Introduction To Electronic Circuits
Professor S.C. Dutta Roy
Department of Electrical Engineering
Indian Institute of Technology Delhi
Module No 01
Lecture 28: Bipolar Junction Transistors

This 28th lecture, we talk about bipolar junction transistors.

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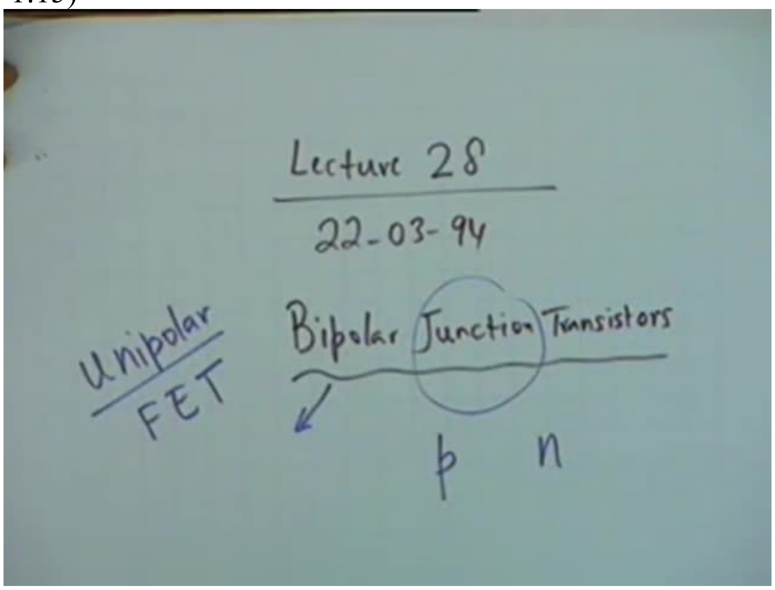

The meaning of the word junction should have become clear to you by now. A junction is created when two dissimilarly doped semiconductors are brought in close proximity of each other. For example, a p and an n type, two dissimilarly doped semiconductors are brought in close proximity of each other, a junction is created. The meaning of the word bipolar implies, the word bipolar implies that there is something called unipolar. Well, in a bipolar transistor, the carriers other current carriers passed through regions of dissimilar impurities, that is carriers pass through p as well as n type of material.

Whereas, there are unipolar transistors in which the current carriers, the electrons and holes passed through only one type of material. All right? We are, we shall not consider such transistors in this course. Such transistorsin which the adjective is unipolar instead of bipolar are also known as field effect transistors, FETs. We shall not consider such transistors in this course. We will consider only bipolar because of their many advantages. Bipolar means that the current carriers have to pass through impurities, pass through materials of different characteristics, p type as well as n type. Now comes the word transistor.

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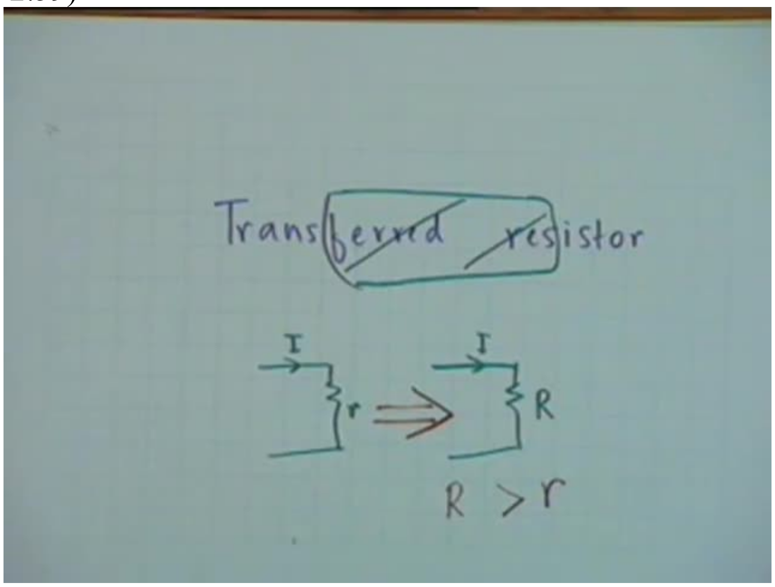

The word transistor was coined from a transferred resistor whereyou delete this portion, then you get transistor. Transistor actually is an abbreviation for transferred resistor. And to understand why it is called a transferred resistor, suppose I pass a current I through a small resistance R and by a device mechanism, by a solid-state device mechanism, the same current is made to pass through a larger resistance, capital R, then obviously the voltage developed, there is a transfer here. There is some transfer mechanism in which the same current, capital I is made to pass through a small resistance at the input and a larg resistance at the output. All right?

Output, that means it is basicallyat least a 2 port, it is not a one port. All right? A transistor is basically a 2 port device in which the same current is allowed to pass through a small resistance at the input and a larger resistance at the output. And this is why we call it transferred resistor. That is from a small resistance, it is transferred to a larger resistance. Provided that the current is a constant then obviously the input voltage smaller than the output quality. The output voltage will be capital I times R and input voltage is capital I times small r.

And if capital R is greater than r, then obviously the output voltage is greater than the input voltage which means that there is application. This is the basic reason why a transistor is called a transistor. Transistor actually means a transferred resistor. Now to implement this concept, that is to allow a current, the same current pass to pass througha small resistance at the input and a large resistance at the output, the implementation is that you have 2 junctions. Instead of one, you have 2 junctions.

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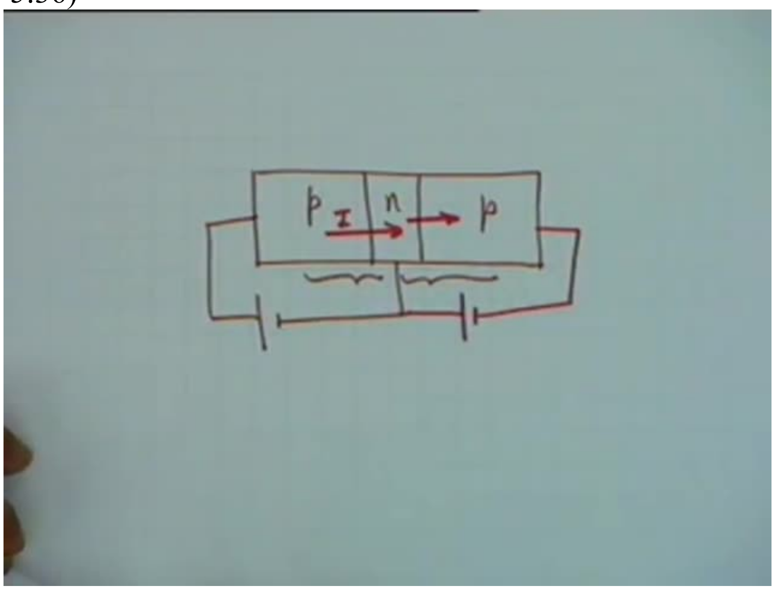

And typically you could have let us say a pnp configuration like this where I am showing only a cross-section. You could have 2 junctions like this.Metallurgically prepared, they are not juxtaposed, that means you do not make a junction and thenjust make a contact between the 2 junctions. No. It is metallurgical fabrication and how it is done, we shall look at it in a moment. But notice that there are 2 junctions here. One is this PN junction and the other is this NP junction. There are 2 junctions.

Now you know that ifthis PN junction is forward biased, if this PN junction is forward biased that as this is connected to a positive supply and this is connected to a negative supply all right, then current will flow through the diode easily. And this current can be a large current.What is the resistance of this junction? When it is forward biased, the resistance is ideally 0 but it is of the order of 10s of ohms, that is about it. On the other hand, is the same current, the current that flows through this junction, let us say capital I, if the same current is forced to pass into the other

P region, if the same current is forced to pass into the other region and this junction is reverse biased, in other words this N is positive and this P is negative.

All right? If I connect a battery across this junction in the reverse direction, in the reverse direction, very little current flows and therefore the resistance of the diode is high, ideally infinite. Now the current that passes through a small resistance in this PN junction, if the same current is forced to pass through the high resistance of a reverse biased junction, then obviously we have achieved our purpose. That is we have transferred a low resistance into a high resistance and therefore this will act as a transistor and that is the basic reason why a transistor can amplify.

But before we do anything, before we go into the depth ofinto a close examination of this current transfer or resistance transfer, let us see how such a device is made. And we shall illustrate only one of the methods which is which gives you what is known as a planar structure. Is this visible? Yes, I think so.

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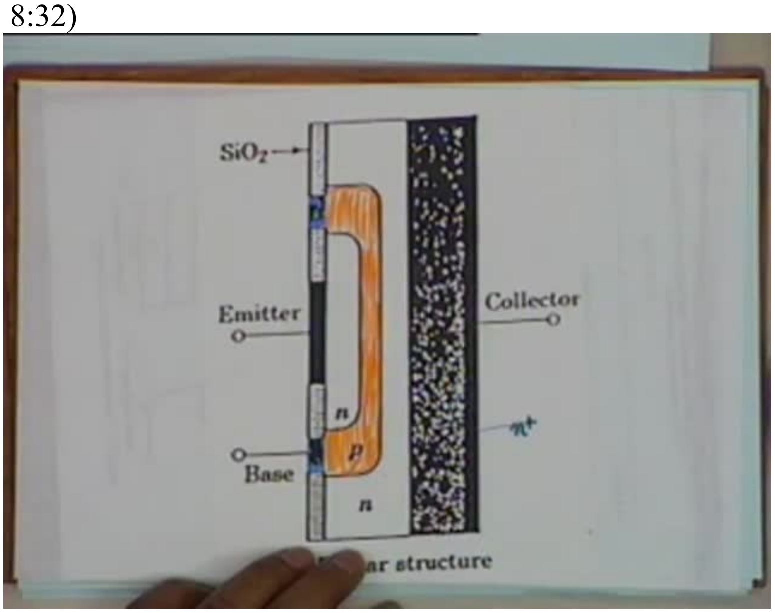

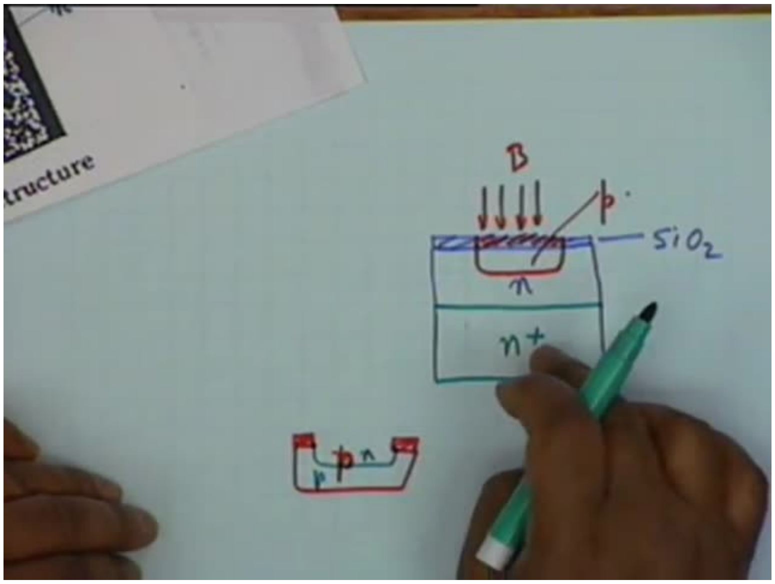

Well, what is done is basically we need two junctions. So what is done is 1st you start with a silicon, bulk silicon which is n +. n + means it is this + times for heavy doping all right? So basically this is a silicon block, silicon chip or wafer which has been which has been impregnated with n type impurity. That means either arsenic or phosphorus, the donor type of impurity and the impurity has been introduced in a large dose. It is highly doped, so it is n +. Now upon this n + silicon is grown a lightly doped n region, likely doped n region. Allthis colour stuff is not there.

What you do basically is takea silicon which is + and then upon this, you grow you grow by passing a gas of that material. There are other methods of doing this. You grow on this an n type region. That is the same silicon but lightly doped, less doped than this all right? Then what you do this, you subject it to oxygen so that so that the upper ocean isoxidised to silicon dioxide. And you know, silicon dioxide is an insulator perfect? Then you make select the etching, that means you make a mask with a window.

You make a mask with a window and pass chlorine or some other etching agent so that this dioxide disappears all right, the silicon dioxide disappears. Andyou allow a gas of let us say boron to pass. And this boron willnot affect this portion of the n type region. What it will do is, it will defuse inside the n region and create what? A p region. All right? Create a p region. Then what you do is you oxidise again. You oxidise again and then make another window all right?

So what we have is on n, no I am sorry, on p you have you have grown silicon dioxide and you have removed a part all right? Then you pass a phosphorus gas for examples so that so that what you do is, you make another n region. So there is an n, there is a p and then n and n + from which let us look at this now.

You have an n +, then you grew an n and by selective diffusion, you grew a p type material. By another selective diffusion, you made another n type material and then you make multiple contacts, gold or aluminium. Gold is the preferred one, you can also use aluminium. Now contact is here. One contact is here, that is below the substrate. That is a metal and this terminal you call collector. Then one contact is here, that is this p type material. Well, thecontact is it could be circular, it could break time, depending on the geometry of the wafer.

So the contact is here so this is called the base contact and a 3rd one is, this black region is also a metal deposition. That is it is a contact with n region and this is called the meter all right? There are 3terminals, emitter, base and collector.

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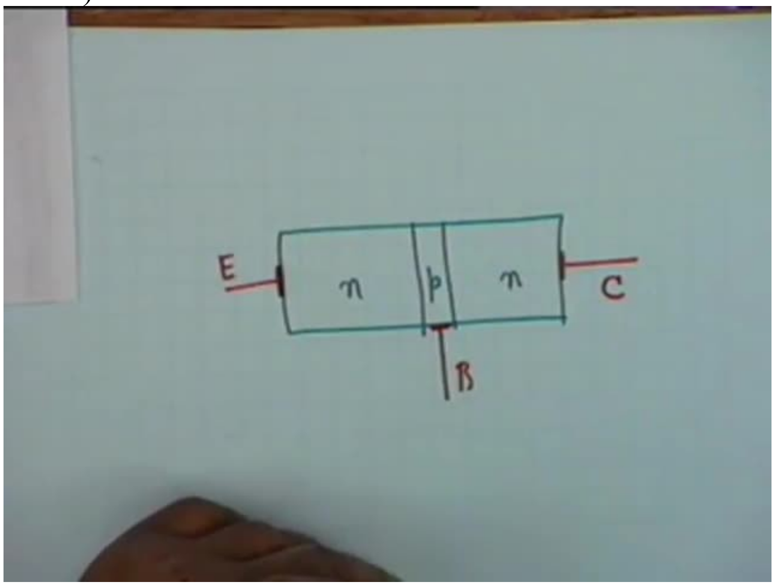

And in a simple diagrammatic representation, we shall simply represent it by means of a block like this though we have n type, p type and n type or stop then we have taken contacts like this. We have taken a contact like this and a contact like this okay. This is my emitter, this is base,this is collector.

Student: Sir, what is the use of n +?

Professor: What is the use of n +? n + is almost like a metal all right? n + is almost like a metal, heavily doped semiconductor and therefore its conductivity is very large and therefore it behaves almost like a metal and then it allows a metal deposition very easily.

You see, whenever two dissimilar materials come in contact, there is a contact potential all right? However, if you make a contact between gold and gold, there would be no contact potential. The differential of conductivity between the metal and the semiconductor, if it is lower, the contact potential will be lower. So thecollector contact is made without a contact potential and the reason is very clear. Collector is usually the output terminal. The collector is to handle large currents and therefore it is necessary that the collector contact be as perfect as possible and it should be able to collect current and this collect carriers, this is why it is called a collector.

So the collector this is usually n + and then a metal contact. Actually, this whole region is collector, n, n + and then the metal contact. The metal contact is between metal and n + instead of n. It does not matter that muchin the case of base and emitter because very large currents will not have to be handled here, very large Power dissipation shall not occur there. Power dissipation occurs mainly at the collector all right? Why?

Because the emitter as I have told you, one of the junctions, the emitter base junction is forward biased all right? And therefore therefore a large currents may pass but at low voltage. So the product of voltage and current is low all right? Whereas the collector base is reverse biased. That is the high voltage and a large current passes. So the collector contact has to be as good as possible to be able to dissipate power.

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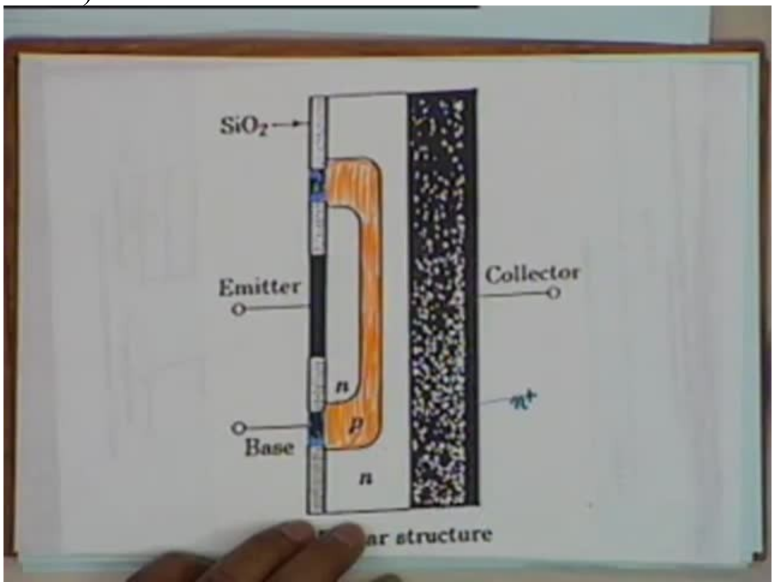

This also shows, it is an interesting question, it also shows that if the collector and emitter are interchanged, in theory, if I give you if I give you a schematic like this, there is no reason why C and E not be interchanged. But the fabrication is such that if you interchange this then the capabilities of the transistor become limited, the power handling capabilities become limited. And therefore, a transistor, in a transistor, the collector is identified by means of a dot. Ifyou see in the laboratory, thecollector is identified and the identified collector is to be used as the collector. If you use it in the inverse mode, that is emitter as collector and collector as emitter, the efficiency of the device becomes limited. Anyways, so you understand how it is fabricated.

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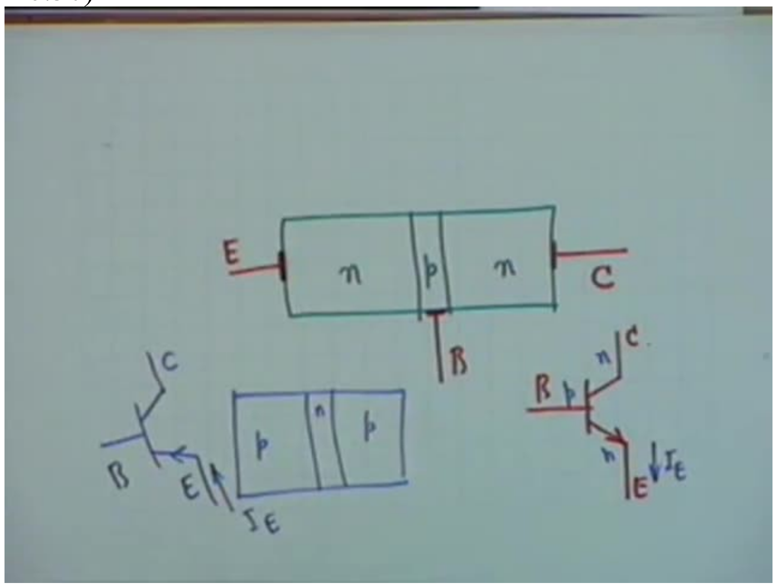

The the Such a transistor is schematically represented as a baseand then a vertical line. This is collector and this is emitter. The emitter is in order to distinguish between the collector and emitter, okay you have to distinguish between the 2 terminals,an arrow is added in the emitter. And the direction of the arrow has a very special significance. The direction of the arrow gives the actual direction of current at this terminal,the emitter current shall be in this direction. It gives the actual direction of the current all right?

And this shows that this is npn. An npn transistor shall be always like this, whereas there is nothing sacred between sacredabout npn. You could also have a pnp transistor in which the base region is n, the other 2 are p. Then this transistor shall be represented by the same symbol but the arrow shall now point in words. It should e remembered that this is the actual direction of the current, the DC, the actual direction of DC. If it is AC, it does not make sense to talk of direction.

Once it will flow like this, another time, it will flow in the other direction and so on. So it is DC that I am talking, actual direction of direct current that flows, it flows out of this terminal, it flows into the transistor in the pnp case. Now let us look at the operation. Howdoes it operate?

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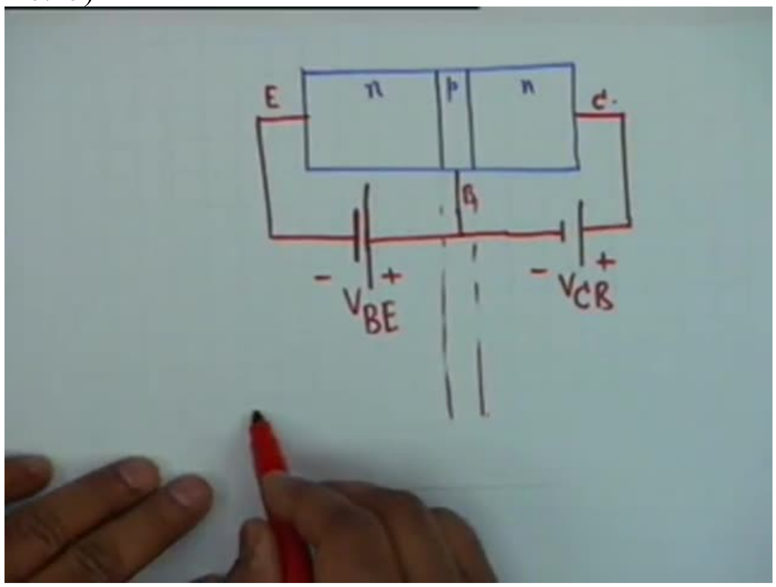

And for simplicity, let us look at an npn transistor. You must have been noticing thatI always drew the base region as a narrow region as compared to the emitter and collector. And it is indeed true, the base is a very thin region and this gives the transistor it's property. If it were very thick, thenyou would not get the property of amplification that we have been talking of. Now as I told you, the emitter base, this is emitter, this is base and this is collector. The emitter base region is forward biased. In other words, pardon me, this is wrong. Is it okay? All right?

The emitter base region V let us call it BE okay? The base is positive with respect to the emitter. This is forward biased. Now and the collector base region is reverse biased. That means you have this polarity is okay VCB +- all right? Now if you look at the barrier, potential barrier, there are 2 junctions now,np and np. If you look at the barrier, well normally normally when there are no biases, suppose these 2 terminals are not connected, the transistor is left open, open circuit it, well then what happens is let me draw it in a separate sheet.

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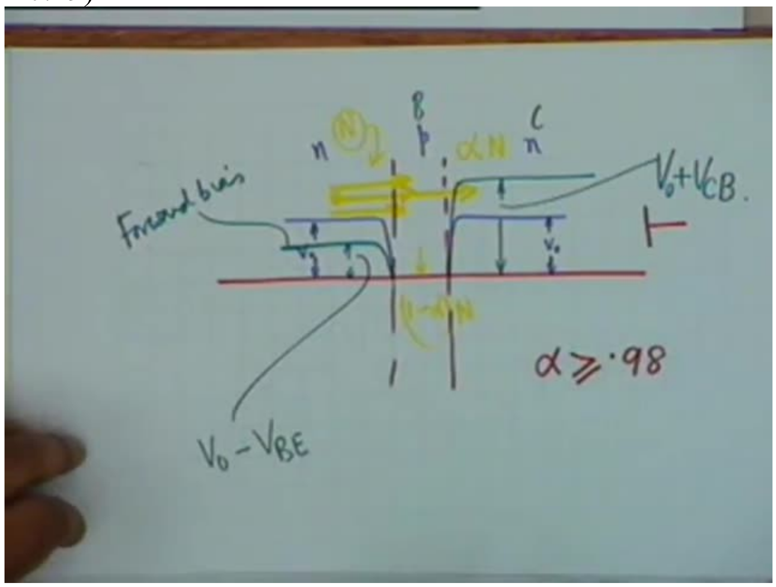

Let us say this is the, this is one of the junctions and this is the other junction. Then you know, normally there will be a junction potential or potential barrier at both the junctions and when the transistor is open circuited both of these will be of height let us say V0, both of these. This is n, this is p and this is n all right? If theinput junction, that is the emitter base junction is forward biased then this barrier shall come down okay? So with forward bias, it would be something like this.

Forward biased and this height shall now be V0 - VBE, the amount of forward bias all right? V0 - VBE. On the other hand, the pn, the collector base junction is reverse biased. So what happens? This potentialbarrier goes up and this height shall now be V0 + VCB. All right? So on the left side, the barrier is reduced, on the right side the barrier is increased. Now it is very easy now to explain what actually happens. Well, because of the lowering of the potential barrier, the electrons which are the majority carriers in the n type, the electrons now get encouraged to go to the base all right?

Electronsgo to the base. Because of the lowering of the potential barrier, it is a forward biased diode and normallyif the other junction was not there, if it was simply p then what would have happened? The current would have passed to the other terminal of the battery and put the battery. All right? But here, the battery is between the n type and the p type. And normally, this electron when it enters the p type region, holes are available and they should haverecombined. They should have recombined with the holes which means that they would simply pass on to the battery.

But this region is so thin that the possibility of a recombination is very little and most of the current most of these electrons pass overto the n region. Most of these electrons, they enter the p region with a velocity, with a kinetic energy and before they encounter a whole to recombine, well theyfind themselves in the n region. It is so thin that they is simply pass over and therefore most of the most of the electrons pass over to this region all right? A little portion, a small number of electrons, let us say a fraction alpha if we say that capital N number of electrons enter here, then a small portion, 1 - alpha N, they pass to the, they recombine in the base region.

Themajority of it, alphatimes n, they pass into the n region. What happens when they come to the n region? What happens? They go up the potential barrier. After all these are electrons and this is reverse biased. In other words, there is a battery with a positive terminal here which is trying to attract the electrons and therefore they are encouraged to climb this barrier, electrons can climb very easily. Electrons are encouraged to climb the potential barrier and pass to the battery which the effect theend result is that most of the majority carriers which start from the base, I am sorry which start from the emitter.

You understand the meaning of the word emitter now. They emit electrons. That is why it is called emitters. Well, most of the electrons are emitted by the emitter, the pass over to the collector. Some of them, a small portion cannot pass because they recombine. But most of them, in fact alpha, this fraction is greater than 0.98 greater than equal to 0.98. About 98 percent of electrons pass over to the collector region and a small portion, about 2 percent, they recombine in the base region all right?

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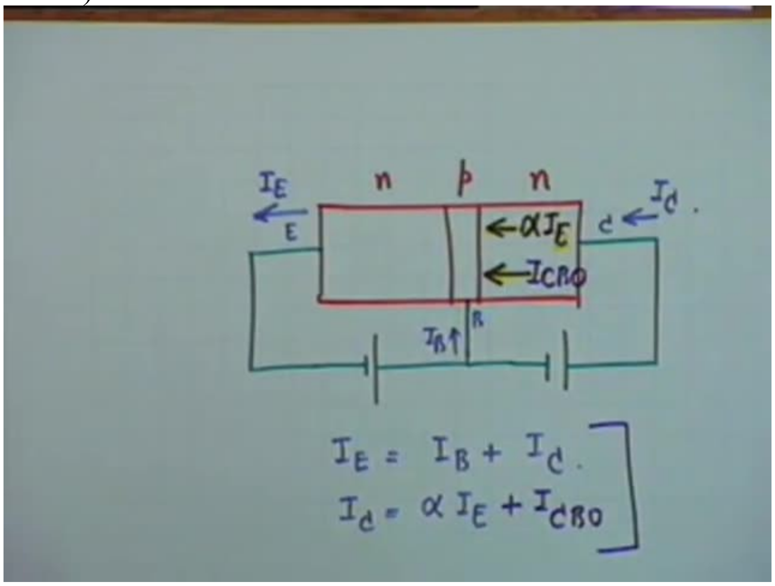

Now in terms of current, let me draw this figure again.This is p, n, n, this is the emitter region, emitter base is forward biased and this is reverse biased which means that you have positive and negative here all right? Nownotice carefully what is happening. What is happening?This emitter, let me name that, emitter, base,collector. This emitter emits electrons. When it emits electrons, what is the direction of current? Current is in the opposite direction and therefore, the current, when the emitter emits electrons, a current IE flows out of the emitter terminal into the battery. All right?

Now these electronscross over to the n region, some of them get lost. Some of them go, some of them recombine which means that it is as if this potential this positive terminal collects them. And therefore, electrons passing like this which means that a base currency flows like this,I sub B. Is that okay? And most of these electrons are collected by the collector which means that a current I sub C enters like this. So the relationship between the currents shall be I sub E by KCL, the total current entering, this is a 3 terminal device, the total current entering must be equal to the total current leaving.

So I sub E equal to I sub C + I sub B. Not only that, there is a relationship between I sub C I sub E. I sub C is almost equal to I sub E except for a small deviation and therefore, I sub Cis equal to alpha times I sub E where alpha is very nearly equal to 1. But it is less than 1. Alpha is less than

1 but very nearly equal to 1. Now in addition, in addition to this cause of current, there is another reason for a current flow and this is the minority carriers. All right? This junction is reverse biased. Now you know that in a reverse biased junction, there is a reverse saturation current and what is the direction of this current? Obviously, this is the direction of the current. All right? So due to I sub E due to I sub E, the current here is alpha I sub E.

Student: (())(28:57)

Professor: Yes. I will get wiser now.

Alpha I sub E, this is due to the electrons and due to the reverse biasing of the junction, this junction, there is a current I CBO which normally in a diode we call IS, the reverse saturation current. Here we call it I CBO, collector base junction and O stands for saturation all right? I CBO and therefore I sub C is alpha IE + I CBO. These are the 2 basic relations in a transistor. All right? The directions…

Student: same for pnp…

Professor: I amcoming to that. The directions have to be done carefully. That is why I 1st took the complicated case where the direction of the current and the direction of the majority carrier flow are opposite to each other.

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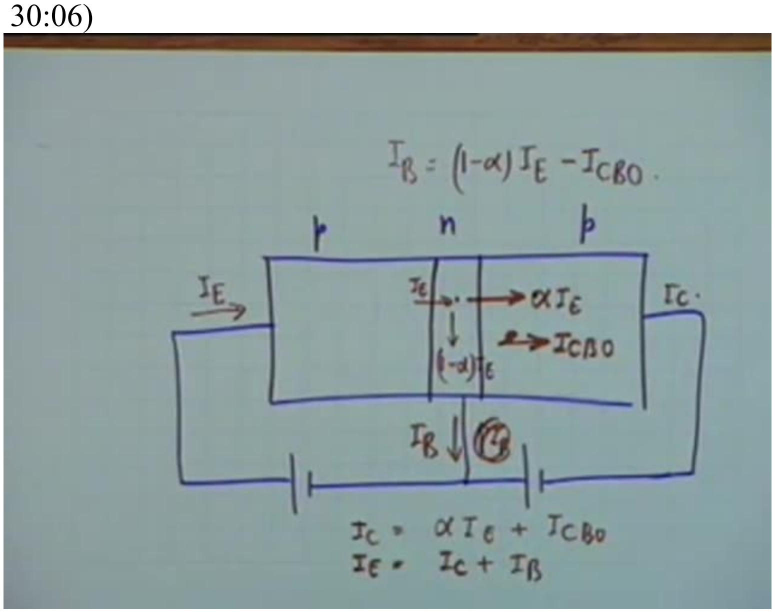

In a pnp, it is much simpler. In a pnp transistor,it is much easier to see in a pnp transistor. What is happening? We have, this is positive and this is negative and this is positive and this is negative. Therefore the current that enters now in the emitter region, IE, it enters because the emitter region emits holes, not electrons all right? Sothe direction of flow of carriers is the same as the direction of the current. I sub E enters here and alpha well let us see I sub E enters here, a fraction of it goes to the base, 1 - alpha IE and the other faction goes into the collector which is alpha IE.

In addition in addition there is a current, which direction now? Same, that is I sub CBO all right? So you can also now write a relationship for the base current. This is also obvious now. It is obvious that I sub C is equal to alpha IE + I CBO.I sub E equal to I sub C + I sub B as in the npn transistor. There is a 3rd relationship which is obvious, that is I sub B should be equal to yes?

Student: It is in the reverse direction.

Professor: That is correct.I sub B must now flow in this direction.

So I sub B is 1 - alpha IE.then?

Student:minus

Professor:- I CBO, correct. These are some of the fundamental relationships of transistor operation.

Student: Sir.

Professor: yes?

Student: (())(32:23).

Professor: Clear in this? Yes, there is current due to minority carriers.

Student: (())(32:39)

Professor: no, this alpha IE.yes what is wrong with this?

Student: alpha is the total number of majority carriers that passed through this.

Professor: No, alpha is not the total number, alpha is the fraction of the minority carriers. Well, these are minority carriers here. I am sorry. These are majority carriers here, minority here, then they become majority carriers here. In a forward biased junction, it is the majority carriers which take over. In a reverse biased junction, it is the minority carriers which take over. And therefore we ignore the minority carrier current all right? Okay.

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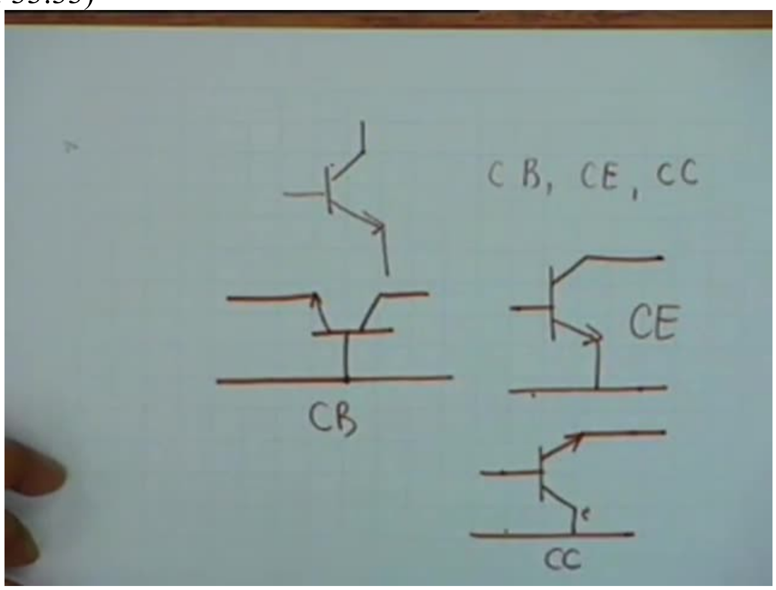

Now let us take a transistor and symbolically all right? Let us take a transistor in which well you know this is the symbol for transistor,npn transistor. Depending onthe common terminal between the input and the output, there are 3 kinds of configurations. These are called common base,common emitter and common collector. Well, a common base transistor is like this. That is simply a reorientation of the terminals, that is you apply an input. What kind of a transistor is this?npn, not pnp.

The arrow goes out okay. So the base is common between the input and the output and therefore this is called common base whereas this is the common emitter connection, input is between base and emitter, output is between collector and emitter and similarly you could have a common collector amplifier where the input is between base and collector and the output is between emitter and collector. This is the collector. This is called CC, common collector. This is CB, common base and this is common emitter, CE connection.

And the characteristics, the DC characteristics, DC characteristics, the amplification characteristics, the switching characteristics, all of them differ depending on the configuration and I must also point out that the most commonly used configuration the common emitter for its advantages. Let us look at these characteristics one by one. The common base for example.

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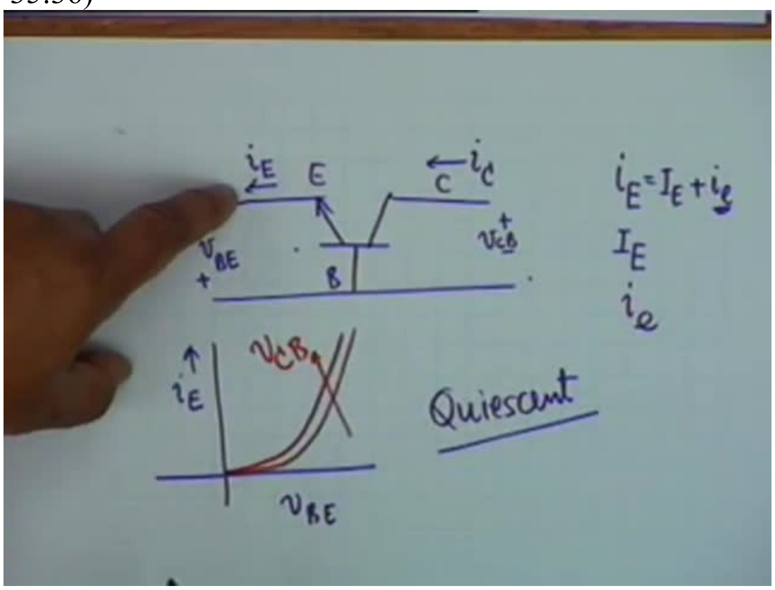

The common base is, this is collector, emitter and this is the base. Now obviously, in order to draw the DC characteristics, it is not a one port now. A diode is a one port and therefore you draw current voltage characteristics and that is it, nothing else. Here, that are 2 votes and therefore the characteristics now shall consist of 2 sets of curves. One is for the input and the other is for the output. Howeveryou must consider interaction between put an output. In other words, supposeyou indicate this voltage, what should benormally the polarity of this voltage?E shall be?

Student: E shall be negative.

Professor: E shall be negative and this shall be positive.

So VBE we call it. This is B, VBE, B is positive, E is negative. What about this polarity? V collector would be?

Student: positive.

Student: positive.

Professor: Collector would be positive and this would be negative. So we call it VCB. C is the positive terminal and B is the negative terminal.

What about the current? This current shall go out. Now note the nomenclature. We are using small i and the subscript is capital E. This terminology shall stand for the total current total current. Now let me introduce this terminology right away. WhenI say total emitter current, I use this. The DC emitter current, I use this, DC. And the AC part of the emitter current, I use this. All right, this is the terminology that we shall be using. The AC incremental part. In other words, small i subscript capital E shall be the sum of the DC and AC part.

This is the DC part or the quiescent part, quiescent,Q U I E S C E N T. This has a special meaning in the case of a device like this. Quiescent means in absence of any signal, in absence of an AC. If small iE is equal to 0, then it is i capital I sub capital E all right? If small i sub small e is the AC or the incremental part. This is the signal part. This is the part that we wish to amplify. All right? Okay, besides terminology, the current in the collector shall flow like this and we call this I sub capital C. Obviously, the input characteristic shall be the characteristic of IE with variation of VBE.

But then what is the effect of VCB? This also should have an effect, VCB should have an effect because the 2 junctions are in close proximity of each other. It is found that if VCB is very low, if VCB is very low, then the diode current you understand that this is simply a diode, this is a base emitter junction diode. And therefore the characteristic should have been simply this. If I plot IE vs VBE, the characteristics should be like this. All right? Now VCB does have an effect. If VCB increases, well, the diode current increases.

But there is a small variation. This is the direction in which VCB increases. All right? There is a small effect of VCB on the input diode characteristics. The input is obviously a diode,iEvsVBE.

The output characteristic is now extremely important. The output characteristics, that is IC vs VCB all rightthis is influenced tremendously by the emitter current. Why? Because majority of IC, most part of IC consists of a contribution due to IE.it is alpha times IE.

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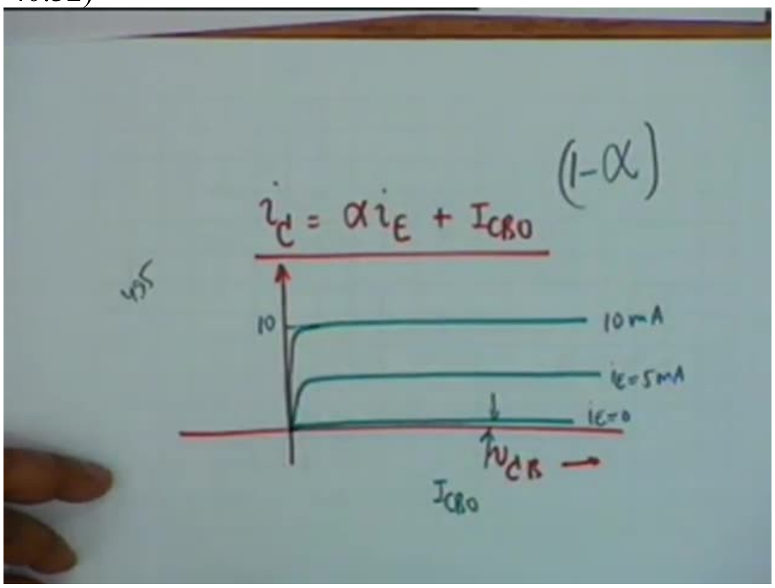

There is a small contribution to the reverse saturation current, that is you know that i sub C is equal to alpha times i sub E + I CBO. In other words, if I plot, now we also notice that this characteristic is independent of VCB okay? I sub C is independent of VCB and therefore if I plot this vsVCB, I sub C it should be a straight line parallel to the VCB axis. It is only determined by the emitter current IE and I sub CBO. When the emitter current is 0, when IE is 0, a small current should flow like this where this difference isICBO all right?

When IE is let us say 5 milliampere and alpha is 0.99, then the collector current should be 4 point how much? 95. 0.99 multiplied by 5?

Student: 4.95.

Professor: 4.95. Approximately 5. So the current shall rise to approximately 5 milliamperes.

When IE, this curve is for IE equal to 0, maybe this is for IE equal to 5 milliampere and so on. If IE is 10 milliampere, well the curve will rise like this. So the collector characteristics shall be a set of parallel lines like these. That is for equal increment of IE, there is equal increment of collector current. Is that okay? And collector current, that is this level is approximately equal to the emitter current. This will be approximately equal to 10. Is that clear?

The common base characteristics are extremely simple. The collector current is approximately equal to the emitter current. The difference is because of the factor, 1 - alpha.Why does this rise? This arises because there is recombination in the base region. That is one reason why the base is made very thin. So that recombination can be ignored. All right?

Student: Excuse me Sir.

Professor: Yes?

Student: Sir, collector base voltage is greater than the breakdown voltage, what will that mean?.

Professor: okay, good question. If the collector base voltage iscontinuously increased,if the collector base voltage, it is a reverse voltage mind you, if it goes on increasing, then somewhere or the other, one of the 2, either diode or avalanche shall take over and then the current shall rise like this.

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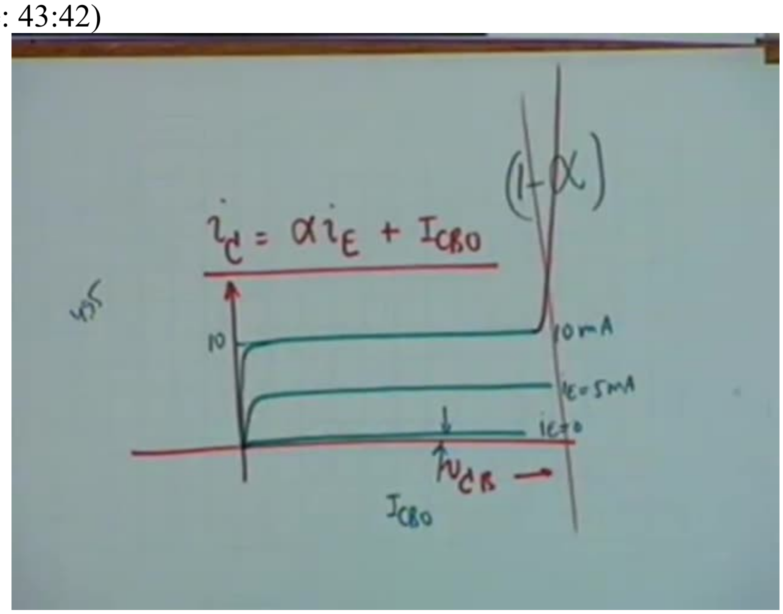

One never goes to this region. Why? Because the power dissipation capability, every transistor has a certain power dissipation capability and no transistor is made, is fabricated to dissipate the zener power. No transistor.Zener only with diodes. This operation may be irreversible and therefore one never goes beyond that region. So every transistor comes from the manufacturers with a spec of Pmax, that is you must not hesitate more than this amount of current. Any other question?

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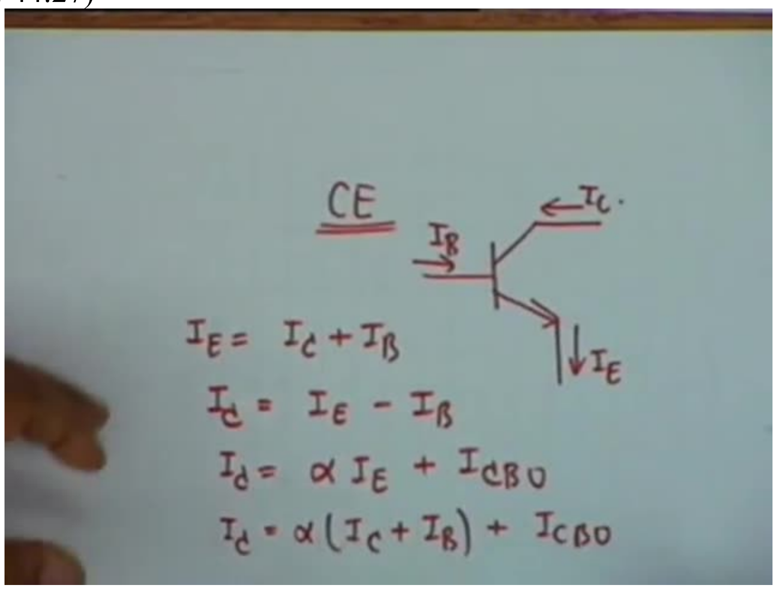

Let us look at the common emitter characteristic now. In common emitter, this is I sub E, this is I sub B and this is I sub C. The input current is now IB, not IE. The input current is IB but of course this position is valid, that is IE equal to I sub C + I sub B which means that I sub C equal to I sub E - I sub B. Is that okay? You also know that I sub C is alpha IE + I sub CBO All right? What we want to establish is the relationship between I sub C and I sub B, we do not want IE into the picture because the input current is now IB.

And therefore, I write this as I sub C alpha I sub C + I sub B all right?+ I sub CBO. I want you to look at this carefully.

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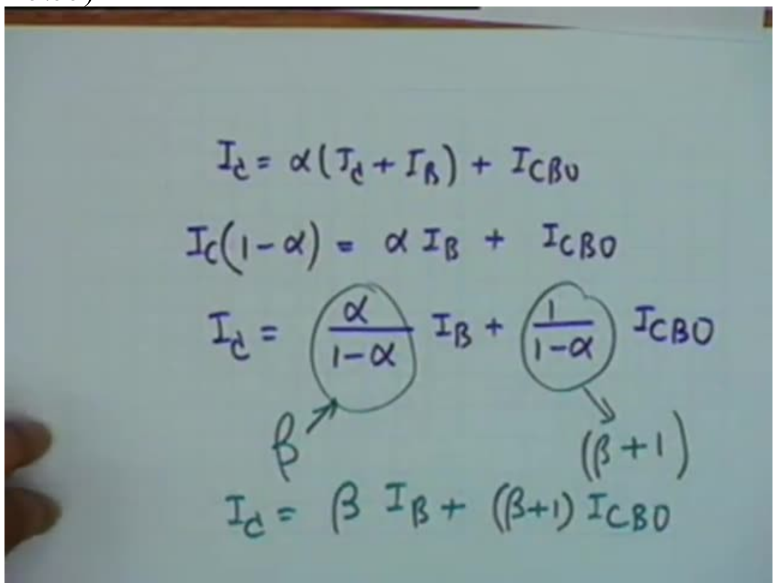

What I have is I sub C alpha I sub C + I sub B + I sub CBO which means that I sub C if I take this to the left-hand side, 1 - alpha shall be equal to alpha I sub B + I sub CBO all right? That means the collector current is now alpha divided by 1 - alpha times I sub B + one by one - alpha I sub CBO. All right? Look at this quantity, alpha by 1 - alpha. If alpha is 0.99, what is the value of this? 99.Is not it right? If alpha is 0.98 then?

Student: 49.

Student: 49.

Professor: 49. Okay.

So it isvery sensitive to small variations in alpha. This quantity is called beta. This quantity is named beta. Then you can see that 1 - alpha is nothing but beta + 1. Is not it right? If I add 1, I simply get 1 by 1 - alpha. Agree? Andalpha is a quantity slightly smaller than unity, beta is a quantity usually much larger than unity and therefore, my relationship is IC equal to beta IB + beta + 1 I sub CBO.

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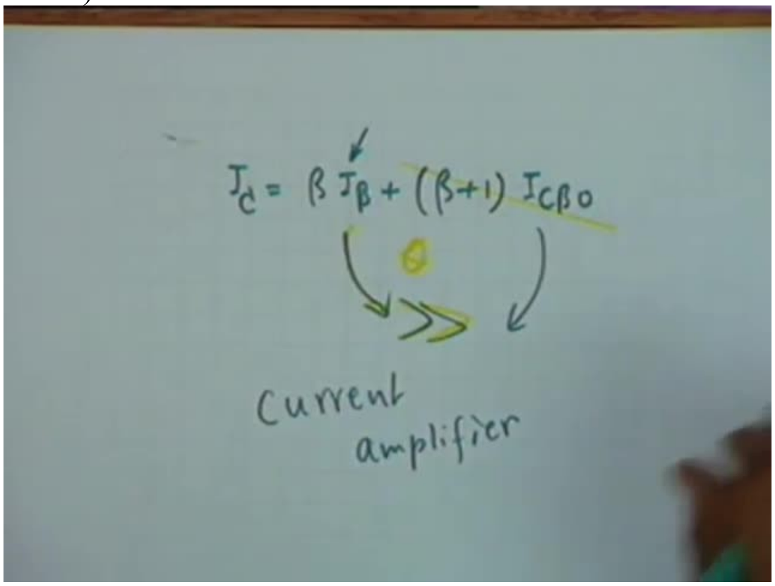

Take a specific case . I sub C code to beta I sub B + beta + 1 I sub CBO. This current, I sub CBO is usually a very small current of the order of microamps, we guys of the order of 100. So 100 times microamps become 0.1 milliamps. I sub B is of the order of milliamps and we guys of the order of 100. So this quantity becomes of the order of 100 milliamps whereas this becomes of the order of 1 milliamp. Was it 1 or 0.1? 0.1. And therefore, this quantity would be negligible compared to beta IB and this is the ideal situation.

Ideally, we do not want I CBO. Ideally, we do not want I CBO. Why do not we want it? Because I CBO is a function of temperature. This is one of the reasons and the other reason is, it does not change with IB. That is if I inject a signal at the base, this quantity remains a constant. Nevertheless, this quantity is much less I beg your pardon. The 1st quantity is much greater than the 2nd quantity. This quantity is much greater than the 2nd quantity. Now this shows a very interesting thing that if you put a 1 milliampere at the base, at the collector you could get 100 milliampere which means that the transistor in the CE mode acts as a current amplifier.

A transistor in general can amplify voltages because of transferred resistance, lowresistance to high resistance. A transistor in the CE vote can amplify currents by a factor of beta. Beta is alpha divided by 1 - alpha.

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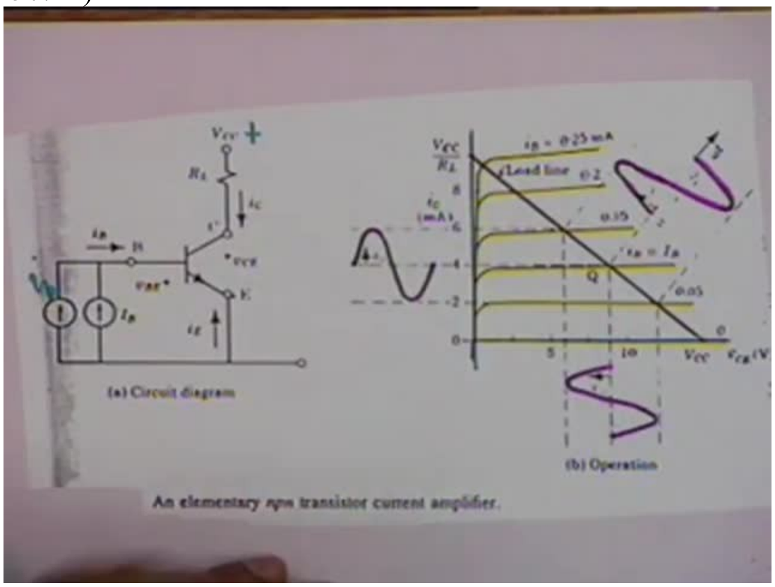

I want you to look at this figure before we disperse. I have shown here a common emitter, is the figure all right? I have shown here a common emitter connection. Collector, emitter, base. And to the collector is connected a positive supply, VCC, it is a positive supply. There is a resistance RL here and the current I sub C obviously is limited by RL all right? RL will have an effect on the current I sub C. In fact, VCE this voltage is equal to VCC - the drop in RL which is IC times RL all right?

On the other hand a current I sub B enters here and you can see that it contains 2 parts, one is the DC part or the quiescent part and the other is the signal part, small i sub small b okay? And it is this current, I sub C or this voltage VCE which varies in accordance with I sub B. This characteristic shows this more clearly. This is the line which gives a plot of VCE equal to VCC - I sub C RL. It is superimposed on the characteristic curve and the intersection of this with the quiescent condition, that is IB equal to capital I sub capital B gives the operating point Q.

And Q, the symbol Q no longer for quality, Q is quality in resonant circuits. This Q is for quiescent point. It is from here that we will start our next lecture after the midsemester break.