Fundamentals of Power Electronics
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Lecture – 40
Improvements to series regulator

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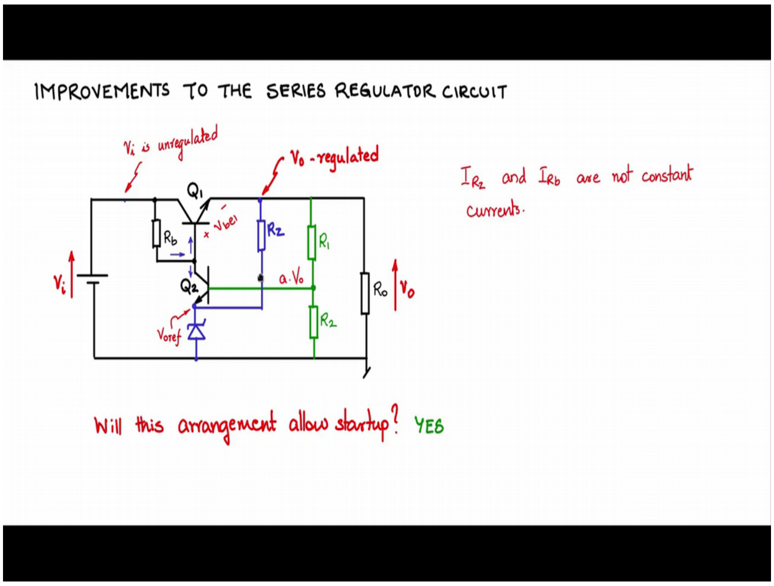

Let us now discuss some improvements that can be made to the series regulator circuit, so that the precision of the regulation can be improved. So, first let me take up the case of R z, and then next the case of R b. See both these through both these components the current that is supposed to flow through or supposed to be constant for effective regulation. However, V i here is unregulated, and therefore it is a varying voltage.

So, therefore, we cannot strictly say that the current that were flowing through R z and R b are constant. Now, let us take the case of R z. If we shift this R z from here to here, V naught is a regulated voltage node point. Therefore, if we shift this to here the current through R z can be effectively said to constant. So, so let me remove this R z from there, and then reconnect it here in this fashion R z.

And you see that here the voltage is V naught, and V naught is a regulated voltage. And, therefore, it is constant and fixed; therefore the current through R z is fixed. And as a consequence the regulation the V naught reference is much more stable in this arrangement.

However, the question arises will this arrangement allow start up? Means at the time of starting the output voltage is 0, what will happen? At the time of starting V naught is 0, zener breakdown has not happened here also it is 0, a V naught. Q 2 is how to the picture it is off. So, all the input bias currents through R b flows through the base of Q 1 and tries to turn that on.

And the voltage starts getting developed here. Once the voltage starts getting developed here, zener comes into the picture V naught ref is set, and the output voltage will track this V naught ref. So, therefore, we can say that this arrangement will allow start up, and also improve regulation by virtue or some more constant current flowing through R z.

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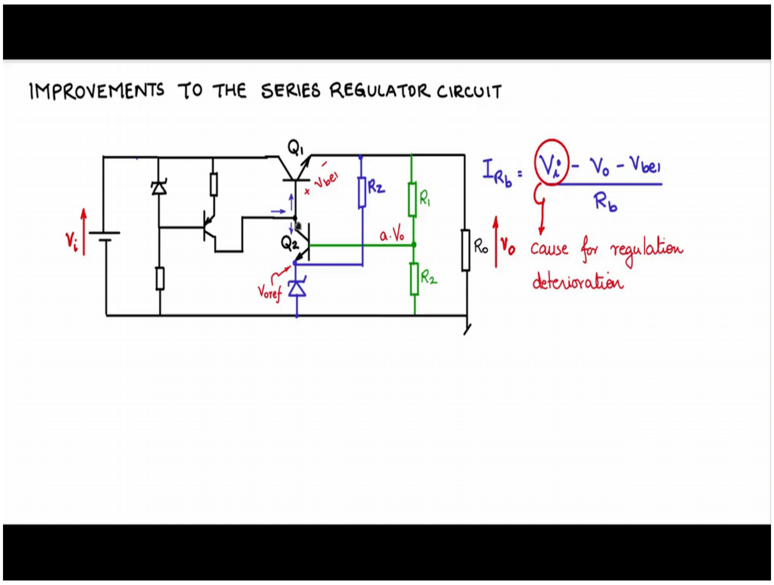

Let us discuss another important improvement in the series regulator circuit to improve the regulation precision, and that is in this current I R b. We saw earlier that for effective regulation I R b supposed to be constant and the I R b splits up into I b 1 base current of Q 1 and I C 2 collector current of Q 2. I C 2 and I b 1 the base current of Q 1 and collector current of Q 2, they commutate among themselves so as to achieve effective regulation of output voltage V naught.

Now, we see here that V i is unregulated voltage which means that it can fluctuate. If it can fluctuate the voltage here, I R b being given by the voltage here V i minus V naught minus V b e 1 divided by R b. V naught and V b e 1 are constants; however, V i is not actually constant because the input voltage is unregulated, so which means it can vary.

So, as a consequence, I R b is not strictly a constant current value, which is flowing through R b, and therefore, this is a serious cause for deteriorated regulation.

So, how do we solve this? One way to solve this is to remove this R b and putting there a current source like this. And, repeating my current source in irrespective of variations in V i, the current here will be constant and there while their regulation will be very precise for the circuit for any variation in load and line. We also know that a current regulator can be made using the zener shunt regulator.

Let us make that and introduce that this point. So, let us make some space. Let me put in the current regulator circuit a resistance a pnp, and the output of that connected here, and then I have a zener, and the resistance here. So, look at this, this is a zener which give me constant voltage that is applying between these two points I am showing. V b is constant, so essentially V z minus V b will be come across this resistance.

And this resistance being fixed V z minus V b e by this resistance will be a constant current flowing through the emitter, and thereby a current which is alpha times the emitter will come into the collector, and then flowing here. And the collector current will be essentially constant irrespective of the variations in V i here. And now that is a crucial improvement where this current being constant, the regulation will be very, very precise and effective.

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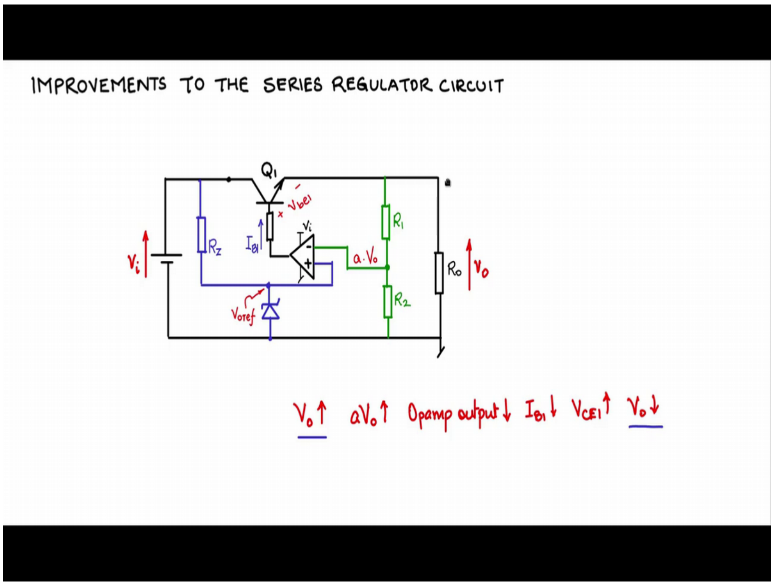

Now, let me discuss another important significant improvement to the series regulator circuit. Here I am talking or replacing this transistor Q 2 itself. The transistor Q 2 we supposed to provide amplification, current gain and also a high input impedance as seen from this side. The same thing can be provided in a much better way by using an op-amp which is supposed to have an infinite gain and almost infinite input impedance. So, let us try to use an op-amp and improve the regulation performance of the circuit much, much, much better.

So, remove this portion this portion which is providing the V naught references still retained, and this attenuator which is actually tapping off the output providing the feedback a V naught is also retained. The transistor portion will be replaced with an op-amp. So, let me have a drive resistor to drive I b into the q Q 1 base. And the I B drive is be obtained from the output of an op-amp like this. So, op-amp is a three terminal device. There are two terminals for power supply. Let us take the power supply for the op-amp from the unregulated voltage itself.

And I will give the feedback tap of point to the minus terminal of the op-amp, and the voltage V naught reference to this point. Observe that the op-amp has infini[te]- infinite input impedance, which means that the V plus voltage and the V minus volt are almost same meaning that there is a virtual ground in the op-amp, even though there is no current flowing through the high input impedance. This means that whatever value of V naught reference you are setting here, the a-V naught will track this V naught reference almost exactly.

Further, there is almost zero current flowing into V plus, and therefore the zener the zener impedance that is R z also does not cause deregulation, because this is essentially have fixed value of current. Now, the regulation action, how does it regulate? Now, let us say for example, this is I B 1 and for example, V naught increases to the some reason, the V naught may increase due to change in V i change in R naught. So, if V naught increases, then a V naught will increase. And then as a consequence a V naught which is given to the minus will be higher than will increase more than the plus V plus terminal voltage which is being held constant. Therefore, the error decreases and the output of the op-amp reduces op-amp output reduces.

And as a consequence I B 1 drive will reduce. And if I B 1 drive reduces V C E will increase, because the transistor Q 1 is pushed more towards the cut off, and as a consequence V C E will increase. And if V C E increases, then the outer loop Kirchhoff Kirchhoff loop will sit with that V naught decreases and is brought back to its original value. Now, this is the regulation action in the closed loop regulation action. Likewise even if V naught decreases, the same sort of regulation action happens V naught decreases a V naught decreases, error increases, I B 1 increases, V C E 1 decreases, and therefore V naught increases and is brought back to its original state.

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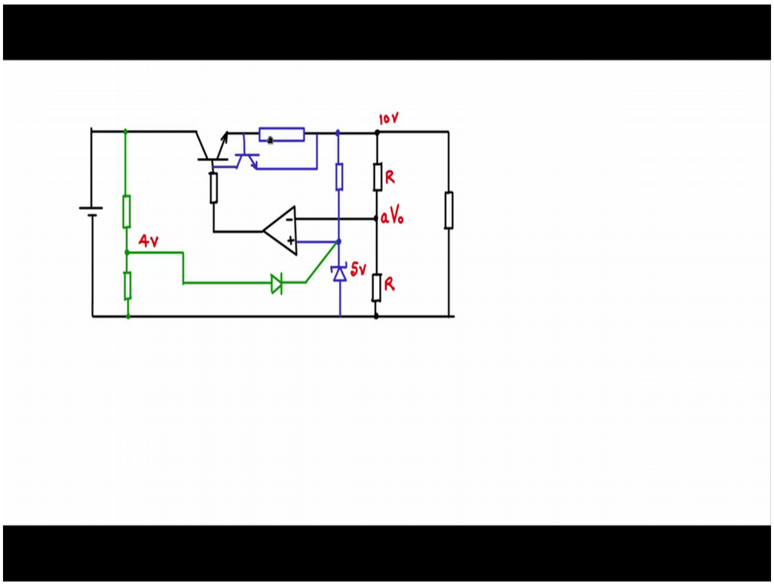

So, to this improved regulator that is the one with the op-amp connected like this, you can improve it still further by placing the zener such that it is start up from the output side rather from the input side. So, let us say we tap the zener input instead of from V i, you tap it from V naught. V naught is a regulated, and therefore this will be well regulated absolutely stiff V naught reference and the one of the most precise regulator that you can have. However, will they start up? So, when you are starting up V naught is 0, this is 0, this is 0, output of the op-amp is not defined.

And, it may turn on this or it may not run on Q 1, but we cannot a designer cannot leave that one to chance; therefore we should ensure or guarantee turn on. So, what we shall put is we shall put a resistance division like this. And at this point, I will tap off put a diode normal diode and connect it there. So, how does this operate? Let me take an example. Let us say we have a 5 volt zener. So, this V naught references 5 volts. This is a V naught, let us say this is R, and R equal which means a is 0.5, and therefore, V naught will be 10 volts. So, if this is 10 volts, input of course will be much greater than 10 volts.

Now, let me set this value, this potential division to 4 volts, then initially on start up 4 volts comes across at this point, and here 4 volts will be available to you if this is an ideal diode or 4 volts minus the drive a drop. Now, this will act as the reference and this will push this [transfer/transistor] transistor and the regulator will come into being. And at this point, it will be 2 times 4 - 8 volts. The moment this potential here crosses 5 volts, then the zener starts to go into the zener breakdown, this will be 5 volts. The moment this is 5 volts, this diode will get reverse bias, because it is 4 volts there and 5 volts here, and covers out of picture, and the zener will set the reference and the operation will be as usual as normal.

Additionally you can also give current limiting for this circuit also it at this point. You can include a constant current limiter like this. Put a resistance there then put a BJT and connected in this fashion. As the voltage across the resistance increases, V b will increase. And it will try to drive remove the drive from the base drive from this main transistor, divert, it will divert the base drive and see that this transistor blocks a higher voltage. You can also replace this with a fold back current limiting circuit too. It will also operate equally well in this case.