Video course on electronics

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Module No.# 02

Transistors

Lecture No. # 6

Biasing Of Transistors

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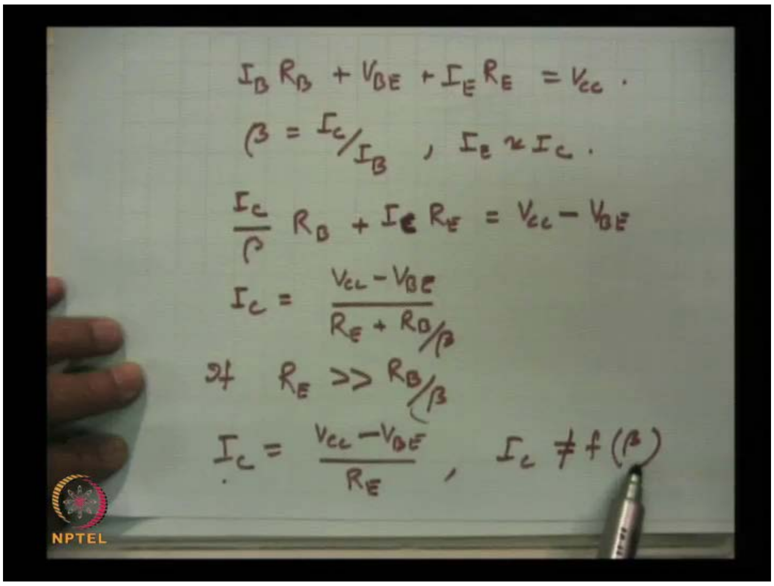

We will continue our discussion on biasing of transistors; we were talking about the self bias, in which we have shown that the collector current was independent of the changes in beta. And I said earlier that a circuit, which shows a stability against one kind of variation will take care of variations due to other reason; that means the cause of variation is material. This circuit is used as a voltage divider also.

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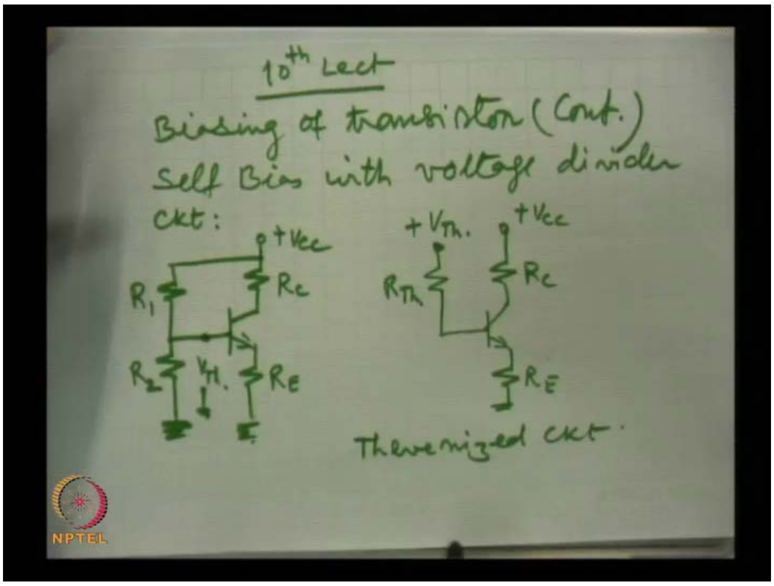

So, self bias with voltage divider circuit. This has certain advantages and those advantages also I will point out, but let us first see, what is this circuit?

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Here, this is the voltage divider circuit in fact, this is the one self bias, which is very widely used. This has certain advantages, which we will point out. Now, this circuit can be thevenized, the single resistance R E has been changed with, it has been replaced by two resistances R 1 or R 2. So, this can thevenized; and thevenized equivalent circuit is this.

This is Vcc, R C, R E, and this is thevenised voltage, and this is thevenized resistance R Th. So, this is thevenized circuit, which is equivalent of this original circuit. This is actually the design is taking this, but for analysis purposes, we thevenized this; we apply thevenised theorem, and we get the value of the thevenized voltage and thevenised resistance. Now, thevenised voltage is what is the voltage, which is observed between this point and the ground, this is thevenised voltage V Th. and if we complete this circuit here this is V cc.

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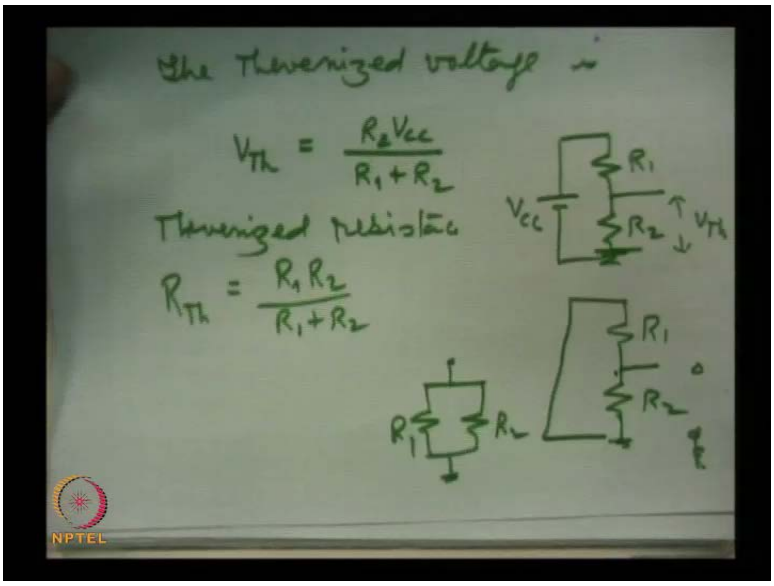

And if we complete this circuit here, this is V cc, then we know that the thevenized voltage will be V Th, this is the current V cc by R 1, R 2. Here, that means we are discussing this circuit. Here this is thevenised voltage V Th and this is R 1, R 2 and this is the battery V cc. So, obviously the current is through the battery V cc by the total resistance and what will be the voltage develop across this, this is the current into R2. So, this is the thevenized voltage which we can calculate, and the Thevenized resistance, this thevenized resistance for finding the resistance between these two points. The Thevenin's theorem as the must have studied that to calculate the equivalent resistance, we have to ground the dc voltage source.

So, this is grounded, so our circuit becomes this. This becomes the circuit R 1 and R 2, so as far as this point in ground is concerned, these two resistance are in parallel. This is grounded, it this is grounded so this is like this. R 1 and R 2 they are in parallel so, R Th is equal to R 1, R 2 by R 1 plus R 2. So, these are the Thevenized voltage and Thevenized resistance is in the circuit

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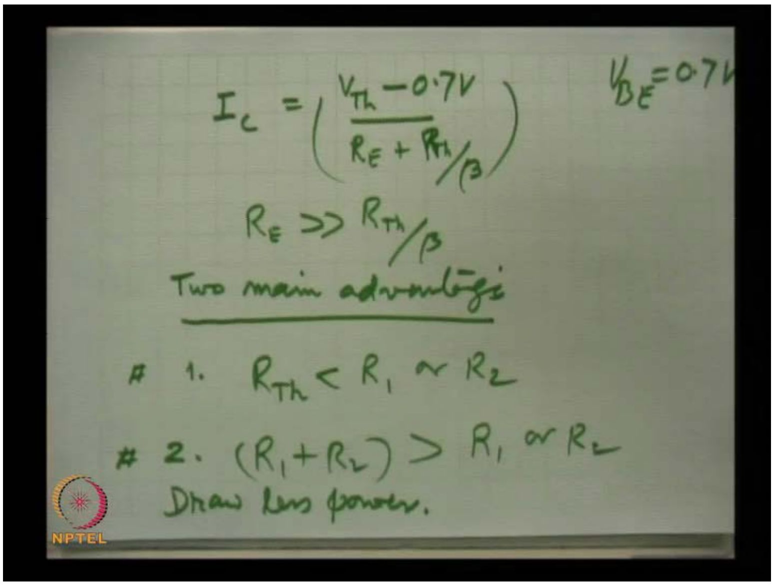

And then that final equation which we wrote for which showed the high stability, that can be the voltage because earlier this terminal was connected to V cc so, that V cc is to be replaced by V Th. So, this is V Th and this is V BE which for silicon transistor 0.7 volts, 0.7 volts divided by RE plus V Th by sorry V R Th Thevenized resistance by beta. This is the expression. And now, so this is the final expression and by making RE greater than R Th by beta, we can make the collector current independent of the variation. Independent of beta that mean it is independent of the variation of beta and this will be highly stable.

I said that in self bias, voltage divider circuit is widely used and it has advantages. I give, I talk about two main advantages, two main advantages of this voltage divider circuit in compared with the single resistance or B circuit. And these advantages are that this condition RE resistance should be large, quiet large in comparison to this. This condition is better than satisfied by Thevenin's circuit, Thevenized circuit. We can see here that when two resistance are in parallel, then the effective resistance is the smaller than either. That is the rule of parallel combination if for example, this is 100 chrome this is 50 chrome then the combination will be less than even the smaller resistance. So R Th thevenized equivalent resistance is less than R1 or R2, and hence when this is low then this condition can be better satisfied.

And so, this amounts to better stability and second point which is important, when we are sourcing our circuit by a battery because the battery will see that the two resistance in series and hence the resistance output resistance, output resistance seeing by the battery is higher. R 1 plus R 2 is certainly having higher magnitude, then R 1 or R 2 individually. So, this is that means it will draw less power so the battery life. This is the important in the case when our circuit is powered by a battery, so the battery life will be higher in this case. So, these are the two main advantages for the circuit.

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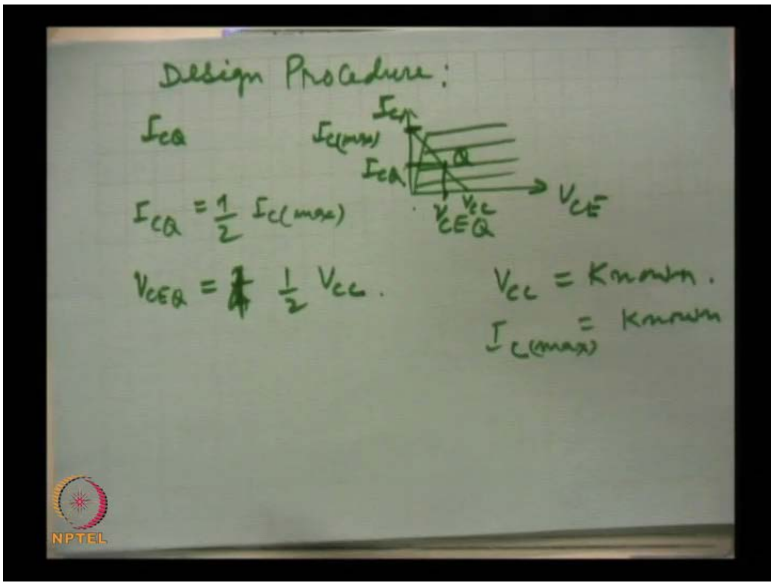

Now, I can repeat the design procedure. Design procedure, you see here if the characteristics are available then we choose the operating point near the middle of the active region, and we already know the value of I CQ. That means the quiescent current, collector current and voltage drop V CQ can be rear. If these characteristics are not available, as is the often case then it is safe because the manufacture described the values of the I C max. So, it is safe to take I CQ to be equal to half of this IC max. So, this point is known and V CEQ can be taken as half of V cc half sorry So, V CQ is known, I CQ is known and we can used certain, whatever we already study that knowledge that V CC known and IC max this is also known, then we can get the value of R C.

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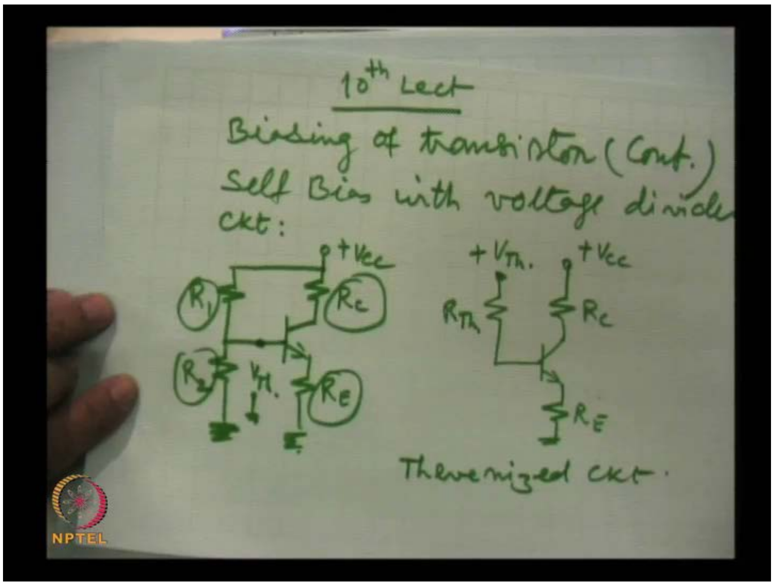

We have to find out the value of R c, R 1, R 2 and RE in the circuit and that is the total design we can assemble the circuit easily.

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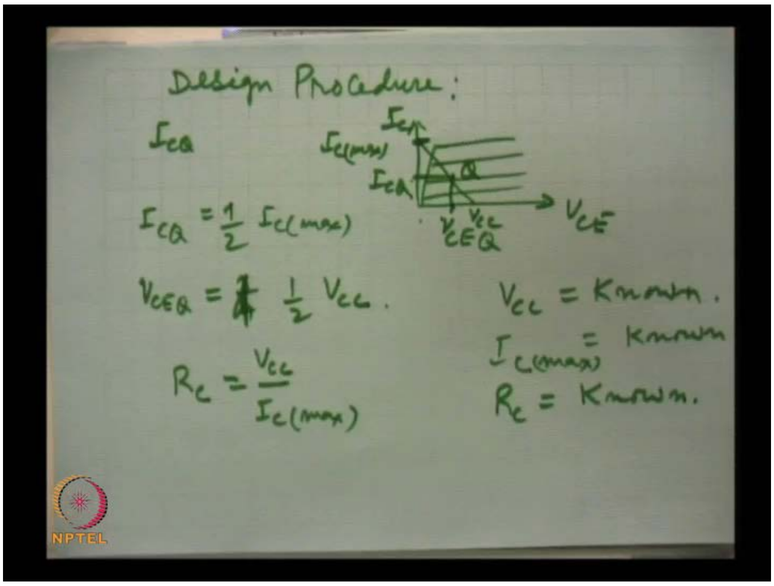

So, R C can be find out from V CC by I C max. So, now R c is also known and we remember that if we substitute, if we use the Kirchhoff’s voltage law we applied this to the collector circuit, then we get this equation summation of the voltage is V CC Vcc. Here I C is flowing so there is the voltage drop here, this is plus minus V CE and this is

R E through which current I E is flowing and I E and I C are same, so same is almost flowing.

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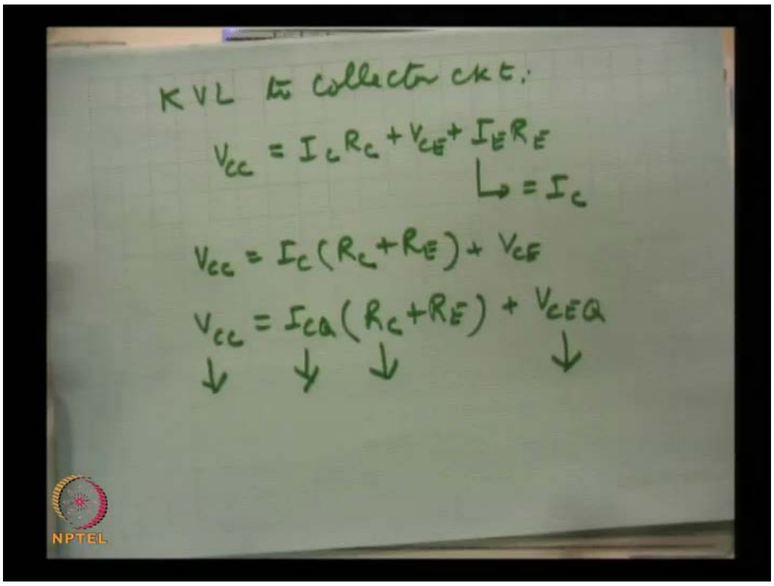

And so, this is equal to I C, R C plus V CE plus I E, R E, but this is equal to, almost equal to IC. So, this equation then becomes V cc, I c and R c plus R E and plus V CE. Now V CE is V CEQ, I c is I CQ so V cc is I CQ, R C, R E plus V CEQ. This is known this is known this is known this is known, so except R E all other parameters are known, so we can find out R E.

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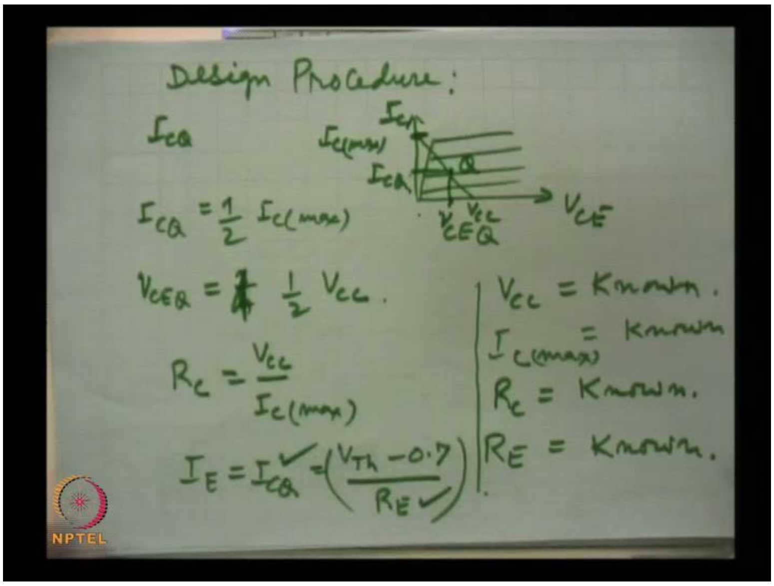

So, in this series R E is are also now known. We have calculated its value, so the R c is known, R E is known and the two resistances have to be calculated, and for that we make use of this I E which is same as I CQ and this is equal to V Th minus 7 by R E. This is the expression which we have talked about earlier. Now, here this is known this is known, so we can calculate the value of V Th.

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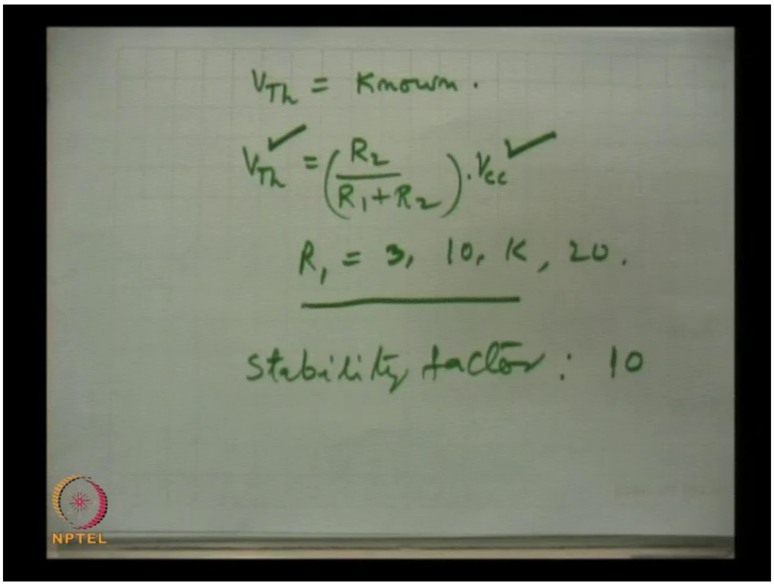

V Th is now known, its magnitude is known. Ones we know this then V Th is equal to, I have just written the expression is equal to R 2, R 1 plus R 2 into V CC. So, this is known this is known. Now, one thing one practice is very common in the design of the electronic circuit that we can assume one of the values R 1 for example, we can assume as a 3k, 6k, 10k or 20k and other can be calculated. This is one way, otherwise if we do not want to use our judgment, we can calculate by using the stability factor. Stability factor for a good circuit may be assumed, and say ten and this will give one relationship of a R 1 and R 2. So, we will have two relation one is here and other will come from stability factor, and by using these two expression, that two the value of R 1 in R 2 can be calculated independent and this way the design is complete, all the parameter of the circuit are known.

So, this was about the self bias and in spite of the fact that this voltage divider arrangement of the self bias makes use one additional resistance, but these two advantage are significant, hence this is most widely used circuit.

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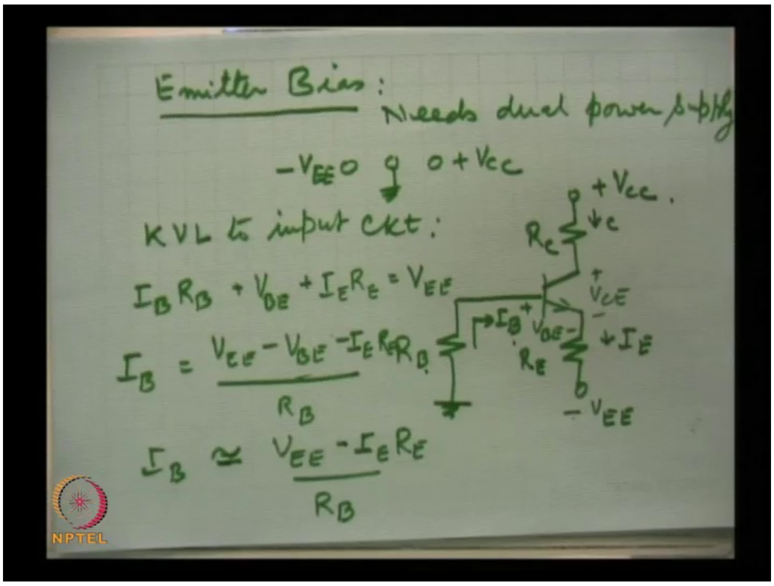

And now, we move to the another biasing scheme and that is Emitter bias Emitter bias As I said in the beginning emitter bias shows stability as high as the self bias circuit but it makes use of dual power supply needs dual power supply And I how explained the meaning of dual power supply and that is two voltages with respect to ground, one is plus V CC other is minus V EE. This power supply is needed to implement Emitter bias and then circuit is simple, and actually this is very popular biasing scheme. Operation amplifier, we will go in details later, is a one of the most important development in electronic.

Today, it is hard to find any circuit analog or digital which does not make use of operational amplifier. So, operational amplifiers are very widely used and operational amplifiers usually make use of this biasing scheme, because it is very simple and stability is as good as the self biasing case. Now the circuit is this R C, R E and this is connected to this point, minus V EE and this is connected from here plus V cc and then this is RB. So, this voltage is usual is V CE and collector current flows here and here is the emitter current and from here flows what is I B.

This is the circuit and we can show here that how stability will be achieved. Let us apply Kirchhoff voltage law to the input circuit, and that will give I B, R B. This voltage is V BE, so plus V BE and then the drop here, this voltage drop, so plus I E, R E and this is equal to this voltage, V EE. This is the minus signs, it will come minus V EE, we have take on this side. And from this we can write I E, I B the base current is equal to V EE magnitude, V BE and minus I E, R E divided by R B. This voltage is very small in comparison to this voltage, these two voltages may be equal which are normally used like that but, there is a not necessary condition. These two voltages differ also, one may be 12 volts other can be 9 so but, normally as I said that equal magnitude of V CC and V EE are used. Now, from here if the neglect this voltage which is small then I B becomes equal to, almost equal to V EE minus I E, R E by R B.

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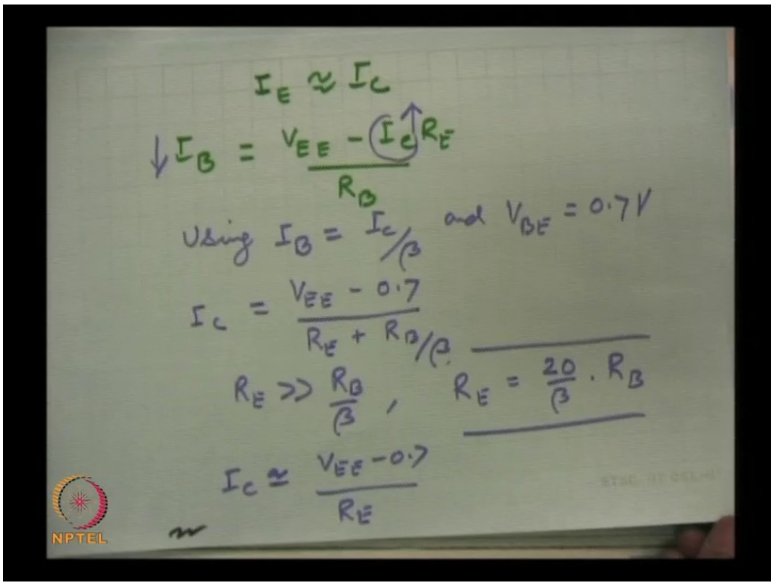

Now, for any reason I E is almost equal to I c and this shows, this is the equation which shows the stability that if this rises current, collector current too rises, this parameter will require higher magnitude and this term will fall. As a result I B will fall and this fall in IB will take care of the rise in the rise of the current, because again the output characteristics if you look if I V falls, the corresponding I c also falls. So, this is that stability and using I B equal to I C by beta and V BE equal to 0.7 volts. This I c can be written as (( )) and if we design the circuit such that this R E is large comparison to R B beta by B. By this very large we mean for example, R E taken twenty times of this factor. This is good enough, if this condition is met than this I C will be very closely equal to this.

We can drop this term and this shows is stability achieved through any variation in the value of beta because final current, the collector current is the irrespective of this value beta. So, this shows that it is highly stable circuit, design the simple, number of the resistance used is smaller and high stability. So, this is very widely used by (( )) scheme for bjt circuit. Now, the only point is that it needs dual power supply, so which is off course easily available, and so when dual power supply is the available we can use this circuit.

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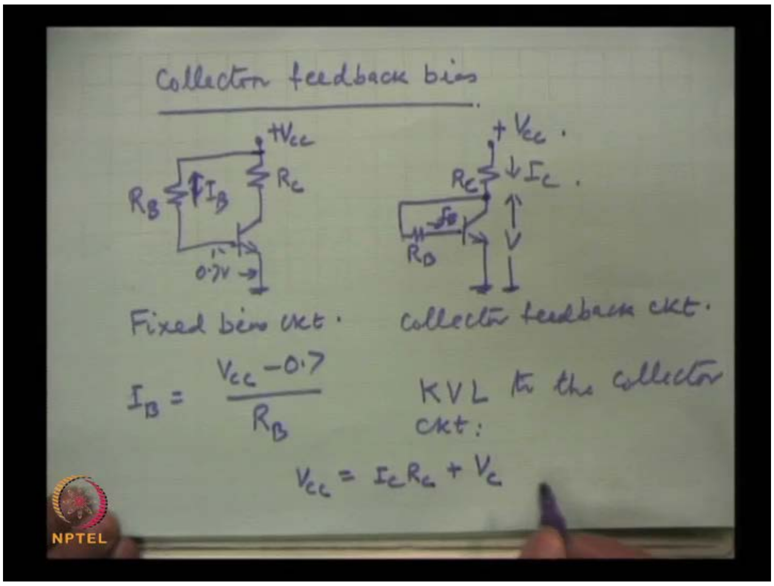

Then the last scheme is collector feedback bias. Collector feedback bias, you see we earlier had this circuit, this was fixed bias circuit. We make a small modification that the terminal is not return to battery, but we can connect here then the circuit becomes this, R B, R C and V CC. This is the collector feedback circuit collector feed back circuit it is a small change, just we have moved this point to the other part of the resistance R c and this provides a stability to the circuit, why? Because here the I B, this was simply I, B was simply V CC divided by R B, this voltage is 0.7 volts and this is all fixed. So, this is fixed bias and it is never used with bipolar transistor. This is here, this voltage between this terminal and ground that will control the current I B and this is variable, we can see, we apply the Kirchhoff’s voltage law to the collector circuit to the collector circuit then we simply get this is I C here so, V CC summation of voltages is equal to I C, R C plus V C.

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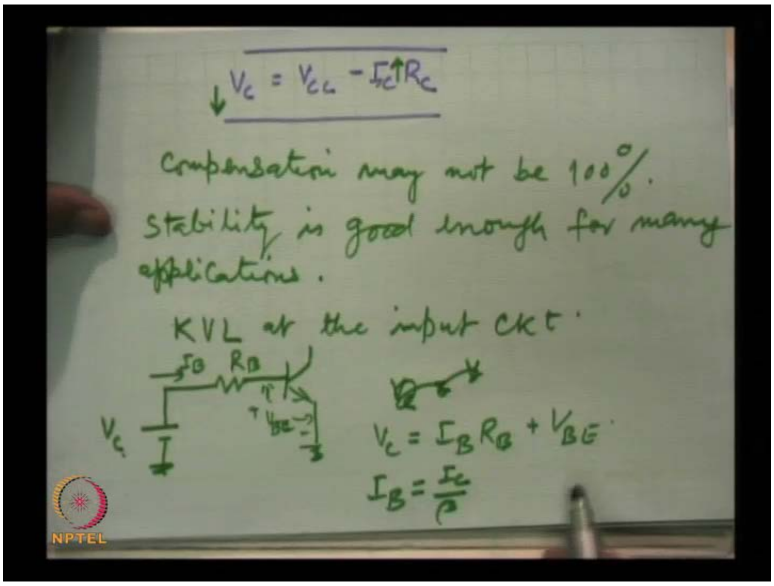

Or we can write that V C is equal to from this equation. V C is equal to V CC minus I C, R C. Now, this is the equation which can explain that how stability will be achieved by the collector feed back and look at here, for any reason if I C rises. So, this term will fall and V C will go down and this V C in this circuit will send smaller current, base current, and that will take care of the rise in collector current. It will check the rise in the collector current and this way the stability will be achieved. Now, so this voltage compensates for the rising current and this compensation may not be 100 percent. And that is the reason it was said, that it is much better circuit as compare to the fixed bias.

Fixed bias is never used, this is much better circuit but the stability is good enough for many applications. And this is widely circuit because very simple to design, makes use of fewer resistance, just two resistance is and in the case of the voltage divider circuit there were four resistor required, so the number is reduced to half. When we talk of a system in which several stages of the circuits are there, then the reduction of the resistance is significant to reduce the cost of the circuit, so that is very important point. Now, if very high stability is not the requirement which is true for many application then the collector feedback bias can be used to achieve the stability and we can talk little bit more about the design procedures.

We applied the KVL, the Kirchhoff's voltage law at the input circuit which gives, I will draw the circuit this is the circuit I B. And when we apply the Kirchhoff's summation of voltages, this voltage is plus, minus V BE. So, then we will get V C is voltage, V C equal to I B into R B, V C is equal to I B in to R B plus V BE and using the relation I B is equal to I C by beta we get from here V C is equal to I C by beta R B plus V BE

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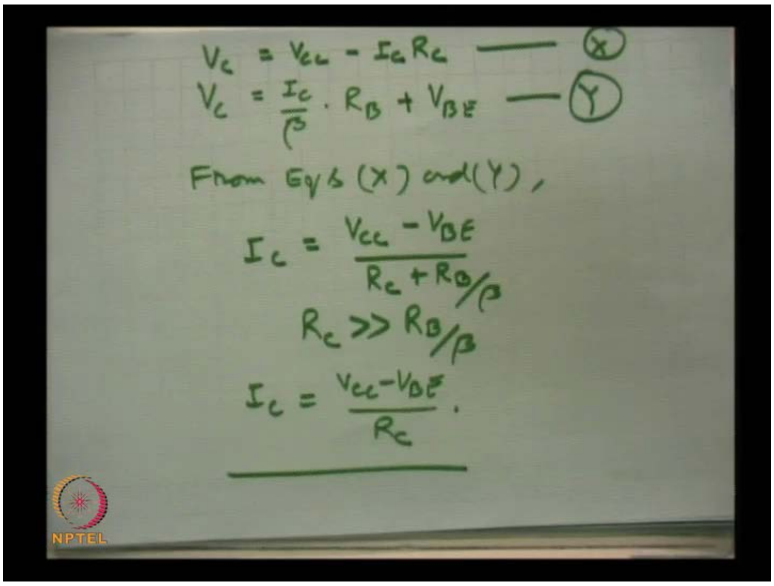

Earlier, this is one equation let us call it y and earlier we obtain the equation V c equal to V cc minus I c, R c, let us call this X and we can eliminate this V c because V c is not known, its unknown quantity. So, this is to be eliminated and we eliminate from here we get from equations x and y, we get I c equal to V CC minus V BE, R C plus. So, if we can take care of this condition R c to be high, compare to R B by beta. Then this will shows high stability, this term can be dropped may be dropped and I c will become equal to V CC V BE divided by R C. And beta is very high, beta is 100, 200 easily, so this condition is very easy to fulfill. And so, this way we have made the collector current totally independent of the variation of beta and hence a stable circuit. As I said that this shows the stability the design is very simple, makes use of fewer resistance and hence it is widely used.

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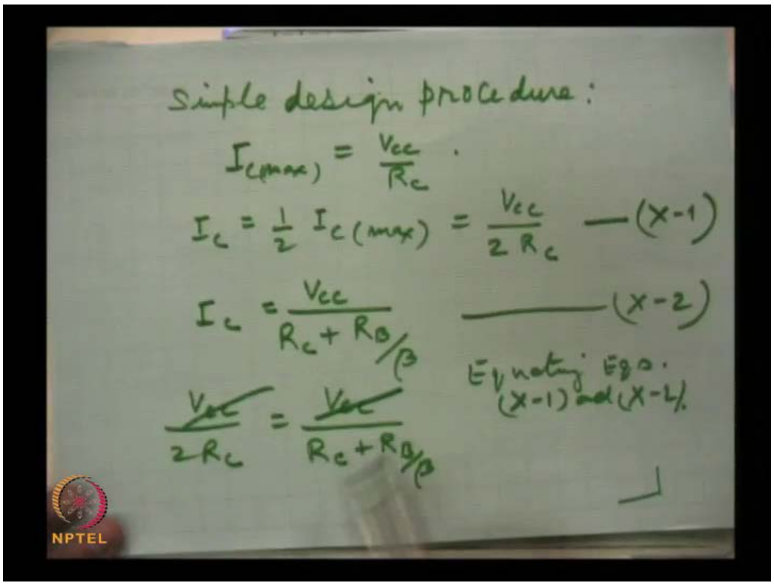

We can go for simple design procedure for this and we arrive at a very simple relation, simple design procedure. We know from the load line or from the maximum current I C, this equal to V CC by R c and this either form the graph we can take, from the where the load line cuts the y axis or we can used this procedure, which is quiet safe to take a half of I C max, given by the manufacture in the manual. So, this will be equal to V CC by just we substitute here I C max, so this is 2 R C. This is one equation, let us called X 1 and the equation which we have talked here, this equation that is if we neglect this is the small voltage then the equations becomes I c is V CC by R C plus R B by beta. Let us called X 2, then from this equation, we can simply substitute for I c this values, so this will be V CC, 2 R C equal V CC, R C plus R B by beta. This is equating, we have obtain by equating, equation X 1 and X 2.

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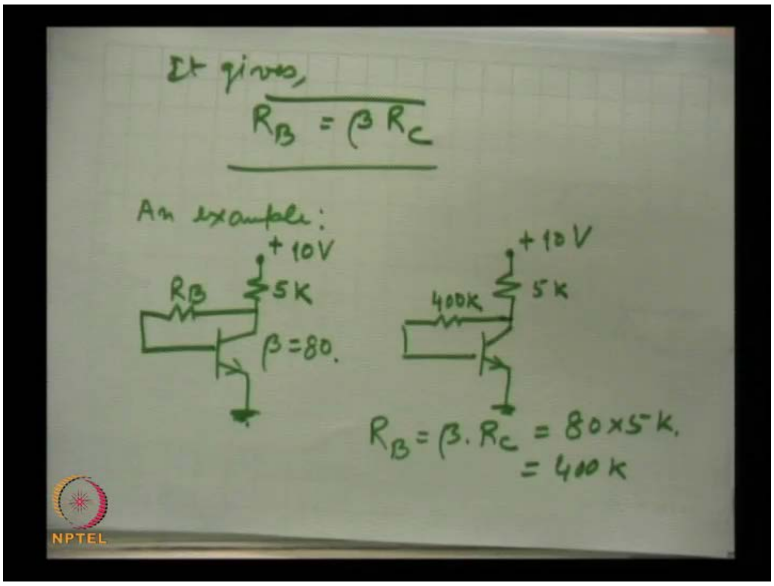

And here this goes and we simply get a relationship that it gives R B equal to beta R c. This is the simple thumb rule for the calculation of the value of R B, only there are two resistance in the R c in R B and one is known from that maximum current relationship, other is known from here. So, the design of this collector feedback circuit is also very simple. I just take as an example that if this is the circuit, if the beta of the transistors comes out to be suppose 80 then we can very easily find out the value of this resistance R B and so, the circuit will be, this is 5 kilo ohms and this is R B from this relation R B is equal to beta into R C and this is 80 into 5K so, 400K. So, this resistance say, 400 K so this way, this will give the midpoint operation for the collector feedback bias because this condition

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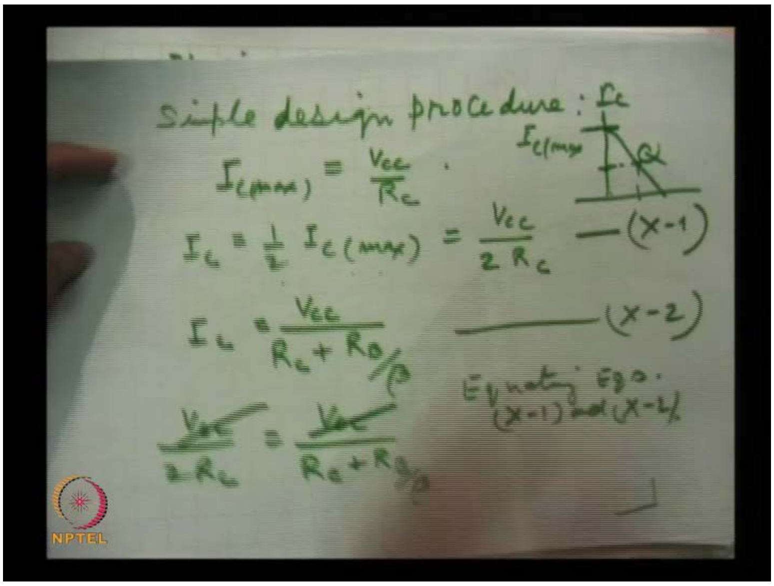

We have used I C is equal to half I C max this is for midpoint, because here this is I C max point and the half of is somewhere in middle. So, we are talking about the Q point in the somewhere in the middle of the active region. So, this is very simple and as I said very widely used, if extremely high stability is not required. So, that finishes this unit two on transistors and the biasing circuit design, circuit thy stability and the design of the biasing circuits. I summaries some of the futures we started with the transistors, the n p n and p n p, for normal operation n p n and p n p work the same way, there is no preference. But as from the discussion you must have gathered that in n p n electron, movement from emitter to collector is that takes the whole working of the transistor and transistor action.

So, and in the p n p the role is taken by the whole electron mobility is higher as compare to whole mobility. So, n p n transistor will perform satisfactorily, will continue perform satisfactorily up to higher frequency ranges. And then we discuss the design of the transistor that the emitter region is most heavily doped, this region is lightest doped and collector is moderately doped. And then from wear we have come to conclusion of these ranges, this we discuses even in terms of what we call, what makes efficient transistors that emitter efficiency, collector efficiency and so on. And base transport factor we discuses and we come out with the same conclusion.

The important thing was, and in that the transistor can be biased such that both junctions can be forward biased, that means we are in the saturation region of the characteristics, and in saturation region the output current and input current both currents are high, but they are independent which is against the requirement for an amplifier. And we can make both transistors reverse biased that is the case again, we are the two currents are fable in thy emitter circuit and collector circuit, but the two currents are independent. Even if we switch off the emitter current, the reverse saturation current in the collector circuit continues to flow and that is not what we required in a amplifier circuit. So, these two states are widely used, and when we used the transistor as a switch that means in digital electronics.

Here the transistor, we are using as an amplifier. So, the requirement is which is very fundamental that the emitter junction has to be forward biased; the collector junction has to be reverse biased, weather now the transistors can be used in three different configuration the common base, common emitter and common collector. Common base circuit is fundamental and is very useful when we talk about the theory of transistors. Transistor actions was explained through the common base circuit, and what is the transistor action that and from wear the name transistor came?

Transistor; (trans resistor), that we transfer the almost the same amount I E to the collector. So, form emitter resistance is forward biased and the resistance is few times of holms, to a high resistance circuit, collector circuit which has resistance of the order of several hundred too few made holms. And this transfer is not possible by simple arrangement of resistances and capacitors, this is possible through a active device which is transistors, and this is known as transistors action. So, transistors action is transferring a certain amount of current from low impedance circuit to high impedance circuit and here, so, this is the active region of the characteristics. There we have seen that the collector current totally depends on the input current which is I B in a common emitter circuit. And then we talked about the three circuits, we will be taking in the next unit. Three amplifier, common base, common emitter and common collector, but let me mention here that common base is rarely used in practice.

The reason is very low input impedance, if a battery is connected then low impedance means, it will drop high current from the battery, so battery life will be extremely poor. There are other reasons; this is no current gain, alpha is the current gain in common base circuit and alpha is actually less than one. The output current verse as input current, so alpha is I c divided by I E and I C is always less than I E, but close to that .So, alpha is the current gain which is close to one, but we less than one hence there is no current gain, but beta which is the current gain in common emitter circuit, and common emitter circuit the input is base current I B is the collector current. So, beta is I C by I B and which is very high, and transistors with current gain 50, 80, 100, 200, 300 are commonly available in the market.

So, this was about the transistors. And then, we talked about the biasing which is the very important part of the transistor circuits. So, a amplifier will require the emitter junction to be forward bias, collector junction to be reverse bias and besides that, that will just saying this that, emitter is forward biased and collector is reverse biased is not sufficient, that requires a proper choice of the operating point. By choosing an operating point, we mean choosing dc collector current and dc drop across the junction V CE. So, that is the proper choice of the operating point, operating point may shift because of three basic reason temperature, aging, replacement of the device. So, we have to design a good circuit, a stable circuit. So, even if the parameter change, temperature changes or the device has worked for long life, so even then quiescent not vary.

And we had discussed the three schemes; the self biases scheme, the emitter bias and the collector feedback bias. And these three schemes are widely used to design circuits. Depending on our requirements and facility available, any one of the three schemes can be picked up and the amplifier circuit can be designed. And so, that we discuss; we will continue our discussion further; and now, we move to the unit 3.