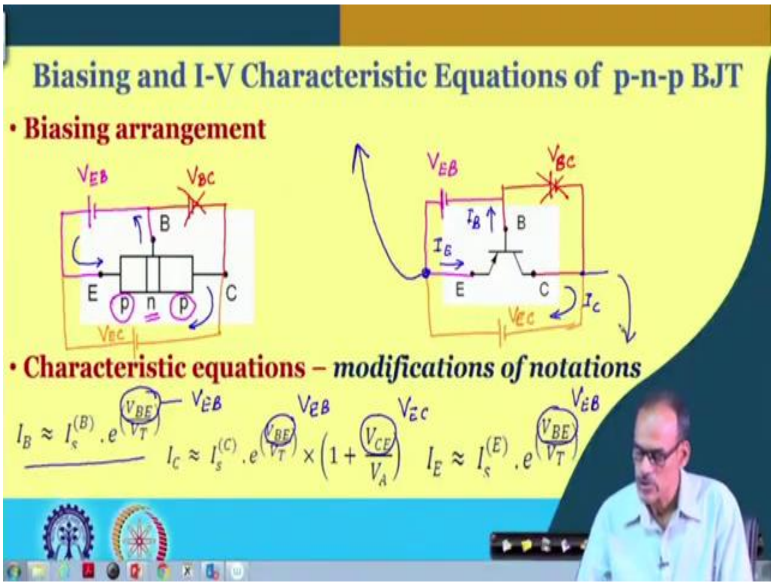
So, we will be going little more detail with this kind of circuit. In fact, we will be varying this voltage and then we will see that what kind of variation or effect it is coming to the collector side that detail when we will be dealing with the amplifier.

(Refer Slide Time: 42:37)



Now, so far we are considering about the n-p-n transistor if you look into the p-n-p transistor on the other hand it is very similar, but of course, it is the 3 islands or 3 regions are different. Namely, we do have p-region and then n-region and then p-region, so we do have p-n-p. And here also to keep the device in an active region of operation base and emitter junction need to be a forward bias which means that at the emitter now we are looking for higher voltage with respect to the base.

On the other hand, the other junction the base to collector junction we like to keep it is in reverse bias, namely the base should be at higher potential with respect to the collector. So, this is the corresponding symbol. So, here, so we may we may consider that the bias here we require such that base at a higher potential and the emitter also at higher potential with respect to on the other hand base. So, we do have higher potential here.

So, either we put the V since the positive side we are connecting to emitter we call it is V_{EB}. So, actually it is V_{EB}, so here also we do have V_{EB}. On the other hand, we do have the other voltage this is V_{BC}. So, V_{BC} it is ensuring the second junction it is in reverse bias and similar to the previous case instead of using this convention or this kind of bias probably we can use the bias elsewhere namely with respect to emitter.

And, if it is sufficiently the collector it is made sufficiently negative with respect to emitter that ensures the second junction base to collector junction in reverse bias condition. So, same thing here also in this view; so, we will be calling this voltage it is V_{EC}. So, we call this is V_{EC}. Note that this for actual operation V_{EC} should be positive V_{EB} should be positive that that is how we are ensuring the device it is in active region of operation. And also if you see based on the polarity of the voltage you can expect the current it will be flowing in this direction.

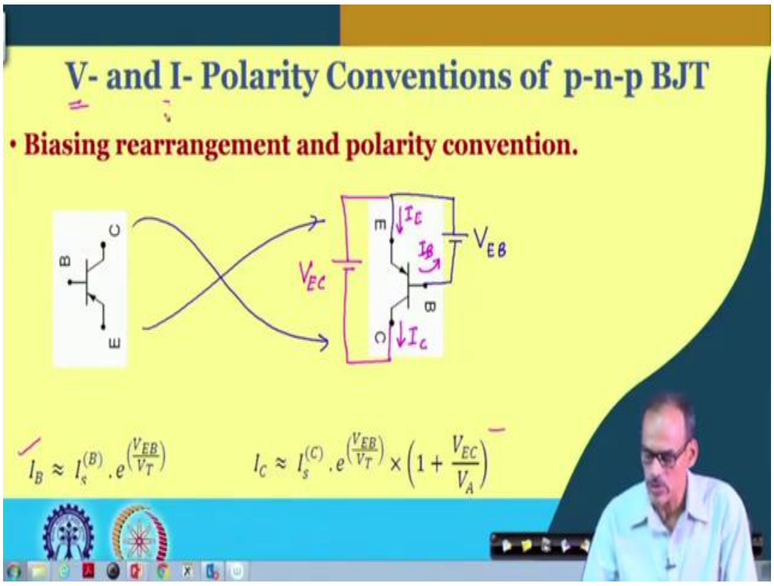
In other words, the emitter current entering to the device and the base current it is emerging out of the base and the collector current also it is emerging out of the collector. So, that is the axial direction of the currents. So, you may say that this is the actual polarity a positive direction of the current and. So, we do have I_E, we do have I_B and then we do have I_C like this.

So, if you compare the notation or seem the equation we have used for BJT this n-p-n BJT with p-n-p what you can see here it is. So, these are the equations it was used for n-p-n. So, with respect to that we simply have to modify this part namely we can make it V_{EB}. So, likewise here we can replace this is V_{EB} and this is into V_{EC}. So, likewise here also for the emitter this will be V_{EB}.

In fact, if you simply change and if you change the polarity of the current positive polarity of the current in appropriately then the same equations what we have discussed for n-p-n that can be utilized for this circuit also. Now, this is the biasing and the how we change the polarity of the currents and the voltages. For our convenience whenever we will be dealing with this circuit since this node it is having highest potential and this node it is having lowest potential if you see across the device.

So, for better arrangement what we will do we will make this is up and this is down. So, we will simply you know rotate 90 degree this device for our convenience.

(Refer Slide Time: 47:40)

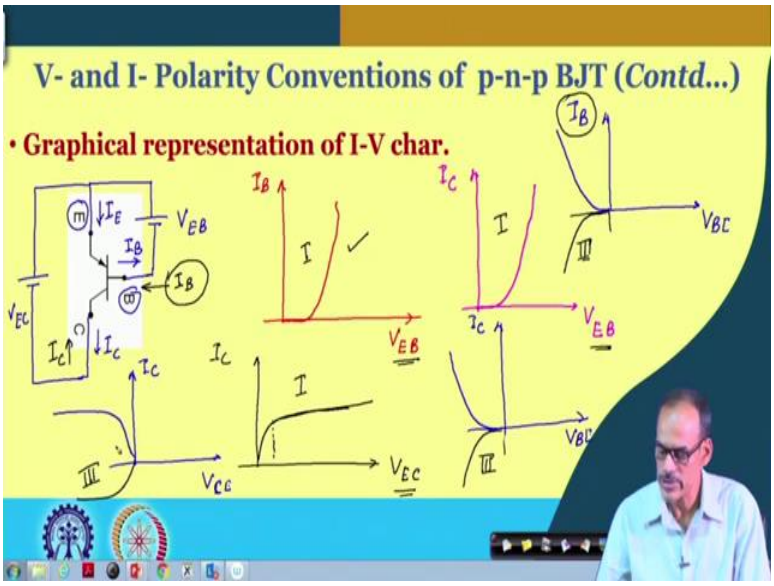


So, if you see in the next slide that is how we have done. We have rotated this device and then the corresponding biases are that can be explained like this the, ok. So, this was the previous one and we have rotated. So, we made the collector towards the lower potential, emitter towards the higher potential and here of course, this is p-n. So, this junction should be forward biased and this is how the corresponding the battery will be connecting here and we call this is V_{EB}.

So, likewise we can the other junction we can make it reverse bias by connecting V_{EC} and the corresponding equation as I said the collector current it is coming out emerging out of the device the emitter current it is entering to the device. And so, what will be this current? This current of course, it is going out of this device. So, you can say part of this current it is going out here as base current and remaining current it is going to the collector from the emitter.

So, that is about the polarity of the bias voltages and the corresponding currents. And rest of the things it will be similar namely the equivalent circuit and so and so. So, let us look into that the equivalent circuit and the maybe little bit about the graphical interpretation also. I think I do have separate slide for that.

(Refer Slide Time: 49:35)



So, going back to whatever the biases we do have here. We do have emitter to base bias here and emitter to collector bias here. And the corresponding base current is in this direction, corresponding emitter current is getting into the device through the emitter terminal and this is I_B, this is what you say V_{EB} and the collector current is coming out of the device and this is V_{EC}.

Now, you may recall whatever the graphical interpretation we do have or representation of the I-V characteristic of say I_B has function up now V_{EB}. So, if you plot this characteristic of course, it will be exponential in this like as you have discussed before. Similarly, when you when you plot the I_C versus V_{EB}. So, V_{EB} it will be of course, like this and I_C versus V_{EC} not V_{CE}, it is V_{EC}. And here also it is having similar kind of nature because of early voltage it is it is having some slight bend and till it is entering into the saturation region.

Now, since we do have V_{EB} here and here, and V_{EC} instead of V_{CE} that makes a slightly different kind of convention with respect to n-p-n. So, sometimes people try to plot I_B versus, so I_B versus V_{BE}. So, actually it is supposed to represent this characteristic and since we are flipping this polarity of the voltage here of course, this will be moving to the second quadrant. So, likewise if we plot the I_C versus V_{BE}. So, here also if we change the polarity of this bias here also it will be in this quadrant; so, likewise if we consider I_C versus V_{CE} that will be in the second quadrant.

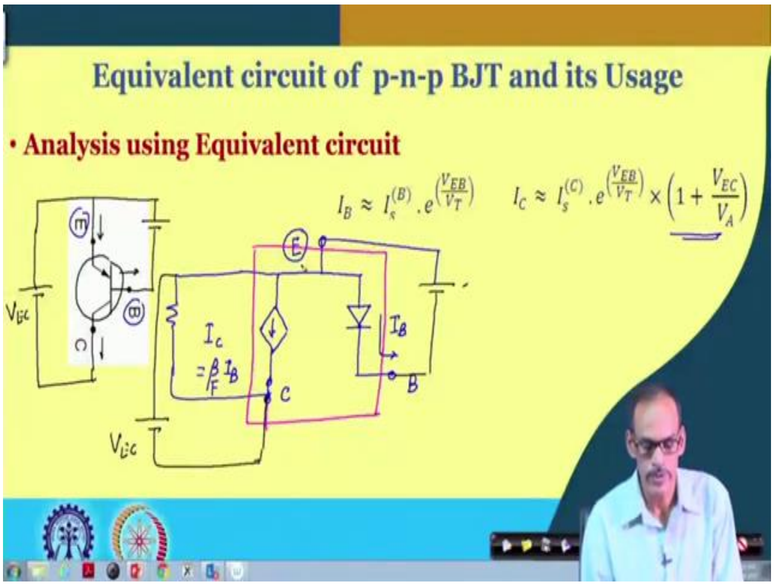
And further to that if you say that no you like to keep the similar kind of convention of the current as well. So, then you need to change the polarity of this current similar to the similar to the n-p-n transistor and then if you follow this one. So, what you will get here it is this if you change the polarity of this one and then of course, these two are having opposite sign, so naturally the corresponding characteristic it will be coming to the third quadrant.

So, if you there are two ways of dealing with n-p-n and p-n-p together either you can use the same convention for n-p-n and p-n-p, but then you should be careful that then the corresponding characteristic curve instead of sitting at the first quadrant it enters to third quadrant. So, same thing for in fact, I_C you also if you follow the convention positive collector current convention it is entering the entering to the device through collector terminal. So, in that case approaches this current it will be going to the third quadrant and same thing here also it will be entered into the third quadrant.

So, we will be discussing this one later, but just to make it aware that there are two approaches to go from n-p-n to p-n-p, namely change the polarity appropriately for p-n-p keeping the I-V characteristic in the first quadrant itself or you can you know follow the same convention of that of n-p-n, but then the corresponding characteristics are entering to the third quadrant. So, probably whenever the situation comes we will be going in detail of that.

Now, similar to similar to the n-p-n transistor for p-n-p also we to manage the or to analyze as a circuit containing p-n-p transistor we need to replace the transistor by equivalent circuit.

(Refer Slide Time: 55:04)



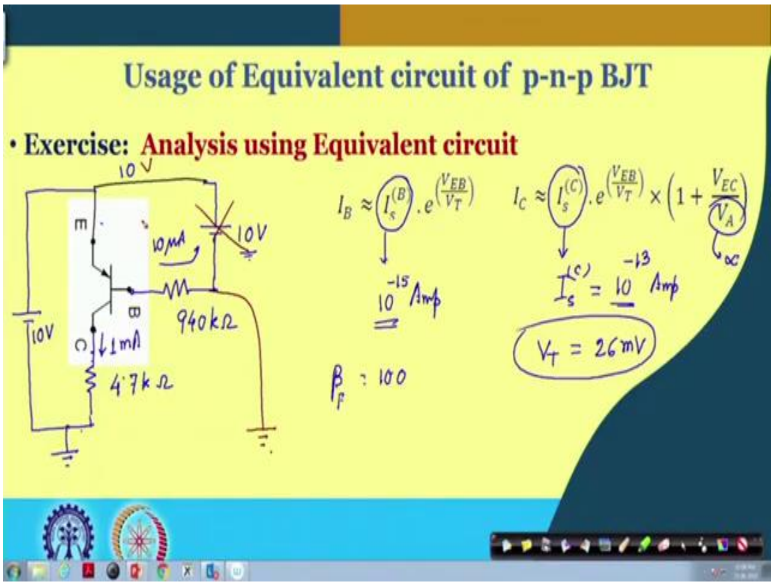
So, probably I do have a separate slide for that. So, we can use this again the same equations and we may have some bias here. Say for example, we may have bias here and we may have some bias here and suppose we are asked to find what may be the corresponding current here, current here and current here. So, instead of really dealing with the equation we may prefer to move to the equivalent circuit. So, base to emitter terminal if you see again we do have a diode

So, we can use this diode. We do have the emitter terminal and we do have the corresponding base terminal. So, we can find, so we can apply the corresponding external bias and then we can find what is the corresponding base current is flowing. And then the emitter to collector you can say that we do have collector current that current it is kind of linear function of the base current. So, we can see that this collector current is β of the transistor times whatever the I_B we do have. So, that is the collector terminal current.

In case if you want to capture these two additional factor of course, you have to consider the conducting path here along with this current control current source. Many here, for many situation in fact, we may ignore this resistance as you have said before for n-p-n and then this is the basic part of the equivalent circuit of the p-n-p transistor.

And then of course, externally we can use the other corresponding bias here. First, we can analyze this part and we can find the corresponding I_B current based on whatever the voltage we are applying. So, likewise here we can apply the V_{EC} voltage V_{EC}. So, this is the V_{EC} and you can find what will be the voltage whether this voltage is appropriate or not to keep the device in active region of operation.

(Refer Slide Time: 57:51)



So, similar to n-p-n let me simply refer to one numerical problem. So, let you consider similar situation let me try to understand that what kind of changes we do have here. Let me have said again 10 V and again let me put the resistance of 940 kΩ. So, we do have 10 V and here we can put a resistance of 4.7 kΩ and we do have 10 V.

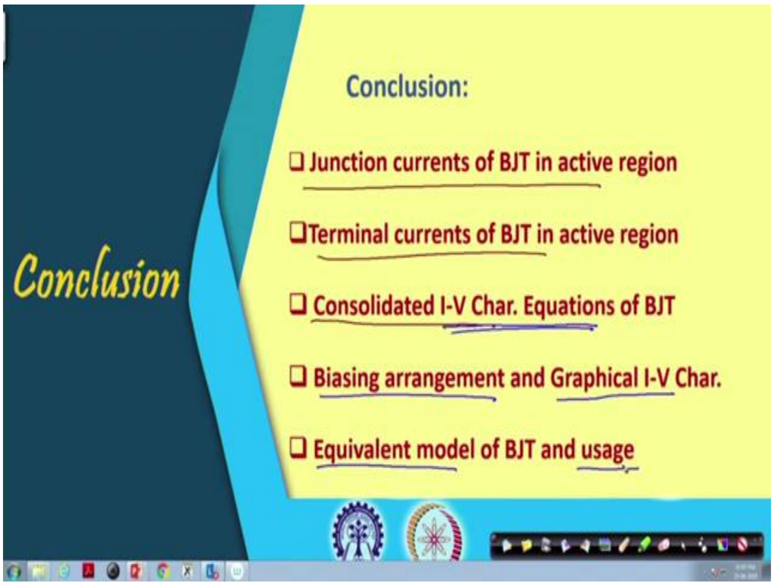
I am using the all the parameters are similar and say let me consider this $I_S^{(B)} = 10^{-15}$ A and $I_S^{(C)}$ reverse saturation current if you call it is reverse saturation current. So, this is $I_S^{(C)}$ for the collector terminal it is 10^{-13} A and similar to the previous case let me assume that this is very high, ok.

And, if you analyze this circuit again of course, we need to get this V_T, you may use 26 mV typically that is what we do for at room temperature. So, here also you can see that the voltage coming here it is the drop here it is close to 0.6, the voltage coming here it will be whatever the voltage you do have plus this I_R drop the base current it is 10 μA and if I take the ratio of these two, on the β = 100. So, that gives us the corresponding collector current is approximately 1 mA. So, the drop across this one is 4.7.

So, if I say that this is ground this is 10 V with respect to 10 V we do have another 10 V here of course, this is also going to be ground. So, in that case, so we do have this voltage it is 4.7. In fact, since we do have the same voltage you need not to use this voltage, you may simply remove this one and you can simply connect these two ground, you will be getting the same circuit because we do have this is 10 V from this one and this is also 10 V, so this is we call this is common terminal.

So, even if you are not using this one you can connect the circuit like this. And, we will be going a little more detail of the circuit later.

(Refer Slide Time: 61:06)



So, what we have covered so far to summarize in this module. We have of course, in the previous part we have discussed about the; we have discussed about the junction currents and then terminal current of n-p-n transistor and then we have consolidated the I-V characteristic. And, in the second part what we have done is that whatever the I-V characteristic, we obtain from the device we have utilized that to analyze a circuit containing n-p-n transistor. And also we have seen that what kind of biasing arrangement we have to do in actual circuit. We also have seen graphical interpretation of I-V characteristic.

And, then most important thing is that later on we have evolved the equivalent circuit or equivalent model of the BJT both n-p-n and p-n-p. And, we have considered relatively a simple example to illustrate that how that equivalent circuit can be utilized to solve numerical problem of the circuit containing n-p-n or p-n-p. I think, this information it is sufficient to move for the next level namely amplifier design.

Thank you.