Analog Circuits
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Week - 08
Module - 04
BJT DC Circuits

Hello, welcome to another module of this course analog circuits, so in the last module I had told you that we will be covering from this module onwards topics on BJT circuits the first in the in this particular module we will be covering the DC configuration various circuits showing the DC configuration of a BJT there is a bipolar junction transistor, so the these circuits where we show the DC solution of the various nodes voltages and mesh currents when a BJT is connected will tell us how to know what are all the voltages and currents present at the various terminals of a BJT and how to connect it for various purposes.

This is important because BJT is a device that needs correct DC voltages at its various terminals, it will not work unless the voltages or currents at its various terminals are at a particular value, now these DC configurations are later on used for AC circuits where an AC voltage or AC current is applied to the various terminals of a BJT and then later on these circuit can be used for various purposes like as an amplifier or as a you know or as a comparator or as a differential amplifier or various other purposes.

So, it is very important to know this DC configurations of the BJT now also I want to emphasize that this is the mod first module where we are actually introducing one of the devices commonly used for analog circuits the bipolar junction transistor, so for all the circuits that we had discussed were either using purely lumped elements like inductors, capacitors or resistors or using op amps.

So, here though we will not cover the devices like MOSFET's or BJT's to a great extent in this course but this particular module and the subsequent module after this will introduce you to some of the concepts that are used in actual circuits containing a device like BJT or MOSFET so let us see what is a BJT.

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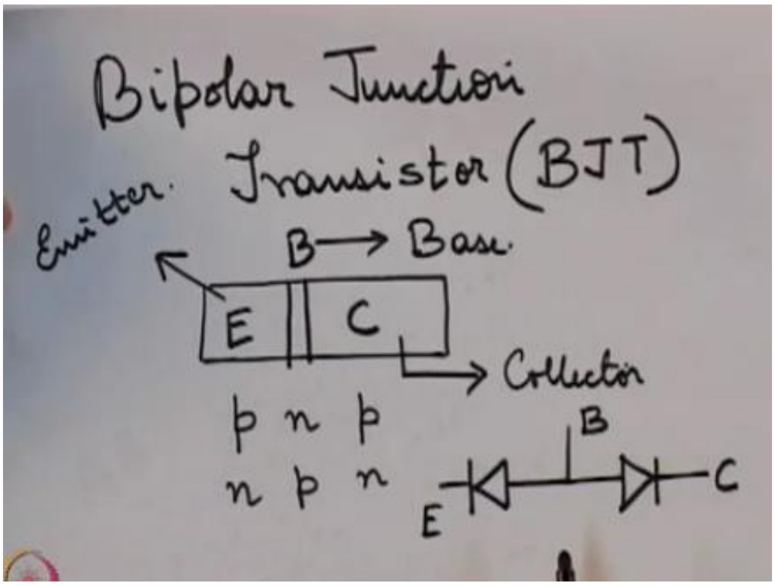

So, the BJT the construction of a BJT is something like this, this is of course a simplified diagram that I am giving the construction of a BJT is usually much more complicated than this, there are 3 distinct regions in a BJT the emitter, the base and the collector, now depending on how these 3 regions are doped we have 2 types of BJT's, one is a p n p and there is n p n.

So, in a p n p transistor the emitter and collector are doped with P type impurities whether whereas in a the n p n transistor the emitter and collector are doped with n type impurities and the base is doped with a p type impurity in the case of a p n p transistor the base is doped with the n type impurity, the area of this or volume of this emitter and collector are usually not the same they are usually different and this since this construction is very similar to that of a diode it might be tempting to construct and equivalent module or equivalent model of this BJT like this.

So, for example, if we want to find out an equivalent model of an n p n transistor where the emitter is based is biased with n type impurities collector is biased with n type impurities and base is biased with p type impurities then an equivalent model might be something like this.

So, here is my emitter this is my base and this is my collector the problem with this model is that this appears to show that the emitter and collector are totally independent of each other and just this base emitter voltage and base to collector voltage is all that matters but that is not the case because the emitter non only depends on the base voltage it will also depend on the collector voltage.

So, I did not want to go into the details of the device physics but if you are interested you can look into a book like Streetman book on BJT's and other semiconductor devices where they given this Streetman in detail of how the collector voltage also influences the emitter voltage and vice or emitter current and vice versa now depending on how these voltages or how these 2 this how these 3 regions are biased by bias I mean voltage biased you can have 3 distinct regions of operation of a BJT.

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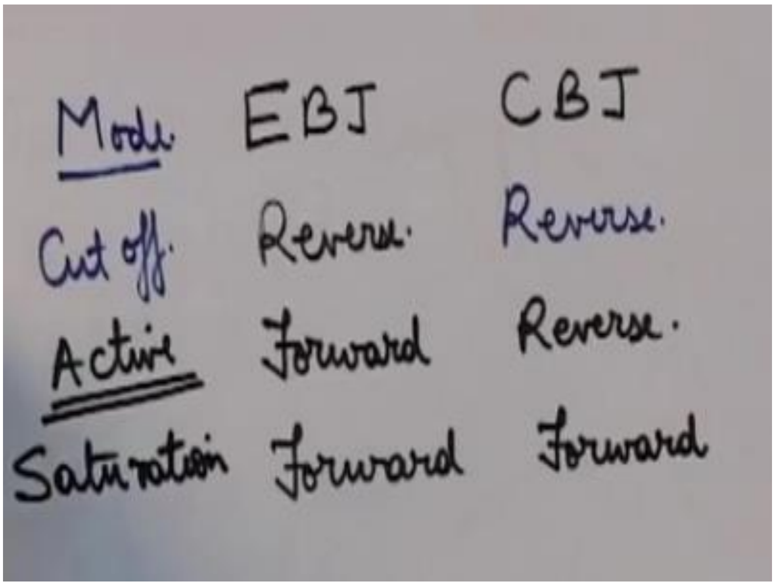

So, if you have your emitter base junction if I write the EBJ refers to emitter base junction and CBJ refers to collector base junction, if the EBJ and CBJ both are reverse bias then the transistor is set to be in the cutoff region if the EBJ is forward biased and CBJ is reverse biased then the transistor is set to be in the active region.

If both the EBJ and CBJ are forward biased then the transistor is set to be in saturation region now for this course we shall consider only the case when the transistor is in the active region now what is the symbol for a BJT this might be well known but still for sake of completeness I shall be discussing a little bit about the symbol.

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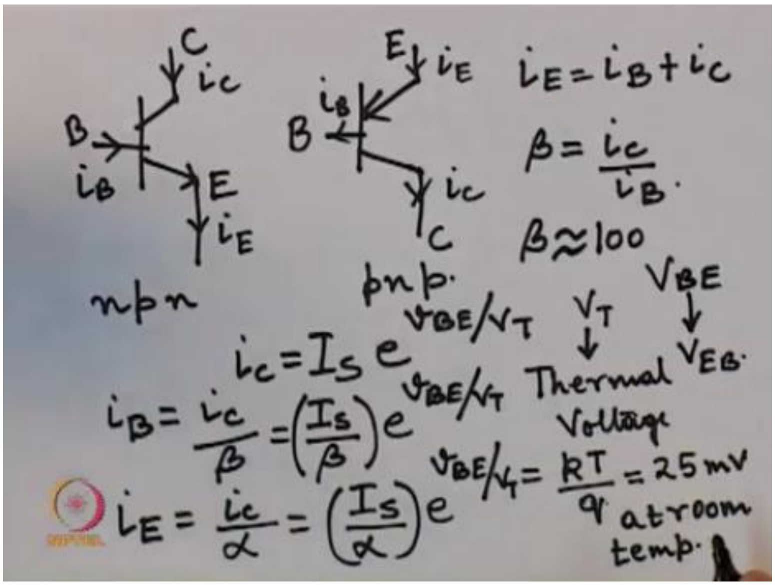

So, for a BJT depending on whether it is of n p n or p n p type so this is a the symbol of an n p n transistor and this is the symbol of a p n p transistor the this terminal represents the emitter, so the terminal with the arrow is the emitter for both cases the central terminal is the base again for both cases and the other one the remaining one is the collector suppose IC represents the collector current IB represents the base current and IE represents the emitter current same here also this is IE this is IB and this is IC.

So, for both these cases we can write IE is = IB + IC this follows from Kirchhoff's law, now this collector current and base current for both these types of these 2 types of transistors is related by a constant beta which is given by IC upon IB usually this IB the base current is a small quantity and IC is a large quantity and therefore beta is quite large and typically a typical value of beta might be hundred.

Now IC is can be written a formula for IC is like this where VBE is the base to emitter voltage IS is a constant I capital IS is a constant and VT is known as thermal voltage this term VT is referred to as thermal voltage and is given by KT upon Q and has a value where this is the Boltzmann constant and this has a value of 25 milli volt at room temperature ok.

So, now that we know this relationship between IB and IC we can write my IB as = IC upon beta which is = IS upon beta VT the emitter current is also related to the collector current by another constant alpha and this turns out to be = IS upon alpha multiplied by e raised to VBE upon VT.

Now this VBE is applicable for a n p n transistor for a p n p transistor this VBE is replaced by VEB because for a p n p transistor the emitter is always at a higher voltage as compared to the base junction where for the n p n transistor the base is always at a higher voltage as compared to the emitter junction, so now that we have these basic relationships we can proceed to the actual circuits so the first circuit we shall be considering is what we call the common emitter circuit.

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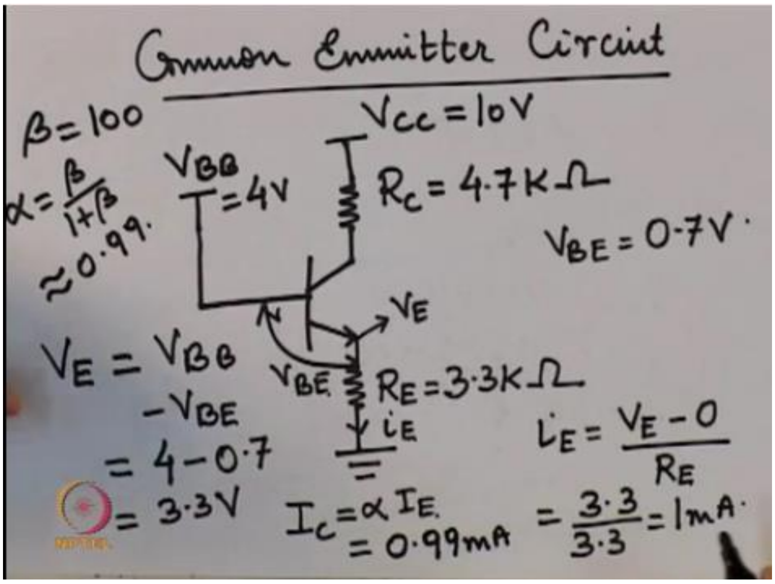

So, in a common emitter circuit we have our BJT we shall be discussing this circuit with a NPN transistor ok suppose VE represents the voltage at the emitter terminal then what is this what is the value of this VE now this as I said this is a common emitter circuit and this kind of shows you how the voltages should be connected at the very various terminals.

So, my collector terminal is usually connected to the supply VCC through a resistance RC the base also need to have its own voltage supply usually we add a biasing circuit to provide the required voltage at the base terminal that is what we will be covering next but for this particular circuit we have directly connected a voltage VBB to the base terminal and the emitter terminal is usually connected to the ground through this resistance RE.

So, as I was saying the voltage at the emitter terminal VE is given by VBB - the base to emitter voltage ok, now this B VBE at room temperature comes out to be = 0.7 so then what should be our VE should be 4.7 which is = 3.3 volts and what should be the emitter current IE should be = the voltage across this resistance which is = VE - 0 divided by RE, so that comes out to be = 3.3 upon 3.3, so this is 3.3 volts upon 3.3 kilo ohms and that is = 1 milli ampere okay so this is how you know we start solving these problems.

Now suppose you are given an additional data that beta for this circuit is = 100 okay then alpha is given beta upon 1 + beta so I leave this derivation of this particular formula as an exercise for you and this comes out to be nearly = 0.99 IC is given by alpha times IE and this comes out to be = so IE I found out to be = 1 milli ampere alpha is found out to be 0.99 so ID will be = 0.99 milli ampere and then if I ask you to find out what is IB, so we know that let me use another sheet

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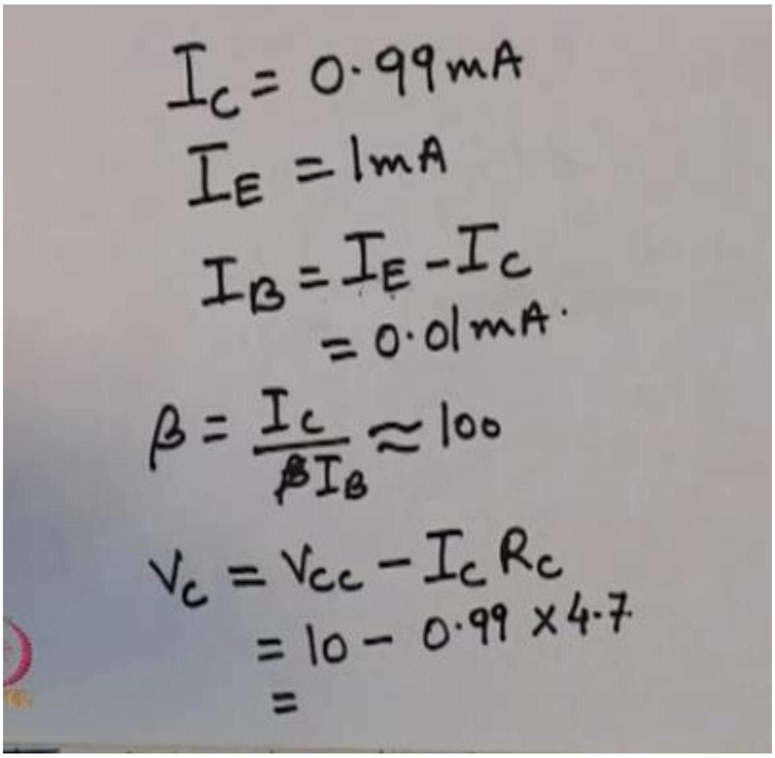

So, I have IC = 0.99 milli ampere IE = 1 milli ampere hence IB will be = IE - IC which is = 0.01 milli ampere, now beta is = IC upon IB sorry IB and that is also verified it is nearly = 100, now if I ask you to find out what is the voltage at the collector terminal VC so VC will be given by VCC - IC times RC which turn out to be = 10 - 0.99 times 4.7 and I leave the evaluation of the final value to you as an exercise.

So, this is how you know we do these derivations you first find out what is the say the base current or the emitter current and then use the values of alpha and beta to find out the other currents, once you find out all the currents try to find out the voltages using simple

Kirchhoff's voltage laws on Kirchhoff's current laws, let us consider another circuit in this particular circuit we will have instead of the base being directly connected to a source we will have a biasing circuit providing the required voltage at the base terminal.

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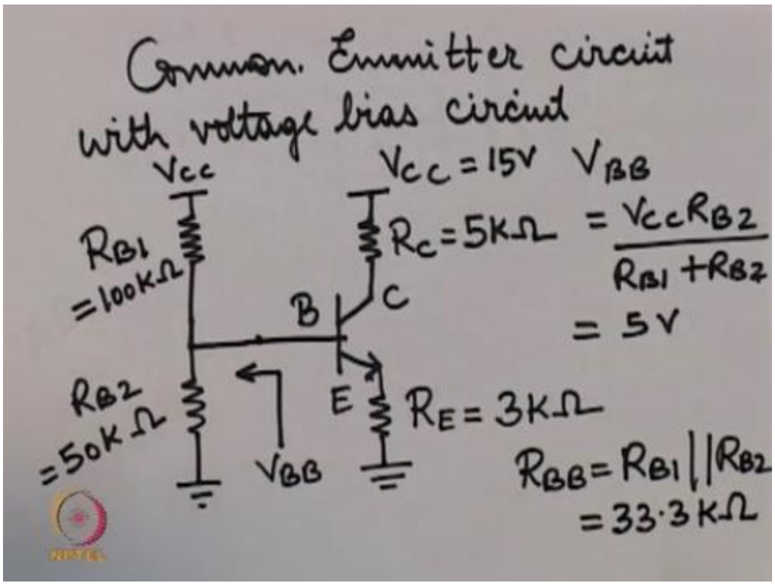

So, this is a common emitter circuit with voltage bias circuit, so the first part of this circuit is very similar to the circuit we just saw, now the advantage of this circuit is that you did not need to separate supplies one for the base and one for the collector the same collector supply VCC is provides the required voltage at both the base as well as the collector ok.

Now assuming that the current flowing through the base terminal is very small these 2 resistances will provide a voltage divider type circuit and depending on the voltage division ratio the required voltage will be provided here, now to actually know the actual voltage that appears across this let us consider the Thevenin equivalent okay.

So, what is the equivalent Thevenin voltage at this point and that turns out to be the way to find out the Thevenin equivalent is you break the circuit here and find what is the voltage appearing here so then VBB the equivalent Thevenin voltage at this point turns out to be = VCC times RB2 upon RB1 + RB2 and this comes out to be = so if my VCC is = say 15 volts this comes out to be = 5 volts and what is RBB the equivalent Thevenin resistance at this point that will be simply the parallel combination of RB1 and RB2.

So, my equivalent Thevenin resistance will be the parallel combination of RB1 and RB2 and that comes out to be = 33.3 kilo ohms so once we have found this out, we can now draw the equivalent circuit of the biasing network, so instead of writing the biasing network we can simply.

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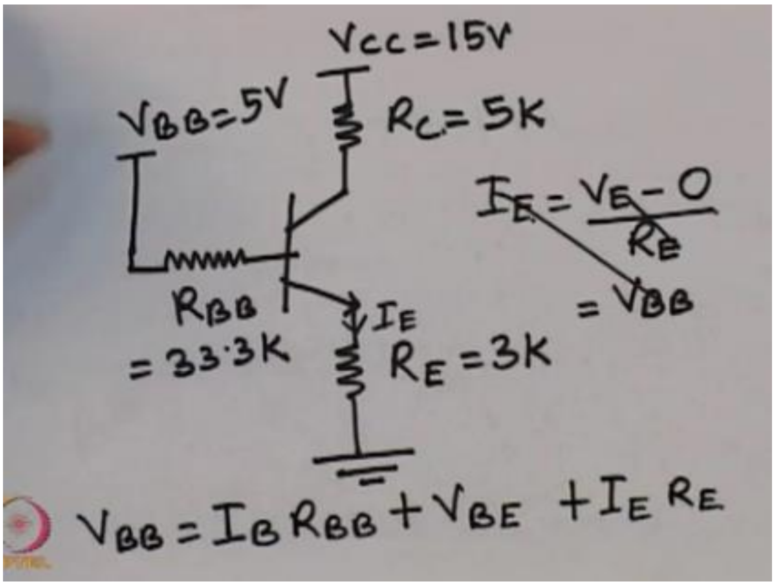

Just like the previous circuit we now have an equivalent voltage source VBB this remains = VCC this is RC this is RE and this is RBB this is = 33.3 kilo ohms VBB is = 5 volts RC is = 5K and RE is = 3K, so now if I want to calculate the individual currents how do I do that VBB is = IV RBB + VBE + IE RE now IB is = IE upon 1 + beta.

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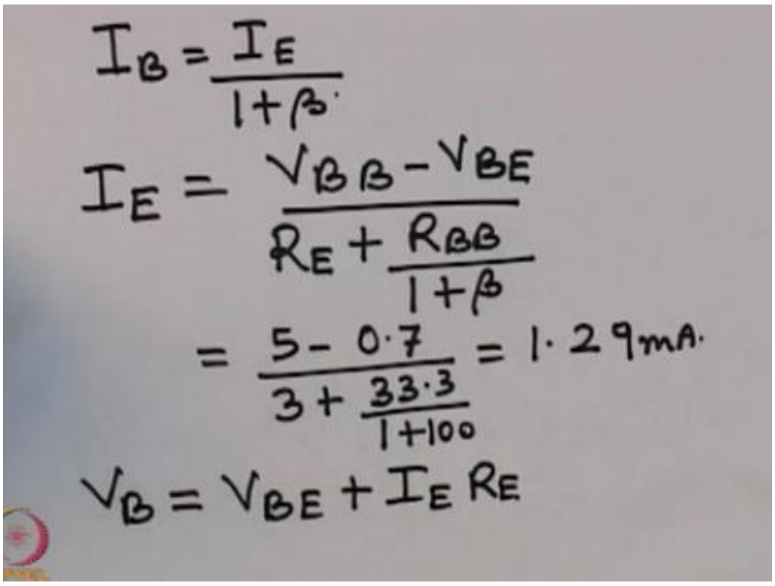

Therefore if I substitute this value of IB into the previous equation okay so I am substituting this value of IB into this equation then what I get is then if I solve for IE what I will get is ok and if I plug in the values then it comes out to be so VBB is 5 volts VBE is 0.7 volts RE is 3 kilo ohms and RBB is 33.3 beta is 100 and this comes out to be = 1.29 milli ampere.

Next if I want to find out the value of VB that is the voltage at the base terminal I know that VB is = VBE + IE times RE, so what I mean is that the voltage this voltage is the voltage between the base and emitter junction and with the voltage drop of RE across RE added to it, so that is given by this formula and that comes out to be = 0.7 I have just calculated IE to be = 1.29 milli ampere and RE is = 3 kilo ohms this turns out to be = 4.57 volts, we can go on like this you know for various other node voltages and currents.

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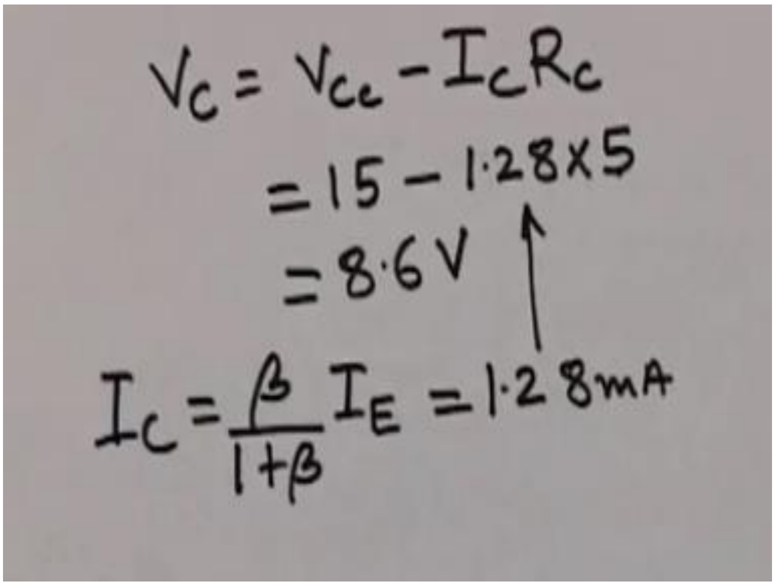

For example let if I want to find out what is the voltage at the collector terminal VC that is = VCC - IC times RD and this comes out to be = 15 - 1.28 times 5 which is = 8.6 volt here IC was obtained from this formula and that came out to be = 1.8 milli ampere this is what I have substituted here, so this way so in summary we can you know the circuit the 2 circuits that I showed you in this module are some of the basic DC circuits that are used for connecting a BJT the one that I showed you here is the common soul common emitter configuration.

We also have common base configuration and common collector configuration may be a more advanced course on BJT will help you understand what the other 2 circuits are but the main point is that whichever be the configuration the techniques used for finding out the DC voltages and DC currents and the various terminals are similar to what I showed you in this module these circuits with their proper node voltages and branch currents that is the base emitter and collector currents.

Once they are set up to these circuits we can then apply our AC signals and make the BJT perform various functions like that of an amplifier or an differential amplifier or a comparator or various other purposes for which a BJT is used. In the next module I will be covering some topics on BJT modeling and also introduce you to what are known as current mirrors, thank you.