Fundamentals of Power Electronics
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Lecture – 32
Shunt regulator

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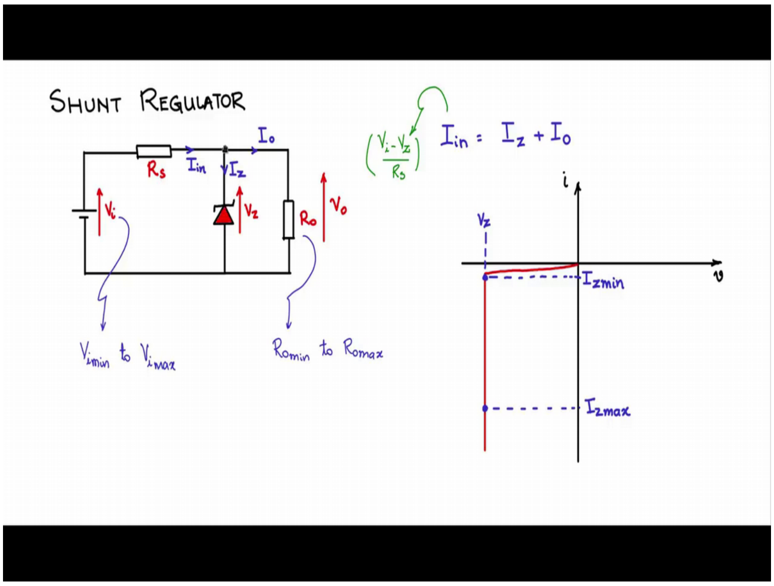

Let us now discuss the Shunt regulator circuit. So, let us draw the input unregulated voltage V i, it contains a series component here and a shunt component here, it is a Zener diode and the load. So, this is the structure of a shunt regulator. The hero of this is this Zener diode. This is V i, the unregulated V i, we will call this as R s, this is V z and this is the load resistance R naught and you have V naught and V naught is equal to V z.

So, if I name this as I s or I in and this is I z and I naught. So, these are the various parameters in a shunt regulator. How does the regulation happen? Basically, V z is a reference Zener, the voltage across the Zener is constant and it tries to maintain V naught constant in spite of the fluctuations in V i or fluctuations in R naught. Let us see how the operation, how the regulation operation functions.

Now, look at the Kirchhoff's current law here at this node. You have I in, I z, I naught. I in is equal to I z plus I naught, I z plus I naught and this is the core equation which performs the regulation. Now, V i can vary from a V i minimum value to a V i maximum value and R naught is not under our control again can vary from R naught minimum value to R naught max value and as a consequence when R naught is minimum I naught is maximum and R naught is max I naught is minimum.

The operation of the shunt regulator hinges on this device which is the Zener diode. Let us try to understand the characteristics of that Zener diode static characteristics of Zener diode and how it affects the regulation performance here. So, let me draw the i v characteristics, this is the v, this is the i and let me take only the reverse characteristic the Zener reverse characteristic which will be something like this, where this line intercept will be V z on the voltage.

So now, this I in here the current is given by V i minus, this is V z point this potential here is V z at this node V i minus V z divided by R s. So, this is the current flows in through here and this current is independent of the value of R naught or value of I naught. So, depending upon the value of R naught there is commutation between I naught and I z to maintain I in fix to this value.

So, the current through the Zener has flexibility. It can operate from a max value I z max to a min value I z min and this in fact, gives you the regulation. If suppose I naught is 0 then the whole of the I in current flows into I z, so the operating point will be somewhere here. If I naught is a maximum value then I z will decrease and it will probably be sitting at min value the operating point will be here. So, it is I z here that actually is adjusting its value. The regulation happens because of the capability of the Zener to take varying currents through it at a constant voltage. The Zener current can vary from I z min to I z max depending upon the value of the load.

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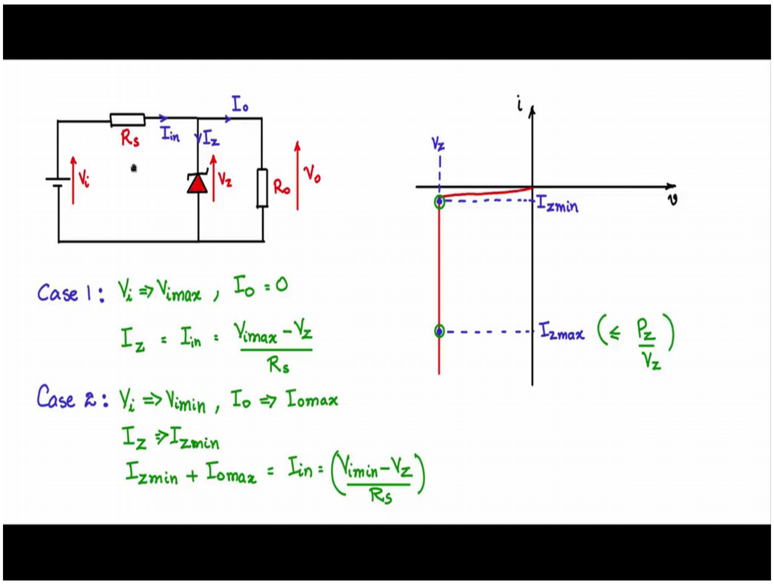

Consider now few operational cases. Let us say case 1. Now, here V i is at its max value V i max and let us say I naught is 0 which means this open circuited, then the entire I in current flows through the Zener. So, I z will be equal to I in because I naught is 0 and that is V i max minus V z divided by R s. Now, this is the max value of the current that can flow into the Zener in this circuit. So, it will get, this will be the operating point it will get positioned here and that will be I z max for the circuit and see to it that it is less than or equal to P z by V z, P z is the Zener power rating.

So, when you go and choose or select a Zener it will have a power rating in the data sheet. So, you will have a 1 watt Zener, you have 400 milli watt Zener. So, whatever that power rating divided by V z Zener V z will be the limiting or the max permissible value of I z. So, this I z value which you calculate here should be less than that so that the Zener does not blow.

The second case, the second limiting case happens when V i is V i min and I naught is maximum, that is when R naught is at a minimum value. So, you have I naught max. Under this condition this I naught plus I z should be equal to I in, there should be a at least the minimum value of I z to pass through the Zener in order that the Zener provides a constant voltage V z.

So, therefore, I z minimum at least should flow through this. So, I z should be set at I z min as the operating point. So, we know that I z min now, plus I naught max should be equal to I in and I in under this case is V i min minus V z divided by R s. So, this is another limiting case where the operating point as for the Zener is concerned is here. So, these two limiting cases will actually determine what should be the value of R s that you have to choose. It will become clear if we work out an example.

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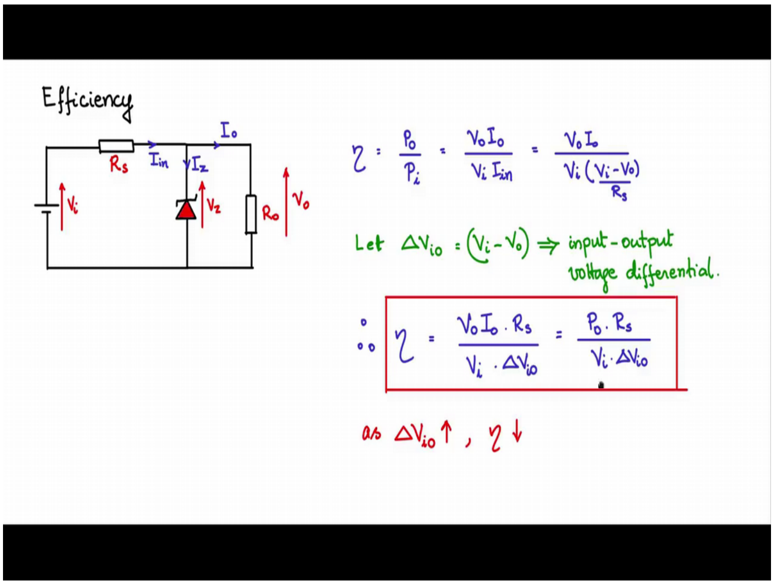

Let us now see what is the efficiency of this circuit? Efficiency is defined as the output power divided by the input power P i, output power which is V naught I naught input power V i I in. So, we can write it down as V naught I naught by V i I in.

Let us express I in terms of input voltage and output voltage. So, we have V naught I naught by V i into I in is V i minus V naught by R s, V i minus V naught by R s and let us define another term delta V io which is V i minus V naught it is called the input output voltage differential, V i minus V naught which is the input output voltage differential.

So, now therefore, we can rewrite efficiency as V naught I naught R s divided by V i into delta V io. So, this will be the efficiency relationship. Observe that as delta V io input output voltage differential increases the efficiency will decrease, which basically means that if I am having a linear shunt regulator let us say with input output differential as some voltage. For example, if I take V i of 10 volts, V naught of 5 volts input output differential would be 10 minus 5, 5 volts. For the same 5 if I am having V i of 15 volt then input output differential would be 10. So, the 15 volt input would have a lower efficiency than that 10 volt input linear regulator.

So, V naught I naught is nothing but P naught which is the which can be obtained from this spec, R s is calculated by design, V i is given from the input spec, delta V io is also an input spec and from here we can calculate the efficiency of the circuit. So, the important thing to note here is the input output differential voltage, higher rate is lower the efficiency.