EE230: Project
1-D Motion Stage

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1 Aim of the experiment

The aim of the project is to use potentiometer for bi-directional motion of 12 V 300rpm DC motor. The operation must be linear such that motor rotate fast as much knob rotates.

2 Pulse Width modulation Circuit

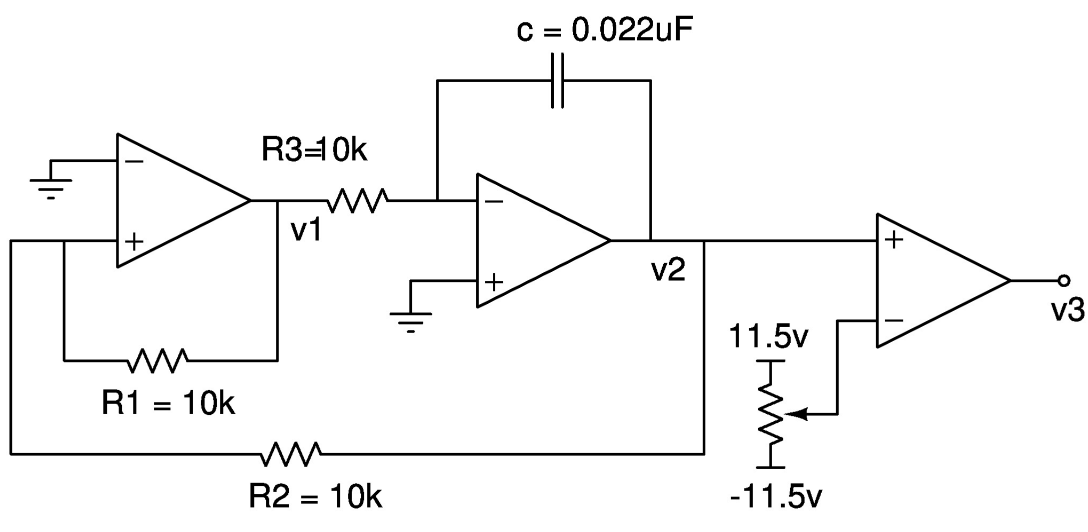

Figure 1: Circuit for pulse width modulation

We are using a Schmitt trigger and an integrator for generating Triangle wave and than we are feeding that triangle wave to the comparator as the comparator will compare the triangle wave to the reference voltage being controlled by potentiometer and will produce a PWM waveform.

2.1 Generating Triangle wave

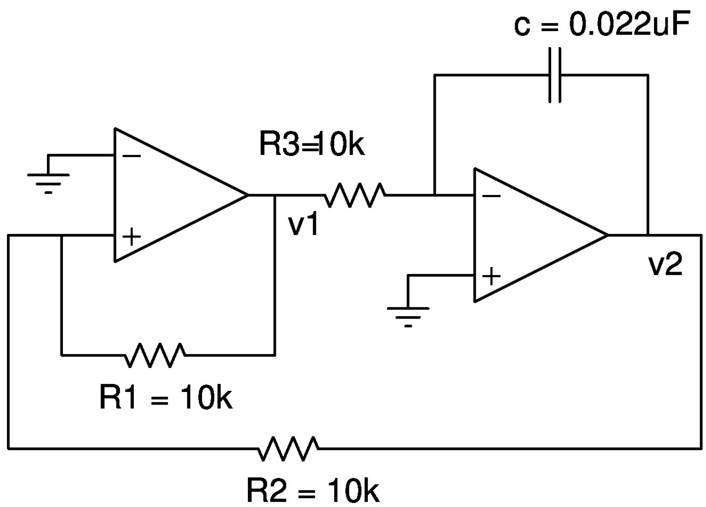

Figure 2: Triangle Wave generator

2.1.1 Integrator

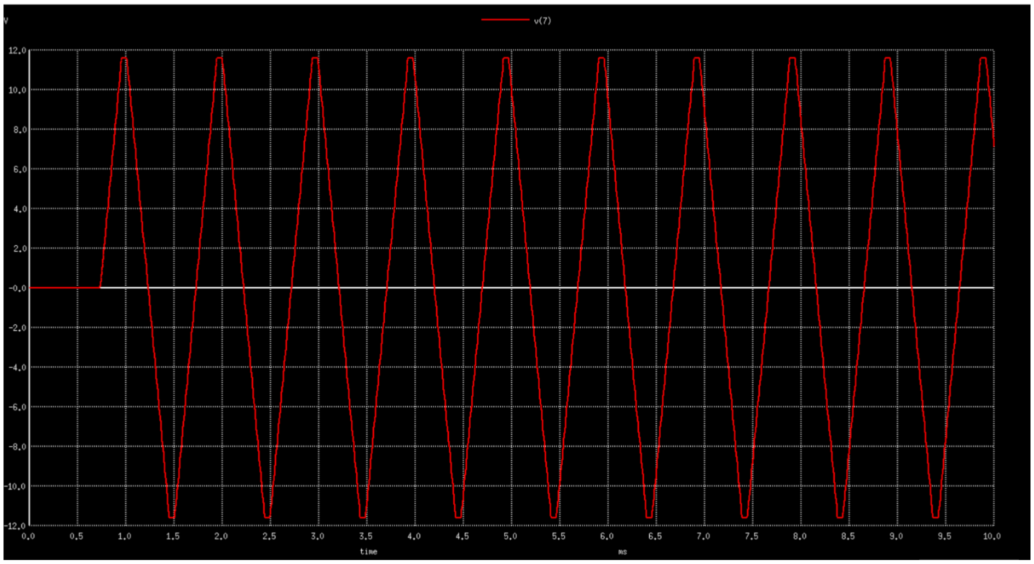

Figure 3: Triangle Wave generator

The current in R3 will be always constant and positive or constant and negative as the output of the out at v1 is always high or low.The capacitor C in the integrator circuit gets charge when current is positive and drains charge when it is negative.As the inverting input of the integrator is grounded so the opamp will always adjust left side of C to remain at zero potential.

2.1.2 Schmitt Trigger

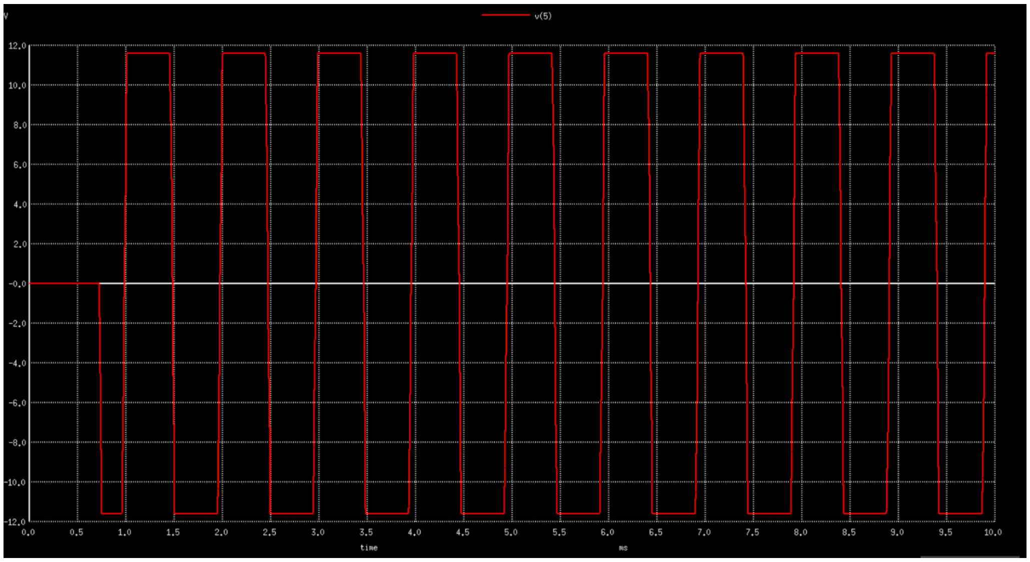

Figure 4: Triangle Wave generator

We have +Vsat = 12v and -Vsat = -12v, The Schmitt trigger output changes when the value v– crosses v+ = 0 V. Using this idea it allows us to calculate the value of v2 when the output of the Schmitt trigger changes. v+ = (10*v2pk - 10*Vsat)/(10+10)

Vsat changes when v+ = 0

It gives us V2pk = 10*vsat/10 = 12v

Hence the triangular wave have amplitude from -12 to +12v;

We want a square wave having frequency approximately equals to the 1kHz from the Schmitt trigger.

We began our work with all resistors having value equals to 10k

I(from 1st op-amp to 2nd one) = Vsat/R3 = C*(dv/dt)

The slope of the triangular wave will be vsat/(R3*C).

slope = 12/(10k*C)

time taken by triangular wave to attain its peak that is to change from -12v to 12v

is (Vsat-(-Vsat))/slope = 24/slope = 0.5msec(desired)

hence the slope should be approximately equal to 48v/msec

substituting that slope in above derivation we get value of capacitor C = 0.025uF

since this capacitor value is not available in lab so we are using 0.022uF(approximately equals to that of calculated)

2.2 Feeding triangular wave to comparator

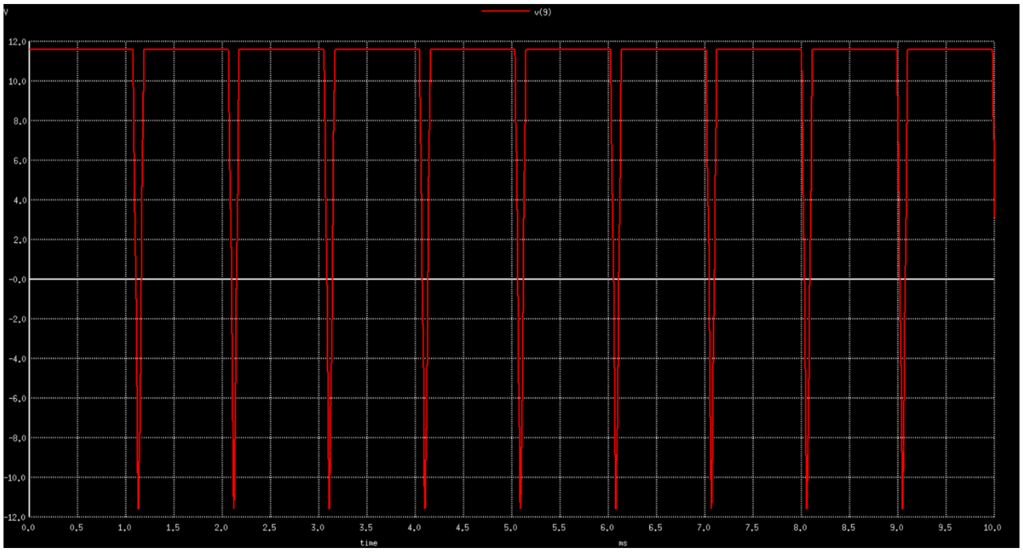

Figure 5: PWM output when reference voltage is 11.5v

The output of the comparator will be high when the output of integrator will be higher than the v- of the third op-amp(reference voltage) and that reference voltage is being controlled by the potentiometer.Adjusting the potentiometer changes the reference voltage that in turns changes time for which the output of comparator stays high.we are adjusting the value of the reference voltage from -11.5v to 11.5v

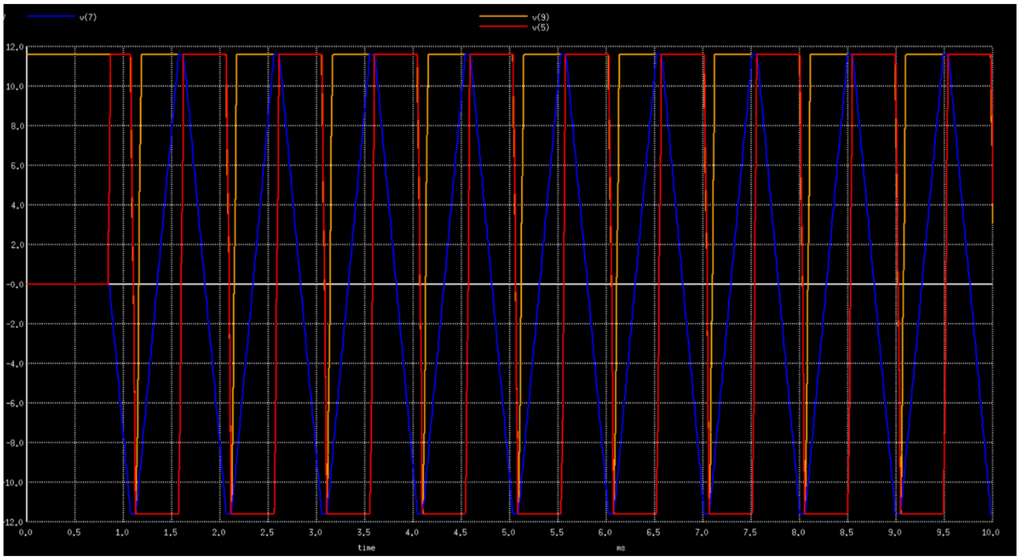

Figure 6: All three output when reference voltage is 11.5v in same plot

3 Observation and Inference

Given table show variation of average DC output voltage with different POT value.

Pot Voltage Va	Average Voltage
0	0
3	-2.85
7	-6.21
9	-8.16
11.5	-10.1
12	-11.5
-3	2.85
-7	6.21
-9	8.16
-11.5	10.1
-12	11.5

Table 1: Variation of average output voltage with different POT dc value

Here positive output will rotate motor in reverse direction as that by negative average voltage.

Inference : First circuit is schmitt trigger which is used to generate square pulse of +L and -L, where L = 12 V saturation voltage. Non inverting terminal V_- is kept grounded. So whenever inverting terminal V_+ crosses zero voltage output will invert.

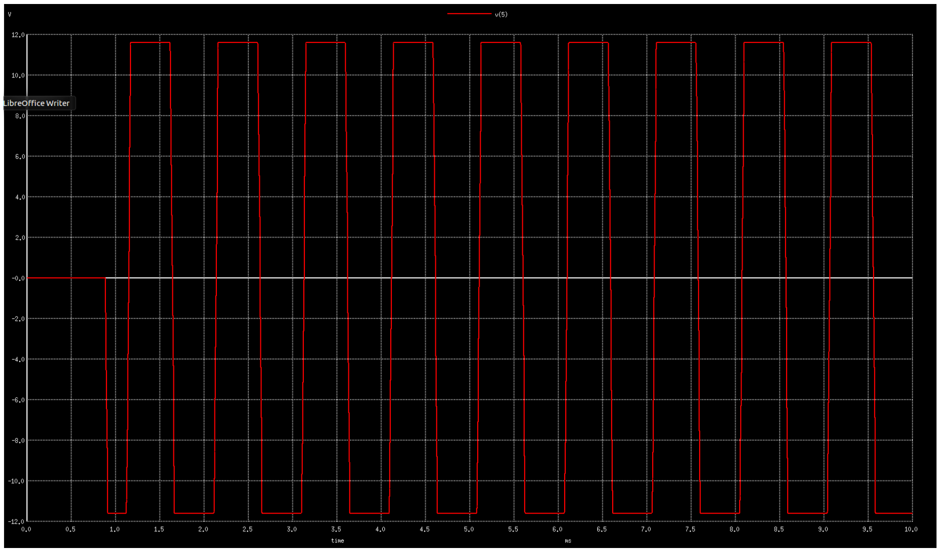

Figure 7: Output Pulse of schmitt trigger

Next, is integrator of which is input is schmitt trigger output. So whenever there is positive voltage at input of integrator, capacitor begins to charge up. So output voltage decreases linearly. Since $V_- = V_+ = 0$ V. Output voltage of integrator begin to decrease linearly. If input voltage at input of integrator were -L then output voltage would have been increases linearly. Rate of increase or decrease of output voltage depends on R and C value of integrator i.e. time constant RC constant.

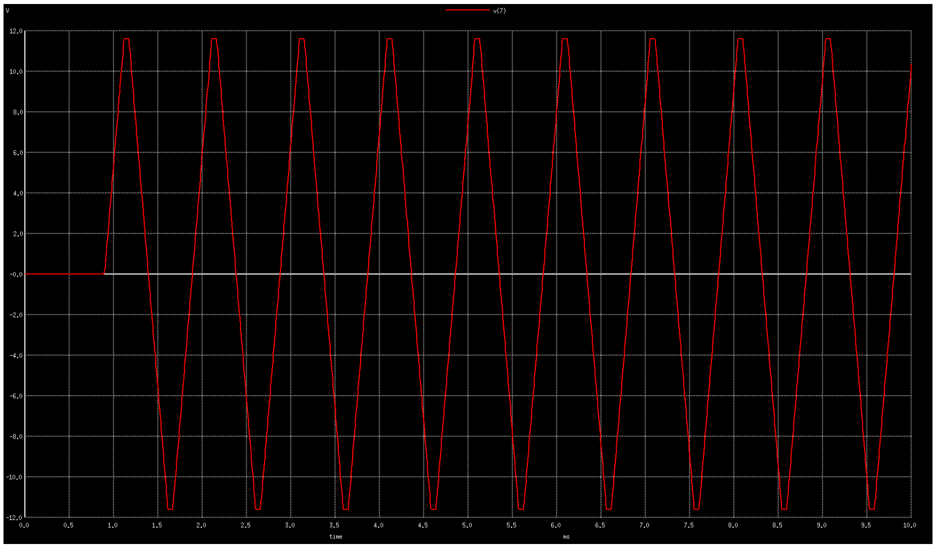

Figure 8: Output of integrator

As output of integrator crosses zero voltage in positive direction the input the output of integrator changes to +L. While if output of integrator crosses zero in negative direction the output voltage of schmitt trigger changes to -L.Hence we get triangular waveform at output of integrator.

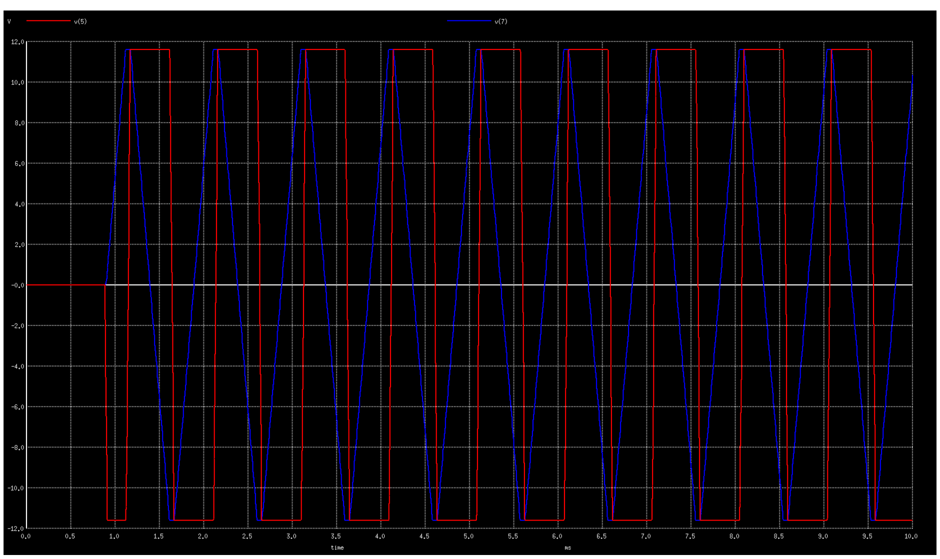

Figure 9: Schmitt Trigger and Integrator

This triangular output voltage feed into comparator at V_+ terminal of comparator while at V_- we have constant DC adjusted by potentiometer. Comparator finally give pulse voltage of 23 V_{pk-pk} of which positive pulse L_+ = 11.5 V and negative pulse L_- = -11.5 V time duration changes changes in accordance with DC voltage supplied as shown in figure.

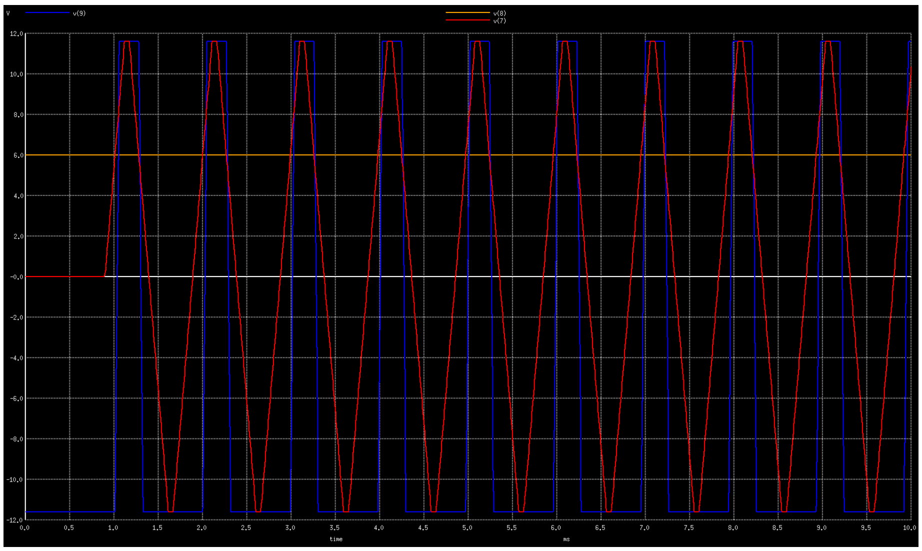

Figure 10: Comparator operation

In figure yellow line which is horizontal is DC input from POT.
Red triangular is integrator output.
Blue pulse is output of comparator.

From graph we can see $f_{int} = f_{pwm}$ depends upon integrator RC value. Also frequency increase with increase of amplitude of pulse input to integrator

4 Appendix

4.1 Simulation Code

```
.include ua741.txt
vss 1 0 dc 12
vcc 2 0 dc -12
r1 3 4 10k
r2 4 5 10k
r3 5 6 10k
c1 6 7 0.022u
```

```
x1 4 0 1 2 5 ua741
x2 0 6 1 2 7 ua741
x3 7 8 1 2 9 ua741
vdum 3 7 dc 0
va 8 0 dc -11.5

.tran .01ms 10ms
.control
 run
plot v(9)       //v(9) is output of comparator
plot v(7)     //output from the integrator
plot v(5)    // v(5) is output of schmitt trigger generate pulse 12 to -12 V
.endc
.end
```

4.2 PWM at different DC

Given table show variation of average DC output voltage with different POT value.

Pot Voltage Va	Average Voltage
0	0
3	-2.85
7	-6.21
9	-8.16
11.5	-10.1
12	-11.5
-3	2.85
-7	6.21
-9	8.16
-11.5	10.1
-12	11.5

Table 2: Variation of average output voltage with different POT dc value

Here positive output will rotate motor in reverse direction as that by negative average voltage.

4.3 PWM Waveform by comparator

$V_a = \mathbf{0}$ **V**

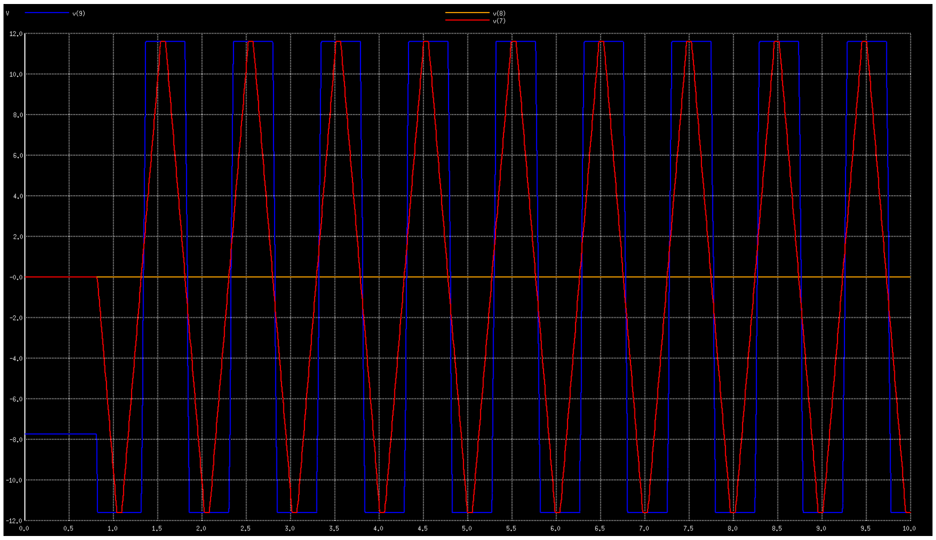

Figure 11: Comparator operation at Va = 0 V

Average output voltage is 0V.
V_a **= 3 V**

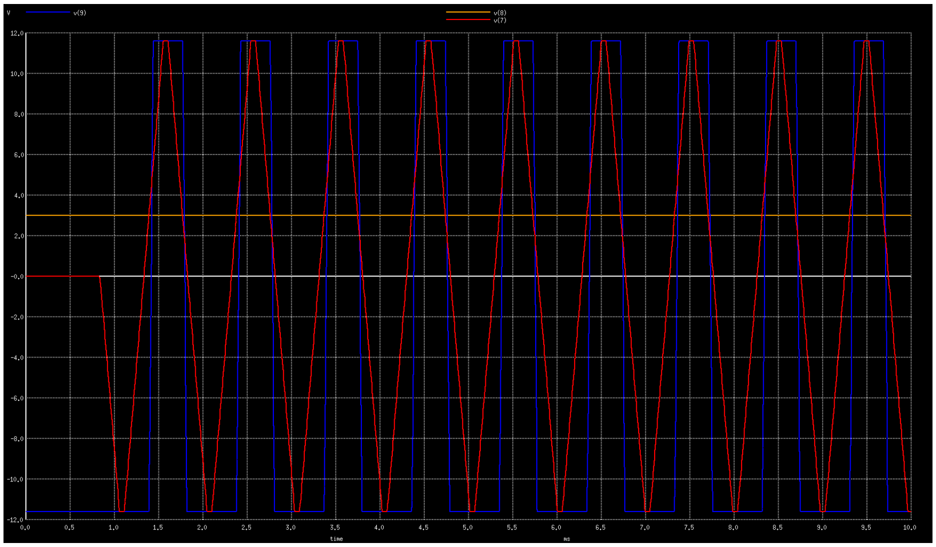

Figure 12: Comparator operation at Va = 3 V

Average output voltage is -2.85 V.
V_a **= -7 V**

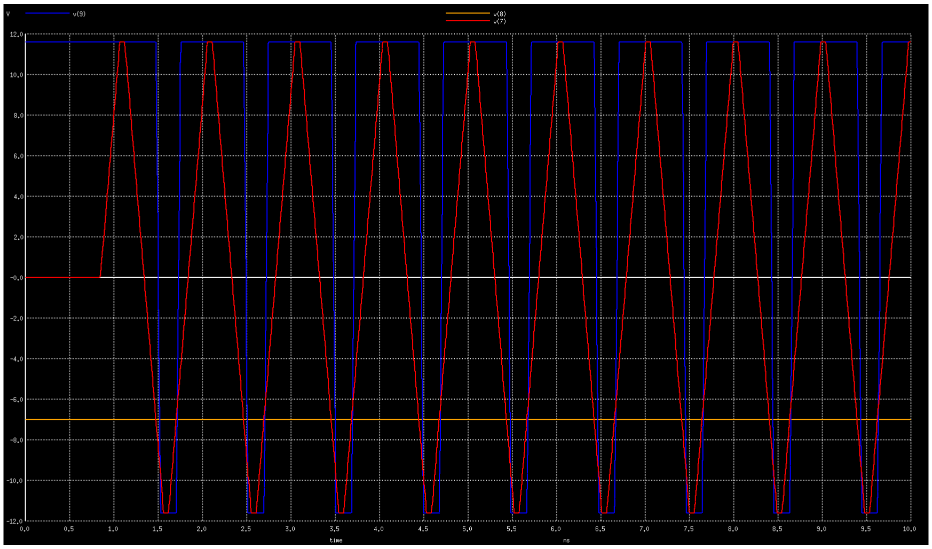

Figure 13: Comparator operation at Va = -7 V

Average output voltage is 6.21 V.
V_a **= 11.5 V**

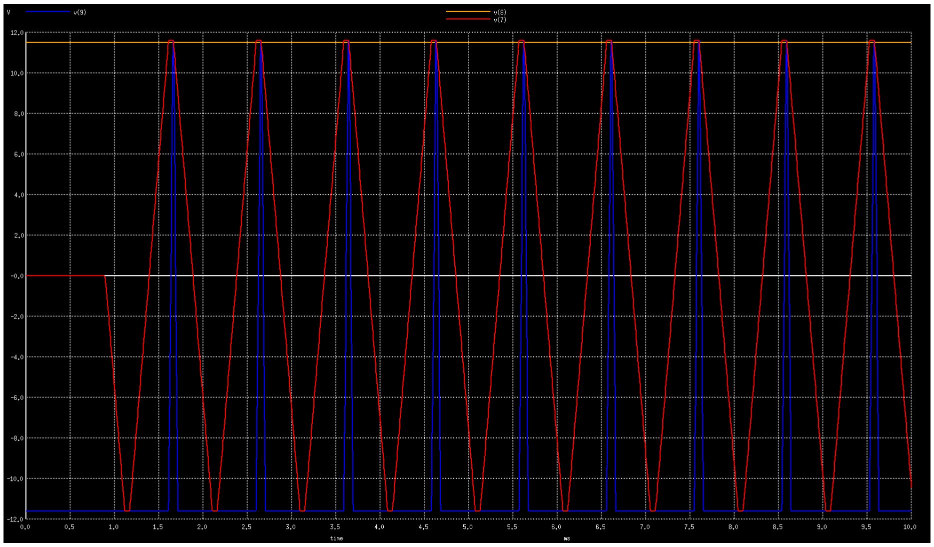

Figure 14: Comparator operation at Va = 11.5 V

Average output voltage is -10.1 V. V_a **= -12 V**

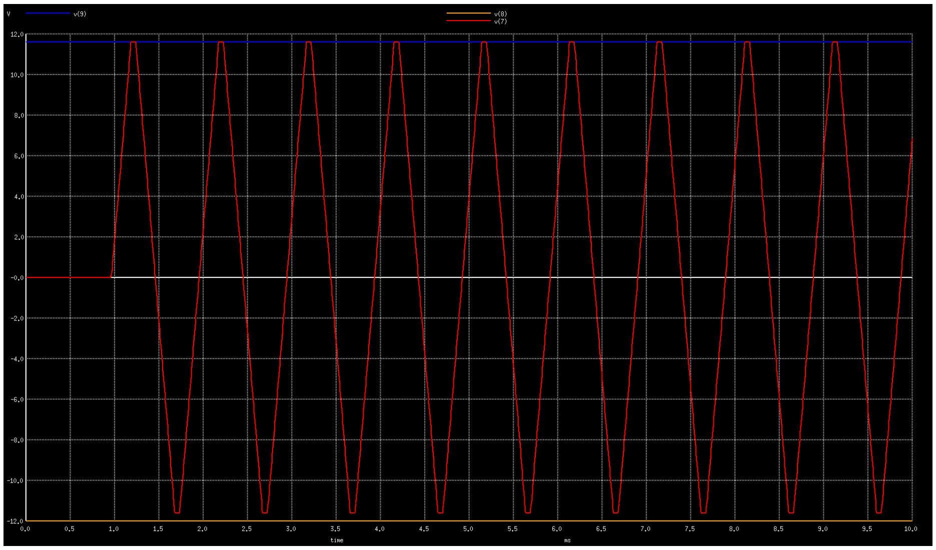

Figure 15: Comparator operation at Va = -12 V

Average output voltage is 11.5 V.

Hence if we increase DC input above (or below) 11.5 V (or -11.5 V) the peak of PWM pulse limited to 11.5 to -11.5 V. Hence peak of PWM predominantly depends upon integrator peak. Same holds for PWM frequency.