Basic Electronics
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Module -5
Power Circuits and System
Lecture - 4
Power BJTs

In the last classes we were discussing about power amplifiers and the power amplifiers are those amplifiers which handle large amount of current, voltage and power. The transistors which are used in the power amplifiers must also have ratings which should be higher than those which are used in small signal amplifiers. Today we will discuss about the power transistors which are used in power amplifiers. They are special transistors which have the capability to handle large amount of current, voltage and also can dissipate large amount of power. The limitations on a transistor, as you know, are from current. That is the maximum current, which is maximum rated current and in power transistors the maximum rated current is in the order of amperes. So, it is a high current.

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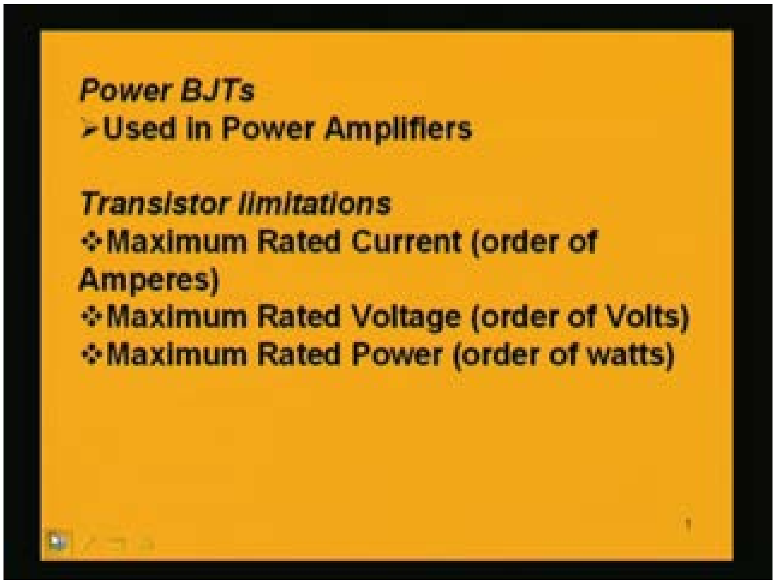

The rated current is a high current which is in the order of amperes. Similarly the maximum rated voltage in a power transistor is also high; it is in the order of volts. Also the rated power for a power transistor, the maximum rated power is in the order of watts. All these quantities like ampere, voltage and watts are high quantities and power transistors are designed with higher ratings and power transistor also have large area.

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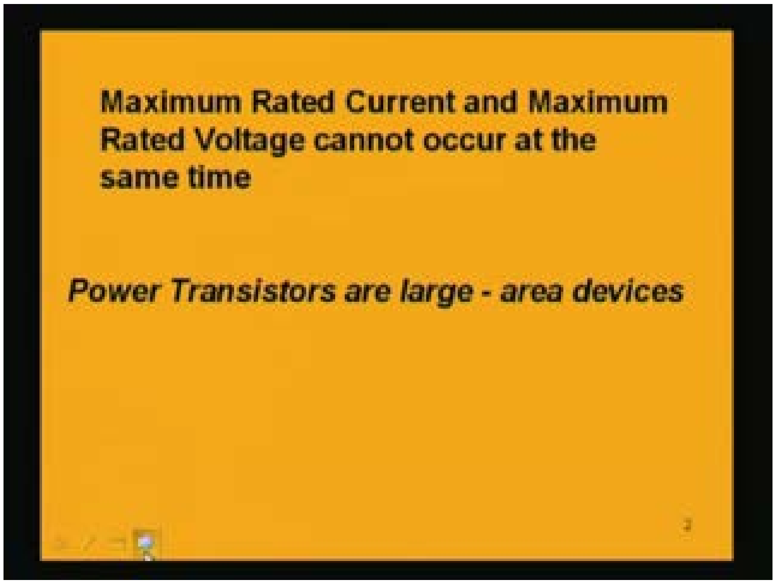

They are made keeping in mind that they have to dissipate large amount of power. So, the area of these power transistors is also high so that the temperature of the junction of the transistor should not be abnormally high. It should be able to dissipate the power and the temperature rise should not be high; that is why the area is also made larger. One thing to be noted is that the maximum rated current and maximum rated voltage, they cannot occur at the same time. If the transistor has a high rated current then at that time the voltage which will be appearing across collector to emitter that will be small and the product of this current and voltage that should be within the rated power which is the rating which is written for a particular power transistor being used.

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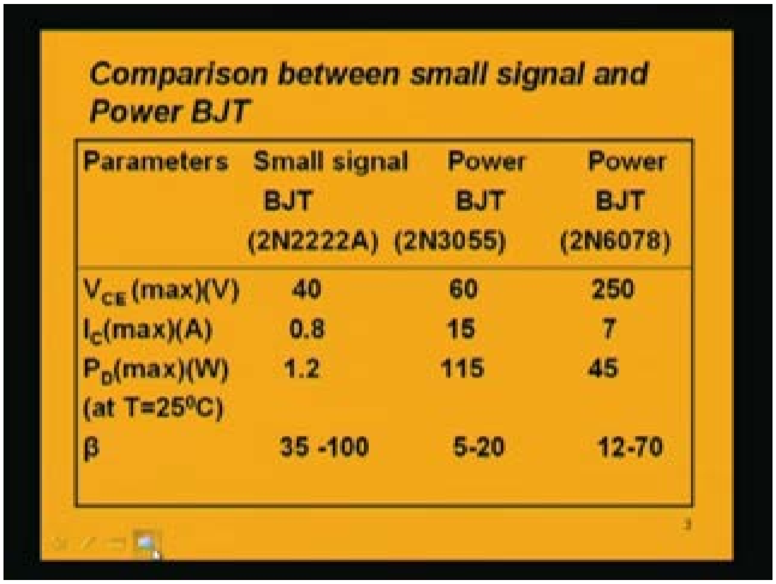

If we compare a small signal BJT and a power BJT as per these different parameters of voltage, current, power ratings, etc., we can very clearly see the difference between these two types of transistors. For example we are taking a small signal BJT with the type name 2N2222A. This is one type of BJT which is used for small signal amplification and the power BJT, its type is 2N3055. Another power BJT also we are taking which has type name of 2N6078 and compare the ratings as per the voltage, current as well as power and also compare the value of the current amplification factor beta.

As is shown in this table if we consider the small signal BJT, the maximum V_{CE} is 40 volt whereas in a power BJT 2N3055, the maximum voltage is 60 volt whereas in the other type 6078 it is even higher. It can handle up to a voltage of 250 volt and if you consider maximum collector current in the transistor, in the small signal BJT it is only 0.8 ampere that can be handled by this small signal BJT. But in power BJT this current is quite high. We can see here that it is around 15 ampere current. That is the maximum rated current for this power BJT 3055 and in the other case it is smaller value 7 ampere. The power rating, maximum power dissipation in the BJT you consider at ambient temperature, which is generally taken as 25 degree centigrade; the ratings are generally specified at this temperature. At that temperature the maximum power dissipation for a small signal

BJT is 1.2 Watt only whereas a power BJT can dissipate up to maximum of 115 watts; the other power BJT can dissipate up to 45 watts.

But the current amplification factor beta value is typically low value in power BJTs whereas in small signal BJTs, it is high. Around 35 to 100 may be the value of beta in a small signal BJT but in power BJT that value is between 5 and 20 for 3055 and between 12 and 70 for 6078 power BJT. The beta value is only lower in power BJTs. It is meant for amplification of power, so the current amplification may be less but overall power amplification will be high.

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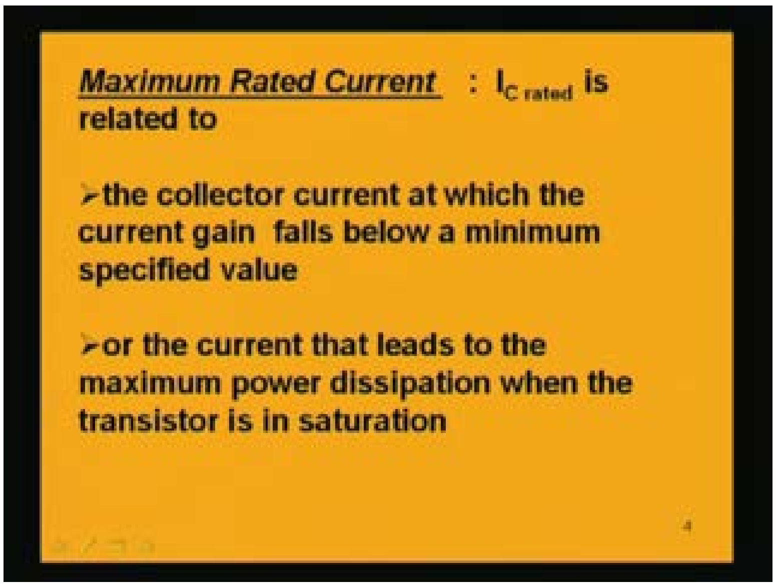

The maximum rated current that is $I_{C\ rated}$ is basically related to the collector current at which the current gain falls below a minimum specified value. The specification of the maximum collector current $I_{C\ rated}$ for a power transistor will depend on the value of the collector current at which the current gain falls below a minimum specified value. That is beyond that minimum specified value the current gain should not fall because beta value is typically low in power transistors. Beta value should not fall below a specified value or specified beta is given below which it should not fall. For that beta whatever the collector current value is that is determining that maximum rated current or the current that leads to the maximum power dissipation when transistor is in saturation. That also is a factor to determine the maximum rated current in a power transistor.

When the collector current reaches the saturation value what is the power dissipation? That value of the collector current when the maximum power dissipation occurs that will determine the maximum rated current. Power BJT current rating, maximum rating is either dependent on the minimum value of beta below which it should not fall or the maximum power dissipation at saturation of the collector current; either of these two may determine the maximum rated current.

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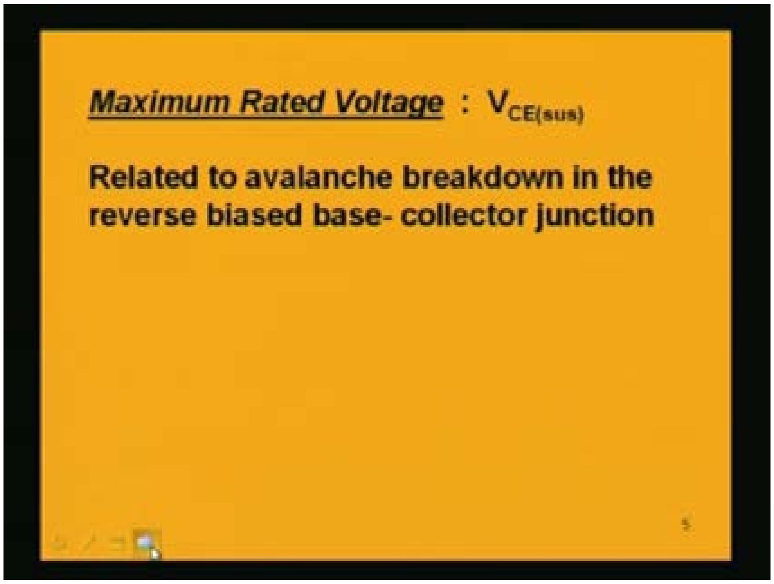

The maximum rated voltage, V_{CE} for a power transistor is related to the avalanche breakdown in the reverse biasing condition because we know that when you go on increasing the magnitude of the voltage in the reverse biasing condition in a transistor, it will lead to an avalanche breakdown when the current rises very sharply. But that will be detrimental to the transistor and we should not operate the transistor in the avalanche breakdown normally. So that is the rating. How far you can go on increasing the voltage is determined by the reverse biasing condition, avalanche breakdown voltage. If we operate beyond that voltage the transistor will have the danger of getting damaged because very high current flows in the avalanche breakdown and it is like short circuiting the collector and emitter; enormously high current flows and it may even lead to melting of the connecting wires because its temperature will be very high. So it should not be up to or beyond that avalanche breakdown voltage which is the determining factor for the maximum rated voltage.

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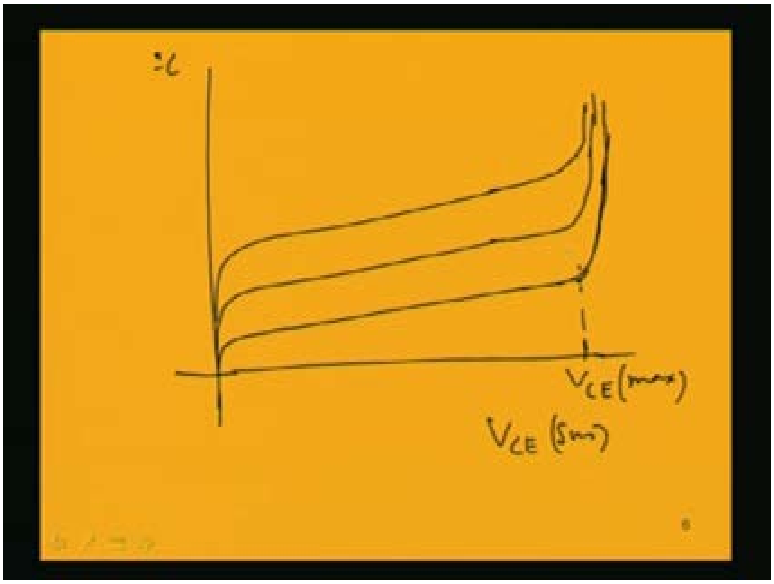

When you consider the reverse breakdown condition, if we revisit the characteristic curve for a transistor, i_C versus V_{CE} say, what happens is that the characteristics are are like this. When you consider the collector to emitter output characteristics, then even if you go on increasing collector to emitter voltage which is reverse biasing the collector emitter because this diode is reverse biased in the collector to emitter junction. When you go on increasing, initially even if you increase the V_{CE} the collector current will not rise much but when you go on increasing till avalanche breakdown occurs that means an avalanche of electrons will come out from the covalent bonds and they will be knocking out electrons due to the kinetic energy they will knock out more and more electrons from the neighboring covalent bonds. So, it will lead to a very high current and that is the avalanche breakdown. At that point actually the collector current will rise to very high value and the collector to emitter voltage V_{CE} is almost same for all the characteristic curves. That means the characteristics curves will crowd around this V_{CE} maximum or this is also called V_{CE} sustained. That means this much of voltage is required for sustaining that breakdown. All the collector current characteristics curves, for different base current we are showing this characteristics curves, nearing breakdown they all will crowd around the same value of V_{CE}; that is called the V_{CE} sustained. That voltage is the maximum voltage or rated maximum for a power BJT.

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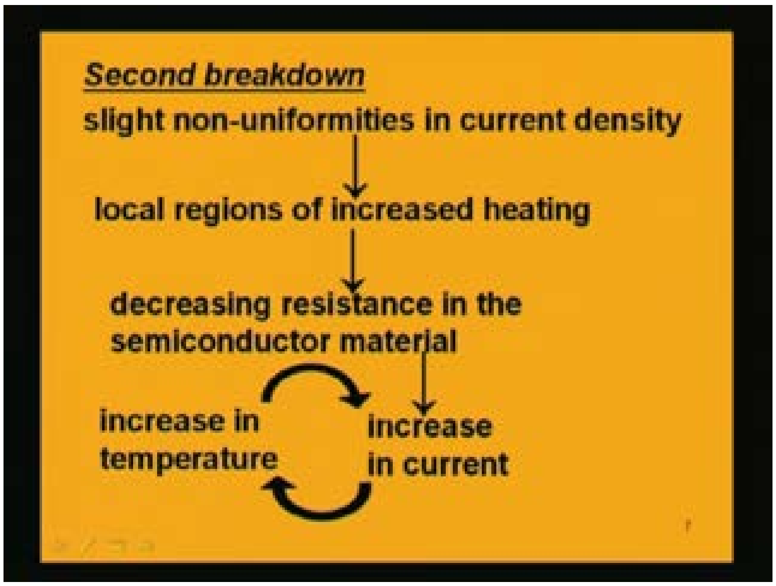

Another rating is also important which is coming from a fact known as second breakdown. This avalanche breakdown, which we have discussed, is the limiting value of the voltage on the power BJT that will be determined by the avalanche breakdown voltage. But another breakdown also occurs in a power BJT which is known as a second breakdown. If there are slight non-uniformities in the current density then what happens is that there will be local regions of increased heating in the power BJT. Due to this non-uniformity in the current density in the power transistor, local regions will be heated up wherever the current densities are higher, then in those local regions there will be heating up.

As the heating of the transistor takes place, the semiconductor material will have a decreasing resistance because heating of semiconductor means more and more carriers will be released and the resistance of the semiconductor will decrease. Decrease of the resistance means again more current will flow. So, increase of the current will take place and increase of the current will mean again more heating or temperature increase. Increase of heating means again current will be increased. The temperature increase means the reverse saturation current also will increase; current will increase again. Increase of current will be increasing the temperature again. This process is like a chain process or it will continue and so what will happen is that finally another breakdown may occur due to this chain effect or cumulative effect of current increase again, increment of temperature; that again is leading to increase of current that will continue and continue until a condition will arise that the current is so high that it may melt the wires connecting the transistor. It will be like short circuiting the collector and emitter.

What will happen is that this is another breakdown due to the local non-uniform current density and we have now another limiting condition being offered or being given by this second breakdown. So, the voltage which is the maximum voltage that it can be operated under that is one is given by this avalanche breakdown that is the breakdown voltage and also another voltage or second breakdown that will also put a limit on the power transistor.

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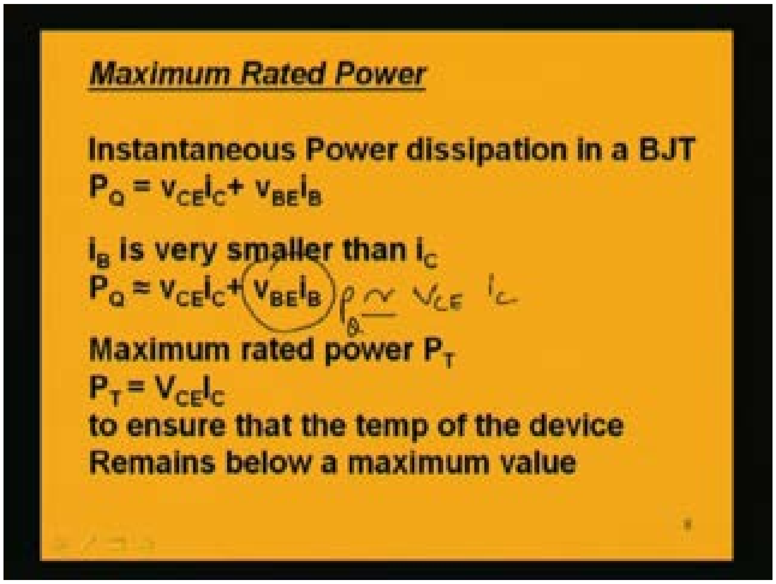

If we consider the power, maximum rated power then we have to find out the instantaneous power dissipation in a BJT. What is the power dissipated in a BJT? Where the power is dissipated basically? That we will have to see. One is in the collector; that is V_{CE} into i_C that will be the power vested in the transistor's collector. Another power is also dissipated in the base and due to base current the power dissipated in the base region is V_{BE} into i_B. This instantaneous power dissipation takes place in two portions of the transistor. One is the collector and the other is the base region but generally, practically i_B is smaller as compared to the collector current.

This part of the power dissipation that is the dissipated power in the base is very small as compared to the dissipated power in the collector. For all practical purposes we can ignore or neglect the power dissipated in the base, so this part can be neglected. We have the power dissipated in a transistor given by V_{CE} i_C, for all practical purposes. This is the instantaneous power dissipated in the transistor. The maximum rated power if we denote by P_T that will be given by V_{CE} into i_C. What will be the rating of the maximum power dissipated in a transistor? It should be that power at which the temperature of the device remains below a maximum value. This is very important because the transistor should not be heated up enormously because of this power dissipation. So, there is a limiting condition that the transistor temperature should not go beyond this value. That temperature is generally denoted and so the power dissipation, the maximum power dissipation is actually related to the temperature of the transistor. It should not go beyond a particular temperature which is specified.

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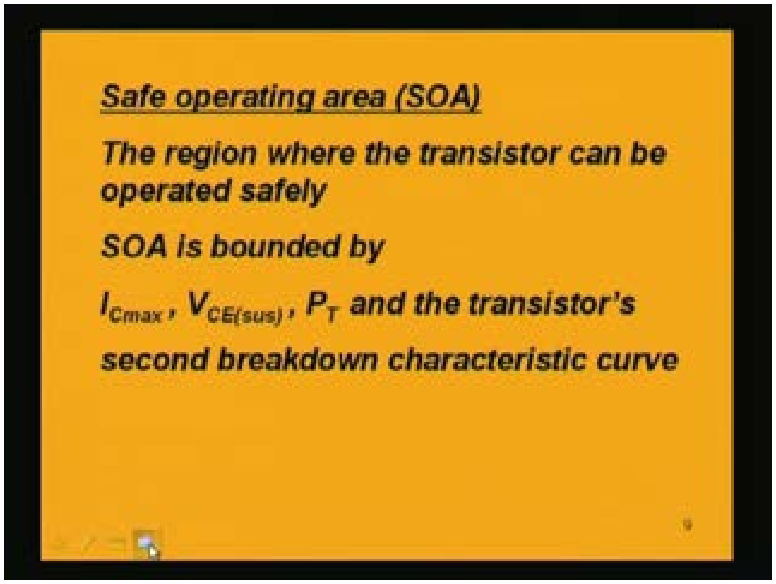

The transistor's operating region which is safe that means the transistor's safe operating area has to be now considered. In the output characteristic curve if we consider, which area is safe for operation of a transistor? We will find basically an area which is safe for operation for the power transistor which will be limited by the maximum collector current, maximum V_{CE} as well as maximum power dissipation. This area or region where the transistor can be operated safely is called safe operating area or SOA and it is bounded by the three quantities of maximum collector current, maximum collector to emitter voltage or sustaining voltage and maximum power dissipation as well transistor's second breakdown characteristic curve; that also we have to keep in mind because there is a second breakdown which may happen and we will have to take into consideration that characteristic of the second breakdown also. We will have an area or a region bounded by all these four parameters within which we should operate the power transistor. So, let us look into that area.

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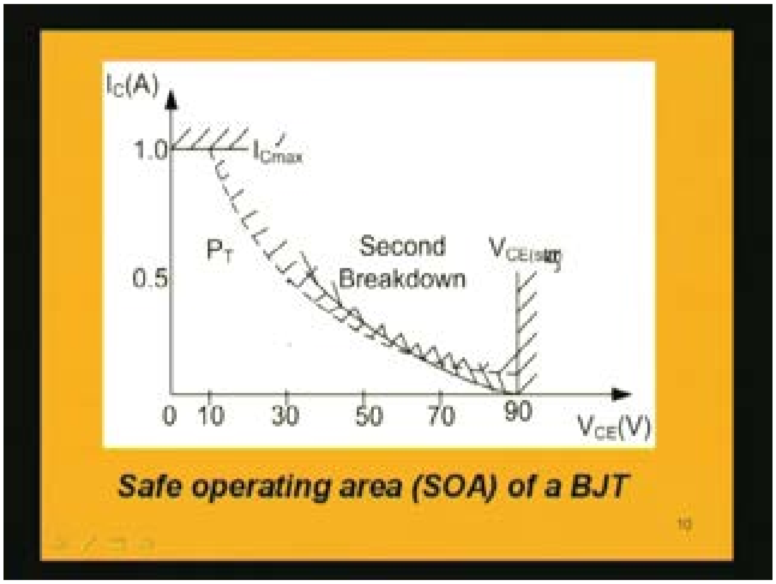

Here we are showing the safe operating area. This plot is having the maximum collector current given by I_{Cmax}. This is just an example having these values. It is not always that this is having only these values but then we are considering a typical case for an example and the V_{CE} sustaining voltage that is here is given by this upper bound on this collector to emitter voltage. The power dissipation in the transistor is given by this curve because we know that power dissipation in a transistor is basically the collector current I_C into the V_{CE} that is collector to emitter voltage.

When the V_{CE} will be smaller, then collector current will be higher. That is very obvious from the output characteristic of the transistor. When V_{CE} is very high, I_C will be less. Basically it will be a hyperbola given by this power dissipation in the transistor and this curve will specify that maximum value of the power that can be dissipated in a transistor. The region below this is the safe operating region. At any operating point you can find out what is the power dissipated in the transistor? At this point what will be the power? It is given by this voltage into this current. In this way, the maximum power at each point if we connect or if we draw this curve connecting all these points we get this curve for the maximum power dissipation which is a hyperbola and also there is a second breakdown region given by this curve. So, the second breakdown also puts a limit on the operating area of the transistor.

At no point of time we should go outside this safe operating area for the BJT or even if we go out we should not stay there for long. Sometime we may go outside this safe operating area or we may operate the transistor outside this area, but it should not be operated for long and for safety we should be within this safe operating area.

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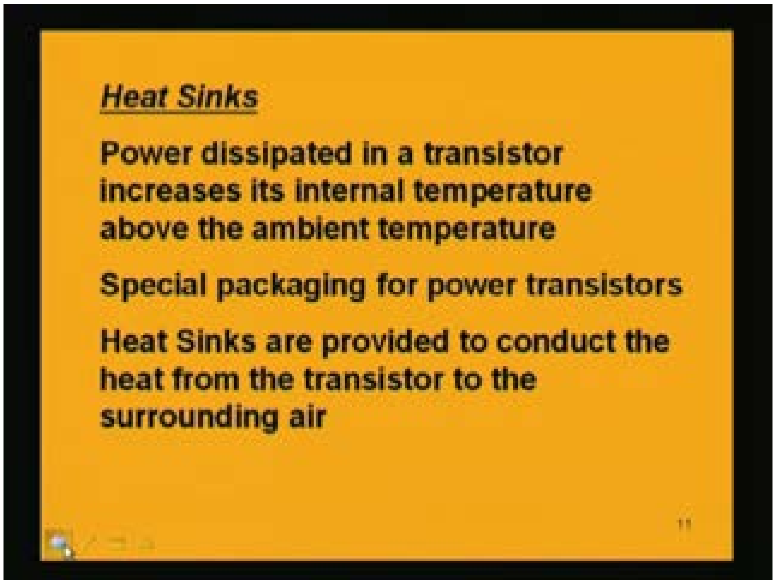

We have seen that the transistor which is used in power amplifier, as it handles high power, what happens is that it increases the internal temperature or the junction temperature of the device and it should not be above the ambient temperature which is specified as 25 degree centigrade. As this power dissipation is invariably associated with temperature increase or the transistor device being heated up, there must be some schemes for reducing the heat. That is why heat sinks are used. Heat sinks are used with the power transistors to take care of this heating caused due to the high power dissipation. There are special packagings for power transistors which will incorporate heat sink and these heat sinks will be just bolted into that transistor which is again inside a case. So, the device will be packaged first with a case and that case will be bolted into the heat sink. The use of this heat sink is that it will conduct the heat from the junction of the transistor into the surrounding air. It will dissipate the heat or it will conduct the heat to the surrounding air so that the junction transistor remains cool. The example of heat sinks and the casings which are used for transistors is shown here.

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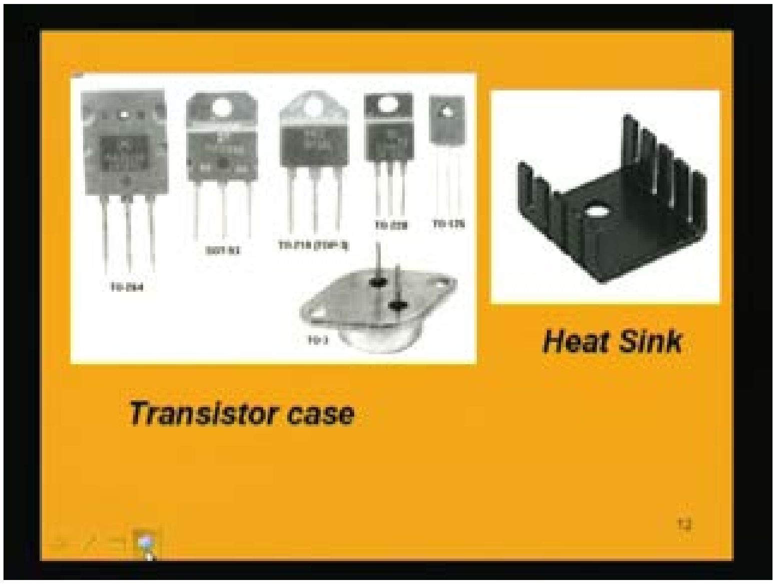

There are different varieties of cases which are used in transistor and here the casings are of different shapes also and the transistor will be inside the casings and apart from these casings the heat sink will be there. There is a hole where it will bolt the transistor case. This is one example of a heat sink.

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The packaging for the power transistor if we look into, it is a sink on which the cases of the transistor are bolted and there are fans also inside the heat sink. Actually the fans will be there for cooling the transistor in the heat sink. It is just a picture for showing the heat sink along with the transistor case. Basically what are there? One transistor which is the device; it will be first put into a case and the case will be again bolted into the heat sink. The flow of the heat is first from the junction device to the case, then case to the sink and then finally sink to the air and we can now visualize this as a flow taking place from the junction of the transistor finally into the surrounding air via this medium of case and then heat sink. What is happening is basically we are visualizing the flow of the heat which is analogous to electrical voltage and current.

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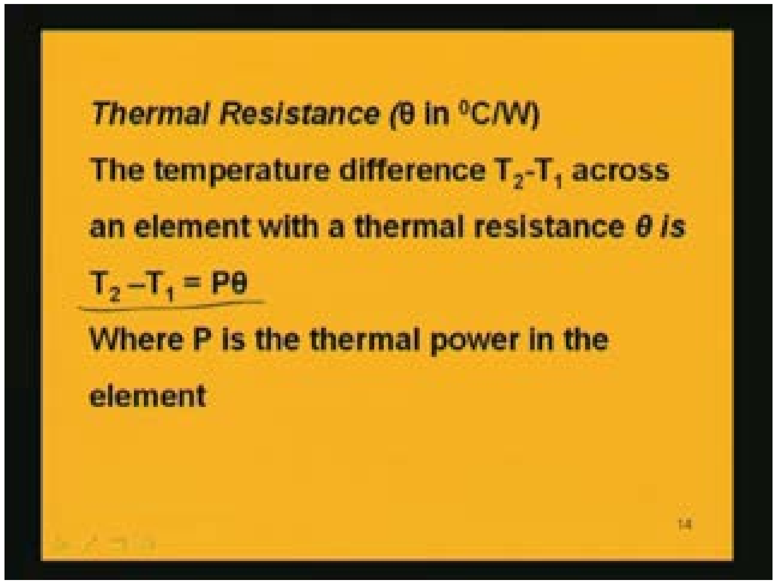

If we consider the transistor power which is dissipated as P that is nothing but the thermal power in the element which is a transistor then across this element the temperature difference which is occurring let us take it as T_2 minus T_1 which is equal to P into theta. Theta is the thermal resistance which is given in degree centigrade per watt. Basically this is analogous to an electrical law like in the left side T_2 minus T_1, the temperature difference if we consider that as voltage, the difference in potential and in the right side this power flow can be considered as the current flow which is multiplied by this resistance theta. Theta is thermal resistance. So, current into resistance is voltage or potential difference. Using that analogy we will now visualize the power flow in that way where the difference in temperature across the element that is occurring because of this power flow through this resistance.

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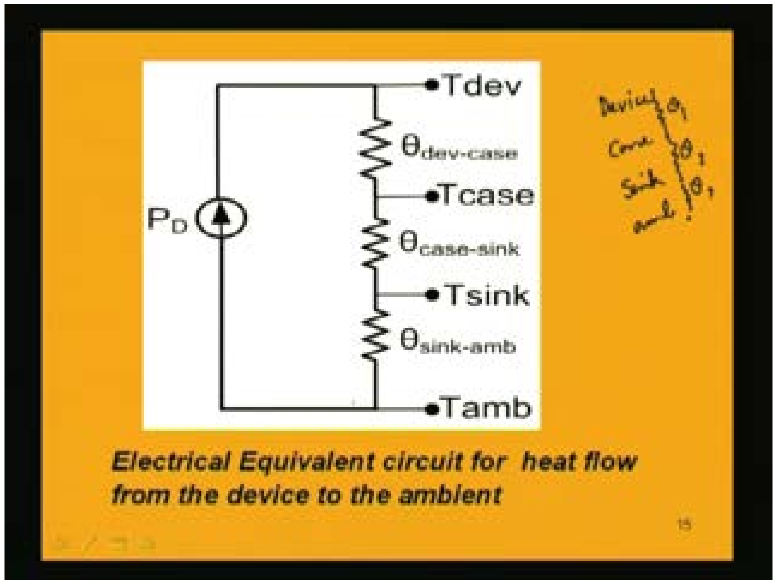

Circuit representation of this power flow or temperature change across an element or a device is shown here. The electrical analog is circuit is shown here where theta is the thermal resistance. We are now considering a transistor but that transistor is not naked; it is first put into a case. How the power flow is happening? The transistor device to case that is the first flow between the transistor junction and the case and then from case to the heat sink and from heat sink to the ambient temperature. So, these are the stages. If we consider a transistor device at this end and ambient air at this other end, this is the transistor device and the other end is the ambient air. In between we have this resistance offered by the case. That means the resistance from device to case and then from the case to the heat sink and then from heat sink to the ambient temperature.

These three resistances are there and $theta_1$, $theta_2$ and $theta_3$; $theta_1$ being theta device to case, $theta_2$ is case to sink and $theta_3$ is sink to ambient. The total temperature difference from the device to the ambient air is T_{device} minus $T_{ambient}$ air which is nothing but T_{device} minus T_{case}; that means device to case of the transistor plus T_{case} to T_{sink} that means case to the heat sink and then finally heat sink to the ambient air. At these two ends this is the current which is actually analogous to the power dissipation. Power is like having a flow from the transistor to the ambient air. That is why it is shown by arrow just to have the analogy with the current flow and what is this power flow producing? It is the temperature difference. As the current flow causes the potential difference between these two points having these resistances, similarly the power flow from the transistor to the ambient air is causing the difference in the temperature from device to the ambient air. So this analogy is used to understand the power flow from the transistor to the ambient air.

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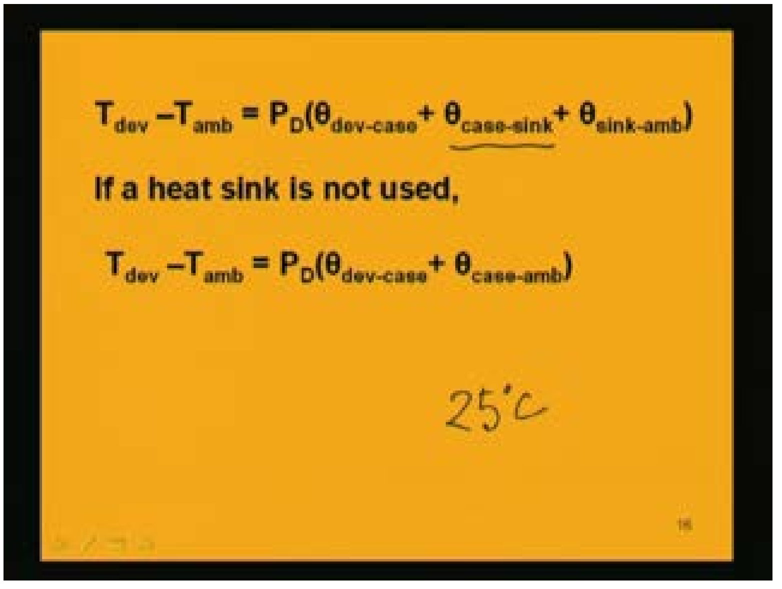

What will be now the temperature difference between the device and the final ambient temperature? That difference is T_{device} minus T_{ambient} is equal to P_D that is like current multiplied by this whole resistance that is theta device to case plus theta case to sink plus theta sink to ambient; so that is written here. It is like same current is flowing, producing the voltage across these three resistances by multiplying it by the resistances. This is when a heat sink is used. If a heat sink is not used then there will be the power flow from the device to the case and the case to the ambient air because in between states that is from case to the heat sink will not be there. This is not applicable when heat sink is not used. We will have simply the difference in temperature between device and the ambient equal to P_D, power dissipation into theta device minus case theta device to case. That is the thermal resistance from device or the transistor to the case plus theta case to ambient and typically the ambient temperature is taken as 25 degree centigrade and the maximum power rating of a transistor is also specified at ambient temperature 25 degree centigrade.

If we are having a transistor rated power as P_D at ambient we mean that at ambient temperature 25 degree centigrade, this is the rated power of the transistor.

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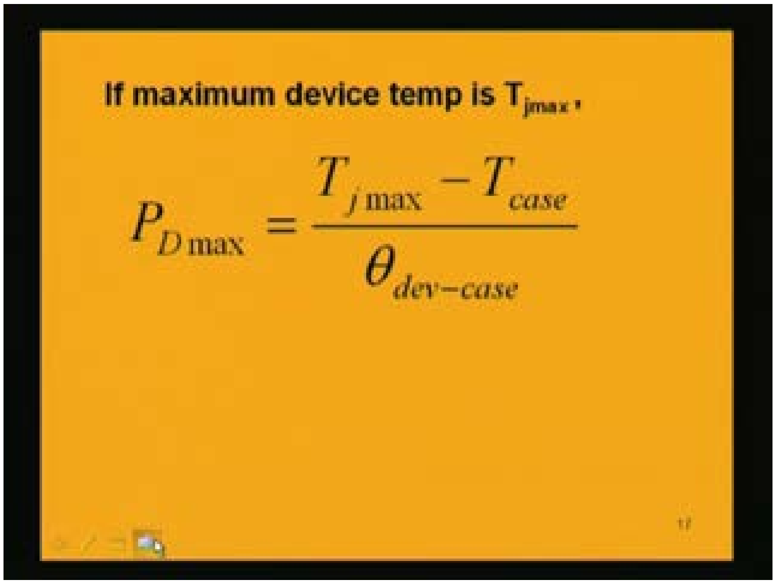

If we consider the maximum device temperature or maximum junction temperature of the transistor as $T_{j\ max}$, then we can simply write down what will be the $P_{D\ max}$ for the transistor? $T_{j\ max}$ minus T_{case} by theta device to case; because here the maximum device temperature $P_{D\ max}$ is meant. Here we have seen that is $P_{D\ max}$ and that will denote the maximum power dissipated in the transistor and also if it is specified that you have the $T_{j\ max}$, the maximum device temperature this difference between $T_{j\ max}$ and T_{case} divided by theta device to case that is the $P_{D\ max}$ we are concerned about the transistor and the case.

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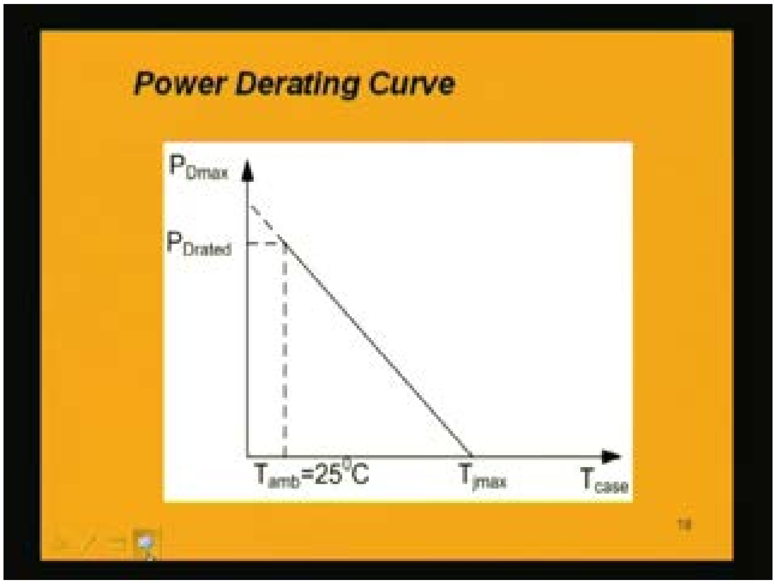

There is a curve which is known as power derating curve which is a plot between the $P_{D\ max}$ and T_{case}. If the temperature of the case is varying the maximum power dissipated also will be changed and this point where T ambient is 25 degree centigrade that means the case temperature is 25 degree centigrade, then P_{Drated} is defined at that temperature. The P_{Drated} or the rated power of a transistor confirms to or it specifies to the ambient temperature 25 degree centigrade which should be the temperature of the case. If it is beyond that if we allow for the case temperature being higher than the 25 degree centigrade then, the rated power will also decrease. Similarly you just have a look here; up to maximum temperature of the case, $T_{j\ max}$ it reaches then the power dissipation is zero. That means we cannot allow any power dissipation when the temperature is $T_{j\ max}$.

This power derating gives the idea about how the maximum power dissipated is related to the temperature of the case of the device or the case of the transistor. We will have to take into care all these factors of maximum current rating, maximum voltage rating and maximum power dissipation of the transistor when operating it for power amplifiers and we should always operate the transistor within the safe operating area.

Now let us try one example relating to this power transistor.

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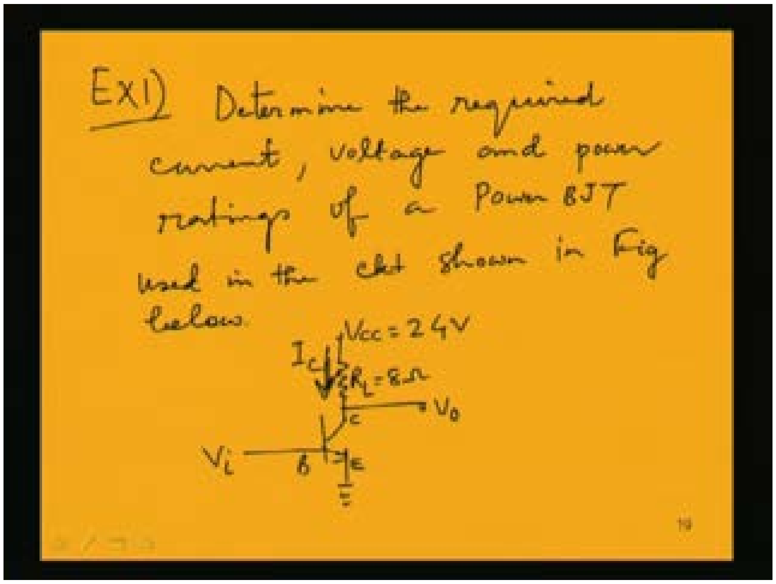

Determine the required current, the required voltage and power ratings of a power BJT used in the circuit shown in figure below. We are given a power transistor with a circuit as shown in figure. It is a common emitter transistor and V_{CC} being applied is 24 volt and this resistance which is the collector resistance or load resistance R_L is 8 ohms, it is given and a signal is applied, V_i. This point is emitter, this point is base, this point is collector and we have to find out basically the ratings of this transistor. It is used as an amplifier using a power transistor. This is the output voltage. In order to know the maximum collector current and maximum collector to emitter voltage we have to draw the load line or we have to write the equation of load line. We can do that if we consider a DC condition; the collector current flowing is I_C in this direction. Writing the equation for this output circuit V_{CC} minus I_C into R_L minus V_{CE} is equal to zero; that equation is the governing equation.

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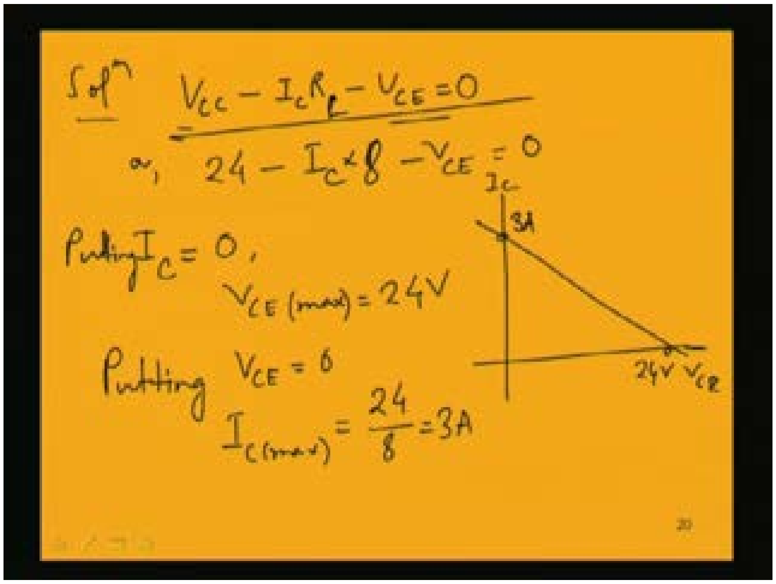

That we will write; V_{CC} minus I_C into R_L minus V_{CE} equal to zero, using KVL in this output circuit. Putting the values, V_{CC} which is given as 24 volt minus I_C into this is R_L; it is written as R_L in the circuit. Actually this is the resistance in the collector and it is written as load resistance because voltage is obtained across this R_L and R_L is given as 8 ohm minus V_{CE} is equal to zero. In order to draw the load line what we require is the maximum or extreme points; extreme points of the collector current and extreme point of the collector to emitter voltage, these two points we require to draw the load line. In order to know the maximum collector to emitter voltage we make I_C is equal to zero. Put I_C is equal to zero; putting I_C is equal to zero what we get is that V_{CE} max that is equal to 24 volt.

One point is known. This is 24 volt and put V_{CE} is equal to zero; to know the maximum collector current we put V_{CE} is equal to zero. Putting V_{CE} is equal to zero what you get? Maximum collector current I_{Cmax} that is found out as 24 by 8 means 3 ampere; this point is 3 ampere. You notice here we are getting 3 ampere, not milli ampere. It is a power transistor. This is 24, so joining these two points we get the load line V_{CE} load line. These two are the limiting voltage and current ratings for the power transistor. What about the maximum power rating of the transistor? To know the maximum power rating of the transistor, we must consider this power being dissipated and find out the maximum condition.

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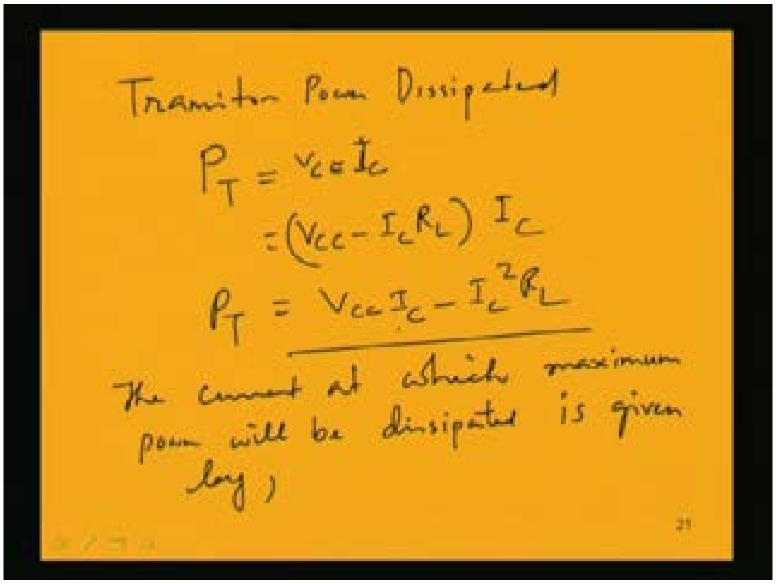

What is the transistor power dissipated? P_T is equal to V_{CE} and I_C; that is the power dissipated. V_{CE}, we can write down; V_{CC} minus I_C R_L into I_C and that can be written as V_{CC} I_C minus I_C square R_L. This power, in order to be maximum we have to find out the maximum condition. So, maximum power can be found out when I_C is maximum. In this expression if we look into, the variable is I_C. We have to find out the condition of maximum collector current for which the maximum power will be dissipated. The current at which maximum power will be dissipated is given by what? Find out the maximum condition from this equation P_T is equal to V_{CC} I_C minus I_C square R_L. We have to define say P_T with respect to I_C and put it equal to zero to get the maximum condition of the collector current.

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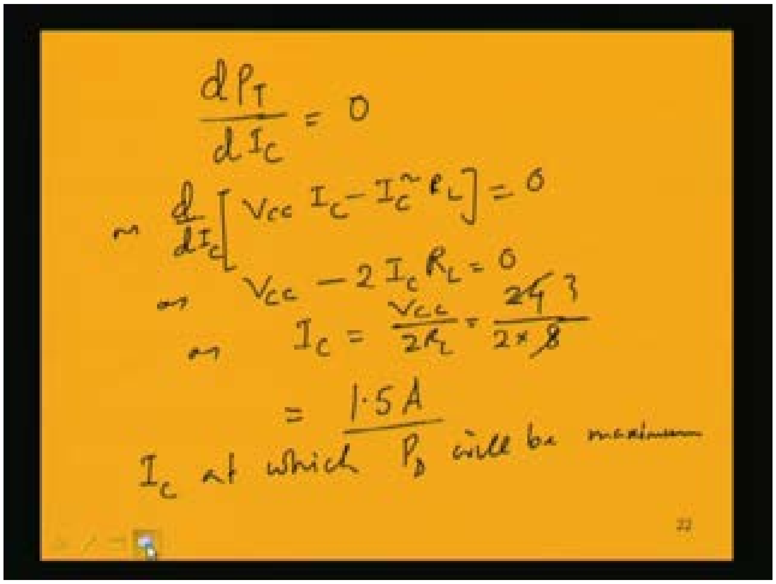

Using that dP_T differentiate the power with respect to collector current, make it zero. That means we have to differentiate this expression, V_{CC} I_C minus I_C square R_L, make it equal to zero. When we differentiate it with respect to I_C, it will be V_{CC} minus twice I_C into R_L that is equal to zero. What is the maximum collector current? We get V_{CC} by 2 R_L and V_{CC} is equal to 24 volt, R_L is equal to 8 ohm. So, we get 1.5 ampere is the current for which the power dissipation will be maximum and this is the current I_C at which P_D will be maximum and what is the corresponding V_{CE} for that maximum power?

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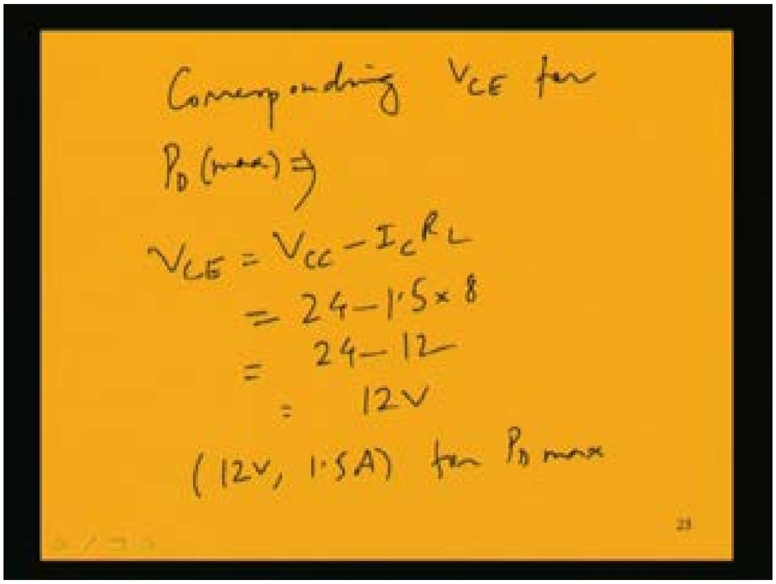

The corresponding V_{CE} for $P_{D\ max}$ equal to simply putting that equation again V_{CC} minus I_C R_L is equal to V_{CC} is 24 minus I_C we have found out to be 1.5 into 8. So, that is 24 minus 12 that means 12 volt. We got the point for maximum power dissipation as 12 volt to 1.5 ampere for $P_{D\ max}$.

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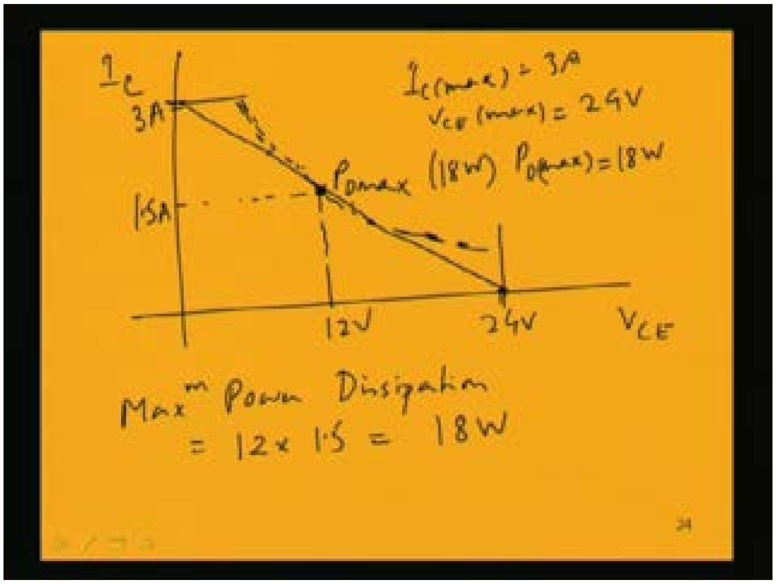

Plotting this on the load line, if we look into the load line again, draw the load line again, I_C V_{CE}, 3 ampere is maximum collector current, 24 volt is the maximum V_{CE}; joining these two we get the load line having the slope of 1 by R_L with a minus sign. This is the maximum collector current which is the maximum rated current for the power transistor, 3 ampere; maximum rated voltage for the power transistor 24 volt and we are now having this point $P_{D\ max}$ around the middle of the load line. Because we are having that point as 12 volt and 1.5, exactly at the middle of this load line we get the $P_{D\ max}$. Multiplying these two, we can get the $P_{D\ max}$. What will be the $P_{D\ max}$? Maximum power dissipation equal to 12 into 1.5 is 18 watts. So, 18 watts is the maximum power dissipation for this transistor.

Here we are getting all ratings of power transistor. The ratings are $I_{C\ max}$ is 3 ampere, $V_{CE\ max}$ is 24 volt and $P_{D\ max}$ is 18 watts. This is the safe operating idea bounded by this. The power dissipation will be like this. Within this will be the safe operating area below this curves and bounded by these two lines and for this transistor we are getting $P_{D\ max}$ at this point and corresponding voltage and current at this. If we have lesser power dissipation; suppose it is somewhere away from this value; here or here, it can be. This is the point where the maximum power dissipation is occurring for that particular power transistor. For different resistance value, R_L if it is changed, we will have different power dissipation. Your point of maximum power dissipation will vary and corresponding voltage and current will also vary. We will have that hyperbola within which we should remain. The product of this current and voltage should give you a value below this for a hyperbola. That is the safe operating region.

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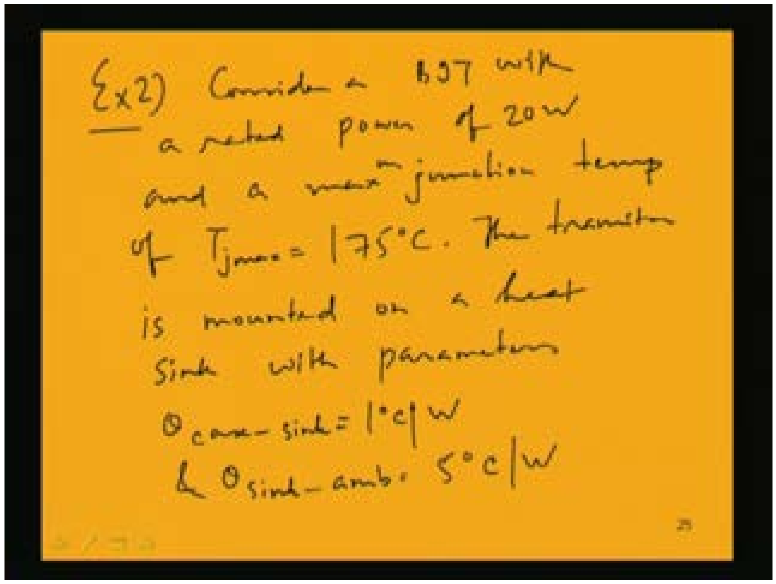

Similarly if we consider a BJT with rated power of 20 watts and a maximum junction temperature of $T_{j\,max}$ equal to 175 degree centigrade. The transistor is mounted on a heat sink with parameters theta case to sink thermal resistance is given as 1 degree centigrade per watt and theta sink to ambient is 5 degree centigrade per watts.

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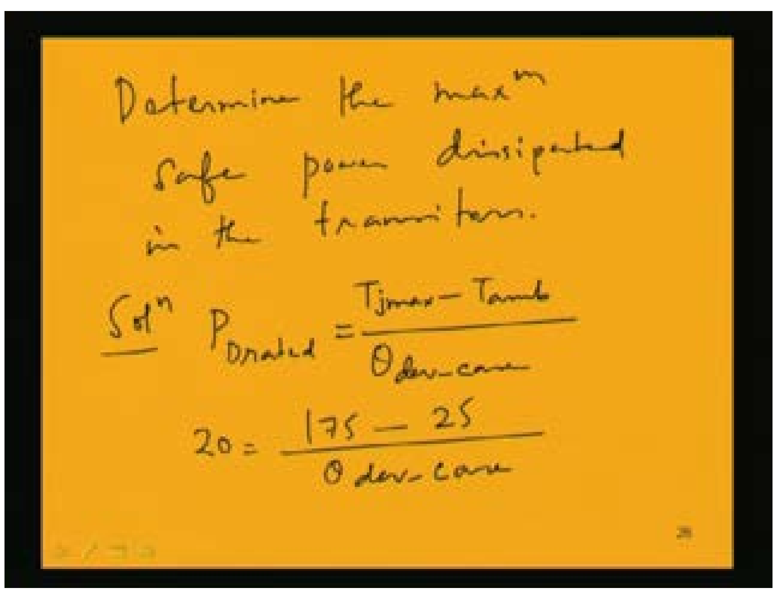

Now you have to determine the maximum safe power dissipation in the transistor. This deals with the problem of power dissipation with a sink. How to find out the safe power dissipation? We know the power dissipation which is rated; $P_{D\ rated}$ that is given by $T_{j\ max}$ minus T ambient. T ambient is 25 degree centigrade; even if it is not mentioned you should know it, divided by theta device to case. So, $P_{D\ rated}$ is given as 20 watts and that is equal to $T_{j\ max}$ is given as 175, T ambient is 25. Theta device to case is not given; we have to find out theta device to case.

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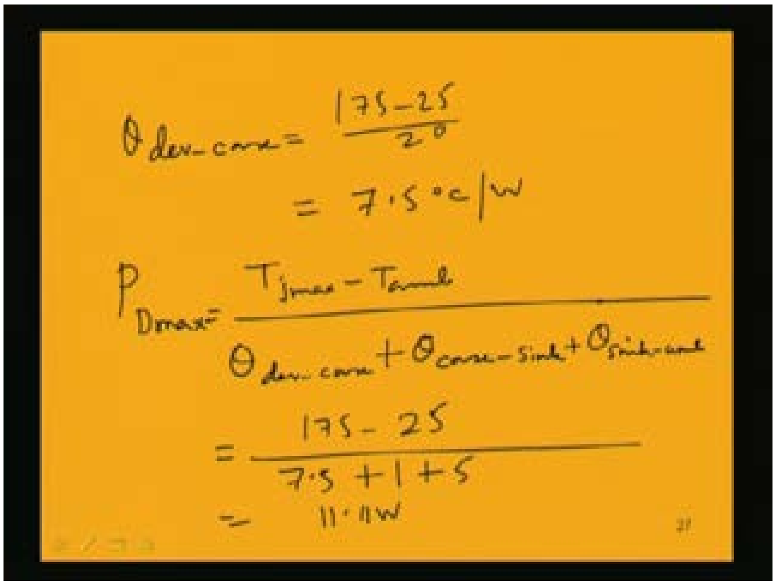

From this we get theta device, thermal resistance between the device and the case is equal to 175 minus 25 by 20. So, that is 7.5 degree centigrade per watt. You are asked to find out the maximum safe power dissipation; maximum safe power dissipation $P_{D\ max}$ that will be equal to $T_{j\ max}$ minus $T_{ambient}$. Heat sink is there; the sink to ambient thermal resistance is given. We will have $T_{j\ max}$ minus $T_{ambient}$ divided by theta device to case plus theta case to sink plus theta sink to ambient. That quantity of the division between these $T_{j\ max}$ minus T ambient and this whole thermal resistance will give you the safe power dissipation and that maximum safe power dissipation can be found out by putting the values of $T_{j\ max}$ 175 minus $T_{ambient}$ 25 and all these thermal resistances if we put, that is given theta device to case we have found out 7.5, case to sink theta is 1 and sink to ambient theta is 5. This value if you calculate, we will get 11.11 watt. This is the maximum safe power dissipation in the transistor, 11.11 watts. Although the maximum rated power is given as 20 watts, the safe power limitation is less than rated power. As you see here 11.11 watts is the safe power dissipation which is found using the sink parameters. Although the rated power, if we consider only from the device to case the rated power dissipation is given as 20 watts but along with the sink and device to case, we will get the safe power dissipation as 11.11 watts. This example shows how the sink effectively introduces safety in the transistor's power dissipation capability.

In today's class we have seen about the parameters of power transistor. Power transistor which is used in power amplifiers have specifications given by maximum current, maximum voltage, maximum power dissipation ratings, as well as second breakdown. We should operate the power transistor well within the safe operating area given by all these upper bounds and we have also seen the use of heat sink to conduct the heat generated in the transistor while dealing with such large magnitude of power and seen how effectively heat sink dissipates the power or conducts it into the surrounding air keeping the temperature of the power transistor within limits.