Integrated Circuits, MOSFETs, OP-Amps and their Applications

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Lecture – 32
Construction and Operation of UJT Relaxation Oscillators

Hi, welcome to this particular module and in this module, we will see another kind of oscillator. They are called uni-junction transistor oscillators or they are also called UJT oscillators, all right. So, when we talk about UJT oscillators, we have to understand; what are uni-junction transistors and why we had to use UJT oscillators? Earlier, we have seen different kind of oscillators, right, if you remember, we have seen different kind of oscillators starting from phase shift, Wein bridge, LC and that is LC is also called tank circuit.

And using tank circuit, we have constructed a Hartley, we have constructed the Colpitts oscillator, then we have seen the crystal oscillators. So, let us see how exactly UJT will work as an oscillator; to understand that we have to see the slide and we can see that like diodes uni-junction transistors are constructed from separate P type and N type semiconductor materials.

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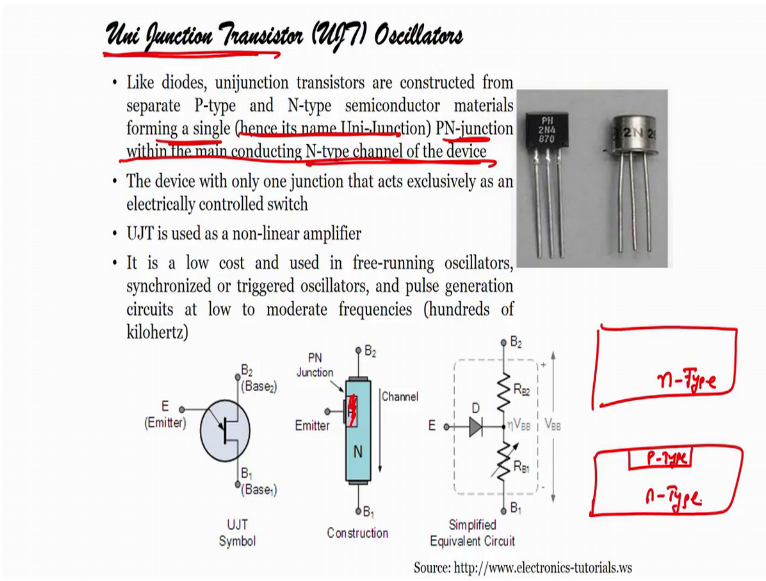

So, you have to understand how UJT works and hence its name uni junction. So, you see uni-junction transistor are constructed from separate P and N type semiconductor materials from a single PN junction within the main conducting N channel of the; device within the N channel of the device you have this P and that is why it forms a PN junction this is a fabrication.

Now, you guys know if I want to dope, let us say if I have a N type semiconductor and I want to have a P type material in N type semiconductor right what is a process step? We should all know let us see, what are the process step.

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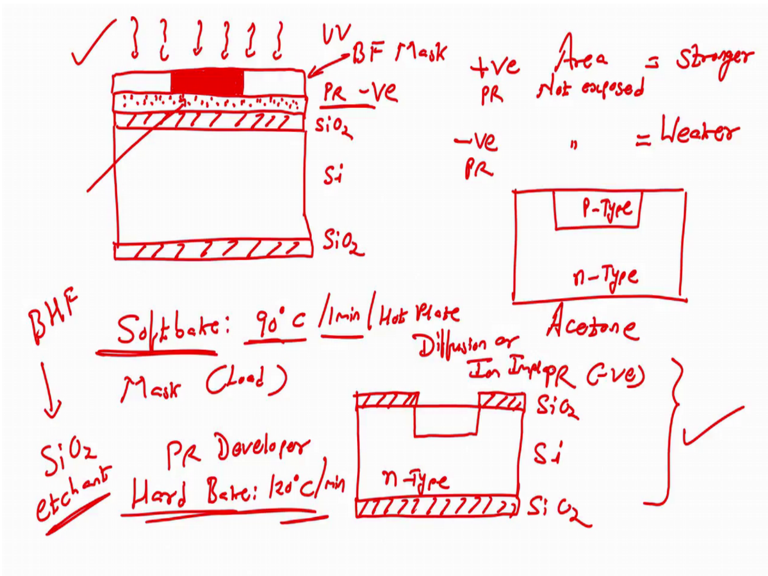

So, what I asked is we need P type material in N type substrate. This is what we need, what we will do? We will take a silicon, this everybody should know now.

We grow oxide, this is our oxide, then what we do? Next step is we had to open a window right; that means that we will spin coat photoresist. We all know this spin coat photoresist. So, let me put photoresist like this. Now what is next step? Next step is we will make it, this is photo resist. This is Sio 2, this is silicon, this is photo red, this is silicon dioxide.

We can grow silicon dioxide using lpcvd, now we have coated spin coated photoresis,t after spin coating we know, it is time for soft bake and we already know that whenever we use silicon, we had to clean it. So, 90 degree centigrade, 1 minute on hot plate correct, then we use mask we load the mask load the mask.

So, I load the mask, how my mask will look like? My mask will look like this. It is a bright field mask, my photoresist is positive photoresist, we have seen that many times. So, now, you should be able to understand, still if you are confused, you ask me in the forum. Do not worry about it positive photoresist ok.

So, now we are loading the mask on the photoresist that is soft baked after that what we will do after that you will expose the wafer with UV, correct, then when you expose the wafer with UV because it is a positive photoresist, what would happen? This area will be intact. So, we cannot use positive photoresist, is it not because if this area is intact, we cannot create a window? So, here we cannot use positive photoresist, we can use, we have to use negative photoresist.

Because in negative photoresist; whatever area is not exposed will be weaker in positive photoresist. In positive photoresist area not exposed stronger, negative photoresist area not exposed will be weaker. What we want is that we need to create a window in Sio 2 like this.

So, that we can dope p type material so that we can dope in this area p type material right. So, to obtain that we have to protect the photoresist on this 2 area right, so, our photoresist should be protected in this 2 area and from other area photoresist we have to etch out that we can do when we use negative photoresist with a bright field mask correct with a bright field mask.

So, after UV exposure, we will develop the photoresist and what we will find after developing the photoresist? We will find that after UV exposure this one with bright field mask and negative photoresist, what we will find? We will find that the photoresist which is not exposed. So, I had to develop it, right, photoresist which was not exposed weaker and got developed photoresist that was not exposed.

So, photoresist which is below this area, it will not be exposed and it got weaker and then it got developed in the photoresist developer, correct. So, now, I have photoresist which is negative Sio 2; silicon, Sio 2 after that I will etch; so, after photoresist is developed I will do the hard bake, I will do the hard baking 120 degree centigrade per minute. It also depends on the datasheet; what kind of order it is to use in the data sheet is already mentioned.

What is the soft bake temperature; how much time you have to heat or bake, same way; what is a hard baked temperature; how much time you have to make everything is given in the data sheet when we use a particular photoresist. So, you have to look at the data sheet.

So, when we do PR developing and hard bake; you get this particular wafer which is shown right over here. Now what we had to do we had to dip this wafer in Sio 2 etchant. What is Sio 2 etchant? We all know Sio 2 etchant very easy to remember buffer hydrofluoric acid; that means, when I when I dip this wafer in the buffer H in BHF, what will happen?

My Sio 2 which is not protected by my photoresist will get etched, we will etched right easy. Now what I will do? I have to remove the photoresist. So, after etching Sio 2, I will dip this wafer in acetone right acetone because acetone is PR steeper.

So, we have to steep the photoresist, all right. So, what I have? I have a window, right; you see here is a window. Now through this window, what we can do? We can dope the p type material, right; this is n type silicon. So, we can now dope a p type material in this silicon. The Sio 2 will not or will act as a mask and we will not allow the dopant to enter in this particular region, right, Sio 2 will act as a mask and we will not allow the dopant to enter in this particular substrate.

So, now we can dope using either diffusion or ion implantation correct either diffusion or iron implantation; what we can do? P type material once that is done; what is the next step? Next step is I had to again; though I can again keep this wafer in the BHF in the buffer hydrofluoric acid and I will see that the Sio 2 is removed.

When Sio 2 is removed, we get the wafer which is what we wanted, correct. This is how we can obtain a p type doping in n type material; that is what he is saying that it like diodes uni-junction transistor are constructed from separate p type and n type semiconductor materials forming a single named uni-junction PN junction within the main conducting n type channel of the device the device with only one junction that x is exclusively as electrically controlled switch.

So, UJT is a non-linear amplifier it is a low cost and used in free running oscillators synchronized or trigger oscillators and pulse generation circuits at low to moderate frequencies this application now you see here it is nothing, but it looks like a PN diode right and then there is a resistor due to the b 2 here and then the resistor due to B 1 which is here, right.

Now, the across the voltage the voltage across this one; so, you have base 1, you have base 2 and you have a emitter, right emitter is nothing, but your P within the N type. So, you have to understand how the UJT works, then only you will be able to understand how you can how you can design an UJT base oscillator.

You as you see that it is used as free running oscillators. It is used as a synchronized or trigger oscillators also used in pulse generation. So, very important you had to understand.

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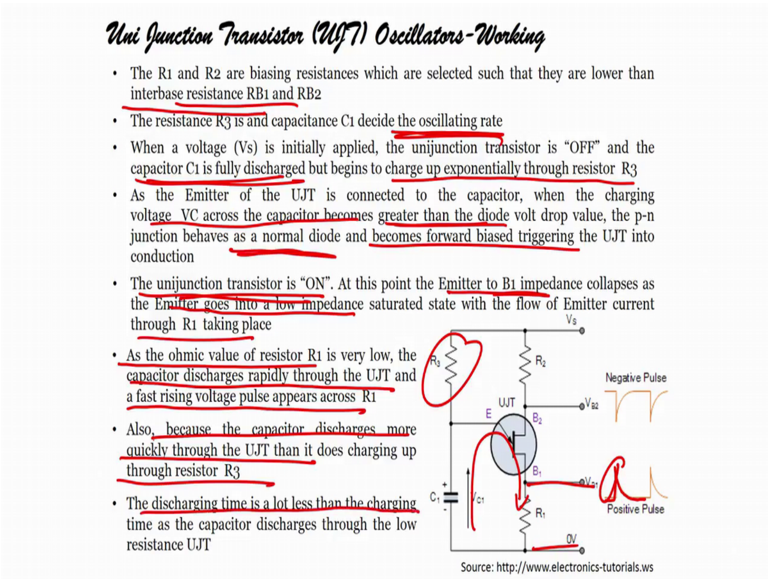

So, let us see; it is working. So, resistance R 1 and R 2 are bias resistors which are selected such that they are lower than the inter base resistance RB 1 and RB 2, right.

The resistance which is caused here RB 1 and RB 2 this resistors are lower than the inter base resistance. The resistance R 3 which is here and capacitance C 1 which is here beside the oscillating rate is R and C will decide the oscillating rate. Now when a voltage Vs is initially applied when we apply the voltage Vs, you see here across this terminal.

The uni-junction transistor is off and the capacitor C 1 is fully discharged, right, when you apply this voltage in junction transistor cannot operate, it cannot operate right and what will happen when it is off? C 1 is fully discharged C 1 gets fully discharged, but begins to charge up exponentially through the resistors R 3 right; this is the start exponentially through the R 3, there is the emitter of the UJT is connected to the capacitor, right.

The emitter of the UJT is kept connected to the capacitor when the charging voltage Vc crosses the capacitor becomes greater than diode voltage drop. So, this is P N junction diode, right, we have seen right. So, when the voltage across this capacitor Vc 1, this one becomes greater than the diode voltage drop the PN junction behaves as normal diode and becomes forward biased triggering UJT into conduction, right.

In this case when your capacitor will start charging through the resistors R 3, this capacitor voltage values increases more than the PN junction diode volt drop, then the UJT will start conducting, the UJT transistor is in on condition at this point emitter to B 1 impedance collapses and emitter goes into low impedance saturation stage with a for load of emitter current through R 1 taking place, correct.

So, it is conducting that is why this is a it goes to the impedance collapses B 1 will go to impedance collapses and the emitter goes into low impedance stage, right, it will conduct. So, as the ohmic value of R 1 is very low, the capacitor discharge is rapidly through UJT the fast rising voltage appearing across R 1. So, when it is conducting the capacitor will quickly discharged through R 1 right, it is a closest part to discharge is the path to discharge for the capacitor, right.

If it is not conducting capacitor cannot discharge through this, but now it is the discharging through this part and then in the resistor across R 1, right, here if I measure voltage across R 1, what will I find? I find that it will result in a fast raising spike. You see fast rising spike. This one also because rapidly such is more quickly through UJT, then it does charging through resistor R 3, right, this discharging time is not less than the charging time of capacitor discharges through the low resistance of UJT ok.

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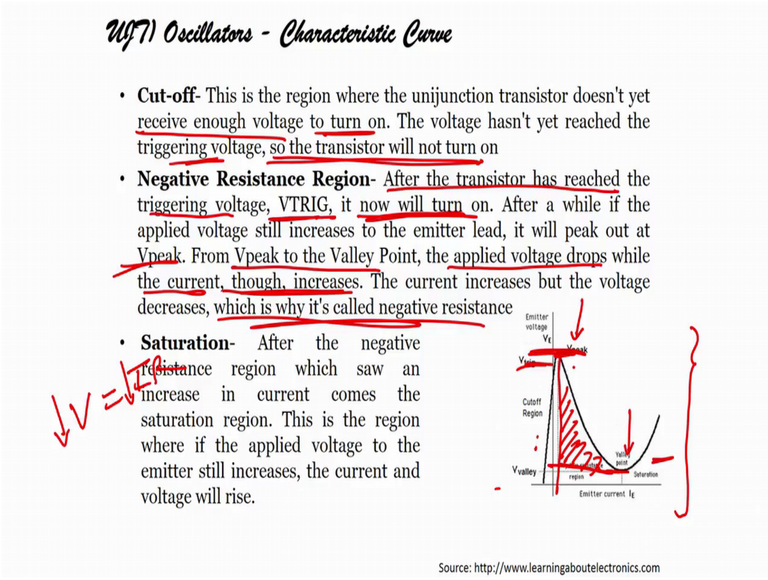

Now, cut off cut off. So, UJT cut off; what is cut off? This is the region where the uni-junction transistor does not yet receive enough voltage to turn on, all right, you see here the emitter voltage versus the emitter current graph, right and you can see; what is a trigger region; what is the highest peak of voltage; what is a cutoff region and what is a value.

What is negative resistance region with a very point where is a saturation region. This everything you need to understand all right. So, go back and see in detail how the UJT works now the voltage is not the yet reached the triggering voltage. So, a transistor will turn on this is a region where uni-junction region does not yet receive this cutoff region you can see here.

Negative resistance region; so, what is kind of region that this is the region where the UJT does not yet receive enough voltage to turn on and this voltage hasn't reached the triggering voltage so that the transistor will not turn on. Now negative resistance region is why it is negative resistance region; why this is called negative resistance region you see negative resistance region, right.

Because when you apply a voltage when you apply a voltage right the resistance should increase or decrease yes of course, particular resistance value right keep on applying voltage what will be the curve of I understand that if they are wide, this is negative resistance because after the transistor has reached the triggering voltage the V trigger, it is now turn on right the transistor is turned on after a while if the applied voltage still increases to the emitter load or lead it will pick out the voltage V peak it will reach here, right.

So, initially it is turned off then when it when it resists this region cut off region right the voltage received the voltage hadn't reached triggering voltage the transistor will be on now the transistor as this triggering voltage which is here this triggering voltage will now will turn on after a while if the applied voltage still increases if I keep on increasing the voltage it will reaches V peak which is here.

Now, if it will lead out V peak from V peak to the valley point from here peak voltage to the valley point which is right over here, right the applied voltage drops while the current though increases V equals to IR, right, if I my voltage is dropping my current should also keep on dropping, but what I see is that at this particular point in this particular region from here till here this particular region, right.

What I see is that from V peak to valley point the applied voltage drops while the current though increases; that means, as if the resistance is decreasing it is a negative resistance, the current increases, but the voltage decreases which is why it is called a negative resistance got it. So, why it is called negative resistance easy right, if your answer is it is not easy, then you have to understand correctly how UJT works, then it will become easy.

Whenever I say easy; I assume that you guys have done some homework and you know how the UJT operates, these are basic devices you should know. So, saturation region let us see after the negative resistance region which saw an increase in current comes the saturation region. This is the region where if the applied voltage to the emitter still increases the current and the voltage will rise, all right.

Now, again it will start rising which is what we are expecting correct.

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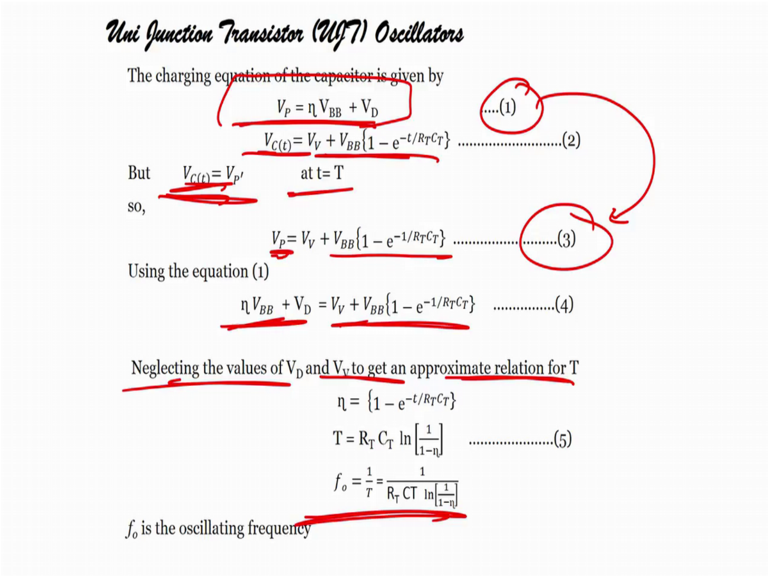

So, if I want to understand the equations the charging equation of the capacitor is given by VP into eta VBB plus VD right VC t is nothing, but Vc t plus V v; V into 1 minus E to the power T; RT, this is exponentially if you see the graph how this equation comes it is very easy to understand, all right.

Now, at VC t V is nothing, but VP at time T equals to T. So, if I substitute the value right what will I have VP which is VC t equals to this value using equation one which is my value of VP I substitute the value of VP here in this equation number 3 right from 1, I substitute the value of VP in equation 3, I will get this equation.

Now if I neglect the values of V d and V v to get approximate relation of t I can get fo is nothing, but one by t one by RT CT log N 1 by one minus eta or fo is nothing, but my oscillating frequency right extremely simple very simple very basic mathematics you should understand you should clearly understand, right.

So, now I have my oscillating frequency for UJT oscillator. So, this is how the UJT oscillator will work. So, now, what we have seen that in case of in case of oscillators, we can have several types of oscillators and now the application of oscillators we have seen mostly in using operation amplifier, but in some cases, we have also seen a crystal oscillator, we have also seen a UJT oscillator, right.

In general, now we have an idea of how oscillators would work right. So, in the next module, let us see, what is noise? What are kind of noise we will just touch the base and we will move to the next texture. So, I will see in the next module, by the time just look at it how the UJT oscillator works, right, I have shown you in an example; how you can fabricate a device very quickly just recalling something that you are learning earlier.

Now, you guys can please understand the process flow for MOSFET as well, right. Similarly, we can say N number of circuits, we can fabricate if we know the process flow all right, if you have any question, I will answer your questions, do not go wrong get confused; do not worry, I will answer equations if you have any all right.

So, now, in the next class, let us see how the noise what is noise and what are kind of noises, till then you take care, I will see in the next class, bye.