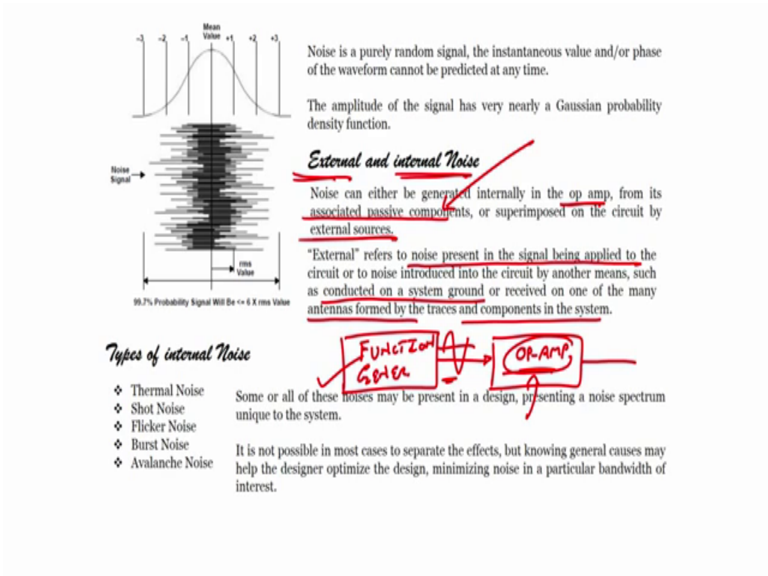

So, if you see the slide, what you see that noise is purely random signal, the instantaneous value or a phase of waveform cannot be predicted at any time. Now, what are external, internal noise, you see external noise internal noise. So, noise can either be generated internally in the top in the op amp from its associated passive components or super imposed by circuit by the external sources. So, the noise can be generated with the help by resistive components in the operational amplifier or it can be super imposed when you design the of different kind of circuit using external sources.

External refers to noise present in the signal being applied to the circuit or to the noise introduced into the circuit by another means, such as conducted on a system ground or received one of them many antennas from the by the traces and components n the system.

So, let us not make our life difficult these signal this noise. So, suppose let us say you have this circuit ok, you have this op amp base circuit. You are introducing you are introducing a signal from function generator or from function generator right. You are introducing a signal from a function generator to the op amp circuit. Then this signal that is generated from this external source may introduce a noise in this circuit, may introduce a noise in the circuit. Op amp itself many have noise generated by the associated passive components, but there is a possibility of a external noise that comes out of the function generator and is introduced to the op amp all right. So, there is a something that we need to take care we need to understand.

Now, when we talk about types of internal noise, then there are several type of internal noise. We will just understand the definition. And we will just see one example to understand the noise. When we talk about internal noises, there are thermal noise, short noise, flicker noise, burst noise and avalanche noise all right. So, some or all the of this noises may be present in the design, presenting a noise factor meaning to the system. It is not possible most of the cases to separate the effects, but knowing general causes may help the designer optimize the design, minimizing noise in particular bandwidth of the interest, bandwidth of interest.

So, there are some there all this noise may be present in the system, and it may not be possible to remove the effect that is caused because separate the effect of the noise on the system. But if we know that these are the noises possibly present in the system at least in the band of interest rate right, we have seen filters and let us say this is the band pass filter this is a band of our interest correct, this is band of our interest. So, at least in this particular band, we can optimize the design such a way that the noise is minimum, the noise is minimum right. So, this is just again an example that at least minimize the designer right, who is designer circuit designer can optimize the design such that the noise is minimized.

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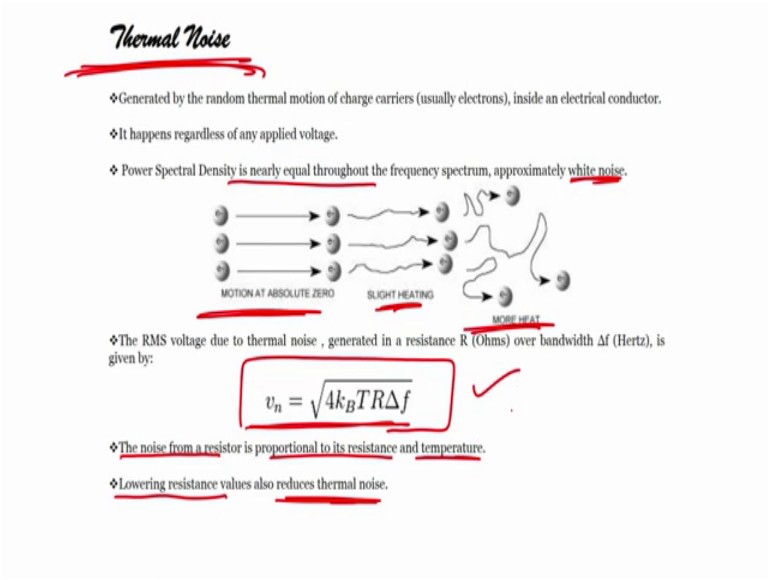

So, let us see what are the what are the type of noises the first noise is thermal noise. So, this noise is generated by random thermal motion of charge carriers usually electrons inside an electrical conductor. It happens regardless of any apply voltage that means, that you see motion at absolute is zero, slight heating will cause randium a random fluctuation or motion of the electrons. And if I apply more heat then it becomes even more random, so this random motion of the electron or the charges or cause would cause a noise ok.

Now, power density is nearly equal through a the frequency spectrum approximately the white noise. The RMS voltage due to thermal noise generated a in a resistance r over a bandwidth delta f is given by this equation. You have to understand or you to remember this equation, we are not deriving this equation, but at last you have to remember this equation ok.

So, noise voltage is equal to under root of 4 k B T R into delta f, where the noise from a resistor is proportional to its resistance and the temperature. And lowering the resistance values also reduces the thermal noise. So, when we talk about thermal noise right, it is noise created by the motion of the carriers. Second is if we increase the heat more or increase the temperature, the noise will increase. If the resistance value is higher, noise will increase; lowering the resistance value will also reduce the thermal noise all right. And you have to remember this equation.

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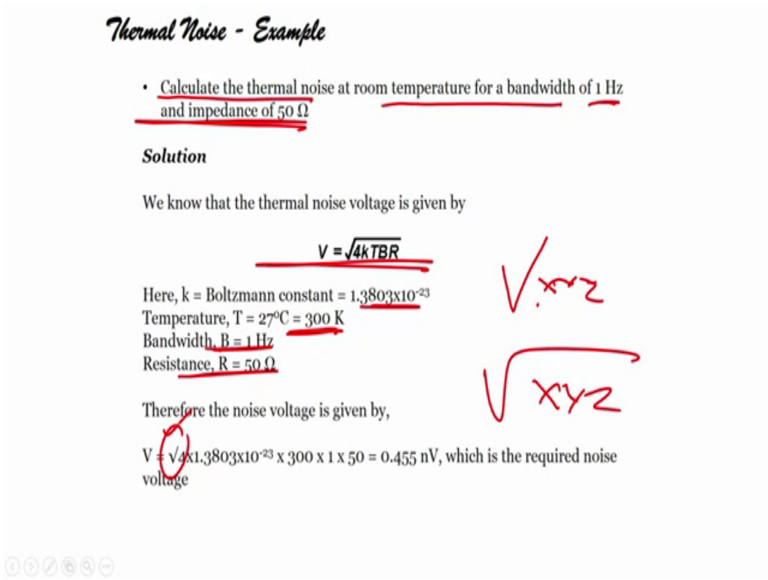

Now, let us see about example of a thermal noise. So, if I am given a example such that calculate the thermal noise at room temperature for a bandwidth of 1 hertz and impedance of 50 ohm. This is the question this is the problem given to us. So, let us see how we can find the solution. We know that the thermal noise voltage is given by v equals to under root of 4 k B T R, where k is bohemian constant, T is 300 Kelvin, B is 1 hertz, R is 50 ohm ohms right. This is given right 1 hertz is given, 50 ohm is given, we should know what is Boltzmann constant ok.

And we said room temperature, room temperature we considered as 27 degree, so 300 Kelvin that was a noise voltage is nothing but under root of it is under root under root whole ok. You do not have to use this symbol write like this. If you just write under root or just under root like this and then write x, y, z value that is consider that it is equivalent to x, y, z all right. So, when you see this symbol here right this is under root. So, under root of what 4, so four is there into k, k is Boltzmann constant into temperature in Kelvin into bandwidth into resistance right. See here 4 4 k Boltzmann constant, temperature, bandwidth, resistant right.

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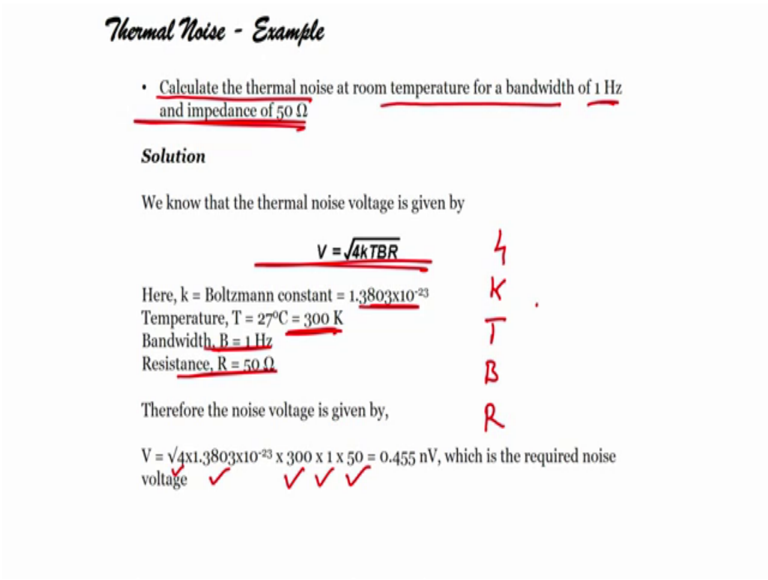

So, if I apply this if I if I write this values I can find out the I can find out the noise voltage which is 0.455 right that is a thermal noise that is generated because in this particular problem ok. So, this is an example of thermal noise.

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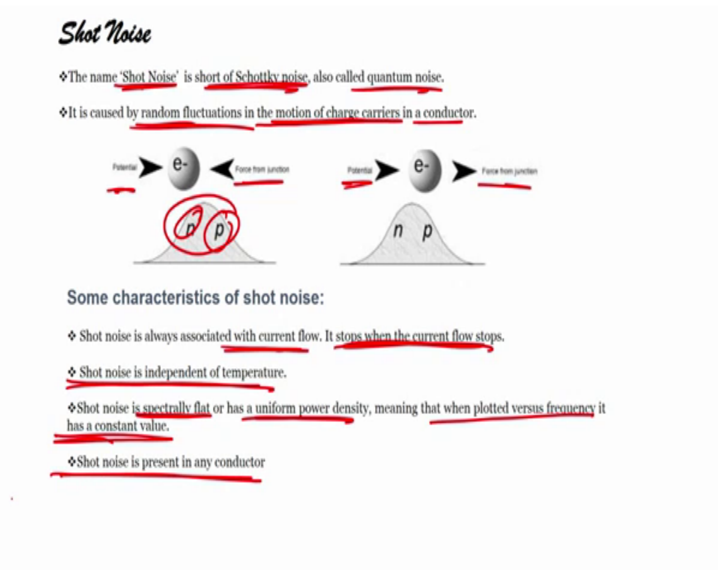

Now, let us see another noise called shot noise, shot noise. So, what is shot noise the name shot noise is shot of Schottky noise also called quantum noise ok. So, shot noise is also called Schottky noise or shot form of noise is also called quantum noise. It is caused by the random fluctuations in the motion of carrier charged carriers in a conductor. You see potential force on the junction, potential force from the junction if there is n and p, what will happen the there is a random fluctuation in the motion of a charged carriers. This random fluctuation of charge carriers in the in the conductor right n is electrons, p is who p are wholes. So, what happens that when there random fluctuation in the motion, this will cause the shot noise.

Shot noise always associated with current flow and it stops when the current flow stops. So, it is not like thermal noise that it is there even when we do not apply any current right. It is just a thermal noise is proportional to the temperature also, but shot noise only comes into effect when there is a flow of current. Shot noise is independent of temperature shot noise is spectral spectrally flat or has a uniform power density meaning that when plotted versus frequency it has a constant value. So, when you plot a shot noise against frequency you will find it has a constant value ok. Next is shot noise is present in any conductor all right, shot noise is present in any conductors, so that is very important to remember.

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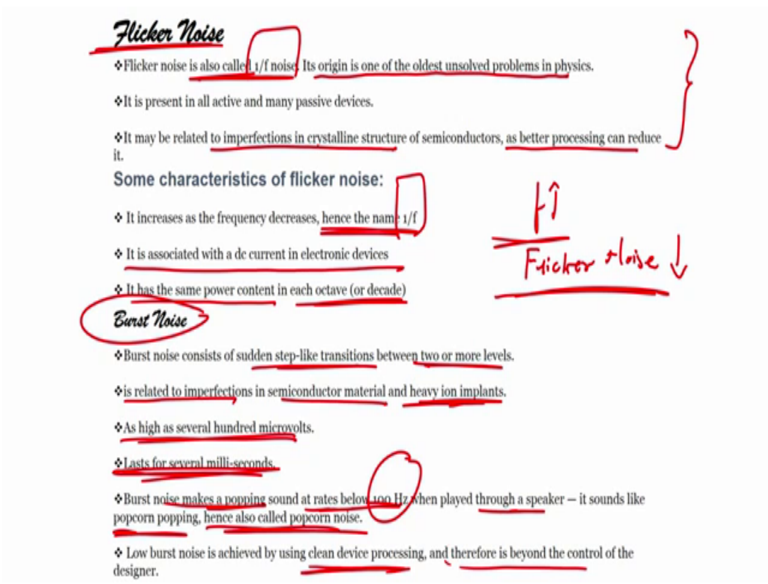

Let us see next one which is our flicker noise and then we will see burst noise. So, what is flicker noise, is a flicker noise. Flicker noise is also called 1 by f noise. Its origin is one of the oldest unsolved problem in physics see from where it originates we do not know. It is present in all active and passive components. It may be related to imperfection in the crystalline structure of semiconductors as better processing can reduce it. So, what does it mean that when we have seen what is impel crystalline structure, the crystalline structure let us say in silicon we have seen 100, it is a orientation right crystalline structure, but how the crystalline structures are if there is a imperfections in crystalline structure then it may cause it may we do not know, but this is just a theory right.

It may cause the generation of flicker noise, but the better processing better processing of the material by reducing the crystalline structure or imperfection in the crystalline structure would reduce the flicker noise would reduce the flicker noise ok. This is what we have we are assuming we are assuming. So, what are some characteristics of flicker noise. So, flicker noise it increase the frequency decreases right. See because what we have found is when we increase the frequency the flicker noise flicker noise decreases or increasing the frequency the flicker noise decreases right that is why the name is given 1 by f noise. As you see here 1 by f noise. It is associated with the dc current in electronic devices; it has same power content in an octave or in each octave or decade right.

Let us see next one which is burst noise. What is burst noise? Burst noise consists of sudden step like transitions between two or more levels. It is related to imperfection in semi conductor material and have heavy ion implants. And there is a heavy ion implantation you will see or you will find there is a burst noise as high as several hundred micro volts lasts for several milliseconds. Burst noise makes a popping sound at rates below 100 hertz you see that is why it looks like a burst all right it makes a popping sound. And played through a speaker it sounds like popcorn popping, and hence also called popcorn noise all right.

So, it is related to imperfection semiconductor. It has and it has a an heavy ion implants right. It is a sudden step like transition. And the voltage is as high as 100 micro volts lasts for several milliseconds. So, when you connect a speaker and you will hear a popping sound at rate below 100 hertz below frequency of 100 hertz. And because of its sound similar to popcorn popping, it is also called popcorn noise; it is also called popcorn noise. Low burst noise is achieved by using clean device processing. And therefore, is beyond control of the design that is about the burst noise.

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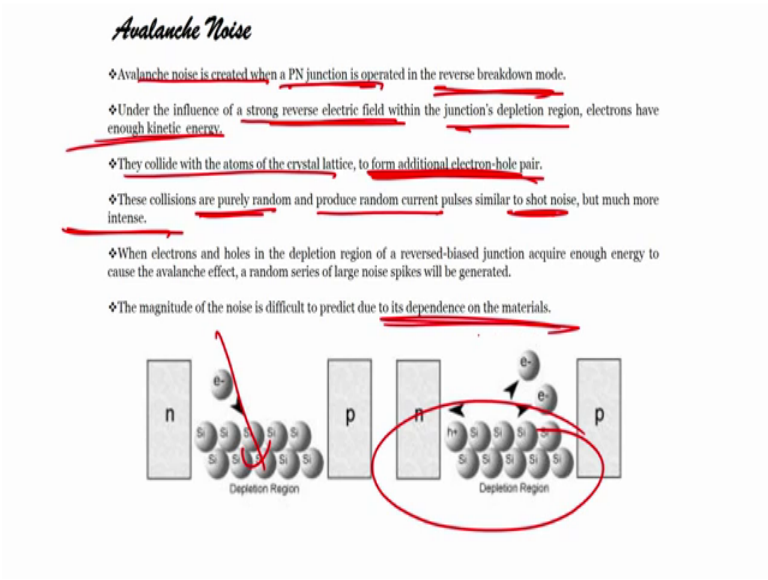

Now, let us one more kind of noise which is your avalanche noise. So, what is avalanche noise. Avalanche noise is created when a PN junction is operated in the reverse breakdown model all right. When is a generated operated in reverse breakdown model. So, what happens under the influence of strong reverse electric field with the junction depletion region, electrons have enough kinetic energy. They collide with the atoms of the crystal lattice to form additional electron pair.

You see when you when you when you deplete the region, when you deplete, the region the electron would have enough kinetic energy and collide with crystals as you can see it is colliding here with crystals and this lurching the electrons further electrons right and forms additional electron-hole pair. This collisions are purely random produce random current pulses similar to shot noise, but much more intense ok.

When electrons and holes in the depletion region of reversed biased junction acquire enough energy to cause avalanche effect a random series of large noise spikes will be generated. The magnitude of the noise is difficult to predict due to its dependence on the material. So, more or less you see what we have found, more or less it depends on the semi conductor material. It depends on the type of material because it depend on the material. Only the thermal noise in particular we have seen that depends on the temperature right, it depends on the temperature.

And next we have seen shot noise, we have seen the burst noise, we have seen the popcorn noise, we have seen the avalanche noise right. So, this will be the end of this particular lecture which is our lecture number 12 oscillators and noise. Now, you guys you have to understand, once you read what are the types of noises right, understand where exactly this noises are generated, and how can you solve, how can you solve or how can you find if there is a noise in an electronic circuit ok. Do something that is your homework, do something by yourself understand how the noise is generated all right.

So, in the next class, in the next class we will see quickly the data sheet of the operational amplifier. And we will we will see some of the parameters in the data sheet, few of the parameters are already discussed in this entire course you will find it when you open a data sheet lot of parameters we have already discussed which are mentioned in the data sheet. Few other additional parameters we will discuss and then we will have a last lecture, which will our recall lecture which will consist of whatever we have done from class one till now, but in a in a little bit faster mode little bit faster mode. So, that you kind of recall whatever we have done till now all right.

After that we will have the experiment classes. After that will have experiment classes where I will show you how to implement the circuit on breadboard, and how to use simulink to solve some of the to solve of the circuits ok. To apply voltage, you see will we will gather the components from the library, we will attach this components to form a circuit we will apply a signal and you will see what is the change in output using the oscilloscope in simulink which just simulation software.

But we will also do the similar study using the breadboard using the oscilloscope, frequency generator and dc power supply, the only three tool will use or three equipment we will use and we will design several kind of circuits related to the operational amplifier all right.

So, till then you take care; read this particular lecture, and I will see you in the next lecture. Bye.