BASIC ELECTRONICS
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LECTURE-11
TRANSISTOR BIASING
(Common Emitter Circuits,
Fixed Bias, Collector to base Bias)

Hello everybody! In our series of lectures on basic electronics learning by doing let us move on to the next lecture. Before we do that let us briefly review the concepts that we learned in the previous lecture.

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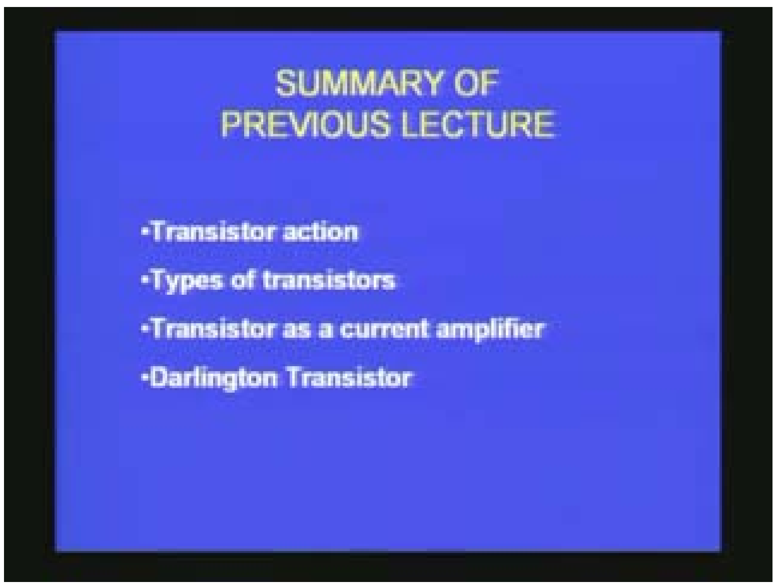

We saw about basic action of a transistor, different types of transistors like npn, pnp, etc., and then we also saw how there is current amplification in the case of a transistor. We also demonstrated using simple circuits. Then we also saw a combination of transistors which is very, very useful which is called Darlington pair transistors. We move on to look at the transistor in much more detail and we will try to see the characteristics of a transistor and then look at the various biasing technique during the course of this lecture.

Before we make use of any device we should fully understand its potentialities and how well it can be used in different applications. In order to understand the full application potential of a transistor we must have a clear understanding of its characteristics. I have shown on the screen a circuit which is used for obtaining the output characteristics of a transistor and this transistor is now used in what is known as common emitter configuration.

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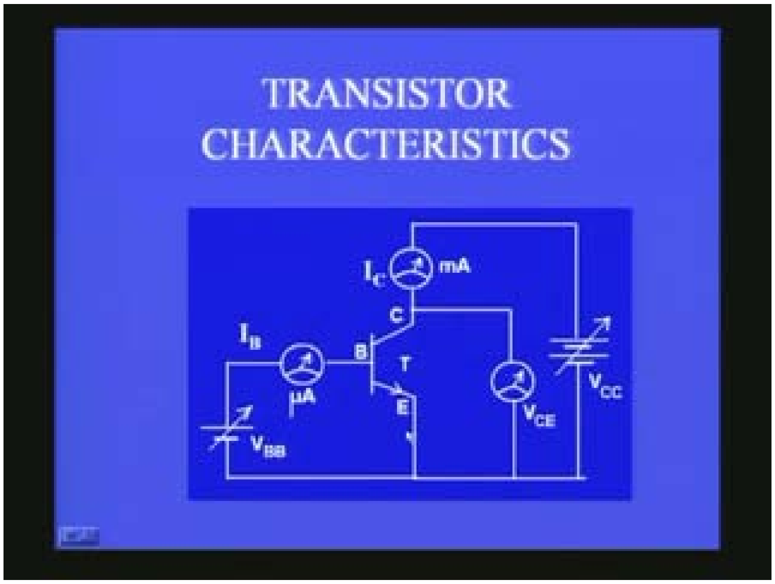

The emitter is connected to the ground here and it is common to both the input side from this side to the left or to the output side on this side and this is called common emitter configuration. There is a power supply here which is called the V_{BB}, for the base supply and this is a current ammeter for measurement of I_B, the base current and there is also a collector current meter which is called I_C here which is in milliamperes. The base current meter is in microamperes and then you have also got a voltmeter which is connected between the collector and the ground or the common terminal which will measure the V_{CE}, the voltage between the collector and the emitter junction. Because the emitter is grounded, this voltmeter will read the voltage between the collector and the emitter.

This is called common emitter configuration and if I find out the relationship between I_B, I_C and V_{CE} this characteristic is called output characteristics of a common emitter configuration transistor. We can also have a voltmeter connected here between the base and the emitter which will measure V_{BE} and if I now plot a graph between the different values of the base current and the V_{BE}, the voltage between the base and the emitter, for different applied values of V_{CC} then we will get another set of characteristics which is called input characteristics of the transistor. What we are now doing is basically on the output side at the collector and the emitter part of the transistor and it is called output characteristics. This is just one example of several characteristics that you can think of. In case of the transistor for example you can also have common base characteristics. Again you will have a input characteristics and the output characteristics but the transistor will have the base as a common terminal between the left and the right side, the input and the output side. Similarly you can have common collector characteristics. Each one of them will give us some information about how it can be used in different applications in that particular configuration. But because common emitter configuration is the most popular and very useful configuration for several amplifier type of applications we are concentrating on common emitter configuration.

The common emitter configuration you have already seen in the circuit. What we do here is you set by first switching on the V_{BB} voltage source. You allow a small current of may be let us say 10 microamperes set in the I_B ammeter. Because this circuit is complete between the base and the emitter you can set a current of 10 microamperes using the V_{BB} power supply by varying this and it will be very, very small voltage that you have to apply in the order of hundreds of millivolts and you will able to measure you have about 10 microamperes current set here. You keep this same current constant, I_B value. You start varying the V_{CC} supply from zero. The arrow here indicates that it is a variable voltage source.

By using a knob you vary the voltage from starting from zero in some specific steps for example 0.5V and then find out the collector current for each of these voltages and also record the V_{CE}. Because the ammeter is a low resistance device which is in series with the transistor the voltage V_{CE} will almost be equal to the voltage V_{CC} that you apply. If you know the voltage you are applying then you do not have to measure this V_{CE}. But in principle this shows that we are now here monitoring the voltage between the collector and emitter. Just by keeping I_B constant you vary the V_{CC} voltage from zero to some fixed value for example 10V or 15V in steps of 0.5Vand record for every step the collector current I_C and plot a graph between V_{CE} and I_C. That is what I want to show you in the next graph.

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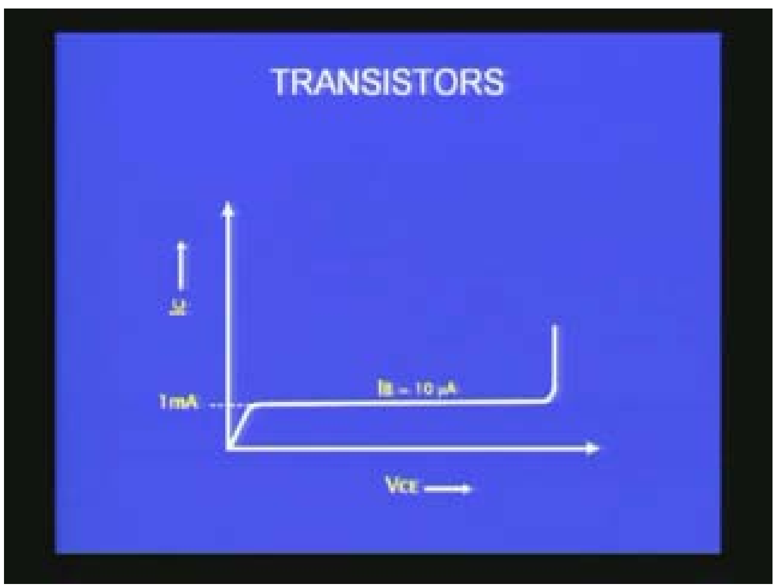

I am plotting on the X-axis V_{CE} the voltage between the collector and the emitter and on the Y-axis I_C the current of the collector for different I_B values. This is one value of I_B I have maintained and you find as we increase the V_{CE} initially for a very small value of voltage variation the current increases linearly and after that for example in this case when the current IC reaches 1 milliampere current irrespective of the voltage you apply on the V_{CE} the current remains constant. If you go beyond some limit, very large voltage V_{CC} then it may even break down and then there will be a large current flowing without any change in the voltage V_{CE}. This is one single characteristic for one single I_B value. When you vary V_{CE} or V_{CC} continuously you get one such graph. What we do is we go back and set a different value of I_B.

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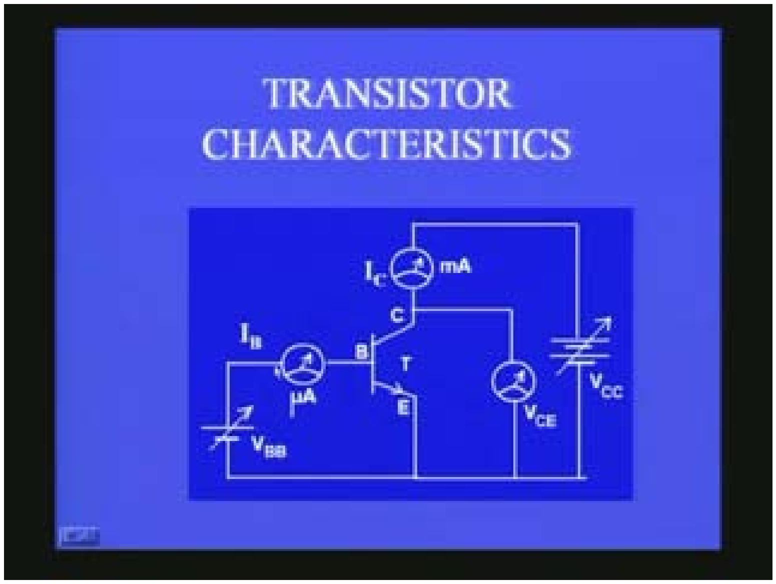

I_{B2} may be 20 microamperes and again repeat by varying this from zero to large value 20V or 15V and record the corresponding I_C and plot them in the graph and likewise you keep on doing for different values of IB and what then you will get will be a figure as shown now.

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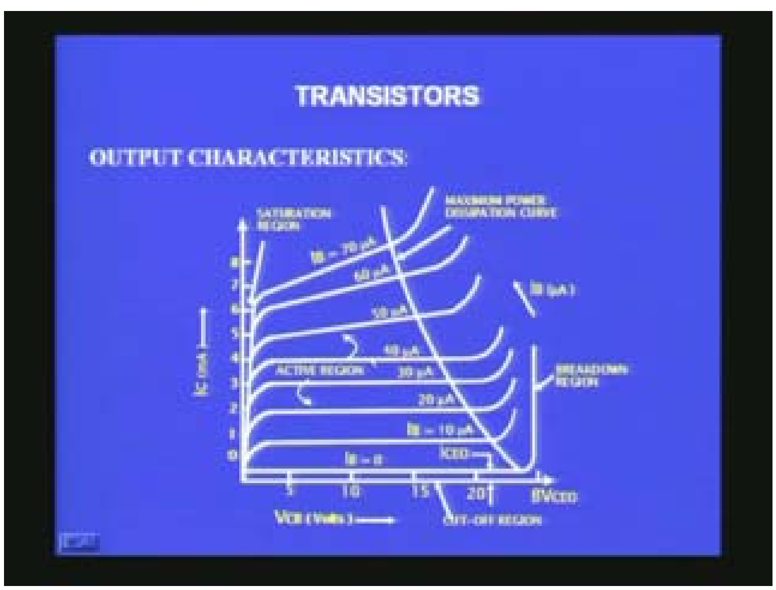

This was the first graph I showed you. I_B is equal to 10 ten microamperes. Now we do with 20 microampere one more time, 30 microampere etc. This will be the family of characteristics that you will obtain for this case for different values of I_B the corresponding values of V_{CE} and I_C. This should be V_{CE} not V_{CB}. Then you should also remember that every transistor comes out with a very specific power rating. That means the maximum power that it can dissipate which is given by the product of V_{CE} into I_C in this case. When it exceeds the maximum power allowed for a given device then we should not go beyond that point.

V_{CE} I_C is equal to a constant. If it is for example 1V if I_C is very small the V_{CE} can be very large. As you change the I_C the maximum value of V_{CE} keeps decreasing so it comes something like a rectangular hyperbola and I should never make my transistor work anywhere in this region which is beyond this curve which is corresponding to the maximum power dissipation curve. This is the region in which we would like to operate and even here there are three different regions that we should identify. One is this region very close to the X-axis which is called the cutoff region. This is the cutoff region below which if I have an I_B I will never have any I_C at all. That is the cutoff region. This is the minimum I_B I should have to make my current I_C have some specific value. Then there is also another region which is parallel to the Y-axis or the collector current axis and this region is called saturation region. The saturation region is the region to which I reach very small variations in the collector emitter voltage V_{CE} I reach this point. Afterwards there is no variation. It has already reached the saturation. All the electrons or the holes as the case may be have been collected by the collector and even if I increase the voltage there is no change in the collector current almost. When there are very smaller values of base current it is almost flat but as I increase the base current the slope slightly changes from being purely horizontal. This also can be understood.

There is a saturation region and there is a cutoff region and the rest of the region in between this maximum dissipation curve and the saturation and the cutoff region what you have is called the active region and this is of very great importance to us. Because all our amplifiers, whenever I use a transistor as an amplifier, I will always try to use the amplifier in this region. I already mentioned to you that the characteristic is very important step forward in designing different circuits. We should understand the characteristics of a transistor. This is the output characteristics of a common emitter transistor and we have seen the active region, in this region.

Any given circuit can be positioned on the characteristics at a given point. This positioning of a transistor at a very given point in the active region is called biasing. A transistor has to be biased to make it come to a very specific point which is called the operating point or the Quiscent point of the amplifier and that is what we are going to look at. Before I do that I will quickly show you a simple demonstration or simulation of the characteristics of a transistor. On the screen you have a bread board and you have a transistor here, the emitter, base, collector are shown here and on this side there is a power supply which has got two outputs.

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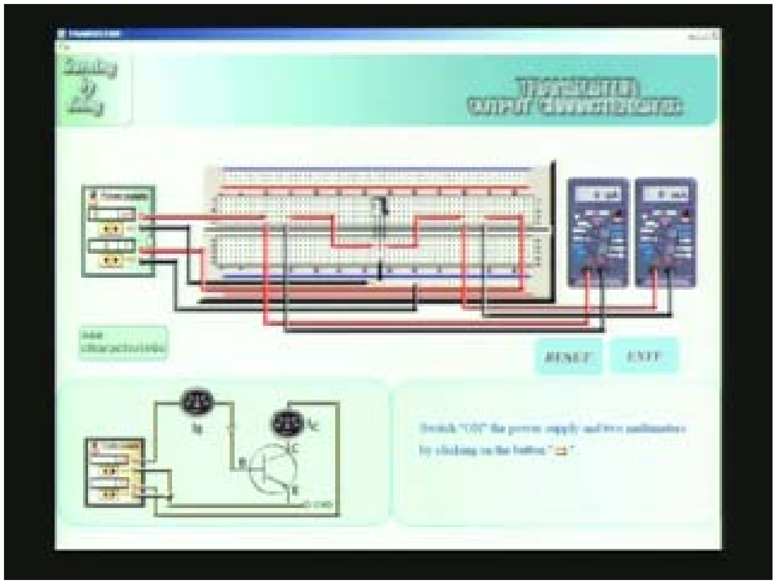

One is for the V_{BB} or the base supply; the other one is the V_{CC} supply that we already saw. Even here the same circuit is shown. There is one I_C meter and there is one I_B meter, current meter and the two power supplies. That is all you require for doing the characteristics of the transistor. There are two multimeters on to your right; the first one is measuring the base current. If you follow the two curves you can see it is connected here with the base supply. It comes in series with the base and the emitter junction of the transistor. Similarly on the collector side I have one more ammeter. The multimeter is used as milliammeter and that is for measuring the I_C, the collector current. I have the two power supplies and I have the two current meters, ammeters and voltmeters all made out of digital multimeters chosen in the current range. All that I have to do is let me switch on the power supply. Let me switch on the voltmeter, current meters, two current meters. I am ready. I will vary the V_{BB}, the base voltage in steps of 100 millivolts and as I vary this the corresponding base current keeps increasing. Now it is 4 microamperes for 400 millivolts. I increase it to 500 millivolts; it goes to 5 microamperes. If I keep doing that for 1000 millivolts or 1V it's about 10 microamperes in a typical case. This is reasonably large voltage. Even less than that, you would get.

I am going to vary the V_{CC} supply which is at the bottom continuously in steps of let us say 0.5 and see what happens to the collector current. I am going to keep the I_B constant, the base current constant and I am going to vary the V_{CC} and for every value of V_{CC} I apply I will measure the collector current. Let me increase. Now it is 0.5 and it is now 0.1milliampere IC. Now it is 1V V_{CE} and it is 0.5; 1.5 it is about 1 milliampere; 2V now it is 1.5 milliamperes. 2.5 its about 2 milliamperes; 3 it remains at 2 milliamperes; 3.5 again 2 milliamperes. Beyond 2.5 even if I go up to let us say 6 or 7 or 8V the milliammeter shows the same value of I_C which is 2 milliamperes. That is what we saw in the characteristics.

Let me quickly come back to zero for the V_{CC} and increase my base current from 10 microamperes to the next value which is for example for 2V, 20 microamperes. Now let me keep increasing the V_{CC} and as I increase please observe what happens to the I_C. I_C

keeps on increasing. The moment I come to 2.5 it is now 4 milliamperes. Beyond that it continues to be in 4 milliamperes. It has already reached the saturation value and it is now 4 milliamperes for all the different voltages that I apply at the V_{CE} voltage. I can keep doing it for different values of I_B and I have shown here the characteristics.

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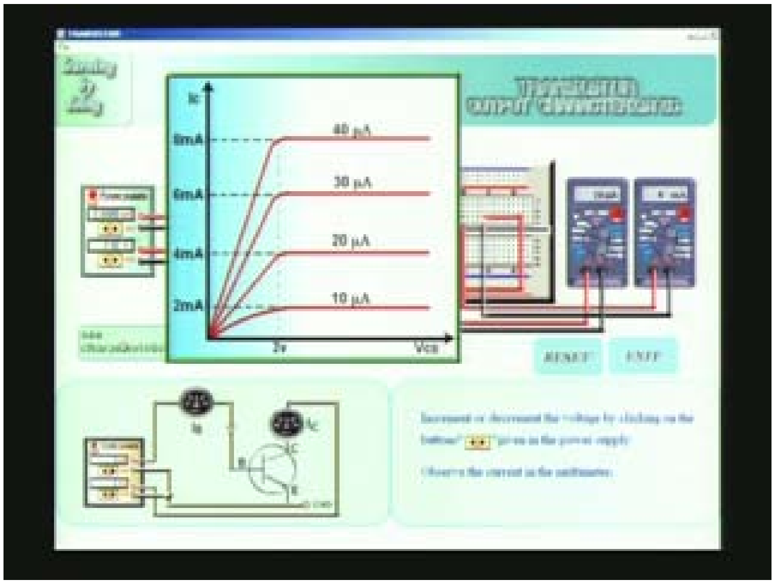

When the voltage I_B is 10 microamperes, the I_C is constant at 2 milliamperes. When the I_B is 20 microamperes it is constant at 4 milliamperes etc., and this is exactly the characteristics that we saw in the previous case when I discussed about the output characteristics of a transistor. We have done a stimulated experiment to observe the output characteristics of a transistor. The same experiment can be performed in the lab and you would get almost similar characteristics.

The transistors are used in building amplifiers.

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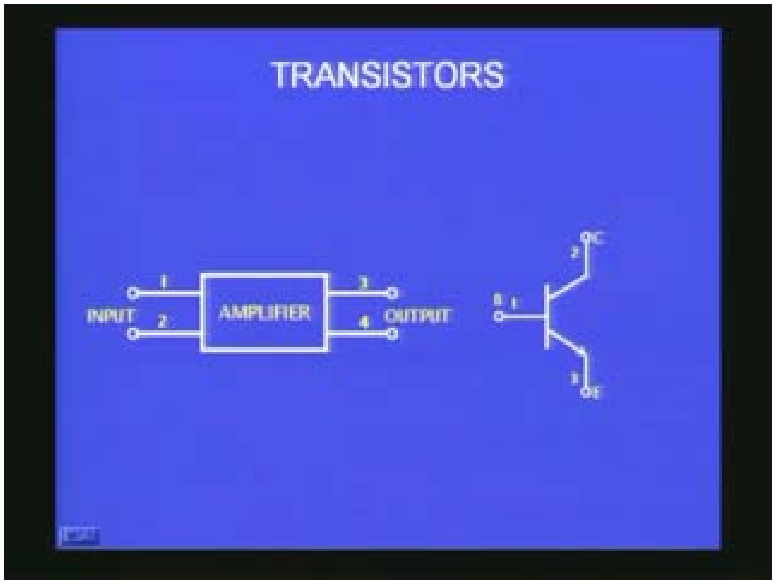

One of the main applications of transistor which is an active device is that it is capable of magnifying any input signal into much larger value at the output. Any amplifier in general should have two terminals at the input. For the input we have to connect any microphone or whatever signal that you want to amplify between these two inputs and there should be again an output terminal with which I will either load a loud speaker if I want a simple audio amplifier or I can use some motor or device which I want to drive after magnification or after amplification.

Every amplifier is called a four port network. We have got four ports; two for the input and two for the output. Four port network can be something like a black box. Black box means we do not know anything about what is inside. So just we assume it to be a black box. An amplifier has got four terminals; two for the input and two for the output you require. But if you look at the transistor, any transistor for that matter is a three terminal device. It has got a base, emitter and a collector. So how do I make an amplifier which requires four port with only three terminal transistor? I must have one of the terminals as common to both input and output and that is how I already mentioned to you that the transistor can be used in different configurations where the emitter can be common for the input and the output in one case or the base can be common for the input, output or the collector can be common for the input, output, etc.

Let us look at the various possibilities. For example the first figure is a common emitter configuration. The emitter is a common terminal. Both two and four belong to the emitter and one and two is the input, three and four is the output as in any amplifier. Similarly you have a common base configuration where the base becomes common to the input and the output and common collector where the collector becomes a common terminal between the input and output.

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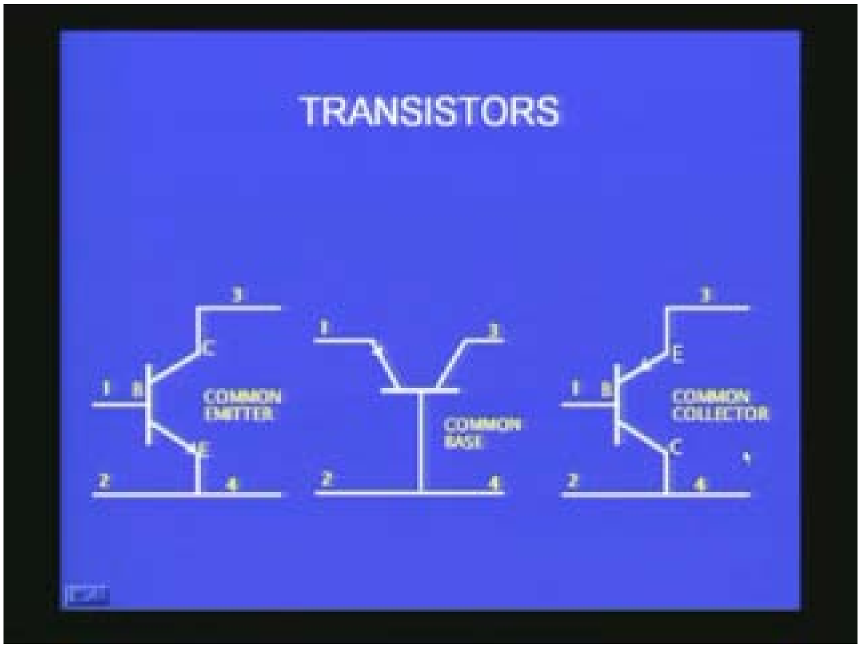

With this understanding we will concentrate more on the common emitter configuration. As I already mentioned to you that provides us with large voltage amplification. How do I make use of a transistor as an amplifier? The first and foremost thing that we have to do is that you must position your amplifier somewhere in the active region of the characteristics of the transistor, whatever transistor that we choose. The moment you get a transistor you should first plot its output characteristics. Then you are very sure of how it will perform in a given situation. Then you should try to position the operating point of your transistor on the characteristics at a given operating point carefully chosen. One has to choose carefully that operating point. How do we choose? That is what is known as biasing of the transistor. This technique is known as biasing. Putting the amplifier or the transistor at a given operating point with reference to its output characteristics is what we call in general as transistor biasing.

If you look at the figure you can see there is output characteristics drawn here; very familiar to you by now and you have to put it somewhere here in this active region. You have put your transistor somewhere here. What it means is every point here will be characterized by a corresponding I_C and a corresponding V_{CE} and a corresponding I_B. To put a transistor on a given point or an operating point on the characteristics is equivalent to saying you must provide a constant value of V_{CE}, constant value of I_C and a constant value of I_B to start with. That is what is called transistor biasing and this can be done in more than one ways.

On the left side there is a circuit which is again in common emitter configuration and you have connected a R_B a base resistance along with a base voltage source V_{BB}. Similarly there is one collector resistance which is here 3 K ohm and that is connected to another emitter voltage which is 15V, the V_{CC} supply as it is called.

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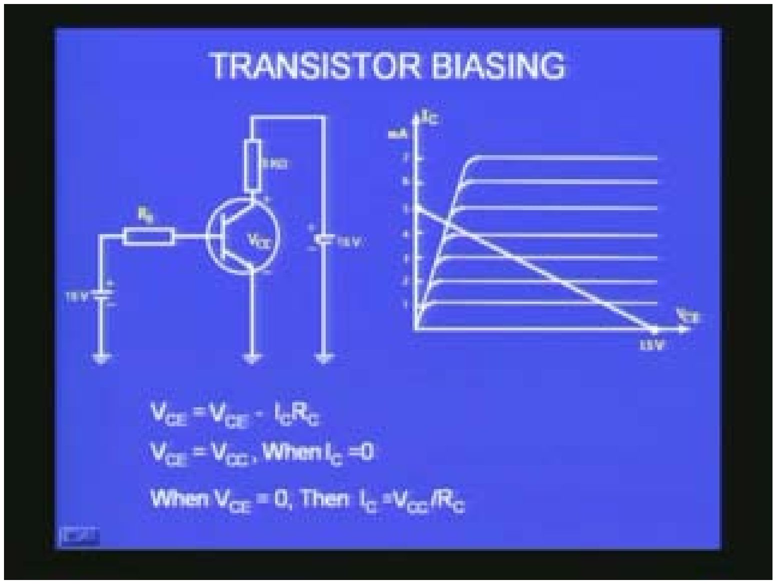

Can I use this circuit to bias the transistor? The answer is indeed yes. You can do that because you have the voltage and the R_B. With this you can forward bias this base emitter junction and you can maintain a constant current. If necessary you can vary these or choose a proper value of R_B and V_{BB} and you can maintain a constant value and this again with a 15V here and the 3K because there is a forward biasing there will be a current in the collector and the emitter and that will correspond to a voltage being developed across the collector and the emitter regions of the transistor. So it is in principle possible to bias in the simplest way by using two power supplies and two resistors.

I have written some equations here which will become very simple to understand I hope. What is V_{CE}? V_{CE} is the voltage V between the C and E, the collector and the emitter region. This voltage is called V_{CE}. The V_{CE} is not the same as V_{CC} because there will be a finite current flowing and that finite current will produce the voltage drop across this 3Kohms resistor R_C and the voltage here will be less than 15V. V_{CE} is V_{CC} that is what I have here minus the voltage across the 3Kohms which is minus I_C the collector current into R_C which is 3K ohms that I have shown here. This is the R_C.

In general V_{CE} in this type of a circuit is equal to V_{CC} minus I_C R_C which is a very simple equation corresponding to Kirchoff's voltage law. The total voltage, if you go along the loop, the algebraic sum should be zero. The 15V should be dropped among these two devices. One is the resistor, other is the transistor and that is what this equation is about. There are two things that I can vary. For example the I_C can change, V_{CE} can change and this becomes an equation which corresponds to a straight line and this straight line equation is called load line because the RC is the load which is connected in series with the transistor. This characteristic of the particular load or the resistor that I connect here is called the load line; DC load line because it is now under the DC condition. I have not applied any alternating voltage yet.

This is the DC load line that is what I showed here. But for a given value of R_C and V_{CC} I will get a very specific load line? How do I do that? Let us assume that I_C becomes zero. That means there is no current through the collector. When will that happen? That will happen when there is no base current or the base current is too small to switch on the transistor, to forward bias the transistor. Then there will be only I_C; the I_C will become zero. When the I_C is zero then the voltage I_C R_C is also zero because anything multiplied by zero is zero and there is no drop across this 3Kohms or the R_C resistor and the entire V_{CC} will be appearing across the transistor V_{CC}. That is what this equation shows. When I_C is zero then this term becomes zero and then V_{CE} is nothing but V_{CC}. That's what I have written here. I know this point; I_{CE} is zero corresponding to the X-axis and at that place V_{CC} is 15V. V_{CE} is 15V at I_C equal to zero. Therefore I put dot on 15V of the V_{CE} graph, V_{CE} line.

Similarly when the voltage across the transistor V_{CE} becomes zero then I_C will be maximum. I_C will be V_{CE}/R_C from the same equation. When V_{CE} is zero V_{CC} is equal to I_C R_C or I_C is equal to V_{CC}/R_C. It should be V_{CC}. I_C is equal to V_{CC}/R_C and this point on V_{CE} is equal to zero line which is the Y-axis corresponds to V_{CC}/R_C. For a given transistor circuit I know V_{CC} and I know R_C. The moment I know these two values I choose these two values I can immediately draw a load line because for drawing a straight line minimum you require two points one point corresponds to I_C equal to zero which is the V_{CC} point on the X-axis and the other point corresponds to V_{CE} equal to zero which is nothing but V_{CC}/R_C which is under Y-axis. The moment I know this point I will take a scale and draw a line between these two and this becomes my load line. That means all my circuits having the same V_{CC} and the same R_C and the transistor will always be somewhere along this line. I do not have to concentrate on any other point away from this line. All the time my transistor will be only along this point. Where it is might depend upon the base current I_B.

If I do not give any base current there is no collector current. So I will be at this point V_{CC}. If I give large current then I will be at this point. In general for different base currents I will find myself somewhere along this line and this gives me the different operating points that I can choose for my transistor amplifier with this specific value of V_{CC} and R_C. If I change my R_C correspondingly the straight line also will change as you can see. Again if I change my V_{CC} again this will change. If I change both V_{CC} and R_C the whole thing will change. If I try to change the transistor the whole characteristics will have to be drawn again. It will be slightly different characteristics that I will have. This is about DC load line. Once you know the DC load line then you can take up a quiescent point on the transistor.

I have given a simple example. If I want to measure V_{CE} that will be supply voltage minus voltage drop across the R_C.

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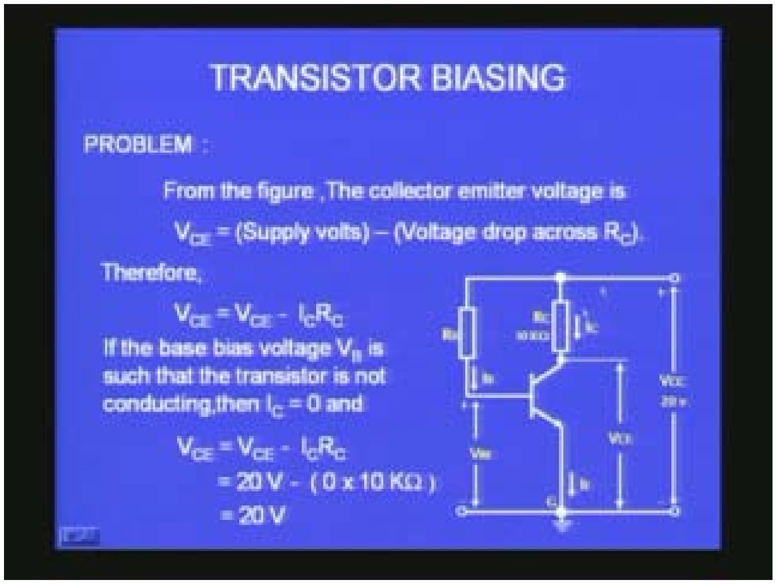

That is what is shown in this figure also and V_{CE} is equal to V_{CC}. Again this has to be V_{CE}-I_CR_C and if the base bias voltage V_B is such that the transistor is not conducting then I_C will become zero and V_{CE} will become equal to 20 similar to what I already mentioned to you and similarly when I_C is equal to zero, V_{CE} is equal to 20 and also when I_C is maximum corresponding to 2 milliamperes, 2 milliamperes into 10K ohms in this case it is 20V milliampere and K will go. 2 into 10 will become 20. 20-20 is zero. That corresponds to the point on the Y-axis. That is 2 milliampere point when V_{CE} is equal to zero. That is how the load line is obtained.

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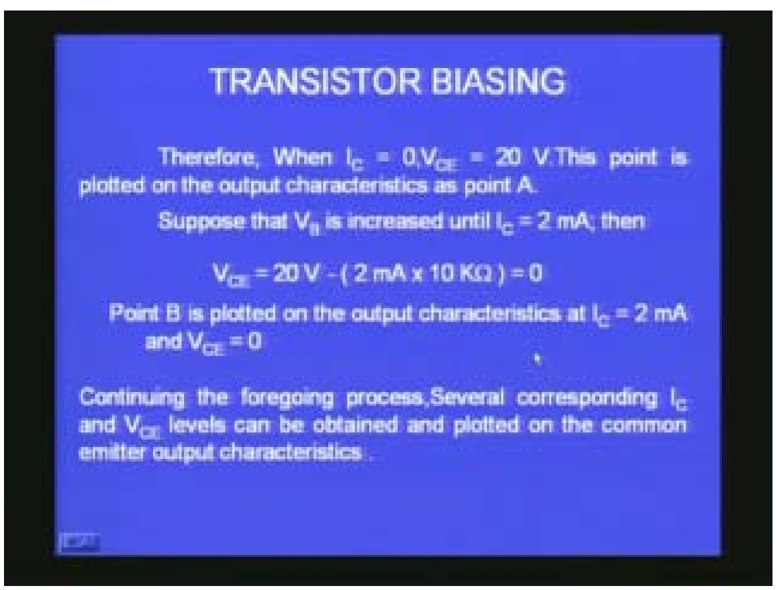

If for example in the given circuit I choose the value of I_C 0.5 milliampere. The 0.5 milliampere passing through 10K will give me 0.5 into 10 which is 5V. Milliampere and

K again will go. 0.5 into 10 gives me 5V. I will have to subtract from 20V supply and V_{CE} will be only 15V.

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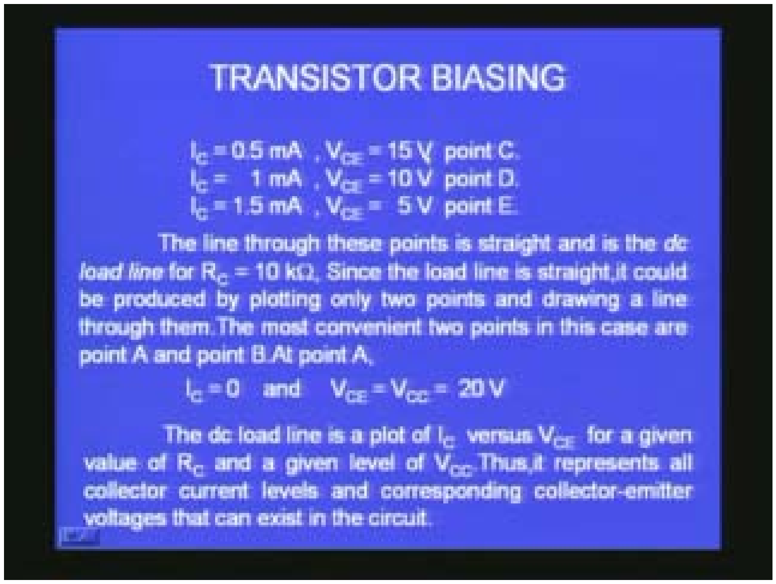

I hope you can see that. This is 20V; this is 5V and 20-5 is 15V. That is what I have here. It will have 15V. Similarly if I have I_C of 1 milliampere, 1 milliampere is 10K. This is 10V. The balance 10V will be across the V_{CE}. When it is 1.5V it will be 5V etc.

There are different points that I can plot on my load line.

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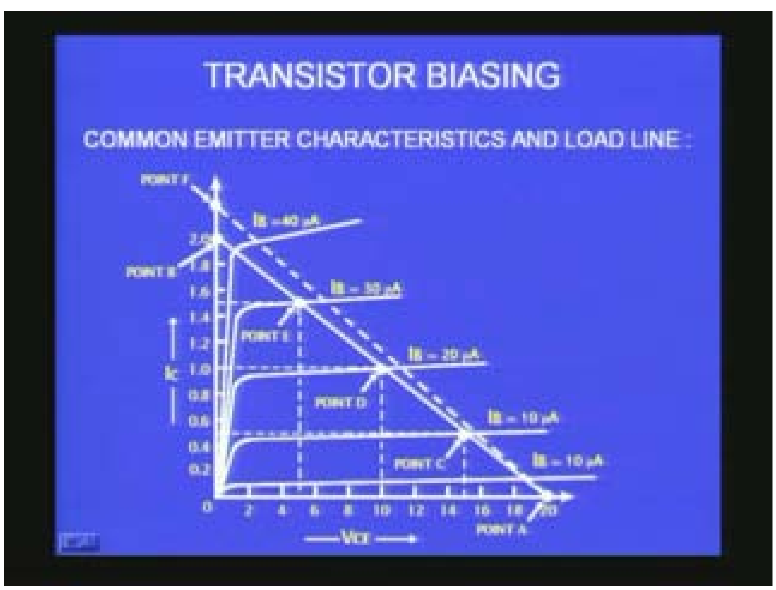

This corresponds to for example 1; this is corresponding to 15V when I have about 0.5 milliampere into 10K. This corresponds to 10V. When I have 1 milliampere I_C this corresponds to 5V. That corresponds to 1.5 milliampere on current I_C. All these points are some chosen points. You can choose any of these points or in between but you will never find anywhere away from this line as long as you have the same V_{CC} supply and same R_C. That is what we mean by a load line.

What is the use of the load line? As I already told you I can choose up to 15 points very quickly. From the big graph I have now confined myself to one single straight line and I have to position myself somewhere along the straight line. Where do I position for the best performance of the amplifier is the next question that I should ask myself. Before we do that now let me see what will happen if I change the load R_C value to 9K. This is the same circuit similar to the previous one except that I have instead of the 10K resistor that I have here I replaced it by a 9K resistor.

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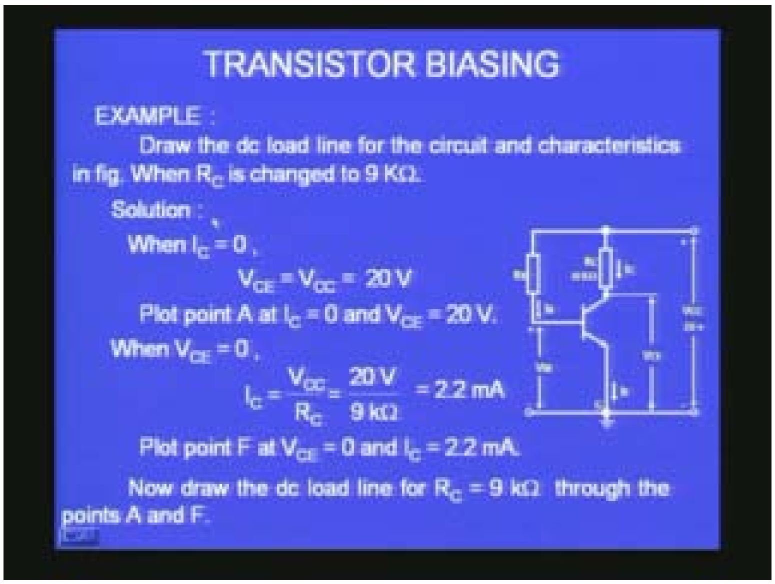

Then what will happen? V_{CC} is still 20V and V_{CE} when I_C is equal to zero is also 20V. One point in the graph is the same 20V on the X-axis. But when you come to the maximum current point or the point along the Y-axis I_C is V_{CC}/R_C. V_{CC} is again 20V but R_C has now changed to 9K and it has become a new current 2.2 milliampere and you will be in new point along the graph which is here corresponding to 2.2 milliamperes. The moment I have this point and this point I can join them by a line here. I have shown by a dotted line and this corresponds to a new load line because the load will change now.

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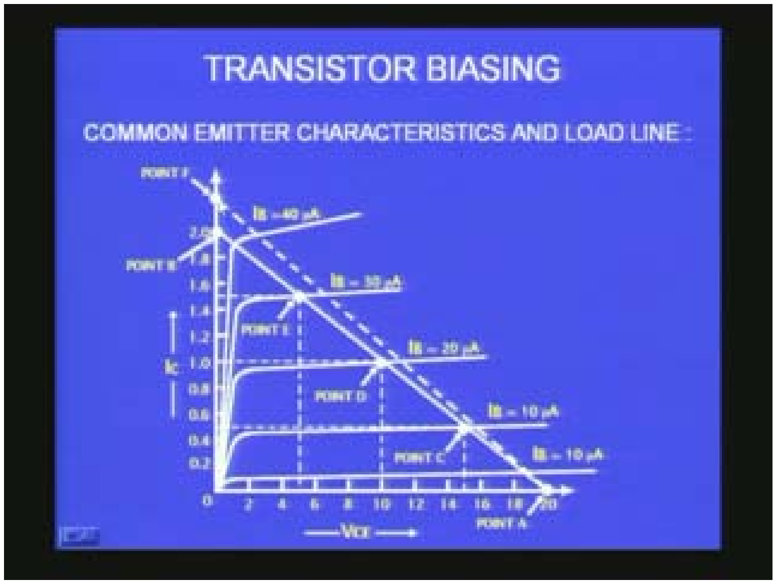

You have changed the load from 10K to 9K. You are obtaining a new line. Right! That load line will change whenever I change the load which is R_C or when I change the V_{CC}. When I change the V_{CC} also it will go somewhere along this line. So it will be a new point and when I change both that also can lead to this type of a new load line. That is what I want to show you. Let us move on to the next point. Let us assume that I put my amplifier somewhere in the middle here. If I put it in here that means I choose I_B to be 20 microamperes; I choose I_C to be somewhere here close to 1 milliamperes and V_{CE} is around 9.5V. If I set all these voltages and currents by biasing my transistor in different ways, I will discuss in detail little later, then I will be operating at this point. This is the Q point of my amplifier.

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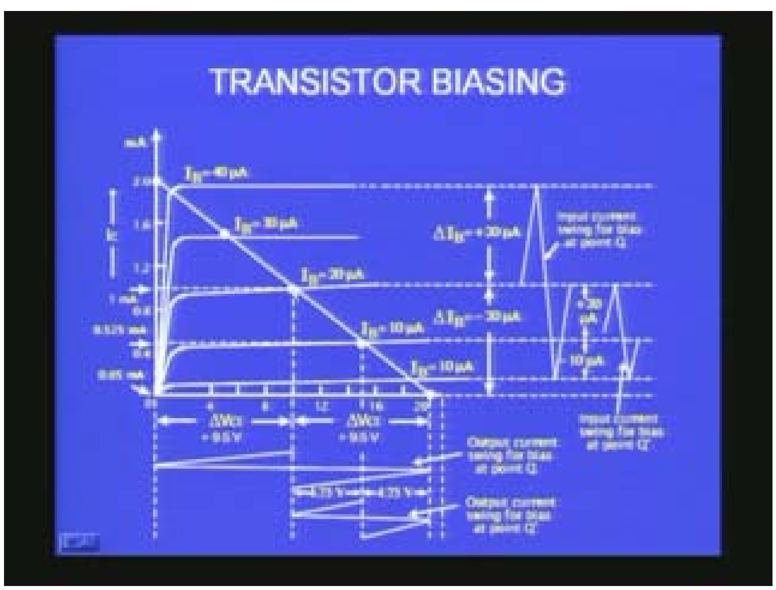

If I apply a variable voltage or the AC signal to the base of the transistor then what is going to happen? Over this voltage which is required at the base to provide a current of 1milliamperes I am superposing another alternating voltage. The effect of this alternating voltage is to vary the voltage I applied at the base slightly by the amplitude of the AC signal. When that happens base current can vary according to this change. When the base voltage together with the AC applied voltage increases I will move along this line and go to may be the new position corresponding to I_B equal to 30 microamperes and when I go down I will come below the operating point Q, chosen point to a value for example 10 microampere below. That means my current 20 microamperes is going to vary plus or minus 10 microamperes due to the AC signal that I apply which is understandable. When the base voltage increases base current also should increase when the base voltage decreases base current decreases.

Operating point will start shifting when I apply an AC between I_B equal to 10 micro amperes to I_B equal to 30 microamperes even though at the beginning no AC voltage was applied I was at I_B equal to 20 microamperes. When this happens corresponding to these two points the collector current also changes. This is around 1.4 or 1.5 milliamperes and this point corresponds to about 0.5 milliamperes. When the base current changes by a very small 10 microampere range the collector current changes from the operating 1 milli ampere to nearly 1.5 to 0.5 milliampere nearly about plus or minus 0.5 milliamperes and that when passed through a R_C of 10K can give me 0.5 into 10, 5V plus or minus 5V. That is what is shown here. I can get a swing of about 10V above this chosen point when I have this point.

If instead of this point I have chosen my operating point at the beginning to be this point then for the same variation of the signal at the input I will be moving from here to here. That is I_B is equal to zero to I_B is equal to 20 microamperes and that way I will get into trouble because this is already in the cutoff region. I should never come into the cutoff region when I am designing an amplifier. It is always good to choose the point which is at the center of the load line so that it allows for equal excursion on both sides of the chosen point. If I go towards this end or towards that end one side the range of available distances are very, very limited and you will get into what is known as distortion of your signal. If I apply a sine wave I will not get a true sine wave at the output. It would be a distorted sine wave because at beyond some point I enter into a saturation region or the cutoff region as the case may be. The general rule is to try to choose a quiescent point which is at the center of the load line. Thereby you will have equal excursions. But this also brings in the concept that there is only limited amplitude of the signal that I can apply without distortion to get it at the output. If my input signal is too large that means it goes from -20 microamperes more than 20 microamperes on the either side I will enter into the cutoff region and the saturation region and it will lead to some distortion in the output. In general by drawing the load line and choosing the Q point I will become very familiar with the maximum amplitude that I can apply at the input to obtain undistorted wave at the output. This also is one of the very important considerations in looking at the load line.

Let us move on to the different biasing circuits. One of them is a very simple biasing circuit that I already discussed with you that is you use the voltage supply for the base and you use a base resistor.

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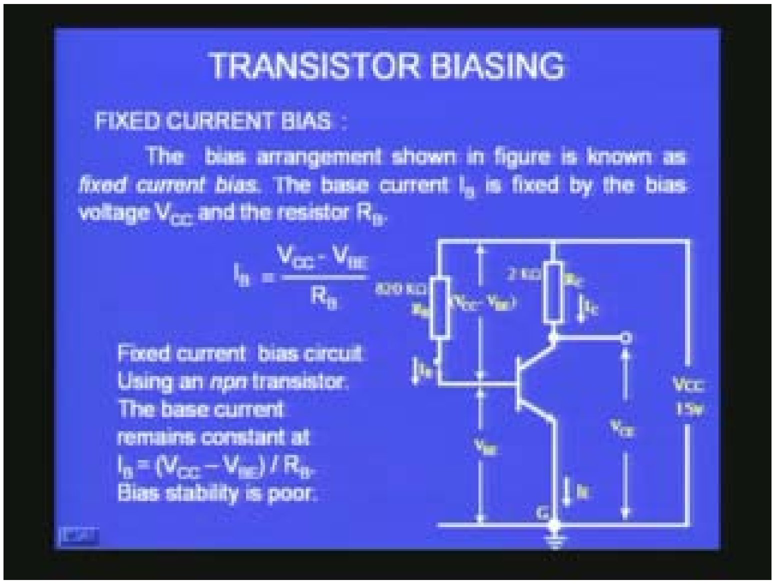

But instead of using a separate power supply for base you already have a V_{CC} supply and I can take the base resistor and connect it to the V_{CC} there. The same V_{CC} is providing the I_B as well as the I_C that I require. This is a very simple scheme of biasing the base by providing a constant current for the base. For considering this type of biasing circuit all the knowledge that you have to have is just simple ohms law and some basic circuit ideas like the KVL and KCL.

Can we calculate what will be the base current for the given case here with V_{CC} 15V and the R_B the base resistance 820K ohm? What is the base current? As far as this circuit is concerned there is a voltage drop across the base resistor and there is a voltage drop across the base emitter junction of the transistor and then you are back at the ground and the voltage across this plus the voltage across the V_{BE} should together add up to 15V according to KVL, Kirchoff's voltage law. I_B is nothing but the voltage available across the resistor which is on this side V_{CC} and this side V_{BE}. V_{CC} - V_{BE}/R_B, the value voltage divided by the resistor is current according to Ohm's law. This is simple assertion of Ohm's law that V_{BE} usually depends on the nature of the transistor whether it is a silicon transistor or germanium transistor. Most of the silicon transistors when it is conducting reasonably well it should be around 0.7V; 0.65 to 0.7 usually it is taken as 0.7. V_{CC}-0.7 by R_B will be the base current. In this case V_{CC} is 15V-0.7 which is about 14.3V divided by R_B which is 820K ohms. If you work out 14.3/820 this is Kilo ohms, that is voltage. The whole thing will come in the microampere. I_B will be approximately few micro amperes. That is what this circuit is used to set.

What about the V_{CE}? Can I get the value of the V_{CE}? Yes. You can also get the value of V_{CE} and I_{CE} from this circuit. This is from the load line. We have already discussed that. 15V you have 2Kohms there is a voltage drop across the 2Kohms and the balance is available at V_{CE}. If you measure V_{CE} you can calculate I_C or if you know what the I_{CE} is you can calculate V_{CE}. But I_C and I_B are related by another factor. That is called beta the current gain, DC current gain of the transistor in a common emitter configuration and the current gain is nothing but almost equal to I_C/I_B. That is the current gain and if I know the current gain of the transistor which also can be obtained from the characteristic curve then I can find. If I know I_B I can calculate I_C. I_C is nothing but beta times I_B. I know I_C. Once I know I_C, I_C into 2K ohm gives me the voltage drop across the R_C. V_{CC} minus R_C is V_{CE}. I can immediately find out what is my V_C, V_{CE}, what is my I_C, what is my I_B. That means I know where exactly on the load line I have my Q point. The biasing now here means choosing the proper value of R_C, I_B and thereby getting a given value of I_B, I_C and V_{CE} and that is what we mean by biasing. This is a very simple scheme of base bias.

I have worked out some values here. Let me see. We want to design a fixed current bias. That circuit I have shown there is using a silicon transistor that means the V_{BE} is about 0.7 having a beta DC value of around 270; typical value and V_{CC} is 15V, the DC bias condition. What we want is we want a 6V V_{CE} and I_C should be around 5 milliamperes. You can choose an approximate value like that.

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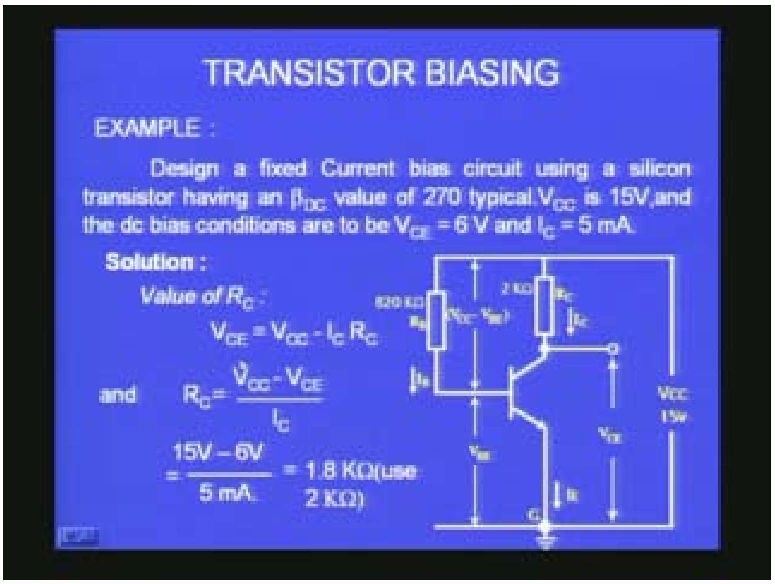

R_C is V_{CC} - V_{CE}/I_C; 15V you want 6V. 15-6 gives me the voltage across the R_C. That divided by the given current 5 milliamperes gives me the value of R_C. 15-6 is 9. 9/5 is around 1.8K ohm. So we can choose 2K ohms which is the nearest value available, preferred value. How do I get the value of R_B? To get R_B, I already mentioned to you that beta dc is nothing but I_C/I_B or I_B is I_C by beta dc approximately. I_C is 5 milliamperes, beta dc is given as 270 milliamperes. If you calculate it comes to around 18.5 microamperes.
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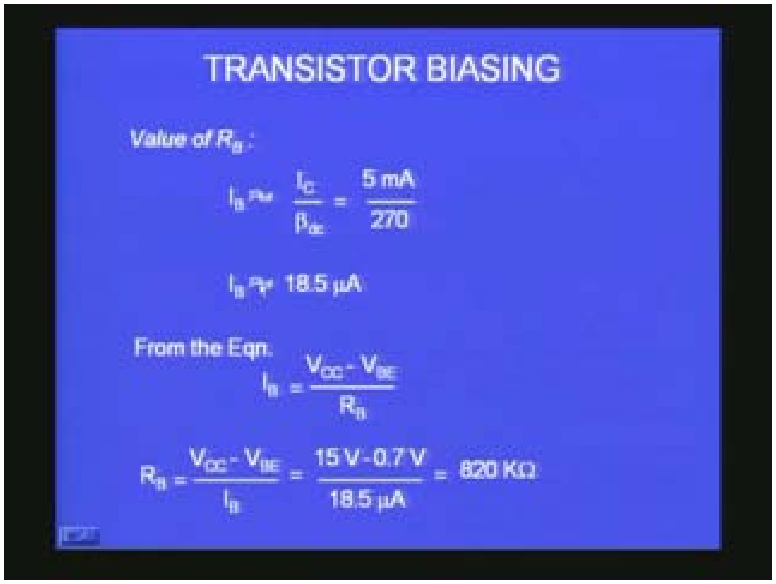

That will be the value of I_B. Once I know I_B I can calculate R_B. I am interested in knowing R_B. I_B is nothing but V_{CC}-V_{BE}/R_B. We have already seen. V_{CC}-V_{BE} for silicon transistor is about 0.7 divided by I_B, which we obtained as 18.5. When I do that I get approximately 820K ohm. When I put 820K ohm here and 2K ohms here and apply 15V power supply in this circuit I am very sure I will be very close to V_{CE} equal to 6V and I_C equal to 5 milliamperes as long as DC gain in the particular point is around 270 which is reasonably close, typical value.

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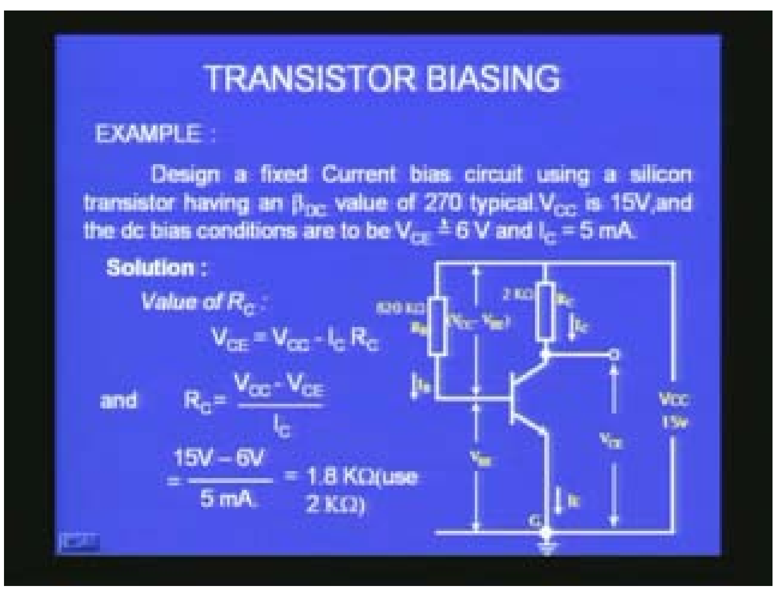

The results of the calculations V_{CE} is 6V and 5 milliampere is given to us and we have calculated that the current is around 18.5 base current and V_{BE} is 0.7 for silicon and the R_B value we obtained is 820.

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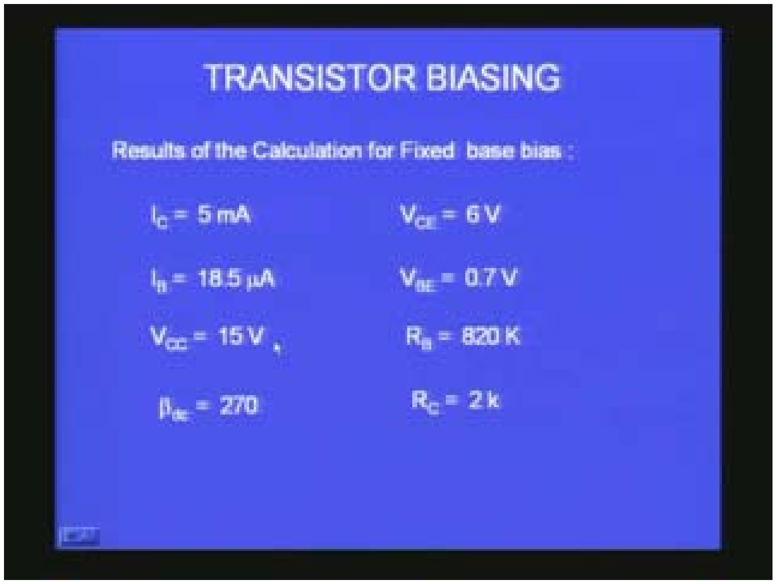

When we do this experiment later on you would find that this corresponds to the value that I have given. May be I will quickly go on to the working table and show you the same circuit and I would measure the different voltages. The voltages will be almost close to the values that we have obtained in this case here. You can see here the same circuit is shown. It is a fixed base bias circuit.

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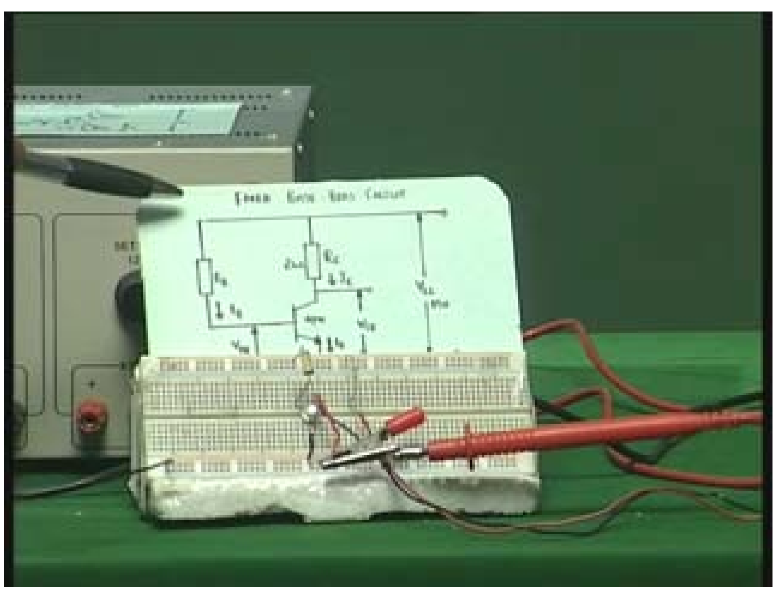

I have chosen from the same VCC supply; resistor R_B I have connected to the base of the transistor and the R_C is 2K ohms. This is the 2Kohm resistor and the color code you can see and this is the 820 K resistor that you just now obtained for the circuit and the emitter is grounded. This is the transistor and between the 2K ohm and the collector I have connected the current meter and this is actually the voltage point. The collector point I have connected here to this multimeter which I will switch on. The multimeter is now switched on and the other end of the multimeter is connected to the ground; the voltage supply is taken from here. Let me switch on the power supply. The power supply reads around 15V, 14.9V

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I connect this power supply to this circuit. The moment I connect I have 820K ohms at the base and I have 2K ohms as the R_C and the transistor is there. I am monitoring the collector voltage and the collector voltage is around 6.72. We wanted to have around 6V. It is around 6.7 and you can see the current is about 5 milliamperes.

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The same thing which we designed there we have implemented here. The voltage and the current are very close. There are some changes for example instead of 6V you are getting about 6.6 and that is because these resistors have got some tolerances as we all know. It may not be exactly 820K ohms and this 2K ohms may not be exactly 2K ohms etc. So due to small variations in these you are getting slightly different value of voltage or current. But this is quite possible in any given amplifier circuit and this small variations in general will not make any great variations in terms of the performance of the amplifier.

Now we saw one biasing circuit which involves a base resistor which is connected between the V_{CC} and the base of the transistor. But there is also another way of constructing a biasing circuit and that I will show you on the picture. You can see on the picture instead of connecting this base resistor to the V_{CC} supply here I have connected to the junction between the collector and the R_C. That means I am getting the voltage from the collector. The collector voltage is used for driving a current through the base.

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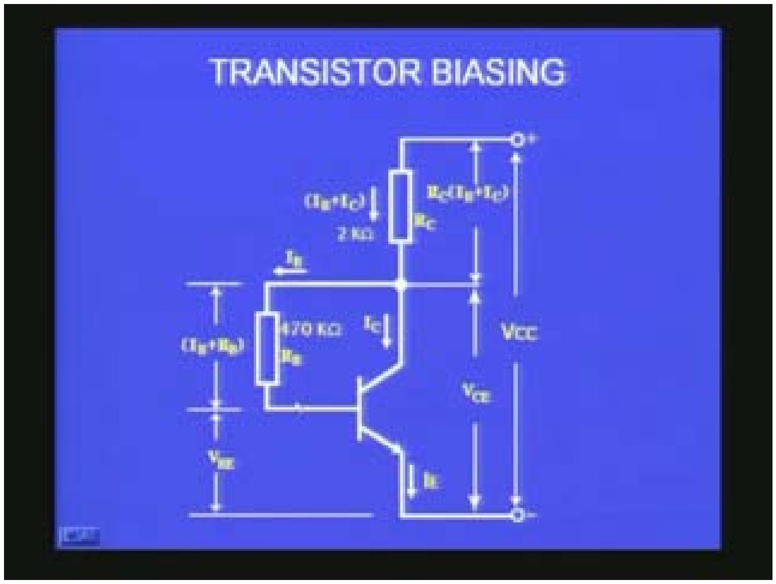

This is called collector base bias. Collector is used to bias the base and now you can see it has got certain advantages over the previous circuit again to understand the circuit all that you need to have is simple ideas of Ohms law.

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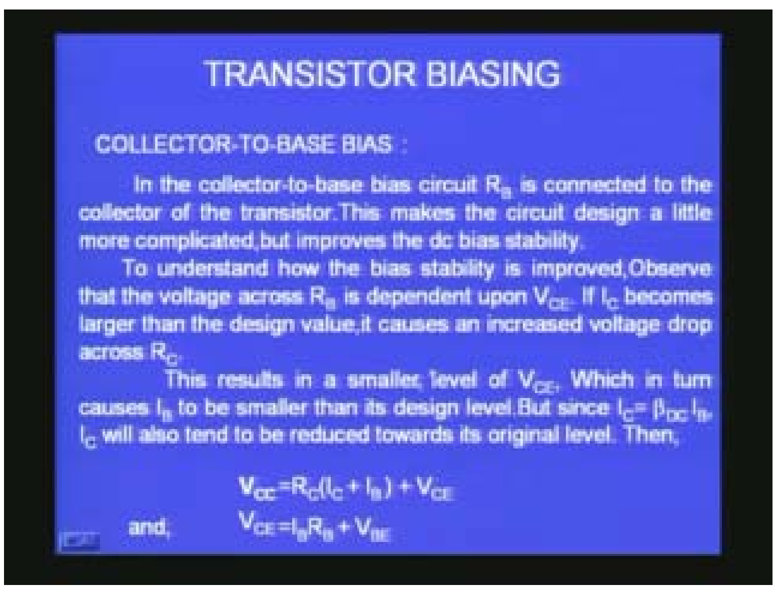

What is going to happen? You have the current flowing through the R_C. The current flowing through the R_C previously was only I_C. Now this is actually dividing here. I_C is the current actually flowing through the collector and there is also another current which is flowing through that. That is called I_B. What flows through the R_C will be now I_B+I_C because the total current I_B+I_C divides into I_B and I_C here and what we get is an I_C there and this comes out as I_B. We must remember in our equation instead of using I_C I should use I_C+R_B for the R_C and V_C now will be V_{CC}-R_C into I_B+I_C. That is what will give you this V_{CC} and to get IC what I have to do? V_C-V_{BE}/R_B. V_{BE} is 0.7 for silicon transistor. V_{CE} is the voltage of the collector. V_{CE}-0.7 divided by R_B will give me I_B.

I have given a problem here. Design a collector to base bias circuit for the conditions specified in the example. What it that? It is same as the previous one. V_{CC} is 15V and now V_{CE} is chosen as 7.5V. In the previous circuit we had only 6V. Now we can have 7.5V. Beta is 270; the current we want is around 4 milliamperes. I_B is I_C divided by the current gain. 4 milliamperes divided by 270. This is around 15 microamperes.

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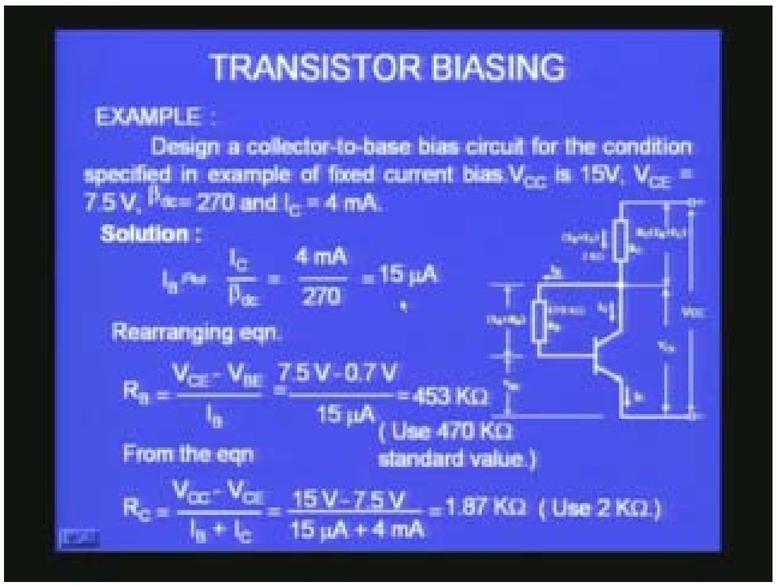

Once I know I_B now I can find out R_B which is V_{CE}-V_{BE}/I_B. It is not V_{CC}. In the previous case it was V_{CC}. Now it is V_{CE}-V_{BE}. 7.5-0.7/15. That comes out to be around 453K ohms. We can use the nearest value 470K ohms as the standard value. What is R_C? R_C is V_{CC} minus V_{CE} divided by total current I_B+I_C. That we already discussed. 15-7.5 divided by 15 microamperes plus 4 milliamperes and the value is again 1.8K or 2K ohms. When I do this you would find again the corresponding voltages will be obtained.

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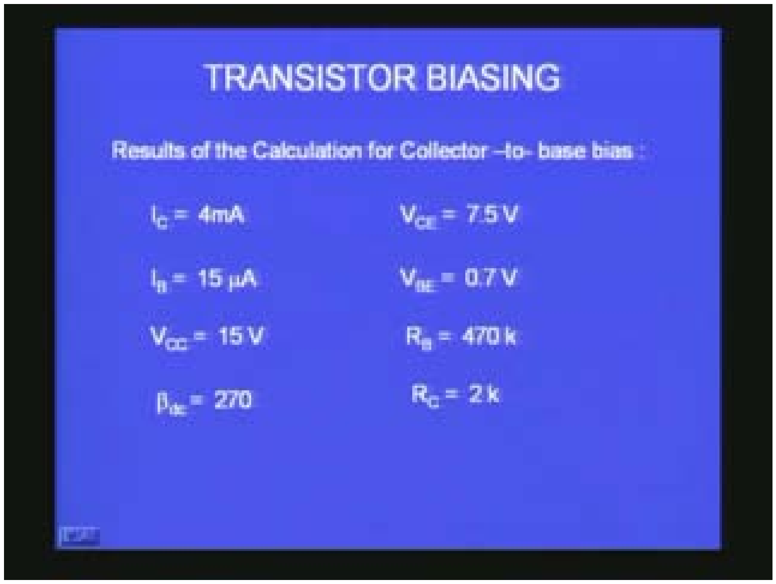

I will quickly modify the circuit and show you the corresponding values. You see the circuit here. It is now the collector to the base bias. The collector terminal is used to collect connect the base resistance and other than that everything will be the same.

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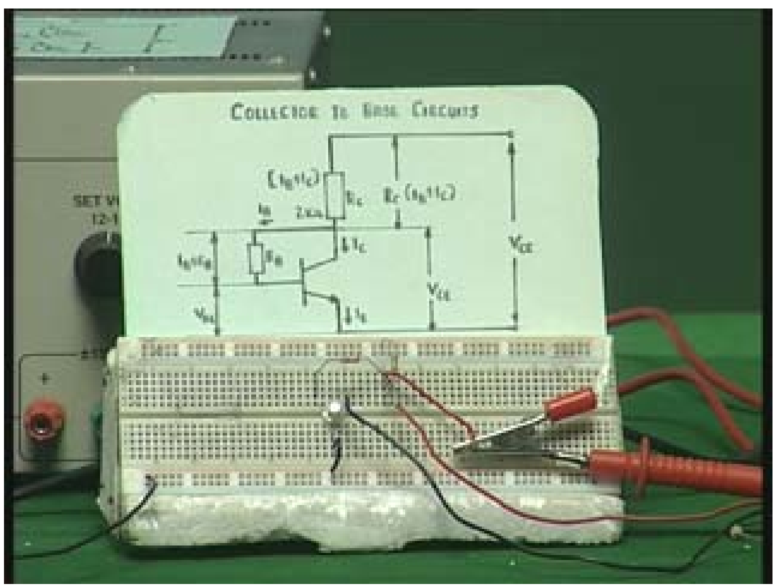

This is the resistor which is connected from the base to the collector. That provides the base current bias. Again we have fifteen volts here you can see about 14 milliampere and I have the current meter here which measures the I_C and this is the voltmeter which measures voltage across the collector. Now I connect the power supply. The moment I connect the power supply I get a current here.

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If you carefully observe it is slightly less than 5 milliampere. It is about 4 milliamperes and the voltage that is measured is 7.76. We wanted 7.5V. That is coming to be 7.7V. The difference I already mentioned to you is due to some small variations due to the tolerances of the resistor. The same transistor I have; the 470K ohm connected here and the 2K ohms as the R_C and correspondingly you get the same value which is almost what you wanted to obtain.

The collector current is 4 milliamperes; the V_{CE} is around 7.5V

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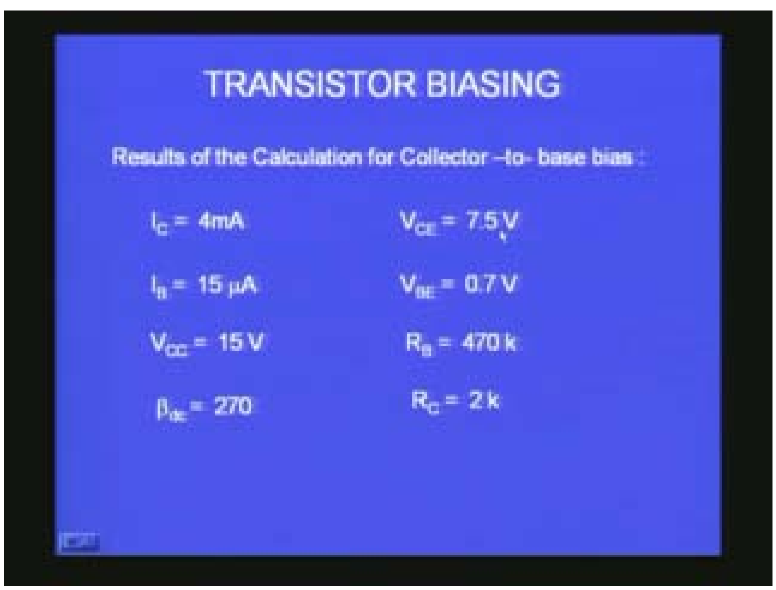

The I_B is 15 microamps; V_{BE} is 0.7 for silicon; V_{CC} is 15V; the RB we calculated to be 470K ohm, very close to 470 and the beta dc is 270, I assume for this transistor; R_C the load resistor is 2K ohm. We have now got two different types of biasing circuits. One is the fixed base bias circuit where I use the V_{CC} itself as a biasing voltage and I put R_B in series along with the base to provide a constant bias for the transistor. The second circuit is instead of using the V_{CC} I use the voltage at the collector V_C to provide the bias and so a resistor connecting the collector to the base was responsible for providing a base current and with these two biasing circuits we will have to have one more better, more useful or more common biasing circuit which is voltage divider biasing circuit with the emitter bias and that I will discuss in the next lecture. That has got slightly better performance in terms of stability.

I use new term stability. I have to explain to you what I mean by stability. We will discuss in the next lecture about the voltage divider bias, the emitter bias and then I will also discuss about stability and how the three different biasing circuits that I discussed will perform in terms of the stability. All those things we will see and then we will move on to look at amplifier making use of the transistor. So far what we have done today is to look at the load line transistor output characteristics and how the load line is a very important part of the design of any amplifier and then we discussed two different biasing circuits, the base bias and the collector to the base bias. Thank you very much.