Fundamentals of Power Electronics
Prof. L. Umanand
Department of Electronics Systems Engineering
Indian Institute of Science, Bengaluru

Lecture – 98
Simulation of sinusoidal PWM

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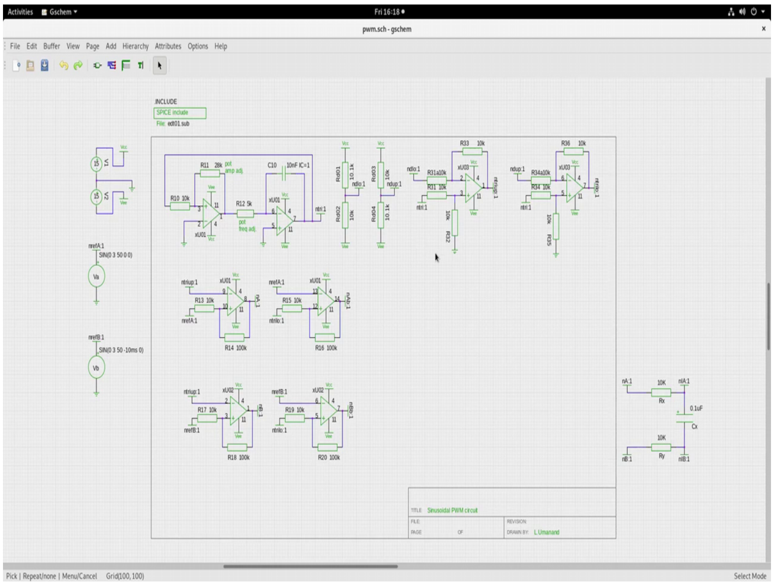

Let us now look at the Simulation of the sinusoidal PWM circuit. So, this is the schematic of the sinusoidal PWM circuit. There are some things which have written outside the page marker. So, here is the power supply, I am using power supply here and this is the reference sign sources, modulating sources. And on this side I am having a filter just to see whether you will be able to get back the fundamental modulating signal and what is within the page border is the actual PWM circuit.

So, let us examine this. So, let me expand. So, this portion here this is a triangle generator. So, simple triangle generator which I have made using op-amps, so you see here this op-amp across the minus in the output I am having a capacitor and then a resistor connected to the minus point coming from some signal. So, this portion here, this portion which I am indicating through the cursor is nothing, but an integrator. So, this is integrating, the output of the integrator I am giving it to a comparator is a comparator with hysteresis. So, main it is a comparator, so, once the value of the integrator crosses this threshold, the trip points you will see the output here going high or low.

So, if it is going high, then this integrator is integrating down. If this goes low negative, then it is integrating up because the inverting integrator. So, the output here will be a triangular waveform going up and down both positive and negative. So, this is the triangle portion. So, to the triangle what do we do? So, the triangle to the triangle we will add a small epsilon voltage to get the v c plus and that is the upper triangle and to this we will subtract a small voltage or the epsilon voltage to get the lower triangle. So, how do we get the epsilon voltage? I am having this Vcc to Vee potential division. This potential division is not of equal resistance. It is slightly offset on the upper side I have 10.1 k and it is 10 k here on a similar attenuator.

On the lower side I have 10.1 k and it is 10 k here. So, when you take the centre points here, this will be slightly negative and this would be slightly positive. So, I am calling this one as n d lower n d upper. So, use that one to add to the triangle. So, to the triangle you are subtracting get using a different stage and you will get the triangle upper and then use the other one to subtract different stage, I get the triangle lower. So, this will be v c plus and this will be v c minus carrier plus and carrier minus. Now, use these two upper and lower carriers to obtain the PWM with dead band or the dead time ok.

So, now if you go to this portion, the comparator section, so you have the triangle upper connected to the minus and to the plus you are having the sign reference. So, the sign reference is this is again a hysteresis comparator and the output of that will be the pwm. Now, the sign reference given to the minus and a triangle lower or Vcc minus given to the plus, this will give you the PWM bar PWM a bar. If this is the for the PWM a this will represent PWM a bar with the dead time. Likewise for the other arm, you use the reference B compared with triangle with the triangle upper career and you will get n B and then use the reference to minus and the triangle lower triangle lower to the plus, you will get n B bar.

So, these 4 signals you used to drive the switches top bottom of one arm, top bottom of another arm. So, if these are given to the full bridge switches, they will generate the desired PWM waveform at the centre of the bridge. For the modulating signal reference I am using sign just giving a amplitude of 3 and 50 Hertz and for the other arm B arm I am giving the same sign signal, but minus 10 milli seconds 180 degrees phase shifted. Now I am having this library. Within the library is the sub circuit for the op amp. Also I have used a generic op amp. Have a look at that one.

And this here filter across the bridge arm A to B, I just put an r c filter to see if you will be able to extract the modulating signal fundamental modulating signal. Of course if you put a higher value of capacitance, you make it a much better purer sign signal. So, now let us simulate this circuit and to simulate this let us go to the terminal window.

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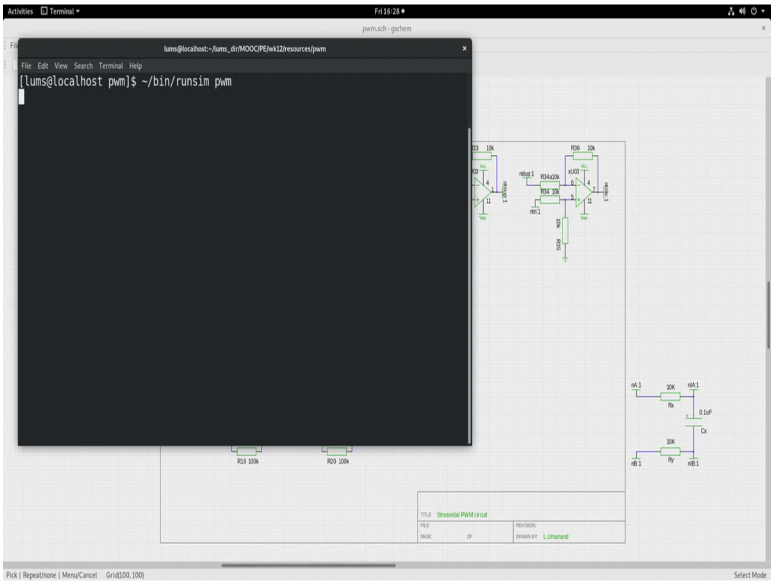

So, I open the terminal window. So, here I will run the simulation. So, before I run the simulation, I would like to show to you the dot cir file. Let us see the dot cir file. So, within in the dot cir file, so we have the trans statement I am going to see up to 40 milliseconds which is 2 cycles.

I am going to use this PWM net and the usual making the background colour white background colour, black and running the simulation. What am I going to see? I am going to see n A and n A bar and the voltage across the centre of v n A minus n B that is across the centre arm of the bridge of the full bridge. Let us now go back to the terminal and run the simulation. I will use runsim pwm. So, it will generate the netlist and then run execute the simulation.

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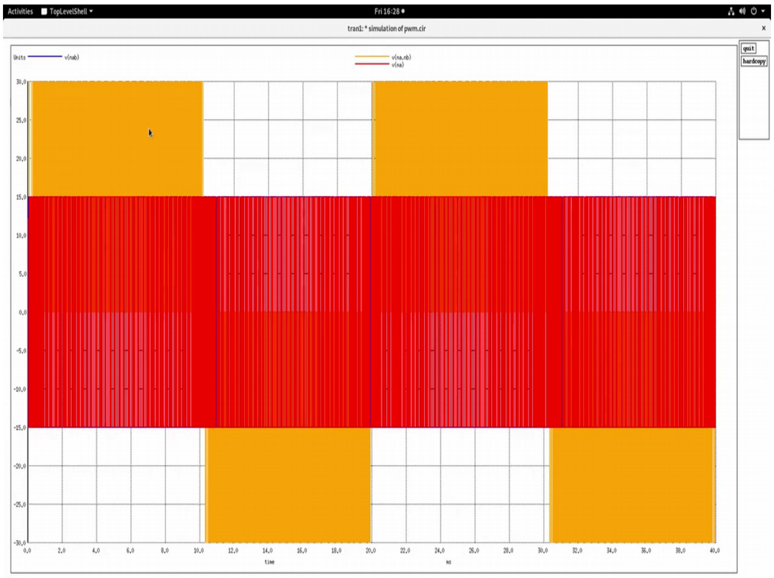

So, this is basically the PWM waveform. The red one here is n a the blue one is n a bar. You are not able to see the blue one here because it is hidden behind the red one. Probably I will expand that and show, you will be able to see the blue here.

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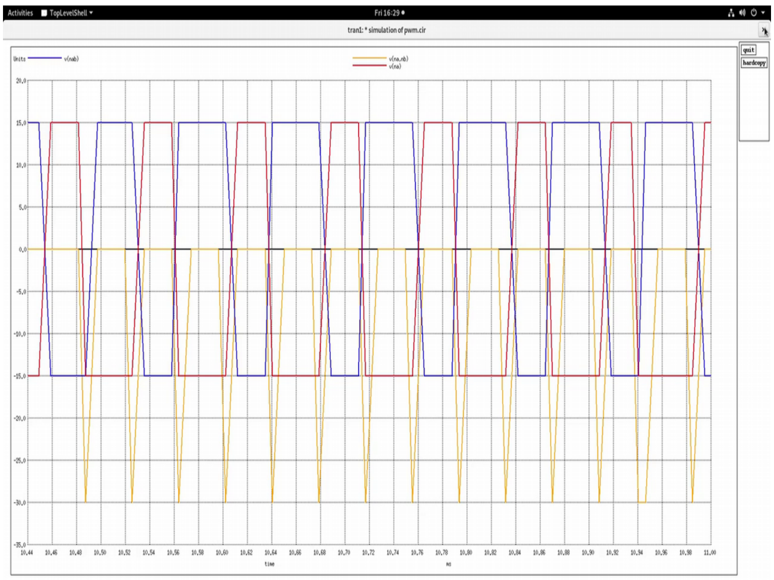

So, the na bar na, na bar na they are mutually exclusive that are being generated; the angle rise time fall time is because of the print steps. So, it is calculating at much higher resolution, but it is printing at a lower resolution of 10 micro seconds ok. Then coming back here the yellow portion is the PWM signal which you are seeing across the full bridge center arm the center portion.

Just to cross check I can see the voltage across the filter. Observe that I have given nA; nA to here nB to here and I have put an rcr filter and across the c, I am observing there is there are two labels nlA and nlB and across nlA and nlB you will see the filtered portion of the PWM signal. So, let us do that you should see a sine. So, let me plot voltage.

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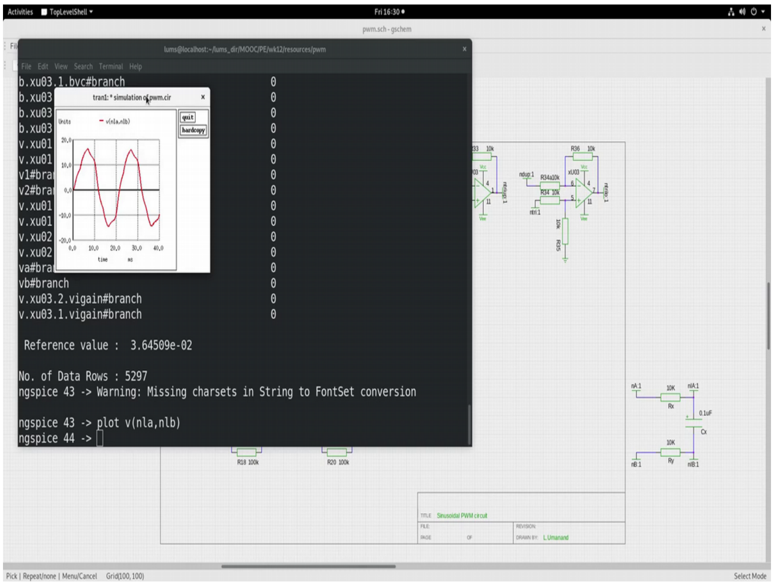

Nla comma nlb, this case in sensitive.

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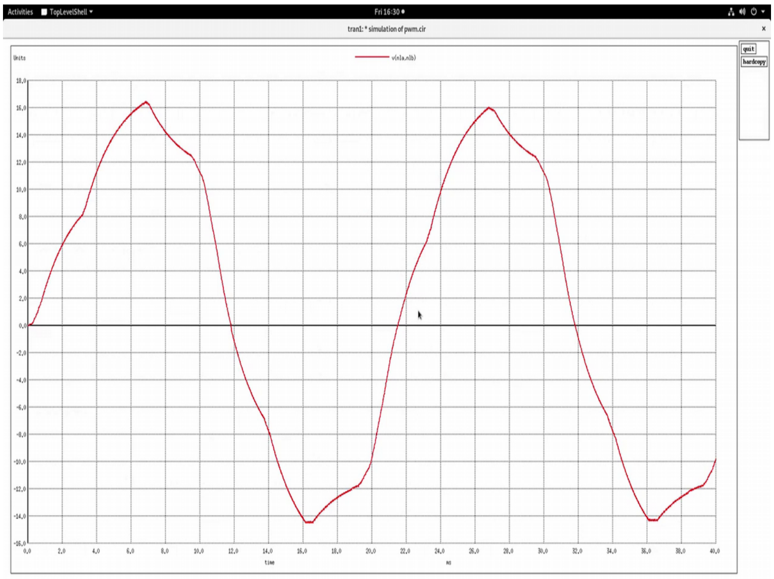

So, you will see that here that the filtered portion I have put a very low value of c, but you can as well put a large value of c and get a much smoother wave shape. Also note that there will be some harmonics due to the dead time that we are giving and the dead time will introduce the harmonics and it will not be as pure as sine wave has expected. The smaller the dead time, the better will be the sinusoidal extraction of filtering. So, now I will leave the circuit for you to explore.