Video Course on Electronics

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Module No. # 02

Transistors

Lecture No. # 09

Biasing a Transistor (Contd)

We continue our discussion on transistors. Now, we take the important aspect of a transistor circuit that is biasing a transistor.

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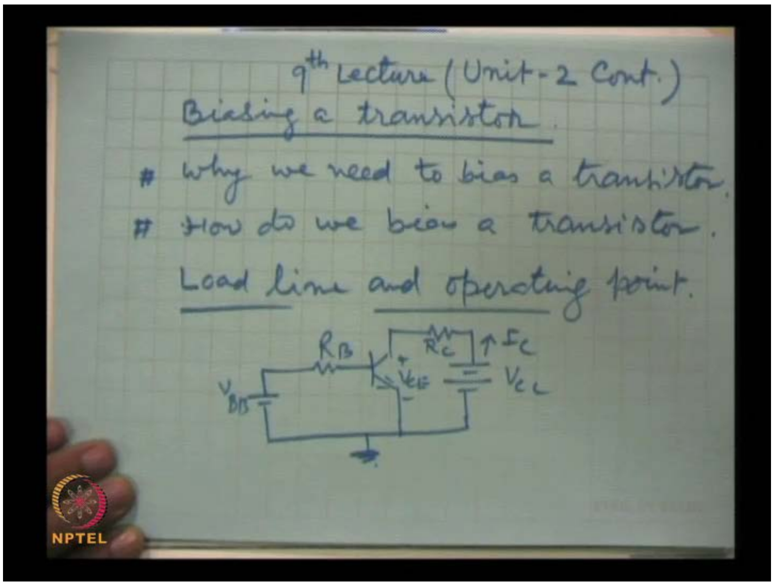

Now, first thing is let us answer a very pertinent, an important question that why do we need biasing?

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And then how do we bias? I am sure you understand the meaning of biasing. Biasing is that the two junctions of a transistor the emitter junction and collector junction have to be provided with a dc potential a dc bias. So, that is known as biasing and the question why do we need a to bias a transistor, because we want the transistor to remain in active region. You will recall that the I-V characteristics of the transistor we divided those collector characteristics into three divisions; the saturation region, the cutoff region and the active region.

The transistor has to be operated in the active region when it is been used as an amplifier. So, that is why we need the biasing of a transistor that means biasing of junctions. And remember for an for an transistor to work as an amplifier the emitter junction has to be forward biased and the collector junction the reverse bias. Now how do we bias a transistor so, we are going to talk about various schemes of biasing and relative advantages and disadvantages of each scheme; but before that because this will need the concept of load line and operating point. First we talk on these points what is load line and what is operating point that we should discuss, for this we consider a small circuit.

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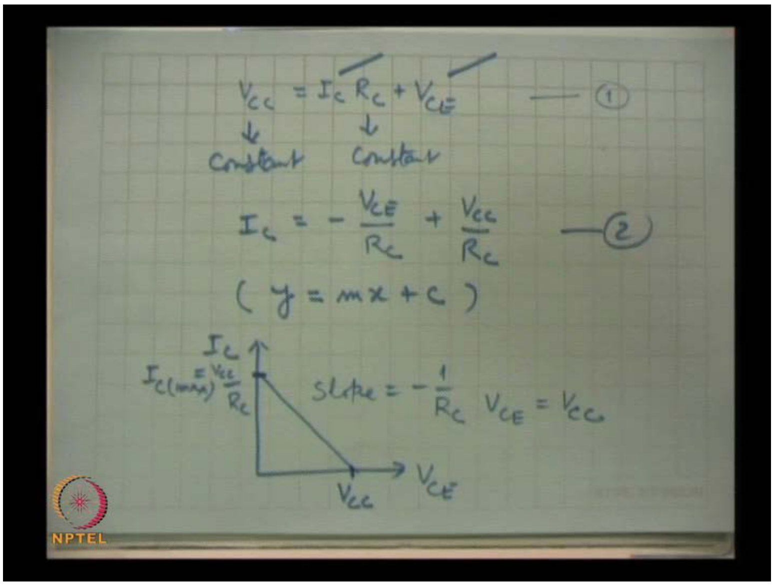

Let us consider this circuit and apply kirchoffs voltage law to the collector circuit. Then we will see that we can write V CC equal to R C into I C and this voltage V CE. So, we get V CC equal to I C, R C plus V CE. Now here R C is constant V CC this is the battery which is also constant, but when we super impose the ac signal on this amplifier like this a coupling capacitor and here is the ac source and the source may be anything for example, signal from a mike if it is a audio frequency amplifier or some other radio signal if it is a radio frequency amplifier. So, this is the ac signal when this is super imposed over this dc then this current and voltages will vary.

So, this is variable and this is variable this two are the variables this two are constants and we rearrange this equation and this equation and we get let us call this as equation one and we rearrange it we get I C is equal to minus V CE by R C plus V CC by R C. Now this is the equation of a straight line and we can compare it with the standard equation you are you must be familiar y is equal to m x plus C. This is the equation of a straight line and this gives the slope of the line and this is the intercept on the axis. So, this is the equation of a straight line and you know how to plot the straight line.

Here on this axis when I C this is I C and this is V CE when I C is 0 then we when I C is 0 here then this will give that a cut that V CE is equal to V CC. This is when I C is 0 so, this gives this point and similarly, here V CE is 0 and that will give this point which is the maximum current I C maximum and this equal to V CC by RC and then we connect these two points and this is V CC the battery which we are using to reverse bias the collector. Now this is called that the slope of this line is minus 1 by RC slope of this line is minus 1 by RC. This becomes a useful line when we draw it over the output characteristics of a transistor like this.

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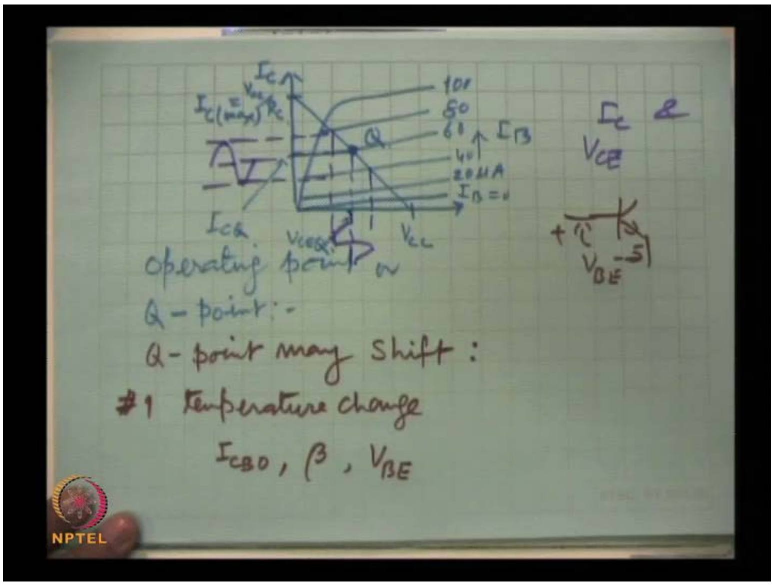

This is I B equal to 0 I B is increasing this way and for example, this is 20 micro amperes 40, 60, 80 and 100. This is I C and you will remember that this is the saturation region, this is the cutoff region and here is the active region. Now this load when it is drawn over this was the point V CC and this is the maximum collector current I C max which is equal to V CC over R C. So, this is the load line, now we choose a operating point and that operating point is also known as Q point operating point or seen as Q point quotient point. Q point by choosing the operating point we mean for example, this point is our operating point Q then that means we have chosen a dc collector current which will be frame in the circuit in the absence of ac signal and similarly.

So, this is this is called actually I C Q that means collector current at Q point and similarly, this is called V CE Q these are the Q point values quotient have point value for the collector current and the voltage drop across the transistor, the collector and emitter junction V CE Q. Now when we apply the ac signal then the currents and voltages will vary for example, here the this is the applied signal this is signal and the output current will vary accordingly and this is this shows that for example, from the I C Q value it will go less on the higher side and similarly, the current lower part of the current will be here this is I C Q and then it will go to the higher side.

So, currents and voltages the I C the collector current will vary and the voltage V CE. I C and V CE both will vary across the Q point. So, I am sure now it is clear what is Q point Q point is choosing the appropriate values of the dc collector current and the circuit and that will give a dc voltage drop V CE Q and the current and voltages the this voltage and this current will vary according to the input signal and for simply settle we take that ac signal is sinusoidal in nature. Now this Q point is the operating point we shift and I will tell you what are the reasons for the shift and we have to choose the operating point properly.

If shifts and if it is closer to the saturation region then distortion output will be distorted. We expect from amplifying circuit that output signal should be exact replica of the input and only the magnitude will vary this magnitude here it is in current form and we will see later that this enhanced current will give the voltage a higher voltage signal also. So, if this shift towards the cutoff region again there will be distortion that I will make clear. Let me first write that why Q point should vary, the Q point may shift because of temperature change temperature change.

I have talked about this point how the temperature changes and the temperature changes from season to season, it changes from place to place for example, in Himachal and Delhi there may be a difference of 30, 40, 50 degrees and also it changes because of the ambient of the circuit. So, temperature change now what are the parameters of transistor which are temperature sensitive. We have talked about the reverse saturation current this is temperature sensitive, because it arises because of the thermally generative charge carriers if temperature falls this will be less, if temperature rises this will be high.

Similarly, beta the current gain you remember that I shown a graph that it varies with temperature with rising temperature it increases beta increases current will increases and with fall of temperature it falls and the third quantity which is temperature sensitive is V BE that is drop this voltage plus minus this is V BE. This is also temperature sensitive and we have talked about the degree of variation with temperature of all these three parameters.

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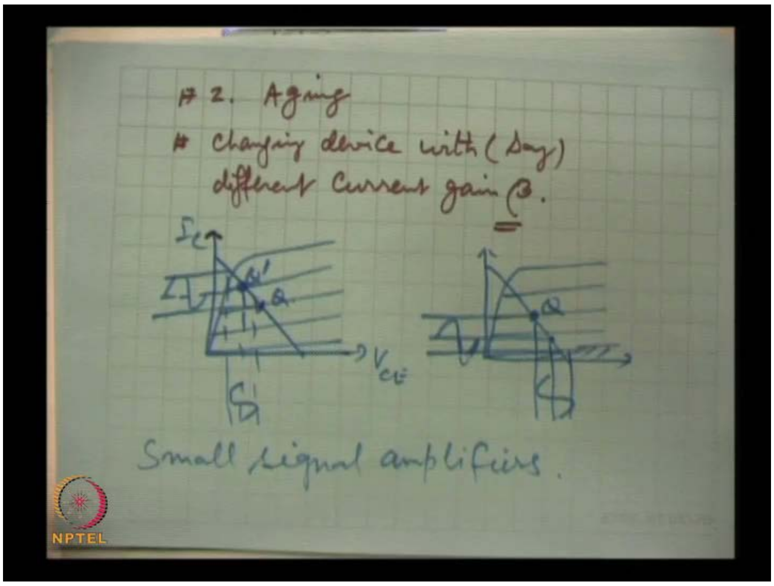

So, this is one cause what is the other, the other two causes are aging, that means continues use of the device for long period may change its characteristics and these characteristics if the biasing circuit is not properly fabricated then this will result in changes in the signal output for example. And the third and last point about this is changing device with say different current gain beta. Why we change the device? As you must have seen in discrete circuits sometimes due to overheating or some bad handling the transistor may be damaged and that needs to be replaced by another transistor.

Now there is a wide variation of current gain beta in the same lot same number of transistors. If you look at the manual of the manufacturers then actually, they give a range of this beta instead of giving a single value. So, this may change the characteristics if the biasing network has not been designed properly now. So, Q points the shift and I can show the shift like this. Earlier we start Q here, but it will shift for example, here and then we apply the ac signal. Then it will not because the portion of the wave which appears in the saturation region that is the region in which the output current does not vary according to the input.

So, in spite of the fact that our input was a pure sinusoidal signal the output may be like that distorted this will happen then for example, we replace the transistor with higher beta or temperature changes it becomes higher then this will happen. While if beta is less then it will change in the other direction, if this was our original Q and if its shifts here and this is the cutoff region and when we apply the signal then the output will be distorted and because beyond it will be independent of the ac signal. So, it will be distorted like this here it should be like this, but this portion will be missing.

So, we will get a distorted output so, that means the two things that we start with the right choice, a right choice is somewhere in the center not exactly in the center, but if it is here and here then this is good enough the choice becomes more strengthen. When we talk of power amplifier where the swings will be very large at the moment we are talking of a small signal amplifiers a small signal amplifiers. So, the Q point has to be chosen properly.

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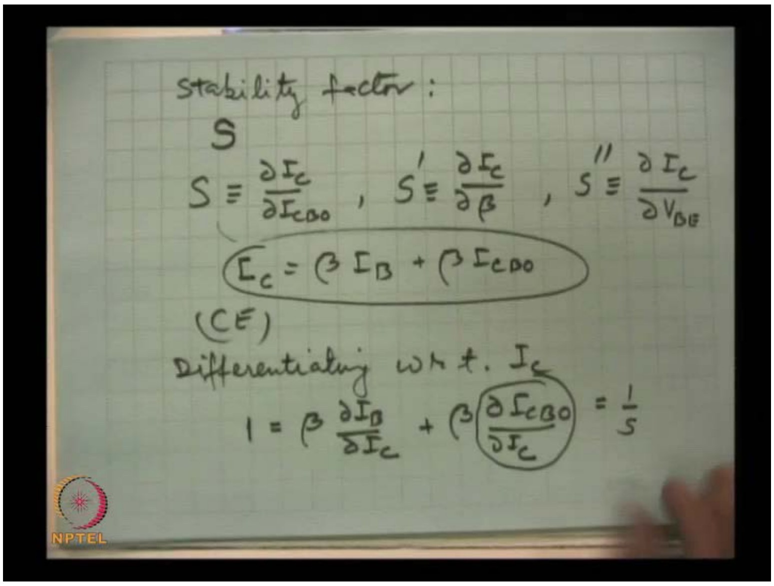

We talked about the variation of the Q point and this connection actually we define a stability factor stability factor for a circuit and this is denoted as S denotes a stability factor. Now this is defined for various variations for example, delta I C over delta I CBO that means change in the collector current because this is temperature sensitive changes in the reverse saturation current. We can say another stability factor which is I C with change in beta the current gain, if current gain changes for any of the reasons stated above then the collector current will change or another that another stability factor which is delta I C by changes in V BE, because you remember that I C is beta I B and beta times I CBO.

So, if I CBO the reverse saturation current in common base if it varies it is multiplied by beta for common emitter circuit and this becomes a significant variation. Similarly, beta changes then the current may change in enter if this voltage changes that will also change the current. Now one thing very important that we have stated various reasons for the variation, but this is a very important statement that a circuit if it shows stability against one kind of variation then it will take care of variations due to other causes as well. I repeat that a cause of variation is in material, if we have taken the design of the biasing circuit if we have taken into account variation of any of this three parameters S, S prime, S double prime this is three reasons.

So, if we have design the circuit to take account of any one kind of variation then the circuit is suppose to remain a stable by stable we mean that the Q point will not shift significantly if the temperature changes aging or whatever the causes we have stated. So, remember that stability is the cause of variation is in material the circuit has to be designed to take into account this stability that means circuit should be stay key point should remain a stable. So, how we this is by fundamental definition of a stability that we can find one expression also for a stability.

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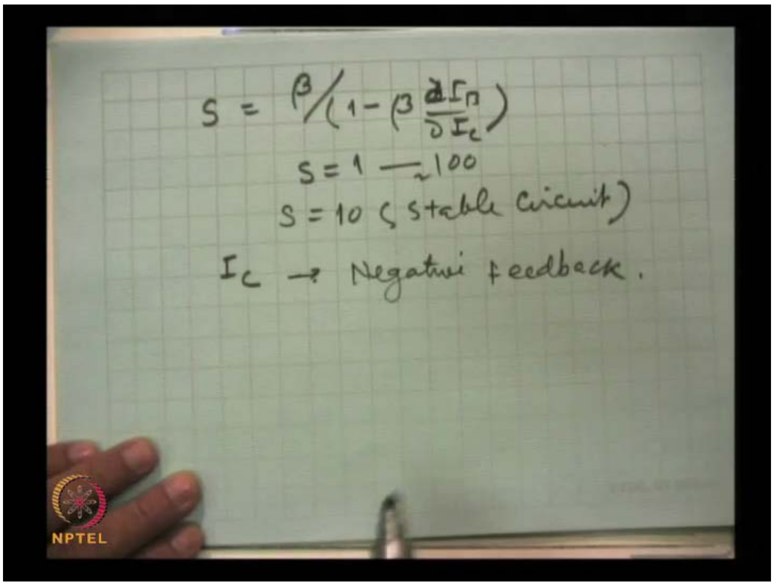

If we for example, differentiate this equation if we differentiate with respect to current that means differentiating with respect to I C this equation then we will get 1 beta d I B over d I C plus beta d I CBO by d I C. Now this is equal to this term this is equal to 1 by S here, this is equal to 1 by S. So, we can write this form S the stability factor is equal to beta divided by 1 minus beta delta I B by delta I C. Now a stability factor may vary the smallest value possible is one and higher may be say 50, 100 or so.

This is ideally stable this is very unstable so, the value of S around 10 is good this is a stable circuit and they want be any significant change in characteristics if the parameters of the circuit vary because any of the causes which are mentioned even. So, what does it basically speak that you know in all circuits when collector junction is reverse bias and emitter junction is forward bias then the output current will be a function of the input current, but here this is differently that input current can be should be made a function of the output current when this happens then we can achieve a stability.

I will explain this point further and this is achieved by using negative feedback. So, I C we are suppose to maintain constant and it should be made independent of the variations of temperature aging and replacement of devices and this is achieved by making circuits which will take account they will take include negative feedback. We will explain this that how the circuit we will design and how will it work.

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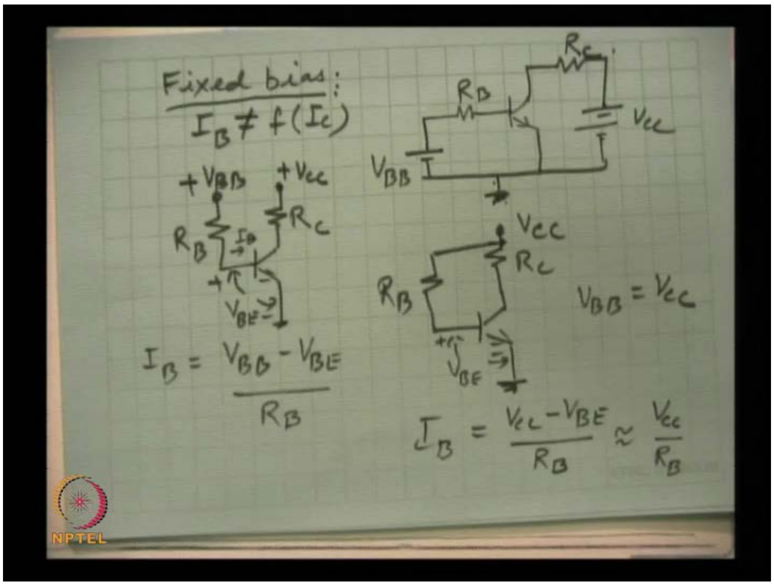

First let us see what is called a fixed bias fixed bias. We will see that I B the input current is not the function of the output current I C. Reverse is always true of course, as long as we have a biased the collector and the collector in the reverse bias and emitter in the forward bias the output current will be a function of this, but definitely in the fixed bias the input current will not be a function of a output current. The circuit let us look at the circuit this circuit this is drawn here in the most primitive way this is not the actual way the circuits are drawn. This needs two batteries, but we can see that even single battery can be used to bias both junctions.

So, this circuit you know you see here that at negative terminal of both the batteries is grounded and this is connected to the base resistance. Similarly, this is connected positive is connected to the collector resistance so, assuming and leaving the other the other terminal of the battery is grounded this circuit can be drawn like this. Here this plus V B B this battery and this is plus V C C this is R C and this is R B and we can write down the expression for the input current this is plus minus V BE.

You know this is very simple as it is here we can write that I B that current which will flowing here I B I B in this circuit is V BB minus V BE divided by R B this was be, but again before the modified here still there are two batteries, but let us see this circuit this circuit. The only difference is between the two that here V BB equal to V CC so, this is the way circuits are drawn for input side we can make a circuit like this where V BB is equal to V CC and on the output side we can make a circuit if some calculations have to remade and here now I B will be equal to V CC because V BB is equal to V CC minus V BE divided by R B.

This is 5, 10, 15 volts this voltages is very small so, in many situations this can be neglected and then this I B will be approximately very closely actually equal to V CC by R B. So, this is I B is fixed is constant while we have seen that the stability requires that I B should be the function of I C which is not here that is why it was called fixed bias. So, this variation term is a 0.

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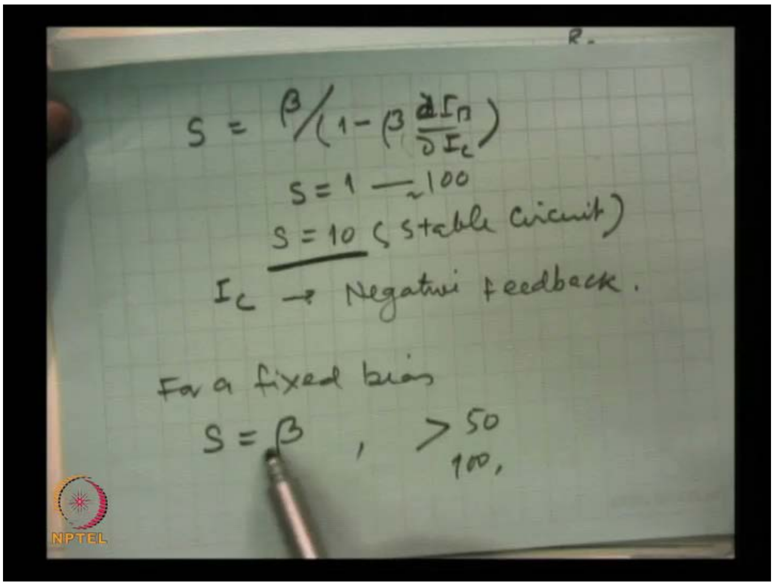

So, if we put it this is 0 for a fixed bias. A stability factor is equal to beta if this is 0 then S is equal to beta and beta was high this is definitely for all practical transistor beta is higher than 50 and normally 100, 200 and so on. So, this is highly instable circuit I have mention here that for a stability this factor as should be around 10, but equal to beta is very high. So, remember one thing that fixed bias is almost never used in transistor circuits though it is simplest and the design is simple and the calculation is simple, but it is never used. The reason is that the circuit will show high instability the Q point will shift as the temperature goes up or you replace one device with the other.

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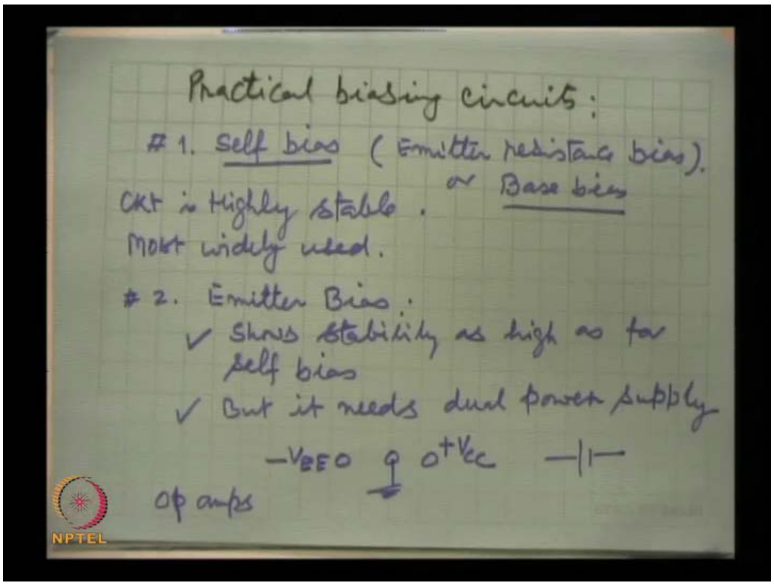

So, what are the practical circuits which are used and that will be considering practical biasing circuits there are practical biasing circuits and there are three circuits one is what we call self bias self bias which is also called emitter resistance bias emitter resistance bias. This self bias this is also called actually base bias, one in the same thing self bias or base bias or emitter resistance bias one in the same thing. So, in this self bias this is highly stable circuit is highly circuit is highly stable and most widely used most widely used to bias a bjt circuit and second is emitter bias, this shows a stability as high as for self bias.

The stability is as high as in the in case one the self bias, but it needs dual power supply dual power supply. Let me explain what is the meaning of dual power supply two voltages with respect to ground this is ground and this is plus V CC and this is minus V EE this two voltages with respect to ground power supply should be able to provide for example, a plus 12 voltage and minus 12 voltage should be available and both with respect to ground. If we take single battery and we connect this point and this point then this is only one battery this may give either a negative voltage and or a positive voltage, but both voltages cannot be obtained from a single battery of course, we can design to provide two voltages with respect to ground. So, this is called dual power supply.

Now emitter bias while it shows a stability as high as in this self bias, but it meet a dual power supply this is also a very popular bias in this scheme almost all operational amplifiers op amps they make use of this scheme.

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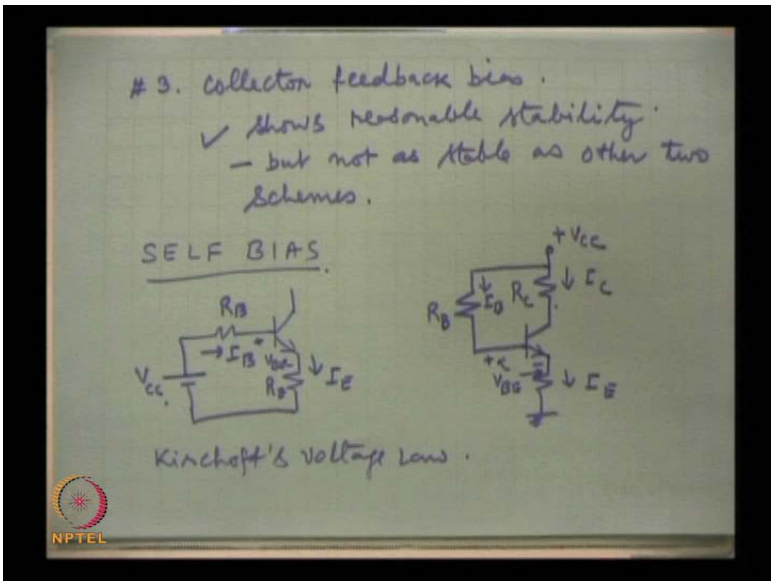

The third one is collector feedback bias collector feedback bias here the stability is reasonable shows or executes reasonable. Stability, but not as stable as other two schemes or arrangements circuits, but this is very simple circuit as we will see makes use of fewer resistances and if stability is not the prime criteria then this is very widely used. Because there are many situations where a little bit variation of the Q point that means with reasonable stability we can work the circuits. So, there collector feedback bias is used so, these are the three practical circuits which are used self bias, emitter bias and collector feedback bias.

We will discuss one by one these schemes. So, let us first talk the self bias in this biasing scheme one resistance which we are we call R E it is attached with the, you will see that in the fixed bias there was no resistance connected to the emitter, but in this scheme a resistance R E is connected. So, the circuit becomes these are the currents the I B will flow here I C and this is I E. Now if this resistance is removed and if directly emitter is connected then we come back to what is called fixed bias this is the self bias, because inclusion of this resistance. Now this will be the part of the input circuit and I will just show you that how the input current finally, what is going on in the transistor base read here that will be dependent on the collector current.

So, let me redraw just for the input case I draw this circuit and this is this is the circuit for the input side and we apply kirchoffs voltage law voltage law which is nothing simply the summation of voltages. So, we can write that V CC will be equal to voltage drop here. This voltage drop and this current will have a voltage drop here.

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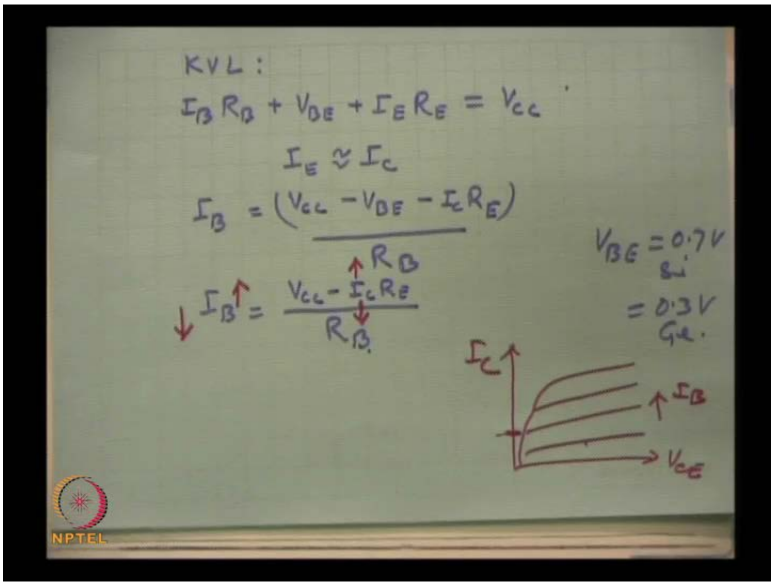

So, the kirchoffs voltage law results in K V L to the input loop gives I B, R B plus V B E plus I E, R E equal to V CC. You will remember a very fundamental thing which we talked earlier that in a bipolar transistor when the emitter junction is forward biased and collector junction is reverse bias in that case the emitter current and collector current are almost same. This deviate is here so, this becomes I B then we write from here I B the expression for I B is I B equal to V CC minus V BE minus I C, R E divided by R B and as I said earlier that this voltage is comparatively a much smaller to other voltages these are that this is around 0.7 volts V B E is 0.7 volts for a silicon transistor and this is 0.3 volts for a germanium transistor.

So, this we can drop to make some simplifications in important salient features remain in that. This is V CC minus I C, R E by R B this is the base current. Now we can see the difference between the fixed bias and this self bias case, here the input current remember input current is a function of output current and this has been possible because of the negative feedback which is introduced in the circuit because of this resistance. If we make R E equal to 0 then this is fixed bias V CC by R B, now this is the negative feedback and that takes corrective measures.

Let us look at this for any reason the collector current goes high then this term will be less and obviously I B will fall down. So, the rise in I C will be checked by fall down in I B, you will remember this output characteristics this is I C this is V CE and here is I B if I B falls then there will be less collector current in the circuit this is the corrective measure that if and if it falls if it fall then this term will acquire higher magnitude and the current input current will increase and that will again take care of the of the falling current it will enhance the current. So, in a nut shell we can say that this circuit takes into account of the variations which may which are bound to occur because of the reasons which were specified earlier and it will maintain the operational point the Q point very close to where we have chosen.

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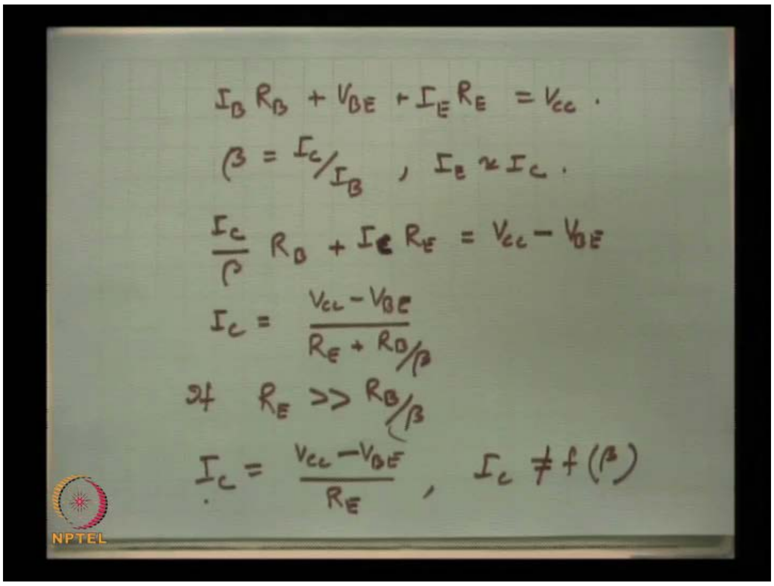

So, this is we can further explain this and this equation which we wrote I B, R B plus V B E plus I E which is same as I C, R E is V CC. Now we make use of the thing that beta is simply equal to I C by I B and I E is equal to I C. So, then this equation becomes I C by beta R B plus I E again I C because I C and I E are the same this is equal to V CC minus V B E or from here we can write I C equal to V CC, V BE by R E plus R B by beta. Now if we design a circuit where I E is much greater then R B by beta, then this becomes of much smaller magnitude as compared to this. So, our expression for the collector current is all becomes independent of variations in beta and this is V CC V BE by R E.

So, the collector current becomes independent of beta and as I made a important statement earlier I repeat that if this circuit was perfectly alright takes into account the variations and the beta then it will also take account of the other causes of variation. The cause of variation is in material so, this is highly stable circuit and here I C is not the function of the current gain beta which shows very high stability and this is achieved because of the negative feedback through the emitter resistance. There is a variation of the circuit which is of most and that variation is called voltage divider circuit self bias, but with little modification that is the one which is most widely used. We will talk about that in the next lecture and continue until about other circuits of biasing.