Design and Simulation of DC-DC converters using open source tools

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Lecture – 23
Multi-Output Converters

There is one more aspect that we need to talk of, discuss and that is on a multiple outputs. How do we handle multiple outputs? Still now we have been studying a single output voltage coming out of the dc-dc converter. But in practice you will see many power supplies and most power supplies have 5 volts output, 3 point 3 volts output, 15 volts output, minus 15 volts output, plus minus 12 so on and so forth. So, most of the commercial power supplies that you have that are available will definitely have multiple outputs.

However if you look at the dc-dc converter that we have studied the control input is only the duty cycle to the switches and there is only one duty cycle available for you to control. In such a case with one control input which is the duty cycle. You can control only one output. What to do with the other remaining multiple outputs? How to get regulation out of that? Now that is an issue. So, that is the focus for discussion in this particular video capsule I will discuss couple of methods with which you can address this particular issue that I mentioned and how you can regulate the other outputs of the multi-output converters.

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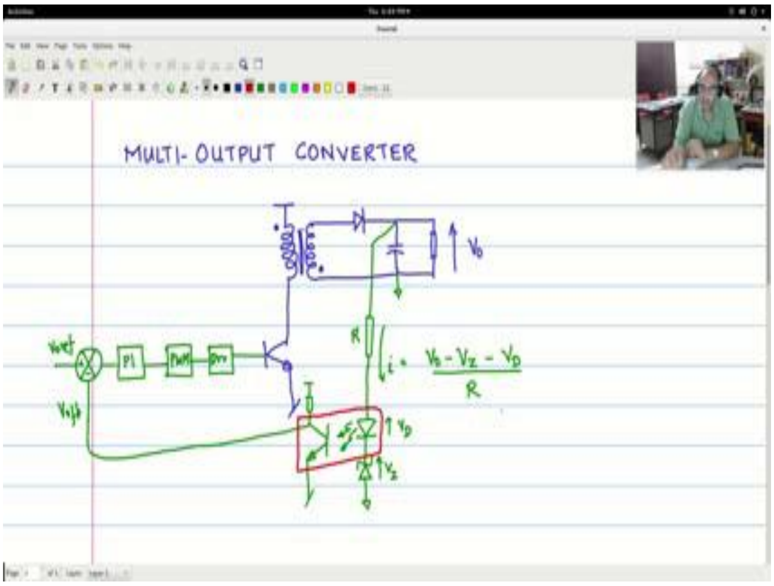

So, let us discus multi-output converters. How do they look like? Take for example, the Flyback Converter. The Flyback Converter; let me draw schematic it has the primary winding and I place a switch by this ground and it has the secondary winding. Now this four which is acting like an inductor and let me put the dot polarities like this. Now recall our earlier discussion of Flyback Converter and this is the Flyback Converter. Now how do we regulate the output v naught? We can regulate this output v naught by means of the close door control topology that we have just discussed and a is as well applicable to even isolated converts.

So, what we can do is let me change the colour. We can sense v naught and give it to a controller. I am not going to put the controller in detail I am just going to say this is v naught curve. Here this is v naught feedback this goes to a controller. So, P I this is P W M and that controls it and this is actually (Refer Time: 04:31) voltage. Now remember that we did go to great lines to create isolation between the output side and the control side, and moment you use a conductor to measure and sense and then give it back into the control side the isolation is lost. So, therefore, in order to maintain the isolation between this portion of the circuit and all the downstream portion and this portion of the circuit, we would like to have an isolation barrier here even during sensing and normally this is done with opto couplers.

So, how this is done; is as follows. So, let me now erase this portion of circuit and at this point introduce an optocoupler. More than a optocoupler you allow some current to blow through the diode like this probably I put I use a zener and I am not going to connect it to this ground I am going to have a different circuit ground which is this. So, it now appears that there is a current flow from this output it goes through this diode zener back again. So, it keeps circulating in this fashion. So, what is the correct value? So, in order not to short circuit I will introduce a resistance here and that is (Refer Time: 06:27). So, let me now put a resistance. So, now, if you look at the current across through here it will be equal to v naught minus v z you see this is v z minus any diode drop (Refer Time: 06:59) incorporate the diode drop minus v d we said this is v d divided by r and r is integral resistance part.

Now, this is the current that is flowing through this diode. Now suppose this diode was part of optocoupler meaning when a current flow through the wire there is a light output. Now this light output is connected to a control switch wire. Now this control switch let us say I placed it in this fashion. You see that the control switch is having the ground which is the same as the control portions of the circuit. All these have the same ground. Now the optocouplers b j t part is having the same ground. So, what happens (Refer Time: 08:13) is that as the current flows through this there is a light on output which is actually acting like a this drive for this b j t and tries to bring it or bias it to its linear v j and more the current more the wires and lesser the v c a drop across the transistor lesser the current lesser the base bias more towards the cut off and more is the v c a drop occurrence transfer the transistor.

So, therefore, as the voltage here is changing which is what we want to sense and we did back. The current here changes and the voltage drop across this also accordingly changes. Now use that as a measure use the voltage drop across the v c a of this optocoupler output as a measure about change in the output voltage and use this is what we declared appropriate. Appropriately you can tap the voltage and the collector point or the emitter point to see that the overall the close loop is negative feedback that is important. So, therefore, now we have a means of sensing the output voltage in an isolated manner. Now this portion will be the optocoupler.

I have just indicated to you the optocoupler action and I have just drawn a line here to this point, but there are other parts other circuits that will coming here and here (Refer

Time: 09:47) filters and the attenuators or probably even amplifiers that come in the picture anyway. This is (Refer Time: 10:02) feedback with incorporation of an isolation and optoisolation in close loop in isolated curves.

Now the let important point I like you to see is that with one control topology circuit, you can control one set of switches either this or in the case of the push pull full bridge and half bridge circuits, you can control the other switch to the other set of switch because the duty cycle or coupled in the sense that the same duty cycle can be applied to the other side too. Only thing is that the mutually exclusive and this particular and one switch is on the other switch is off and the other switch is on that this particular the first switch would have been off.

So, therefore, still control input wise there is only one control input which is one single duty cycle control which can control one output. So, one output of the multi-output Flyback Converter can be taken care of this controlled manner one above the others. So, now, let us look at that particular point.

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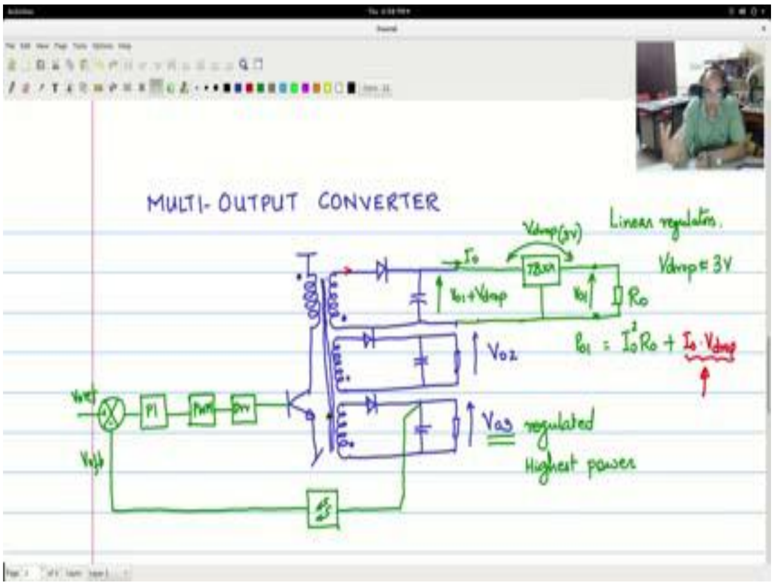

So, now assume that I have two more windings like this all wound on the same court. So, this will become v naught 1 this will become v naught 2 and let us say for example I have one more and that is not 3 and all these are on the same winding and which means that they are all coupled and I am indicating the coupled by these lines. Now you can put the dot polarities too. So, let us say only one come out in the group or given back for feedback and let me indicate the isolation sensing boundary optocoupler boundary in this fashion. So, let us say that you have used optocouplers sense the output voltage and sense sent it back on control. So, v naught 3 is regulated, but v naught 1 and v naught 2 are not regulated what we will do. So, one very popular method which people use is to use linear regulators.

So, normally the highest power output, the output that is suppose to handle the maximum power the large power is done is given by close to the other low power once or handled by small three terminal regulators called linear regulators. So, these there are many linear regulators. You may already have heard of the 7 8 x x series; which means 7 8 1 2 means 12 volt regulators, 7 8 1 minus 15 volt regulator, 7 8 0 8 volt regulators so on and so forth. That is one such series, but there are many, many, many armatures are many, many three terminal require regulators.

Now, we also have nodes of low drop regulators. What is basically means is that you now have a load here this is your r naught and the load is not connected here any longer and what is the drop across this, v drop that is it v drop. Now v drop is he has to be compensated by this dc-dc converter output and therefore, accordingly the windings of that particular supply should be enhanced to take care of this v drop. So, in the low drop regulator this v drop value is very small. So, typically v drop is of the order of this is the order of 3 volts in many most of the normal regulators at minimum of 3 volts will drop here has to drop across the regulator, which would basically means if your output spec here is v naught one and the spec and the output of the, the spec at the output of the dc-dc converter here should be v naught one plus v drop of the regulator.

So, if it is 3 volts there maybe not 1 plus 3 volts. Not only that we have to enhance the power spec also because the windings will have to carry that extra power. So, if you have a load current i naught max which is flowing through or not. Now i naught into v drop these also the power that this particular winding has to handle. So, p naught one has to handle i naught, r naught plus the extra amount of i naught into sorry it would handle i naught square, r naught plus i naught into v drop.

Now this is the excess power that the dc-dc converter should be capable of handling to take care of this v drop there. So, the current carrying capability and the size of the core may slightly increase because of this. If one uses the low drop volt regulator v drop can be as low as point 5 volts and you will have a very less dissipation and drop out there. And you will not loose of much on the size of the transformer core. Likewise for the other winding also, likewise for this other winding to you can put three terminal regulator and accordingly adjust the output required or output requirement of the regulator the of the dc-dc converter.

So, with the regulator what will change is only the v naught requirement and the power requirement output power requirement for the regulator and other portions of the design was still remain the same. You can still use the (Refer Time: 18:58) design file to do the design of multi-output regulators and in fact I have output of the last weeks this one and example of the Flyback with multi-output. You can now study that in this context point we have just discussed now. So, this is one (Refer Time: 19:22) which you address them regulation of all the outputs of a multi-output converter.

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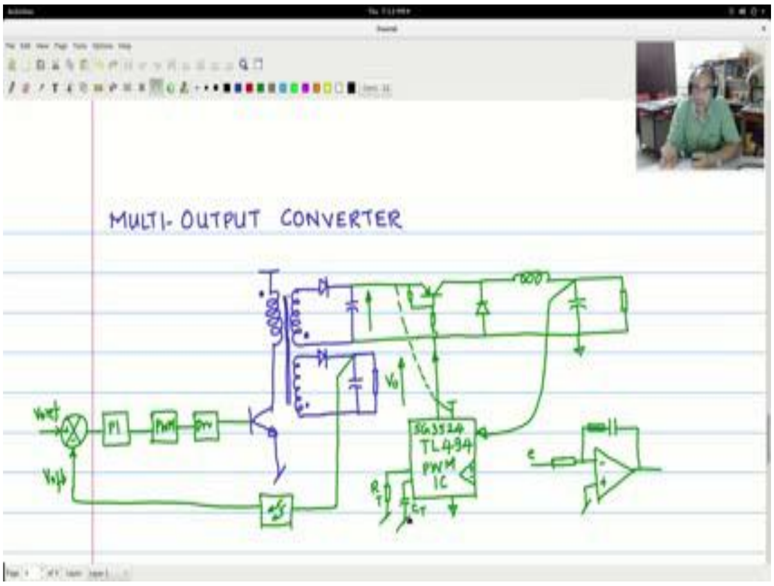

I shall now in this state another method of tackling this regulation of multi-output converters. So, let us say I will take the same example of Flyback, but you should understand that you can apply these principles to any of the isolated converters not necessary that it should be a Flyback it could be a forward converter, it could be a push pull converter, it could be a half bridge converter or even a full bridge converter. So, now, let us say that we have these two outputs. I just taken two without loss of generality and let us say the bottom one I will feed it back through opto isolation barrier. So, we are not disturbing the (Refer Time: 20:26) isolation that we have achieved by use of transformer. Now with this we can regulate v naught of this. So, this is regulating, but how to regulate this voltage.

So, in the general in the discussion that we just now had the previous model method; we had used the three terminal regulators a linear regulator. The problem with the linear regulator is that it is dissipative and therefore, the efficiency comes down and size becomes higher. So, therefore, the plan now is that we will try to use a non-isolated converter here. So, this is an input to the converter. Now let us say you want to have a buck operation I can use a buck converter like this.

And have an inductor capacitance and a circuit something like this. Now driving this device is better if you push this device on to the negative rail that is the return rail. So, that you can drive with respect to its base if it is on the return rail or you want to keep it on the upper rail, you can use a p n p transistor or p device. Now let me just show a symbol blocks of the circuit, that all would be referred to this particular ground.

So, now let us say that I replace this b j t with a p n p type. So, we could have a b j t something like this p n p base. So, let us say we have a small register drive like this and having that out. Now this get drive can come from a standard modulator. Now standard modulators are available in the market very very less expensive. For example, t l 4 9 4 is a typical modulator which is commonly available it is around 10 to 12 rupees and this will generate P W M. You have to give it a supply and the supply and it should have a ground. So, let us say I chose this as the ground and you refer it to that ground. So, you still there is no link to the ground of the others (Refer Time: 24:16). Now the output of the regulator itself can be the supply. The output of the dc-dc converter itself can be the supply. Now you may ask a question the output of the dc-dc converter is not regulated.

So, then can it act as a supply for t l 4 9 4 type of devices that is the P W M I C. You can ask in the market for a P W M I C. Most of this type of a P W M I C's you also have another name I can say s g 3 5 2 4, s g 3 5 2 4; this is also a P W M I C very much expensive they have very large supply voltage range. If that t l 4 9 4 goes from 8 volts to 30 volts and likewise even the s g 3 5 2 5 2 4; which means that these P W M I C's can take unregulated voltage for their v c c.

So, this would give out a P W M which will drive this particular device on and off. And most of the I C's they have inbuilt internal components too which can act as comparators and deference amplifiers and also even P I controllers. You can use you can make a P I controller with an op amp using a very simple circuit topology like this. So, let us I have ground, this is a resistance, and let us say you have a capacitance across the output and the main supply and you are having an error coming in through here. Now this is an integrator.

So, this integrator is like I control and you can also make a P I controller by also including a proportional part of the, for this controller. So, you have a proportional and the integral controller. So, this would be a P I controller. So, with we have one op amp there are normally 1 to 2 op amps available most of these P W M I C's. So, one op amp can be a controller, one op amp can be a deference amplifier and things like that. So, you feed in the voltage to the controller and to the appropriate pins make use of the internal op amp's to make the difference out of that the error of that we need to the other op amps think to make the P I controller and that output is fed to an internal P W M. So, there is facility for setting the frequency of your switching frequency for this buck portion of the converter with the help of timing registering the capacitors.

So, these would be the r t and c t for the local P W M I C. Now this P W M I C is referred this P W M I C any other ground is referred to this, output itself which is also same as that of the input and input to this buck regulator and the output of the P W M is directly controlling the switch and the output the P W M is coming out of the controller which is within this and your feeding this sensed output in here. So, if this portion this green portion which I am showing here with the mouse is a full (Refer Time: 28:37) close loop buck regulator that we discussed till now and even simulated.

Now instead of the linear regulator this buck regulator can replaced that and then this will definitely have a much better efficiency because this will not inter pose except for the on state drops something like that one the efficiency of this will be much higher than the linear regulator. So, you one can use one of these types of non-isolated regulators non-isolated dc-dc converters to act as regulators in multi-output converters. So, that way all the outputs of the multi-output converter will the regulated and give you proper and expected outputs.