Fundamentals of Power Electronics
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Lecture – 92
Simulation of close loop control

We shall now look at the Simulation of buck converter in closed loop. So, let us open this buck close dot sch, which is the closed loop schematic for the buck converter.

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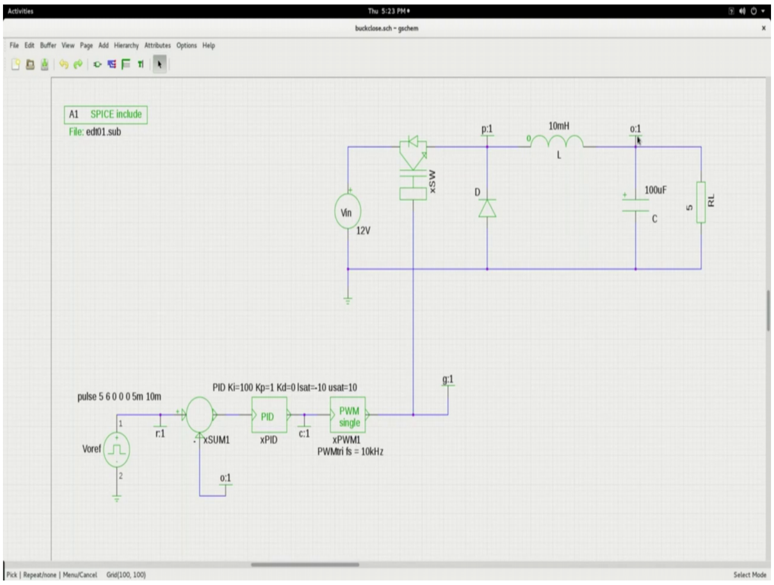

You can use the same approach for any other converter too, let me zoom in yes. So, you must be able to recognize this portion, you see that this is a dc source 12 volts, this is the switch power switch which we will be controlling through some duty cycle. And you have the buck converter portion L and the C which we used in the open loop simulation and the inductor will freewheel, when the switch is off or the switch is on the inductor will charge. So, all those things you know.

And I have put some load right load of five ohms that will give me around somewhere around one amp of current. Now, the changes that we have made is here in the control portion, which ultimately is going to control the gate drive of the switch. So, what is it that we have done? We had actually included the PWM in the open loop itself and we are given a constant voltage here. Now, instead of the constant voltage, we are now having a controller, a comparator and the feedback.

Now, the feedback is given through this label and you see that when we discussed in theory we had connected this directly to the output, but then instead of cluttering up the schematic, you recall that we had given a label here called o and same label if I copy it and put it here, it is equivalent to saying that I have made a physical connection between these two points. So, this output voltage is actually now fed back to this point. So, here you are having a difference amplifier plus and minus to the plus I am giving a reference voltage.

The reference voltage as you see here is not a constant I have given a kind of a pulsed disturbance. So, that we will actually see that the output is tracking this pulse disturbance but; however, in actual practice you will see that this will be a pure constant set point value. Now, the difference between the set point and the fed back voltage, the error is fed to the PID controller and the PID controller has some parameters Ki parameter for the integrator, Kp parameter for the proportional, Kd for the differential. I am not totalizing it I am setting that to 0, there is lsat that is the lower saturation limit set it to minus 10, usat the upper saturation limit setting it to plus 10. You have control on setting it to still lower values too.

Now, this output is finally fed to the PWM which will generate the appropriate duty cycle pulse and give it to the power semiconductor switch here. Now, this is the total closed loop circuit of the buck converter and this is the closed loop portion and this in fact, is the controller with these parameters. Now, let us see what happens when we simulate, all these things now you know how to import the file and this is the inclusion of the edt01 dot sub.

Now, before we go to the simulation what is it that we have added? We have this is one block; this a new block that you would not have seen till now, and this is another block that you would not have seen till now. This is nothing but a summer, this is one of this is this has been built using the analog behavioral model of Ngspice likewise PID is also built using the analog behavioral model of Ngspice. I will just show you how that block; the model for that block has been incorporated in edt01 dot sub.

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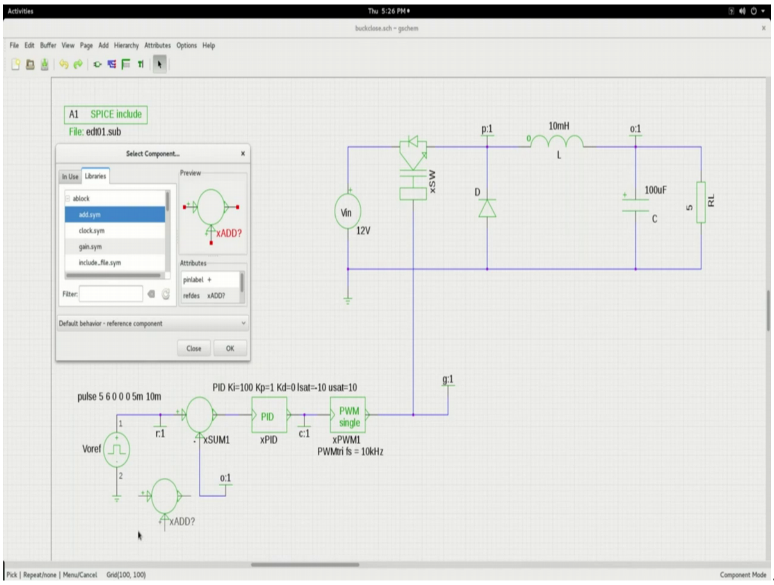

Now, these two blocks are available in the ablock library. So in the ablock library you see added. So, this is the symbol and that is what we have pulled and kept it there this symbol you recognize that.

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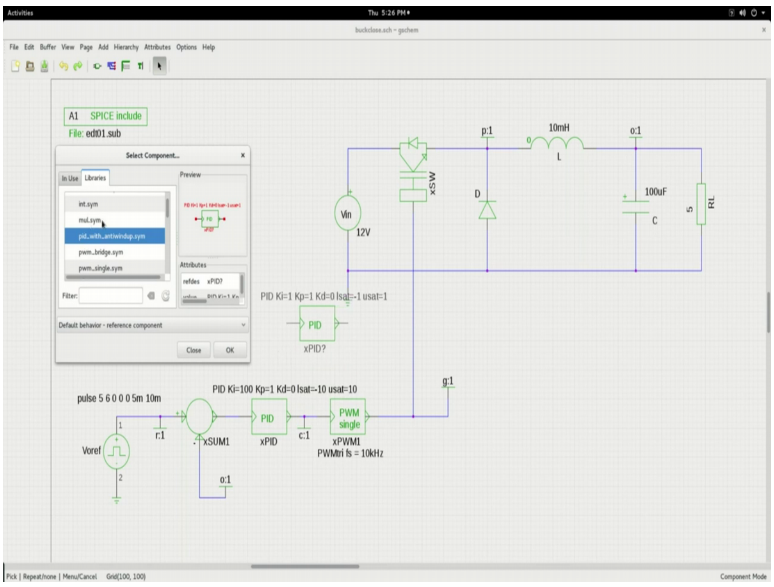

And then the other file is the PID this is the PID and this is what we had; we have used here. So, this is available in that ablock folder of the library. So, now, let us save all this and the schematic let us use our well known process which is first we will go into that directory and generate net list.

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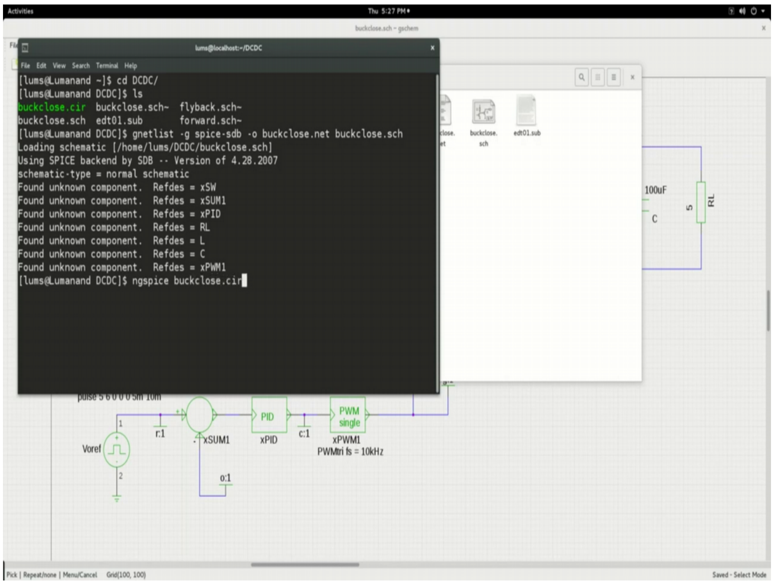

So, this is the net list or command and I think you recognize this I am using the buck close dot sch and generating the buck close dot net. So, let us generate the net list and you would see here that the net list has been generated. And now, let us go on to the ngspice environment and call buckclose dot cir.

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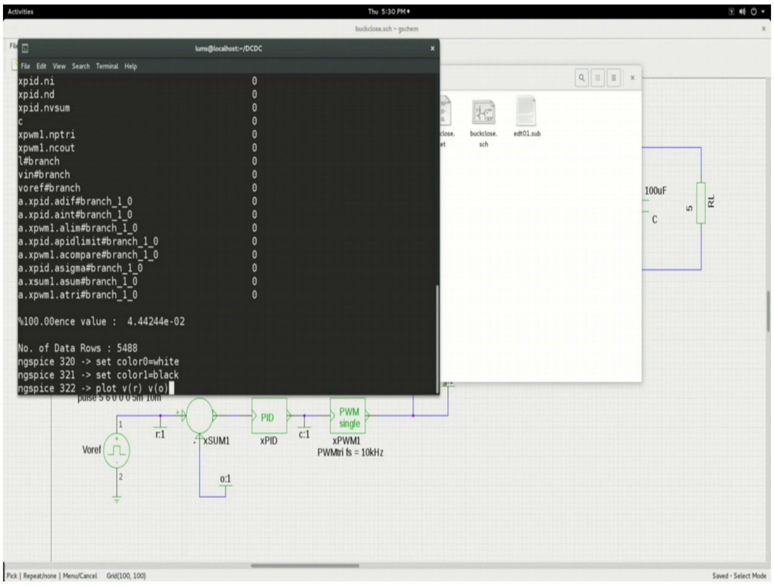

Plot; now, I want to plot the reference and the output, just to see whether the output is tracking the reference. So, let me plot r and the output o.

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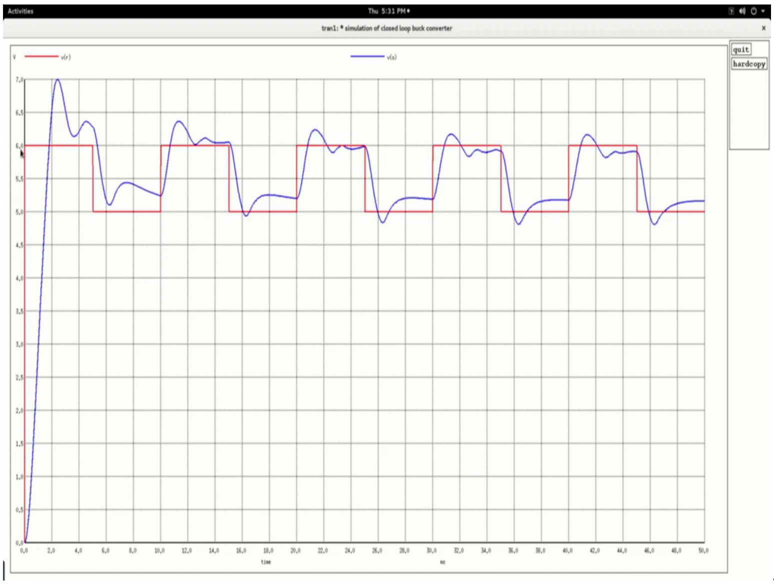

So, you see the red waveform is the reference waveform and the blue waveform is the output waveform it is trying to track the reference waveform. Of course, though it is not the tracking is not too good we may have to tune the PID parameters, there is a measure of control and you see that it is getting controlled between 5 and 6 volts. Now, what I would like to do is quit on this environment, I will go and adjust these parameters. Now Ki is the integral constant Kp is the proportional constant.

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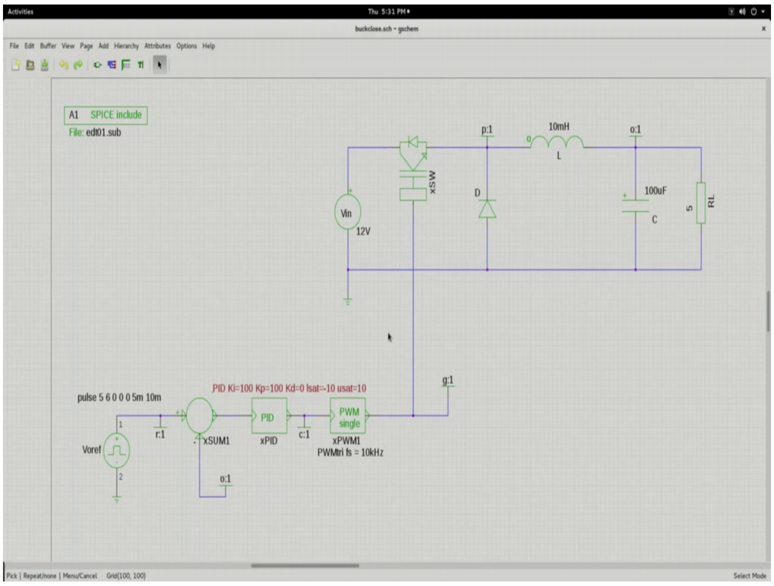

And let me change the proportional constant to a larger value, so that the dynamics is improved. Now, we will have to do all these things in step by step, but I am trying to do it in the one big step just so that we save some time, but you can play around with these parameters here. Now, let me save this and then let us go back and generate the net list.

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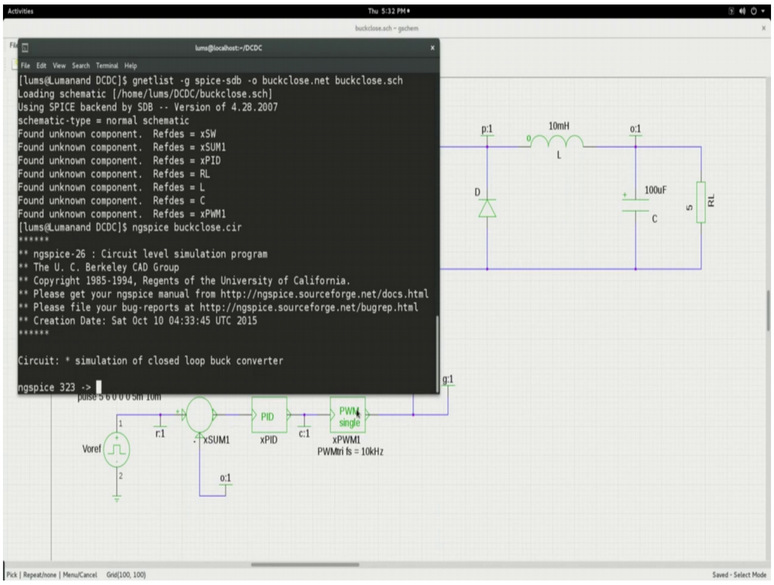

And I will go into the ngspice environment, run that.

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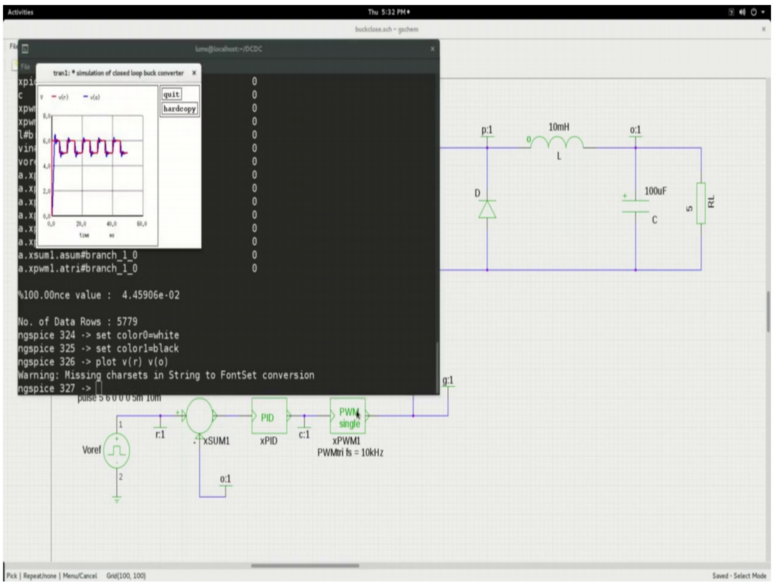

And let me do these settings and we can now see the same waveform v r and v naught.

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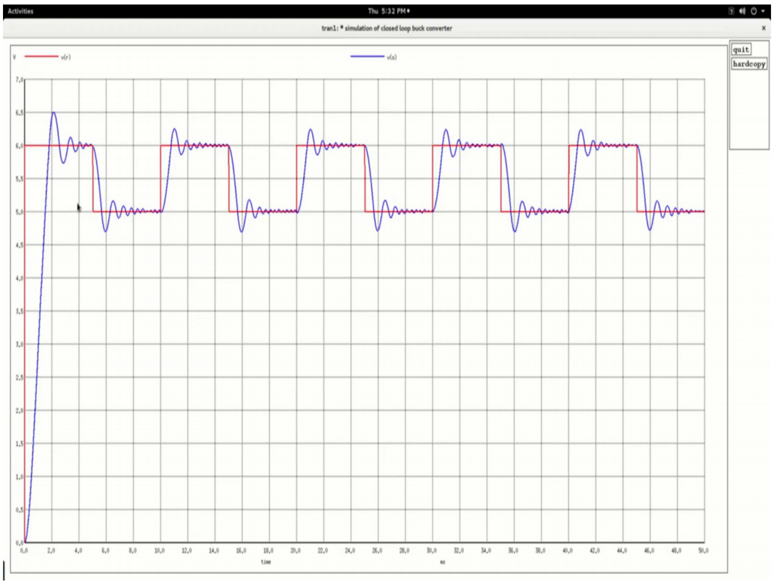

So, you see it is much better you see that the waveform is more closer in tracking the dynamics are better; basically because you have improved the dynamic response by the choice of Kp.

Of course, I will leave it to you to play around with all the different parameters and also the parameters of the buck converter, L and C's and just try out through that. This pulse the kind of a reference is just for this purpose of learning so, that you see that there is some effect the output is trying to track the input and output is coming to a desired value. In practice it will be constant let us say you want to give an output of 5 volts your set point will just be 5 volts, it will reach the set point 5 volts and continue to stay here without all this jiggly-wiggly wave shapes. So, this is just to show that the buck converter output can be regulated. So, now here you see that.

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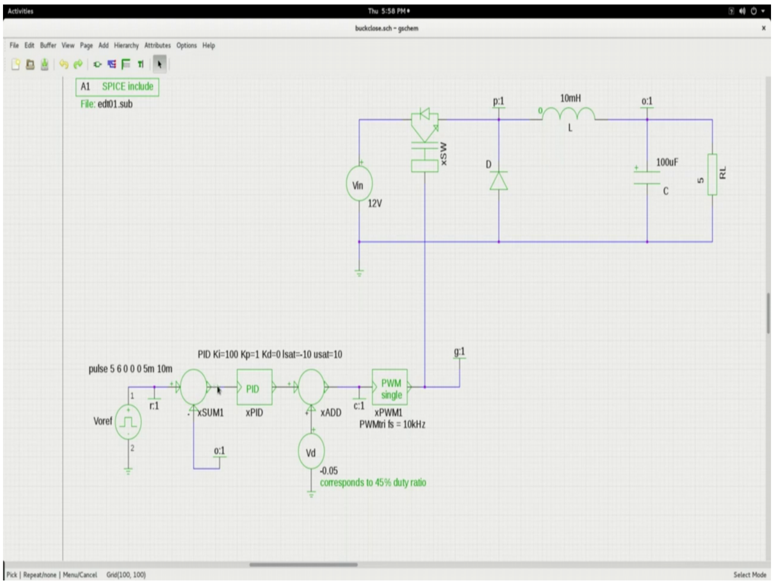

This of course, is the same buck converter circuit you have the PWM block here, which is giving you the appropriate duty cycle and on this side you have that reference; and then you have the feedback coming from this o label here; o label which is connected at this point, this is the error is passed on through the PID controller. And the output of the PID controller corresponds to d hat; corresponds to the deviation in the duty cycle a voltage corresponding to that.

Now, here on the other terminal of the hat adder we are having a dc voltage and here I have given minus 0.05 to correspond to 45 percent duty ratio. So, this is the nominal value or the operating point value which I am giving it as a feed forward term and this plus this will be this control voltage and this is d plus d hat, with even the variation that is coming due to unwanted reasons and it is coming from the controller. This goes into the PWM and controls the switch. So, this is how we have this feed forward time here.

So, I would also like to simulate it and then show it to you this will not take much time, I will put back the those numbers which I put the last time during the simulation of the other buck closed circuit.

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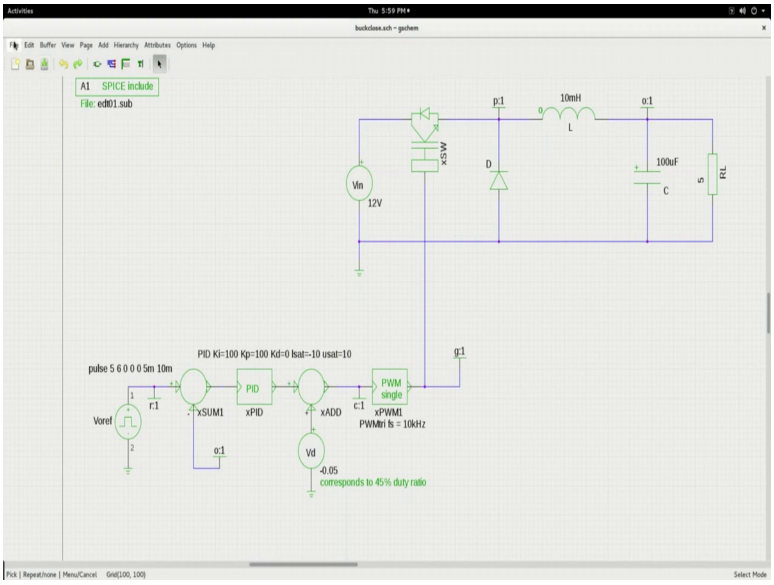

So, let me save it here now recognize that x add is another new block which I have included, PID and xSUM you saw. And x add is also available in the ablock this is the add and you can use that and this is the SUM which is used here ok. So, this is saved and we can go to the folder here.

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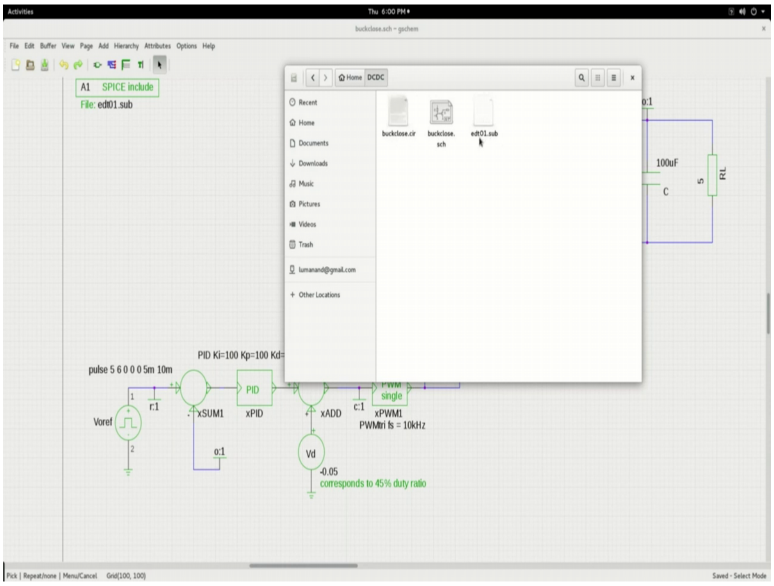

Now, here the buckclose and dot cir and the edt01 dot sub, I did not show you what is there inside edt 0 dot sub you should understand that I have added some things here.

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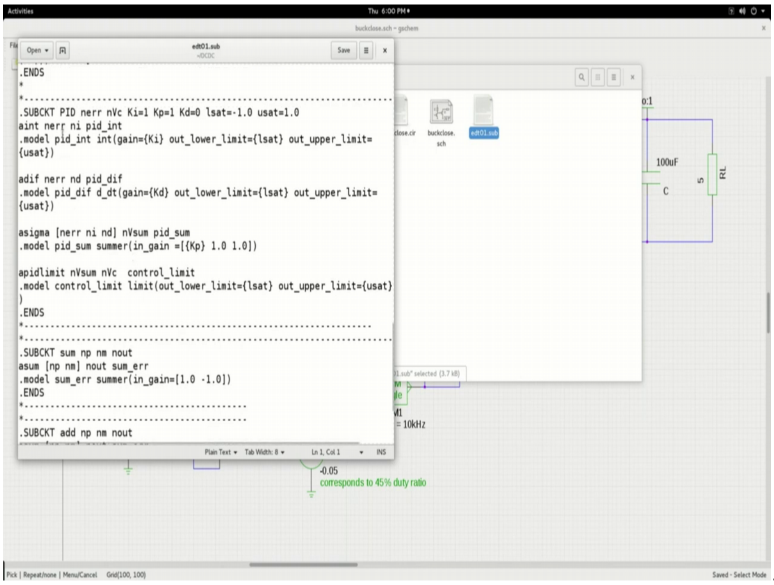

I have added the PID sub circuit, this is again composed of all analog behavioral modeling elements; and these are well defined in ngspice manual. And then I have made a summer and that is also by the analog behavioral model.

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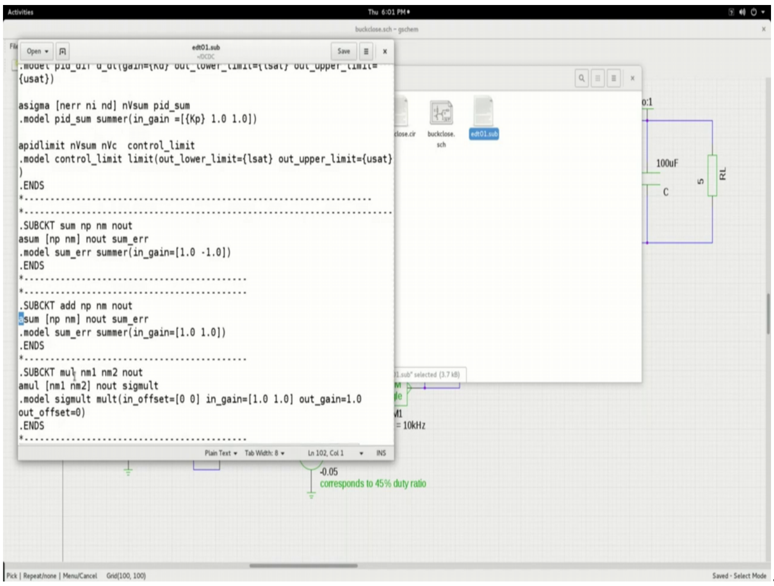

I have made an adder here and that is also ngspice analog behavioral model. I included here a multiplier also, but of course, we are not using it anywhere just kept it here for your reference. So, you will close this.

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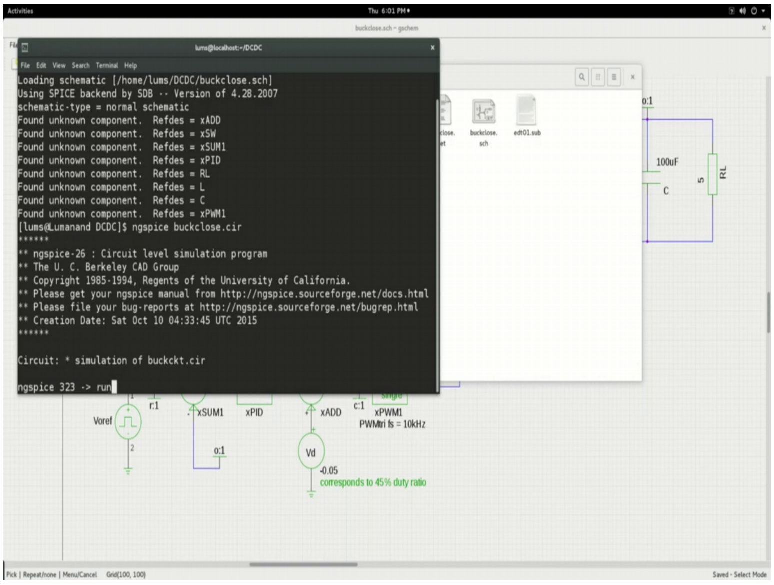

Now, let us go to the terminal and let me go to the directory; cd to the directory and let me generate the net list and you now how the net list generated here, you see and ngspice buckclose dot cir or your into the ngspice environment, you ran the program.

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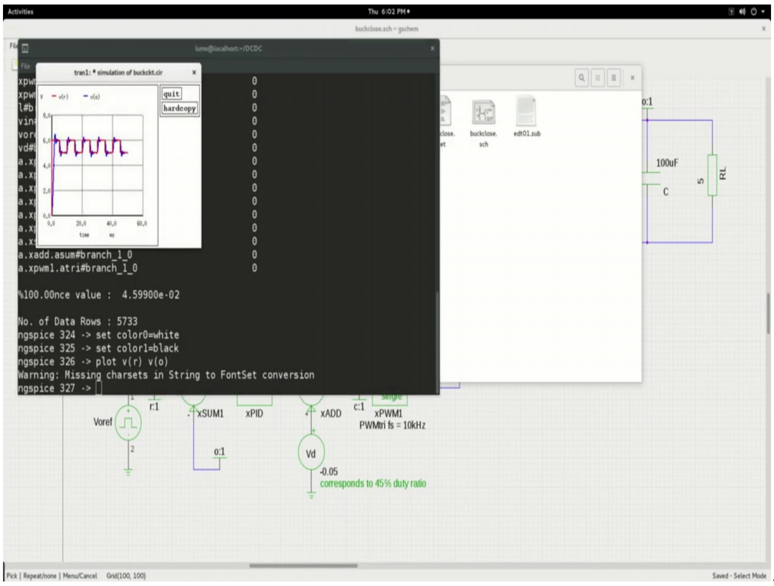

And now let me set the background color to white and set the foreground color to black. Now plot, I want to plot as usual the reference and the output v r and v naught. So, you would see that it gives you also similar kind of performance measures. You could also see what happens here and what is the gate pulses which are given to the switch you could probably see plot v g which will give you the gate signals.

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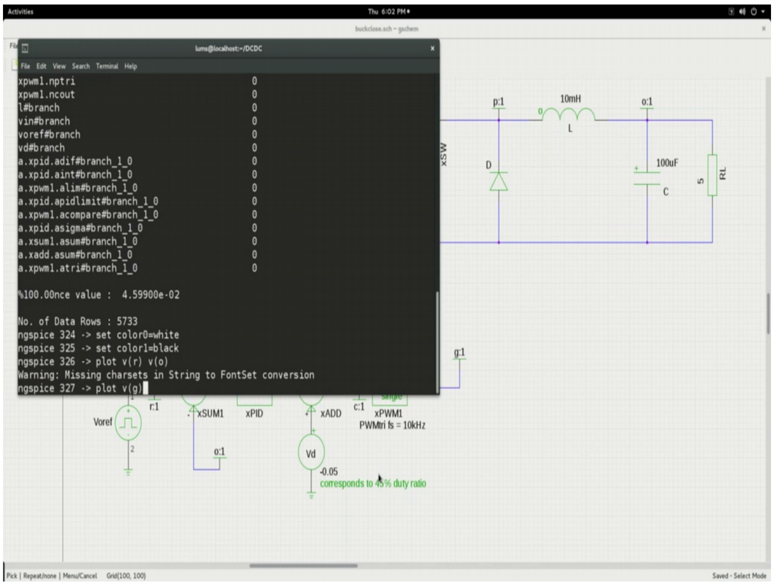

So, this will be the gate pulses which are varying continuously as you would see here and you could also see the inductor current plot i of L along with v naught.

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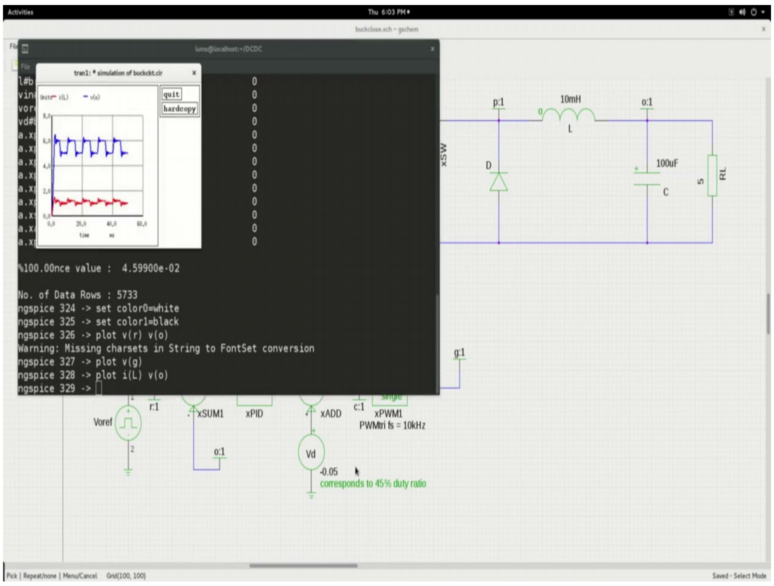

So, you see that because v naught is no longer constant you see that the induct current is also having a lot of variations.

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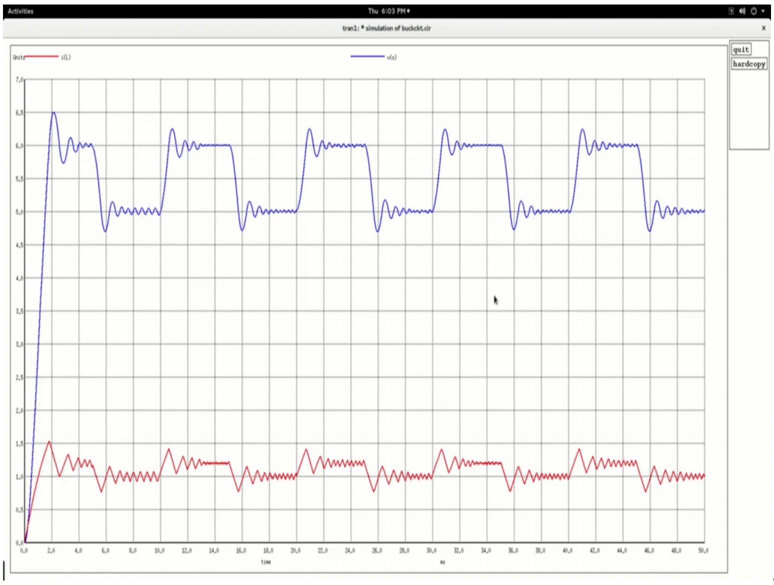

But you could see here probably, in this time span where it is constant it would it will be like what we expect if I increase the amplitude.

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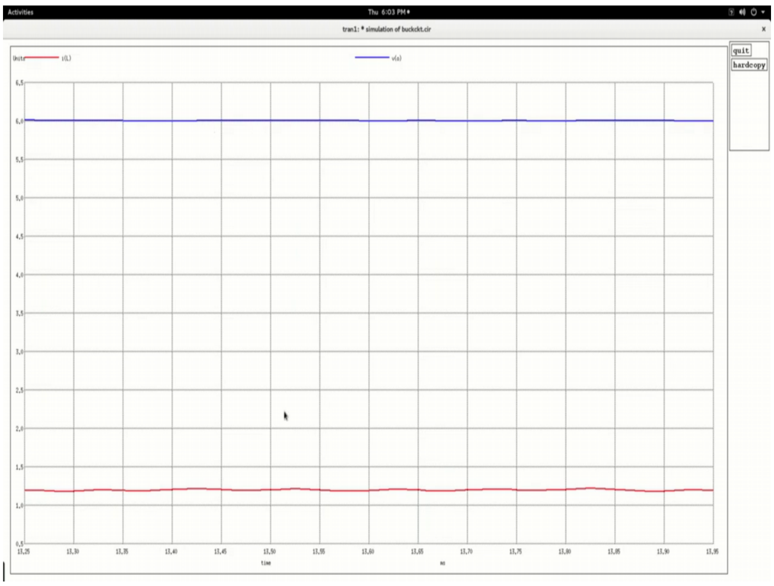

You see this is what we would like expect when it is constant. So, you can play around with the waveforms and the values and you should be trying to forget more inside into this whole close loop system.