EE619A SPICE Project

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QUESTION 1 : Simulation of symmetrical and skewed CMOS inverter, and pass transistor

Minimum sized NMOS parameters:-

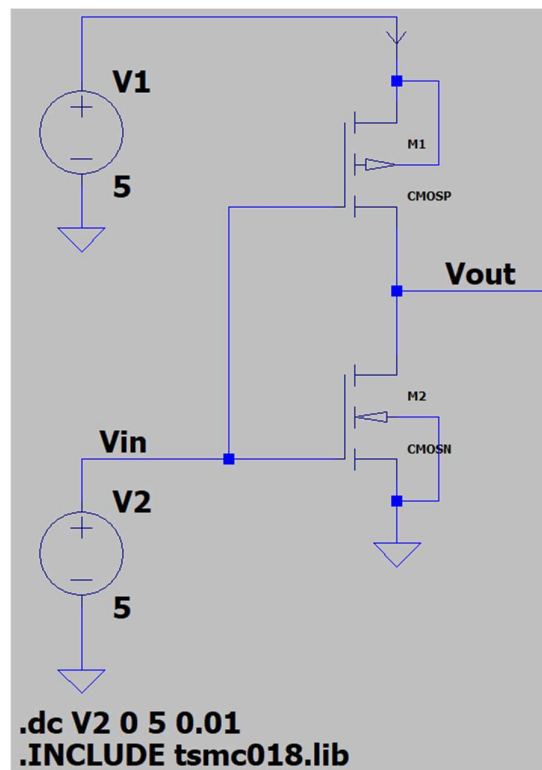Channel length(Ln) = $180\mu m$

Channel Width(Wn) = $400\mu m$

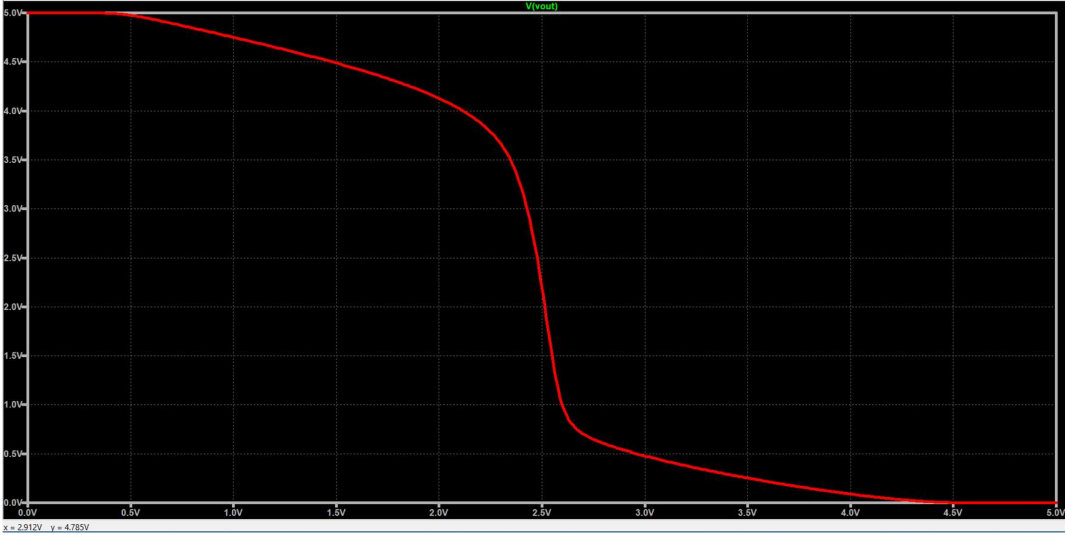Minimum sized PMOS parameters:-

Channel length(Lp) = $180\mu m$
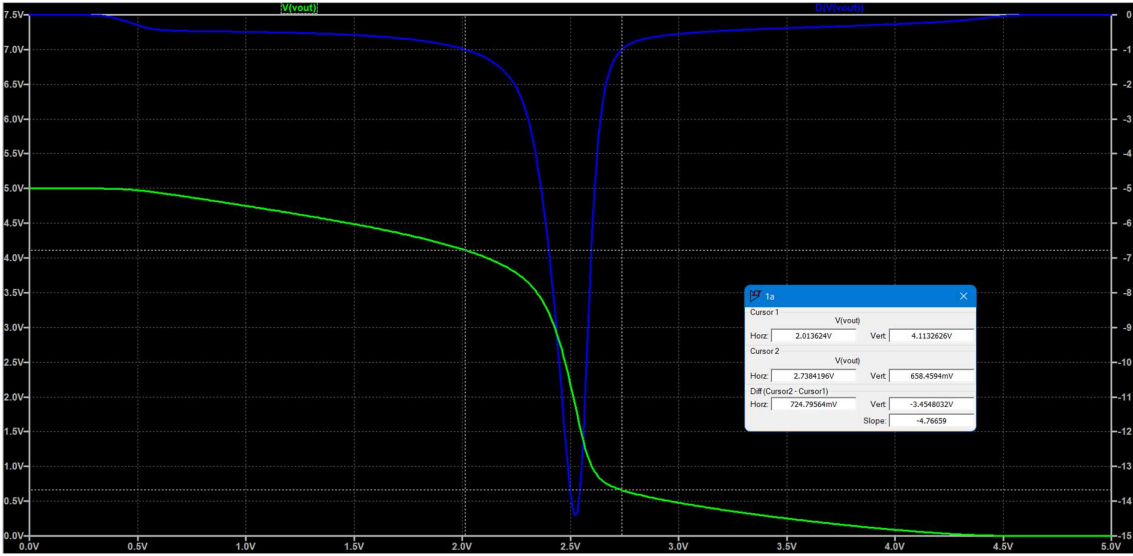
Channel width(Wp)= $800\mu m$

PART A:

Since $2\mu_p = \mu_n$, we take W/L ratio of pmos twice as that of nmos
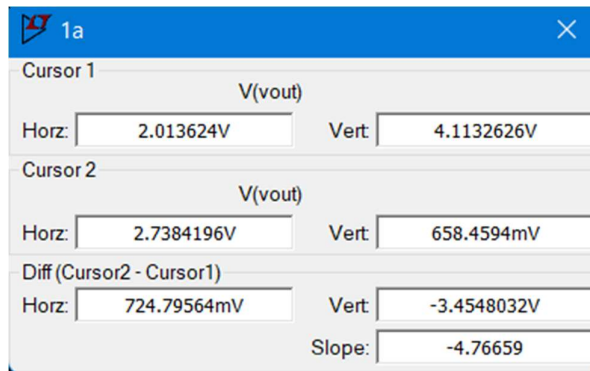
VTC of minimum sized inverter:

Calculation of VOL, VIL, VOL, VOH

VOL = 658.459 mV

VIL = 2.013 mV

VIH = 2.73 mV

VOH = 4.11 mV

High noise margin = VOH − VIH = 1.38 mV
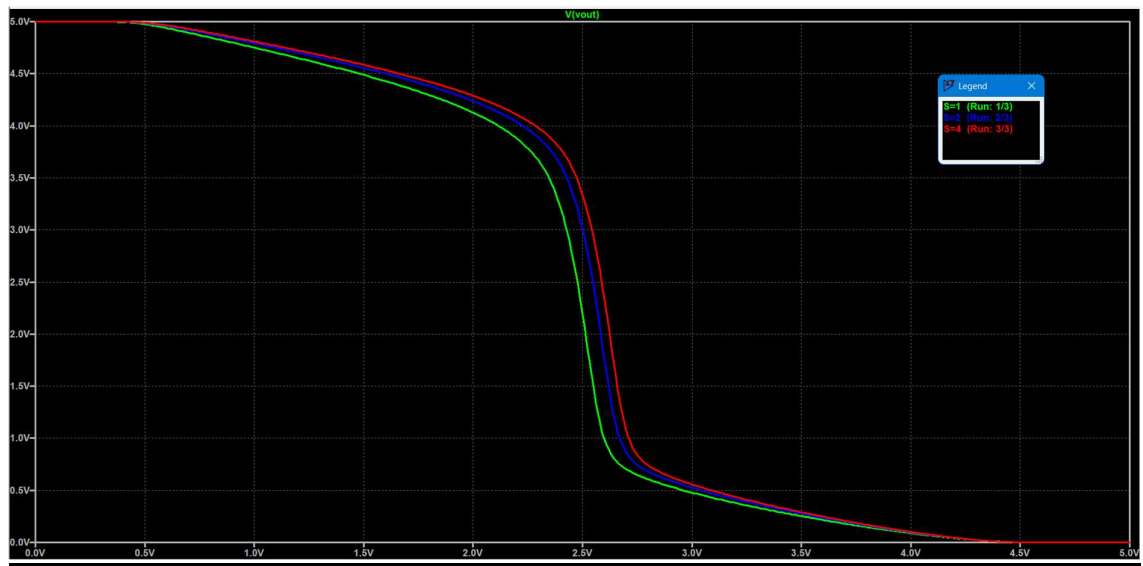
Low noise margin = VIL - VOL = 1.4428 mV

Noise immunity of inverter
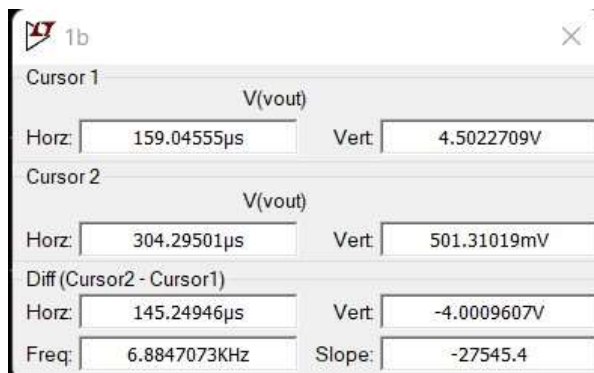
VTC of inverter when S=1,2,4 :-

Schematic:
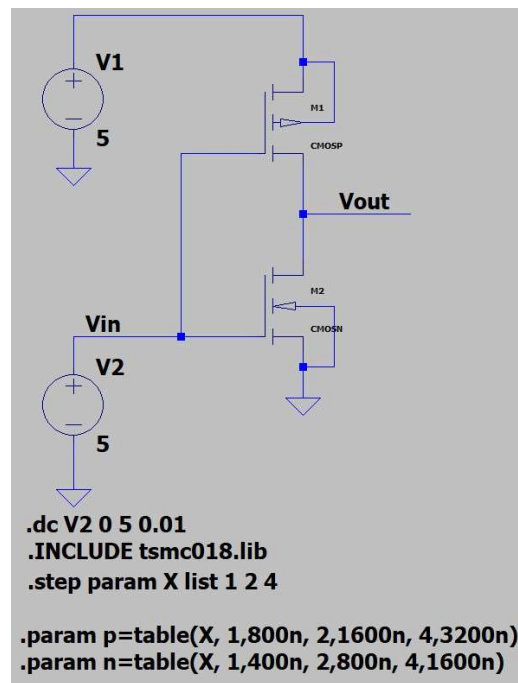
As S increases, VTC shifts towards right
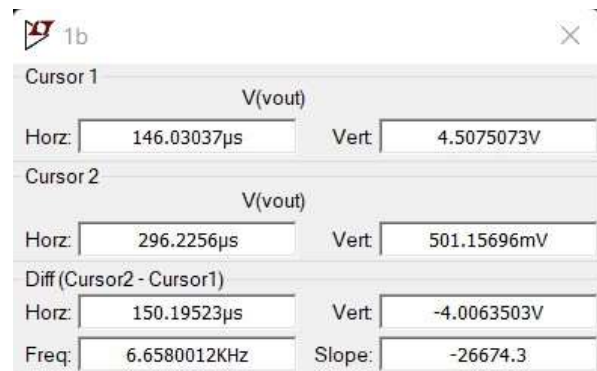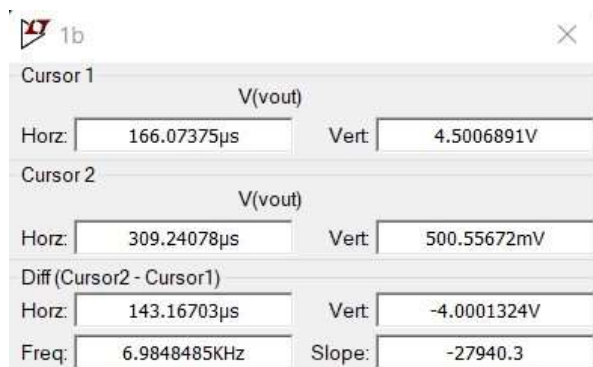
PART B:

(i)   When no external capacitance is attached.

Fall Time :

Fall time delay when S is 1 = 150.19 μs

Fall time delay when S is 2 = 145.24 μs

Fall time delay when S is 4 = 143.167 μs

Rise Time:

1b			×
Cursor 1			
	V(vout)		
Horz:	5.6956607ms	Vert:	501.30472mV
Cursor 2			
	V(vout)		
Horz:	5.840783ms	Vert:	4.5013313V
Diff (Cursor2 - Cursor1)			
Horz:	145.12235μs	Vert:	4.0000266V
Freq:	6.8907374KHz	Slope:	27563.1

Rise time delay when S is 1 = 149.53 μs

Rise time delay when S is 2 = 145.122 μs

Rse time delay when S is 4 = 142.51 μs

1b			×
Cursor 1			
	V(vout)		
Horz:	5.6907015ms	Vert:	500.30008mV
Cursor 2			
	V(vout)		
Horz:	5.8332137ms	Vert:	4.496711V
Diff (Cursor2 - Cursor1)			
Horz:	142.51223μs	Vert:	3.9964109V
Freq:	7.0169414KHz	Slope:	28042.6

1b			×
Cursor 1			
	V(vout)		
Horz:	5.7036161ms	Vert:	501.07964mV
Cursor 2			
	V(vout)		
Horz:	5.8531539ms	Vert:	4.5034566V
Diff (Cursor2 - Cursor1)			
Horz:	149.53779μs	Vert:	4.002377V
Freq:	6.6872727KHz	Slope:	26765

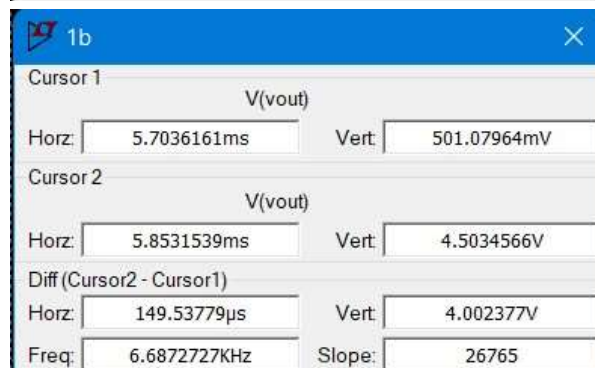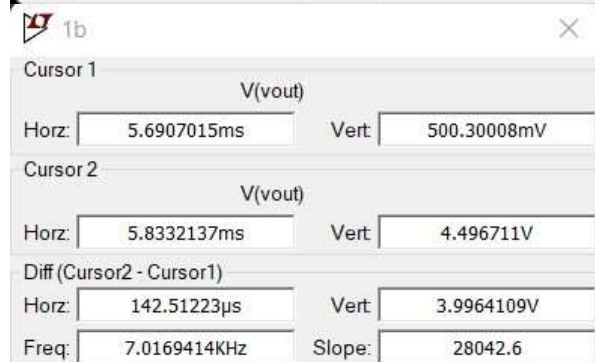(ii)   When external capacitance(5pF) is attached:
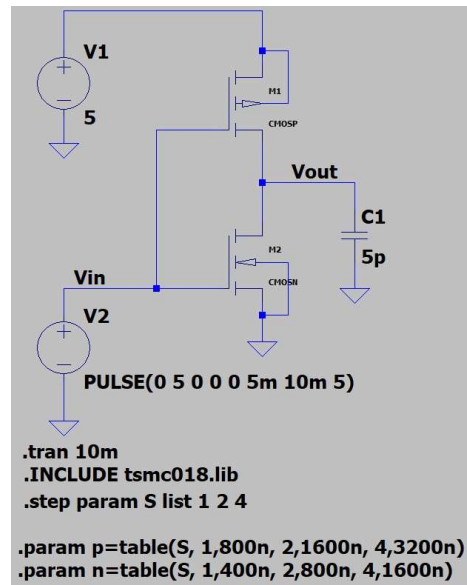
Rise time:

Rise time delay when S is 1 = 149.53 μs
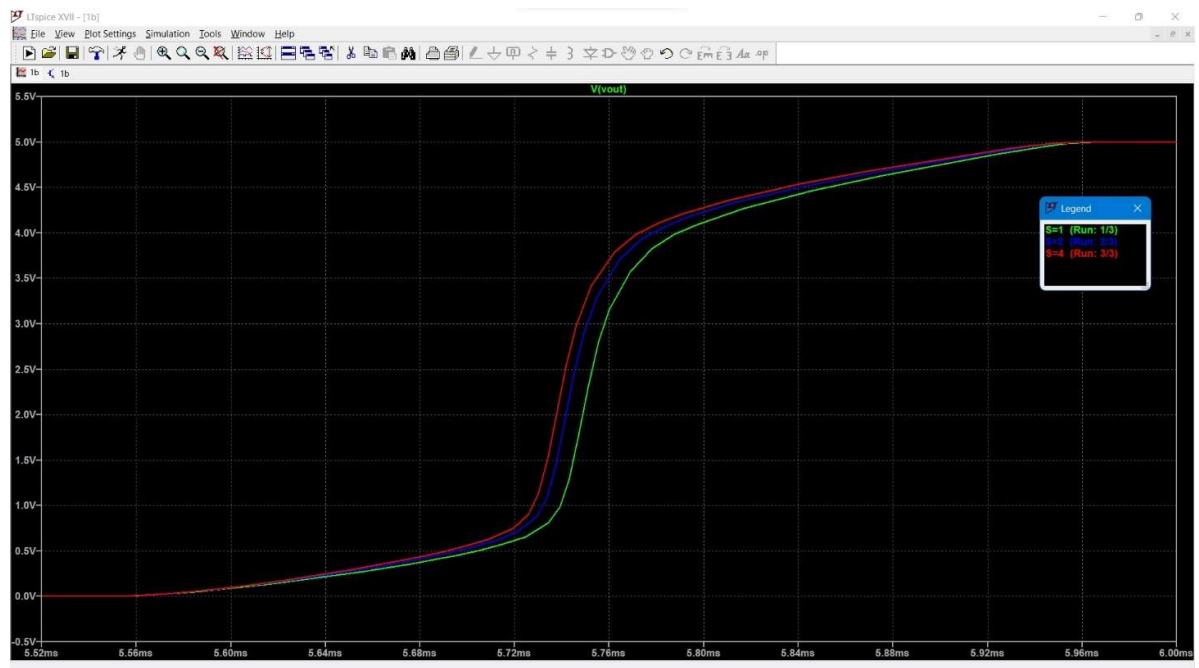
Rise time delay when S is 2 = 145.122 μs

Rse time delay when S is 4 = 142.51 μs

S=1   S=2

S=1

1b ✕

Cursor 1

V(vout)

| Horz: | 5.703752ms | Vert: | 501.3072mV |

Cursor 2

V(vout)

| Horz: | 5.8527896ms | Vert: | 4.5012688V |

Diff (Cursor2 - Cursor1)

| Horz: | 149.03752µs | Vert: | 3.9999616V |
| Freq: | 6.7097198KHz | Slope: | 26838.6 |

S=2

1b ✕

Cursor 1

V(vout)

| Horz: | 5.6953997ms | Vert: | 499.95884mV |

Cursor 2

V(vout)

| Horz: | 5.840261ms | Vert: | 4.5005369V |

Diff (Cursor2 - Cursor1)

| Horz: | 144.86134µs | Vert: | 4.0005781V |
| Freq: | 6.9031532KHz | Slope: | 27616.6 |

S=3

1b ✕

Cursor 1

V(vout)

| Horz: | 5.6907015ms | Vert: | 499.72076mV |

Cursor 2

V(vout)

| Horz: | 5.8342577ms | Vert: | 4.5007104V |

Diff (Cursor2 - Cursor1)

| Horz: | 143.55628µs | Vert: | 4.0009896V |
| Freq: | 6.9659091KHz | Slope: | 27870.5 |

Fall Time:

Fall time delay when S is 1 = 149.41 μs

Fall time delay when S is 2 = 144.989 μs

Fall time delay when S is 1 = 143.16 μs

1b		×
Cursor 1	V(vout)	
Horz: 147.07158µs	Vert:	4.5013236V
Cursor 2	V(vout)	
Horz: 296.4859µs	Vert:	500.20521mV
Diff (Cursor2 - Cursor1)		
Horz: 149.41432µs	Vert:	-4.0011184V
Freq: 6.6927991KHz	Slope:	-26778.7

1b		×
Cursor 1	V(vout)	
Horz: 159.30586µs	Vert:	4.5009051V
Cursor 2	V(vout)	
Horz: 304.29501µs	Vert:	501.14231mV
Diff (Cursor2 - Cursor1)		
Horz: 144.98915µs	Vert:	-3.9997628V
Freq: 6.8970676KHz	Slope:	-27586.6

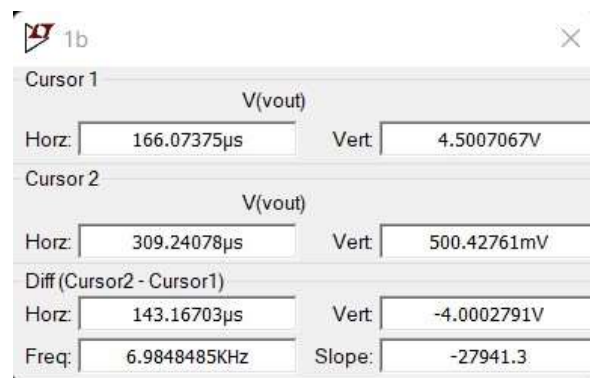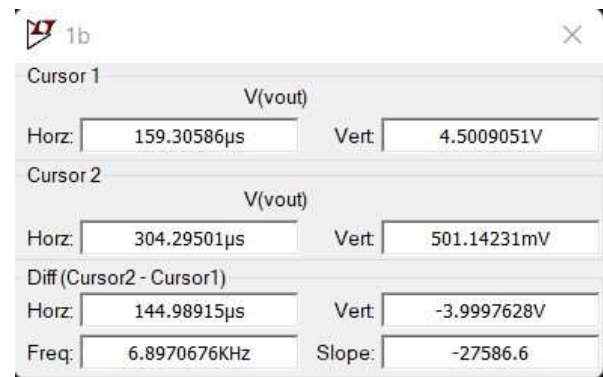| 1b		×
Cursor 1	V(vout)	
Horz: 166.07375µs	Vert:	4.5007067V
Cursor 2	V(vout)	
Horz: 309.24078µs	Vert:	500.42761mV
Diff (Cursor2 - Cursor1)		
Horz: 143.16703µs	Vert:	-4.0002791V
Freq: 6.9848485KHz	Slope:	-27941.3

Current drawn when capacitor is not connected :

Current drawn when capacitance is connected:
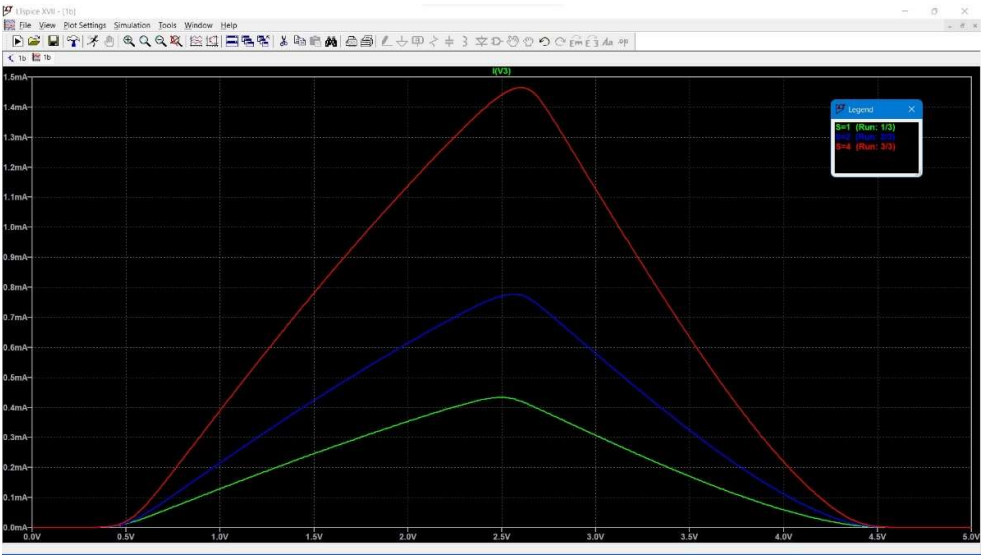
Power dissipation:
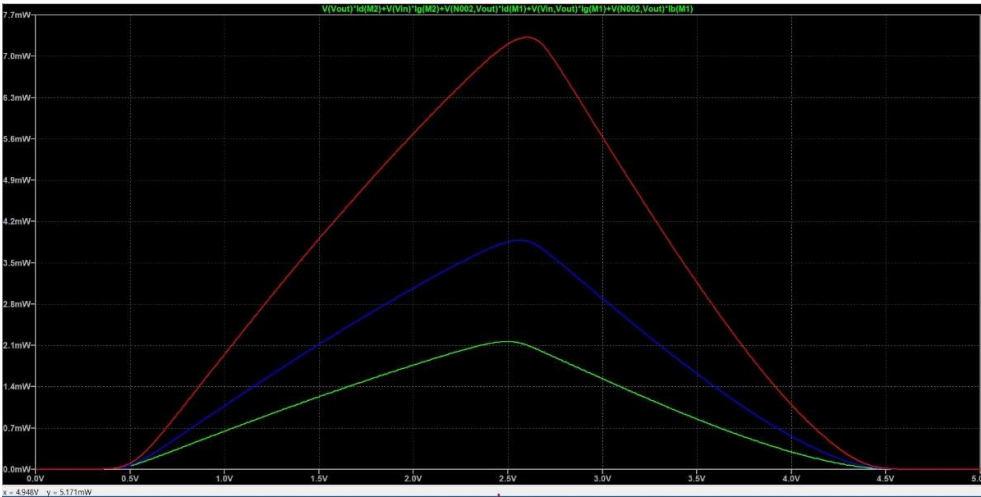
PART C:

(i)   VTC when Kn = 1,2,4 :

As Kn increases, VTC shifts towards left

(ii)   VTC when Kp = 1,2,4

V1
5

M1
CMOSP

Vout

M2
CMOSN

Vin

V2

PULSE(0 5 0 0 0 5m 10m 5)

.dc v2 0 5 0.01
.INCLUDE tsmc018.lib
.step param Kp list 1 2 4

.param p=table(Kp, 1,800n, 2,1600n, 4,3200n)
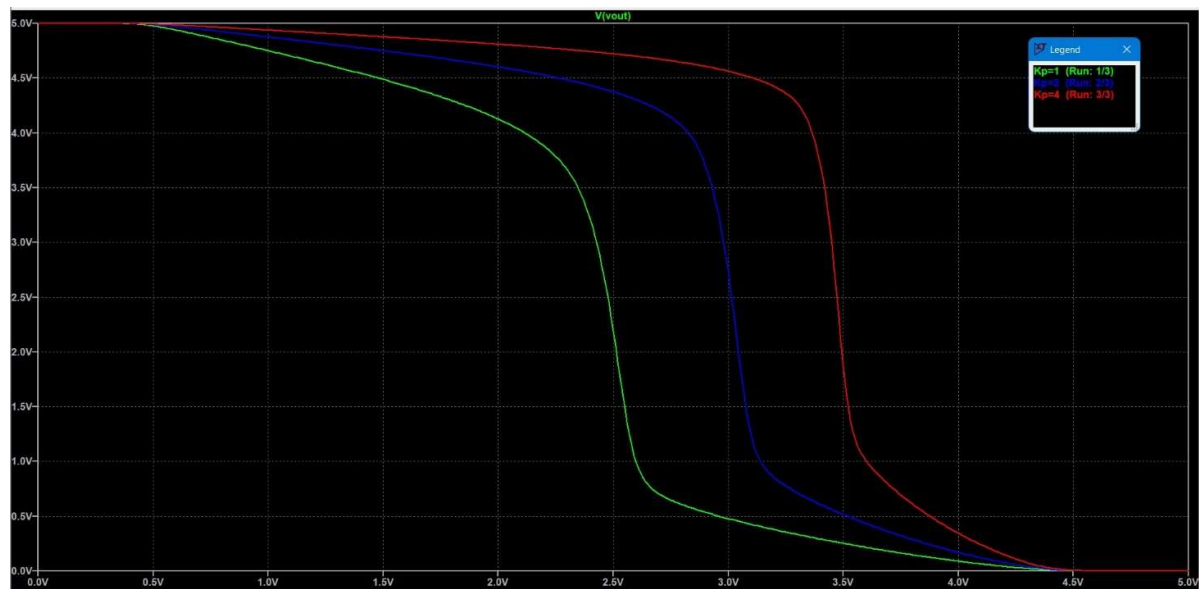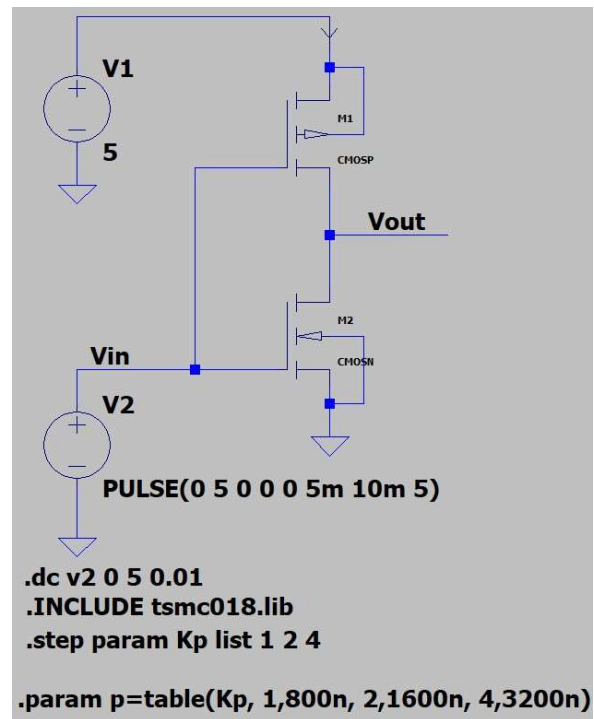
As Kp increases, VTC shifts towards right

PART D:

When Kp is varied(Kp=1,2,4) and Kn is fixed.

(i)   Rise time delays when external capacitor is not attached :
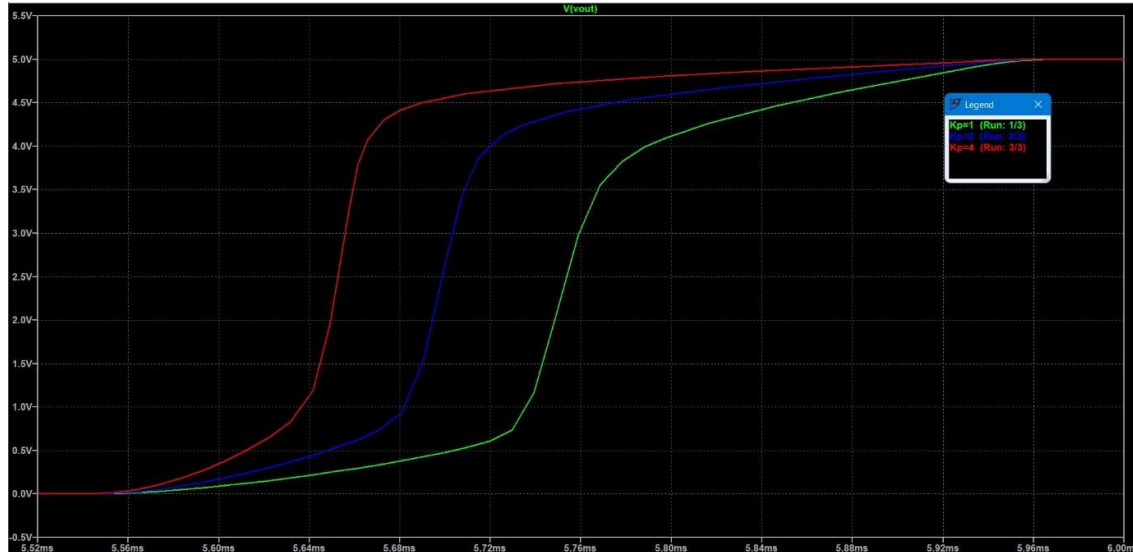
Rise time delay when Kp is 1 = 149.55 μs

Rise time delay when Kp is 2 = 127.11 μs

Rise time delay when Kp is 4 = 78.04 μs

1d				
Cursor 1	V(vout)			
Horz:	5.703491ms		Vert:	500.33486mV
Cursor 2	V(vout)			
Horz:	5.8530506ms		Vert:	4.5028868V
Diff (Cursor2 - Cursor1)				
Horz:	149.55954µs		Vert:	4.0025519V
Freq:	6.6863002KHz		Slope	

1d				
Cursor 1	V(vout)			
Horz:	5.6478956ms		Vert:	501.05884mV
Cursor 2	V(vout)			
Horz:	5.7750082ms		Vert:	4.5002288V
Diff (Cursor2 - Cursor1)				
Horz:	127.11256µs		Vert:	3.99917V
			Slope:	31461.6

1d				
Cursor 1	V(vout)			
Horz:	5.611876ms		Vert:	499.31346mV
Cursor 2	V(vout)			
Horz:	5.6899184ms		Vert:	4.5005952V
Diff (Cursor2 - Cursor1)				
Horz:	78.042414µs		Vert:	4.0012817V
Freq:	12.813545KHz		Slope:	51270.6

(ii)   Fall time delays when external capacitor is not attached :

Fall time delay when Kp is 1 = 78.611 μs

Fall time delay when Kp is 2 = 127.2885 μs
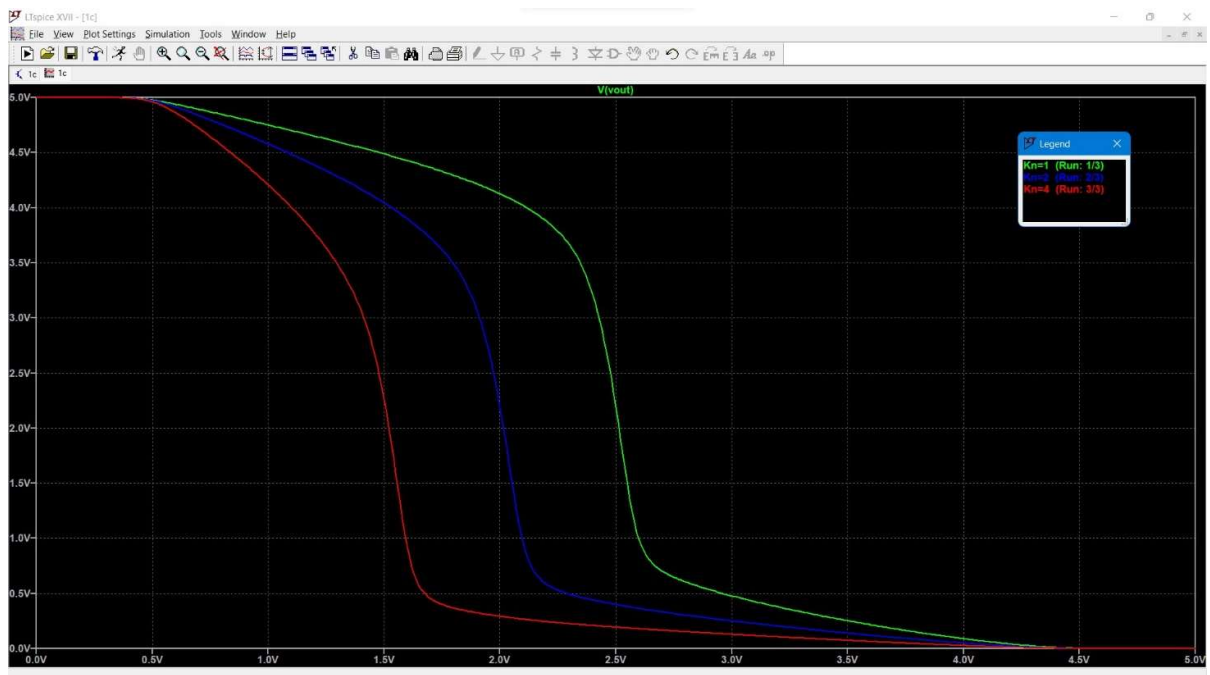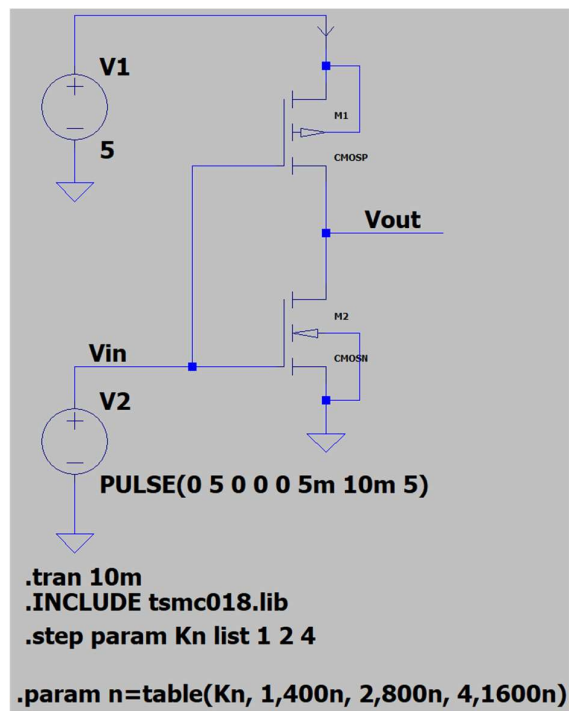
Fall time delay when Kp is 4 = 149.154 μs

1d			
Cursor 1	V(vout)		
Horz: 309.50108µs		Vert:	4.5008997V
Cursor 2	V(vout)		
Horz: 388.1128µs		Vert:	501.58554mV
Diff (Cursor2 - Cursor1)			
Horz: 78.611714µs		Vert:	-3.9993142V
Freq: 12.720751KHz		Slope:	-50874.3

1d			
Cursor 1	V(vout)		
Horz: 224.90239µs		Vert:	4.5009505V
Cursor 2	V(vout)		
Horz: 352.19089µs		Vert:	500.12054mV
Diff (Cursor2 - Cursor1)			
Horz: 127.2885µs		Vert:	-4.0008299V
Freq: 7.8561691KHz		Slope:	-31431.2

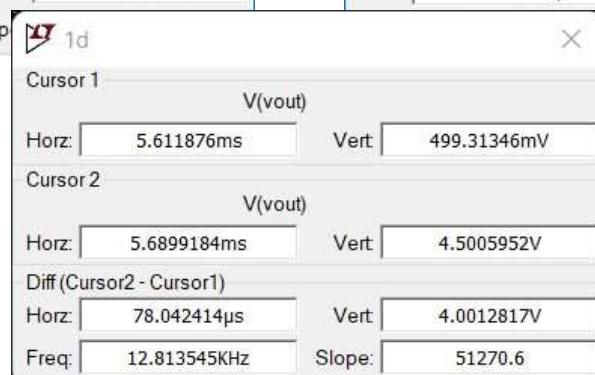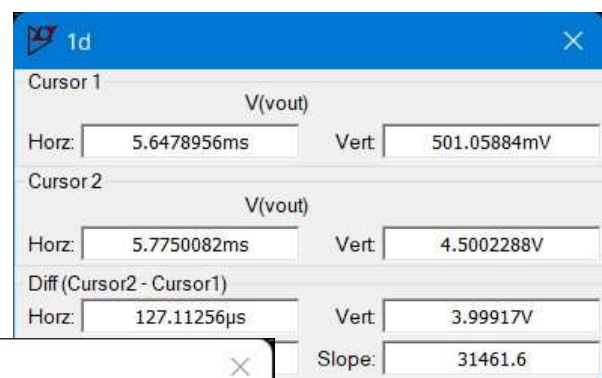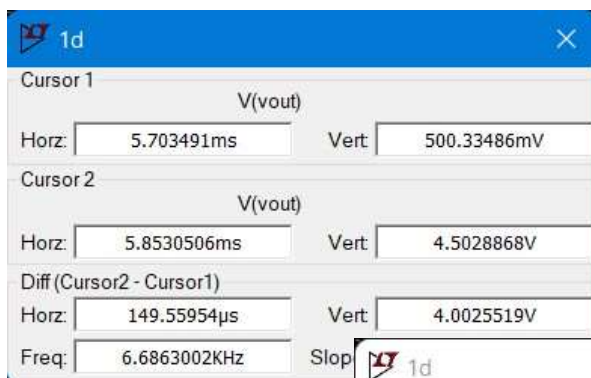| 1d			
Cursor 1	V(vout)		
Horz: 147.07158µs		Vert:	4.5012568V
Cursor 2	V(vout)		
Horz: 296.2256µs		Vert:	501.15696mV
Diff (Cursor2 - Cursor1)			
Horz: 149.15401µs		Vert:	-4.0000999V
Freq: 6.7044793KHz		Slope:	-26818.6

(iii)   Rise time delays when external capacitor is attached :
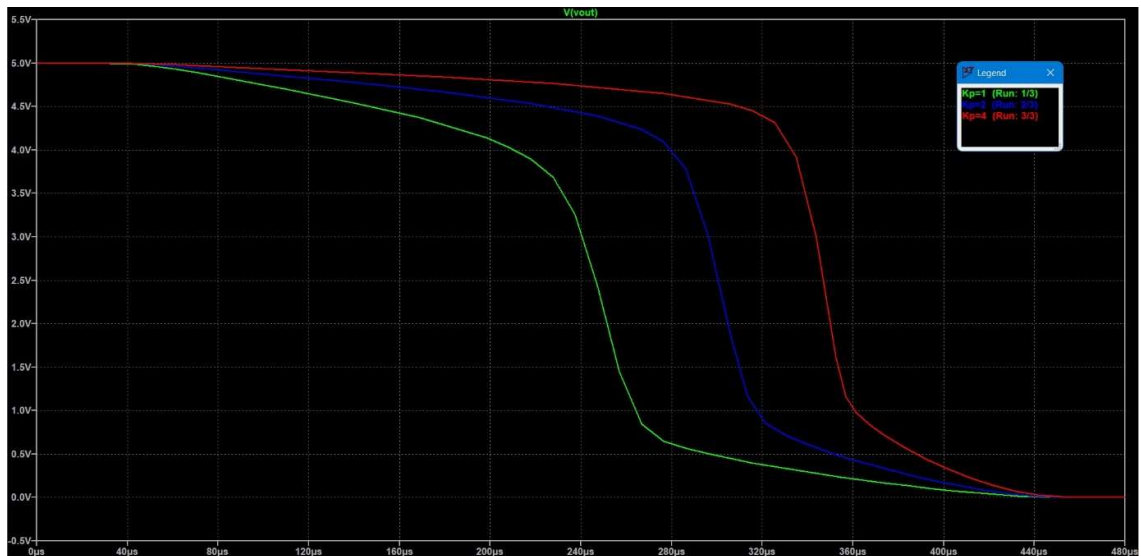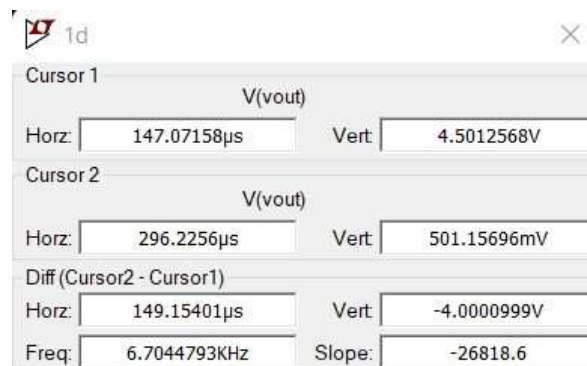

Rise time delay when Kp is 1 = 148.99 μs

Rise time delay when Kp is 2 = 127.243 μs

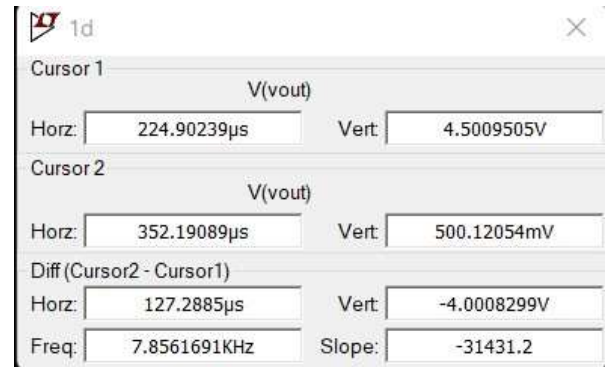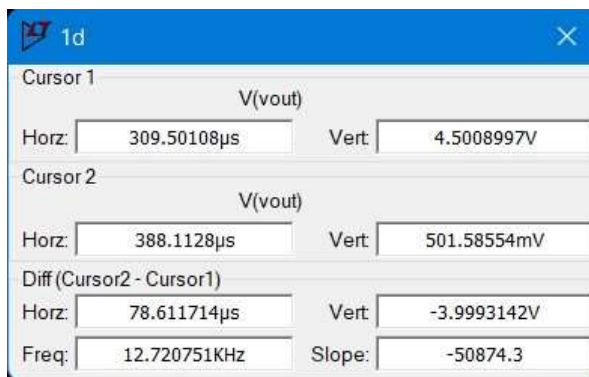Rise time delay when Kp is 4 = 78.303 μs

(iv)   Fall time delay when capacitor is attached:
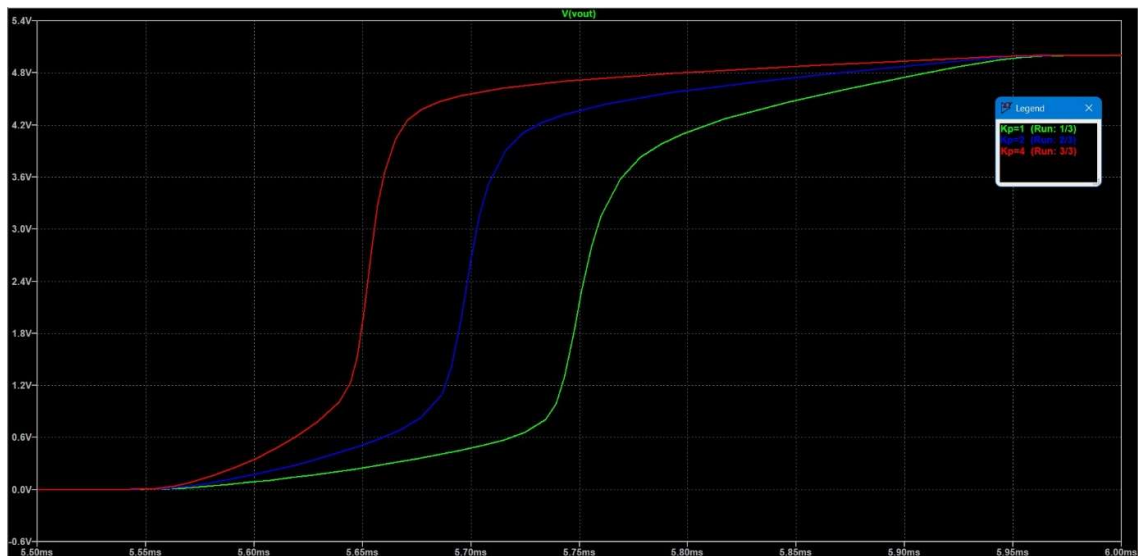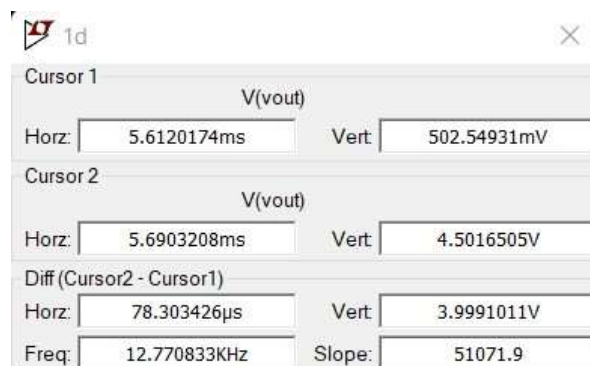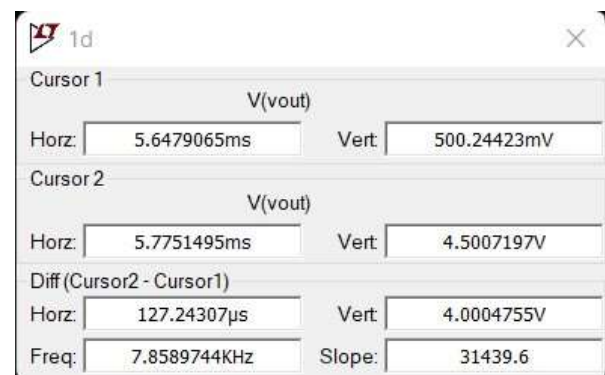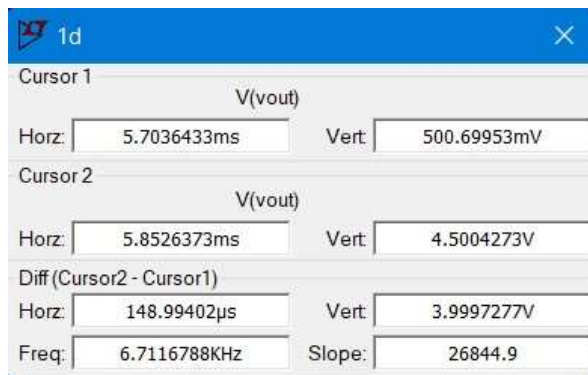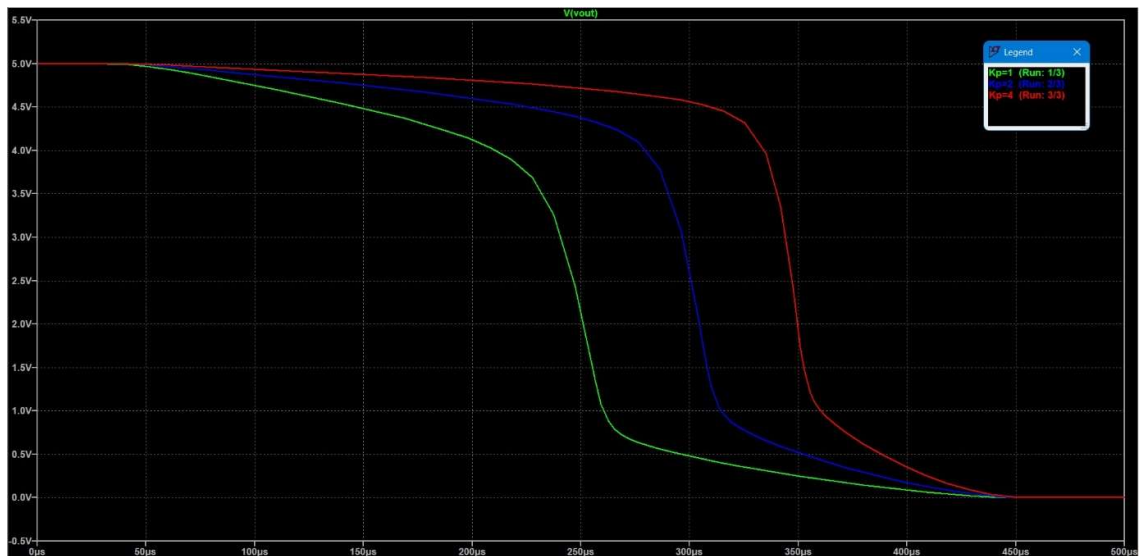

Fall time delay when Kp is 1 = 78.633 μs

Fall time delay when Kp is 2 = 126.89 μs

Fall time delay when Kp is 4 = 149.86 μs

Cursor 1
V(vout)
Horz: 309.38178µs   Vert: 4.5018324V

Cursor 2
V(vout)
Horz: 388.01518µs   Vert: 501.92852mV

Diff (Cursor2 - Cursor1)
Horz: 78.633406µs   Vert: -3.9999039V
Freq: 12.717241KHz   Slope: -50867.7

Cursor 1
V(vout)
Horz: 225.05423µs   Vert: 4.5029261V

Cursor 2
V(vout)
Horz: 351.95228µs   Vert: 501.72725mV

Diff (Cursor2 - Cursor1)
Horz: 126.89805µs   Vert: -4.0011989V
Freq: 7.8803419KHz   Slope: -31530.8

Cursor 1
V(vout)
Horz: 147.23427µs   Vert: 4.5003471V

Cursor 2
V(vout)
Horz: 296.09544µs   Vert: 502.44632mV

Diff (Cursor2 - Cursor1)
Horz: 148.86117µs   Vert: -3.9979008V
Freq: 6.7176685KHz   Slope: -26856.6

When Kn is varied(Kn=1,2,4) and Kp is fixed.

(i) Rise time delay when no external capacitance is connected

Rise time delay when Kn is 1 = 13.824 μs

Rise time delay when Kn is 2 = 16 μs

Rise time delay when Kn is 4 = 25.451 μs

1d			
Cursor 1	V(vout)		
Horz: 5.9802507ms		Vert: 497.89512mV	
Cursor 2	V(vout)		
Horz: 5.9940752ms		Vert: 4.5084905V	
Diff (Cursor2 - Cursor1)			
Horz: 13.824523μs		Vert: 4.0105954V	
Freq: 72.335225KHz		Slope: 290107	

1d			
Cursor 1	V(vout)		
Horz: 5.983455ms		Vert: 504.07875mV	
Cursor 2	V(vout)		
Horz: 5.9994311ms		Vert: 4.501596V	
Diff (Cursor2 - Cursor1)			
Horz: 15.976022μs		Vert: 3.9975173V	
Freq: 62.593805KHz		Slope: 250220	

1d			
Cursor 1	V(vout)		
Horz: 5.9870256ms		Vert: 496.0183mV	
Cursor 2	V(vout)		
Horz: 6.0124774ms		Vert: 4.5006666V	
Diff (Cursor2 - Cursor1)			
Horz: 25.451771μs		Vert: 4.0046483V	
Freq: 39.289997KHz		Slope: 157343	

(ii)   Rise time delay when external capacitance(5pF) is connected:

Rise time delay when Kn is 1 = 16.05 μs

Rise time delay when Kn is 2 = 14.1 μs

Rise time delay when Kn is 4 = 24.91 μs

1d

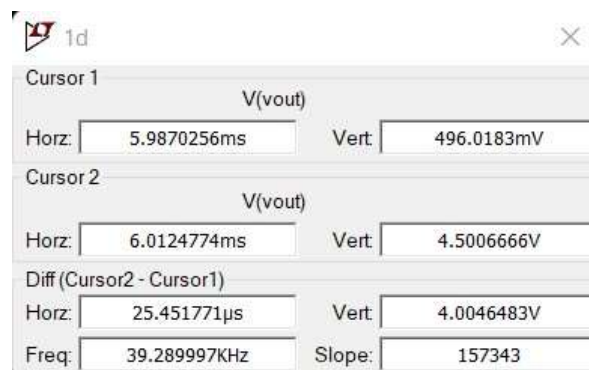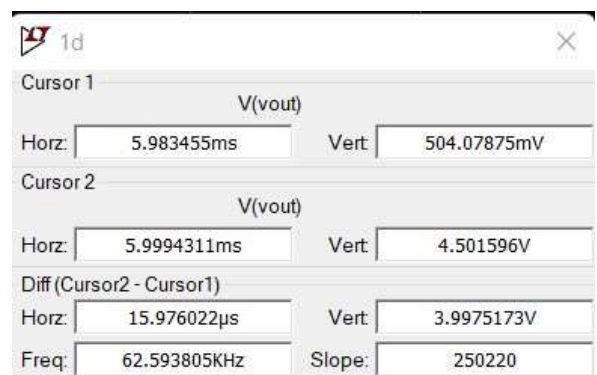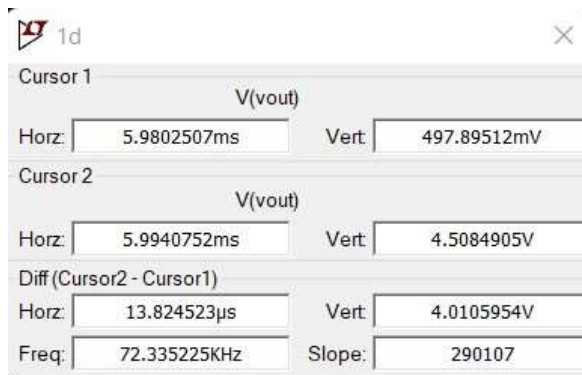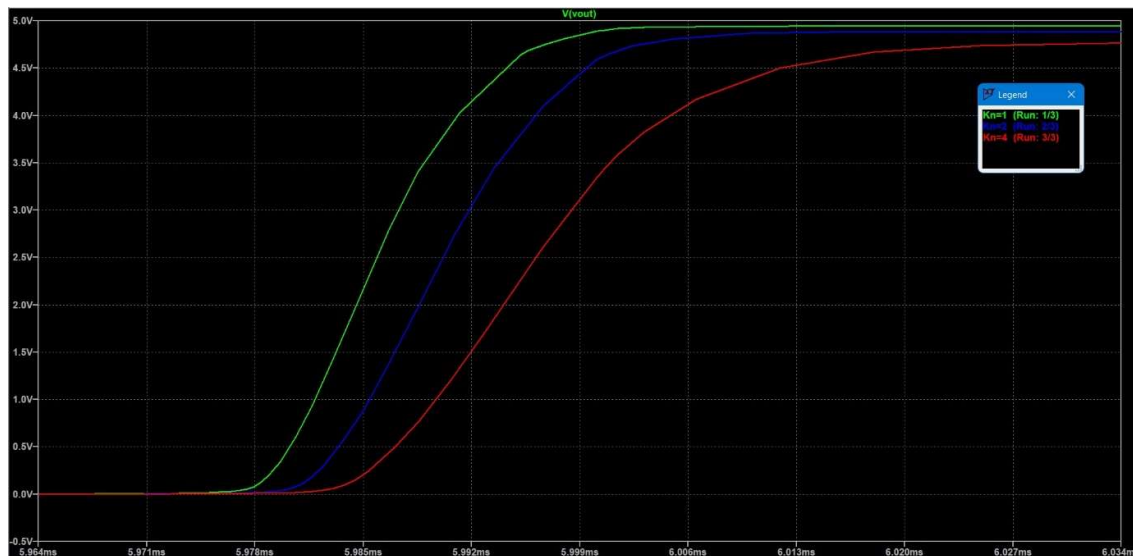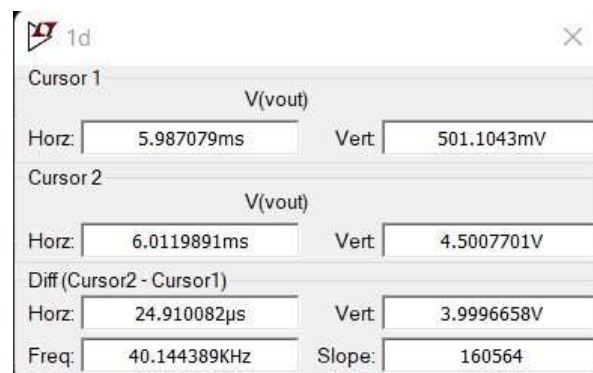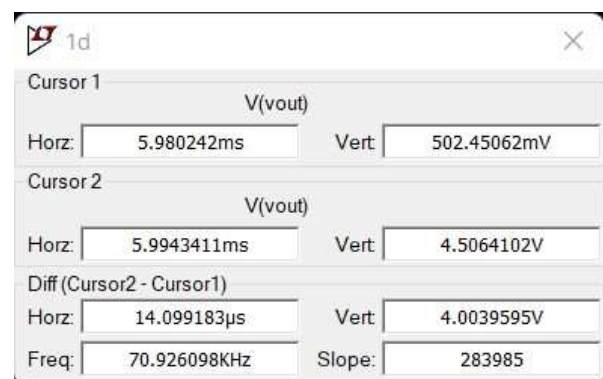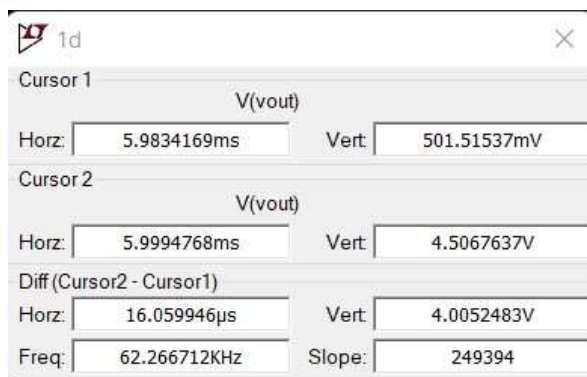Cursor 1
V(vout)

Horz:	5.9834169ms	Vert:	501.51537mV

Cursor 2
V(vout)

Horz:	5.9994768ms	Vert:	4.5067637V

Diff (Cursor2 - Cursor1)

Horz:	16.059946µs	Vert:	4.0052483V
Freq:	62.266712KHz	Slope:	249394

1d

Cursor 1
V(vout)

Horz:	5.980242ms	Vert:	502.45062mV

Cursor 2
V(vout)

Horz:	5.9943411ms	Vert:	4.5064102V

Diff (Cursor2 - Cursor1)

Horz:	14.099183µs	Vert:	4.0039595V
Freq:	70.926098KHz	Slope:	283985

1d

Cursor 1
V(vout)

Horz:	5.987079ms	Vert:	501.1043mV

Cursor 2
V(vout)

Horz:	6.0119891ms	Vert:	4.5007701V

Diff (Cursor2 - Cursor1)

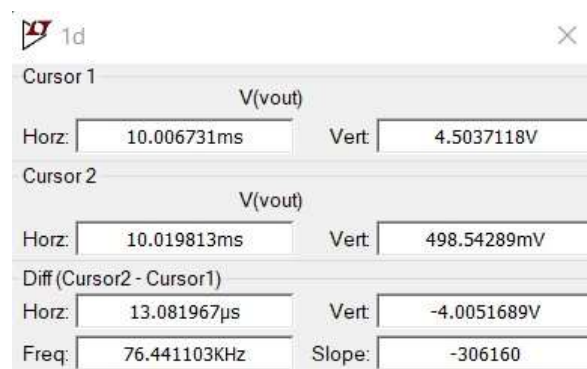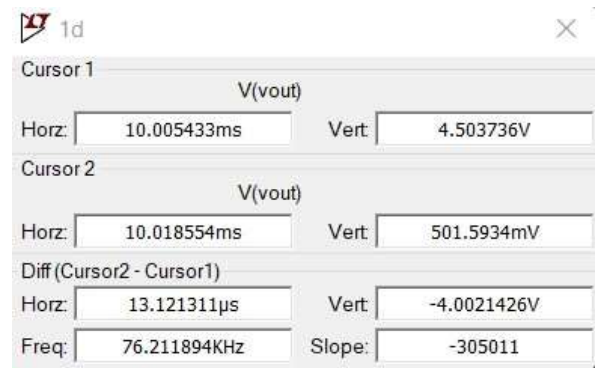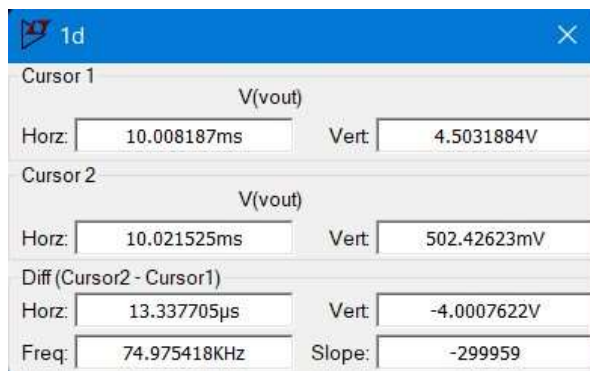| Horz:	24.910082µs	Vert:	3.9996658V
Freq:	40.144389KHz	Slope:	160564

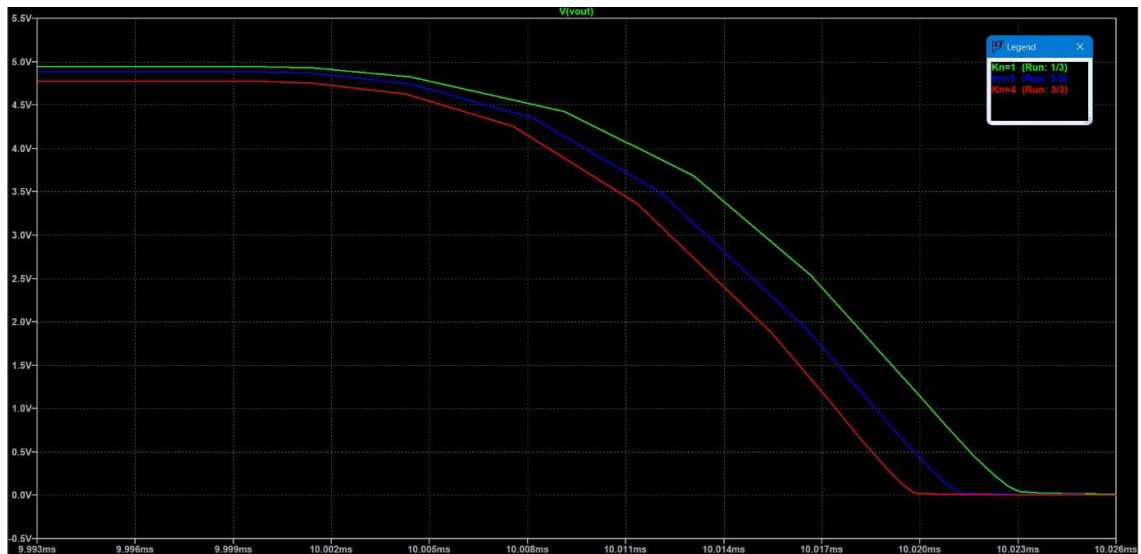(iii)   Fall time delay when external capacitor is not connected:

Fall time delay when Kn is 1 = 13.33 μs

Fall time delay when Kn is 2 = 13.12 μs

Fall time delay when Kn is 4 = 13.081 μs

1d		
Cursor 1		
	V(vout)	
Horz: 10.008187ms	Vert: 4.5031884V	
Cursor 2		
	V(vout)	
Horz: 10.021525ms	Vert: 502.42623mV	
Diff (Cursor2 - Cursor1)		
Horz: 13.337705µs	Vert: -4.0007622V	
Freq: 74.975418KHz	Slope: -299959	

1d		
Cursor 1		
	V(vout)	
Horz: 10.005433ms	Vert: 4.503736V	
Cursor 2		
	V(vout)	
Horz: 10.018554ms	Vert: 501.5934mV	
Diff (Cursor2 - Cursor1)		
Horz: 13.121311µs	Vert: -4.0021426V	
Freq: 76.211894KHz	Slope: -305011	

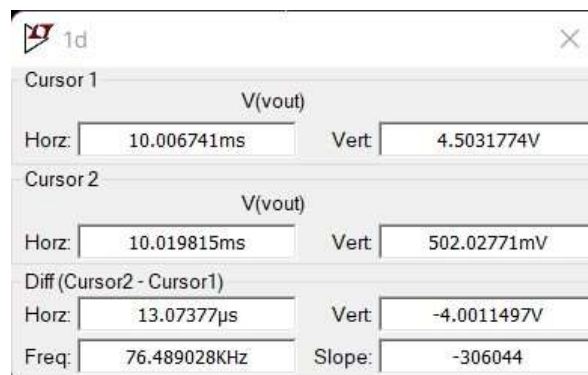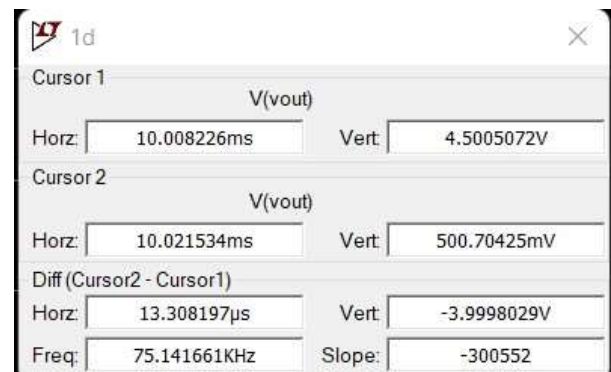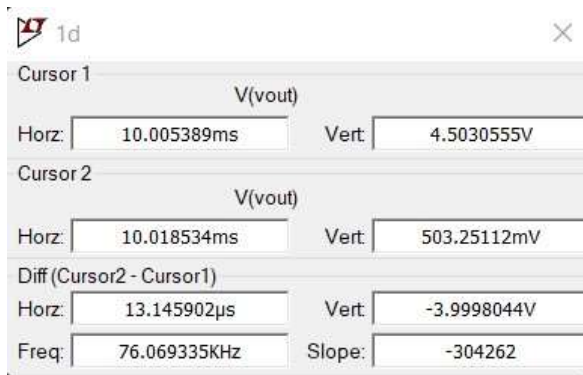| 1d		
Cursor 1		
	V(vout)	
Horz: 10.006731ms	Vert: 4.5037118V	
Cursor 2		
	V(vout)	
Horz: 10.019813ms	Vert: 498.54289mV	
Diff (Cursor2 - Cursor1)		
Horz: 13.081967µs	Vert: -4.0051689V	
Freq: 76.441103KHz	Slope: -306160	

(iv)   Fall time delay when external capacitor(5pF) is connected:

Fall time delay when Kn is 1 = 13.14 μs

Fall time delay when Kn is 1 = 13.3 μs

Fall time delay when Kn is 1 = 13.07 μs

1d

Cursor 1
    V(vout)

| Horz: | 10.005389ms | Vert: | 4.5030555V |

Cursor 2
    V(vout)

| Horz: | 10.018534ms | Vert: | 503.25112mV |

Diff (Cursor2 - Cursor1)

| Horz: | 13.145902μs | Vert: | -3.9998044V |
| Freq: | 76.069335KHz | Slope: | -304262 |

1d

Cursor 1
    V(vout)

| Horz: | 10.008226ms | Vert: | 4.5005072V |

Cursor 2
    V(vout)

| Horz: | 10.021534ms | Vert: | 500.70425mV |

Diff (Cursor2 - Cursor1)

| Horz: | 13.308197μs | Vert: | -3.9998029V |
| Freq: | 75.141661KHz | Slope: | -300552 |

1d

Cursor 1
    V(vout)

| Horz: | 10.006741ms | Vert: | 4.5031774V |

Cursor 2
    V(vout)

| Horz: | 10.019815ms | Vert: | 502.02771mV |

Diff (Cursor2 - Cursor1)

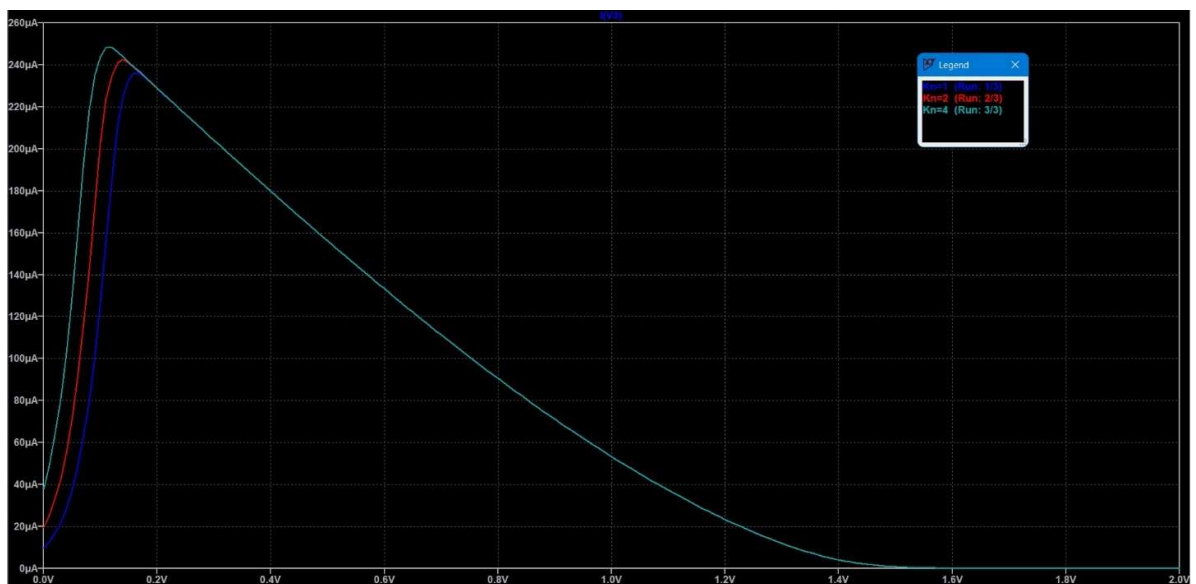| Horz: | 13.07377μs | Vert: | -4.0011497V |
| Freq: | 76.489028KHz | Slope: | -306044 |

Current drawn from the power supply when capacitor is not connected at the output:

(i)   When Kp is varied(Kp=1,2,4) and Kn is fixed
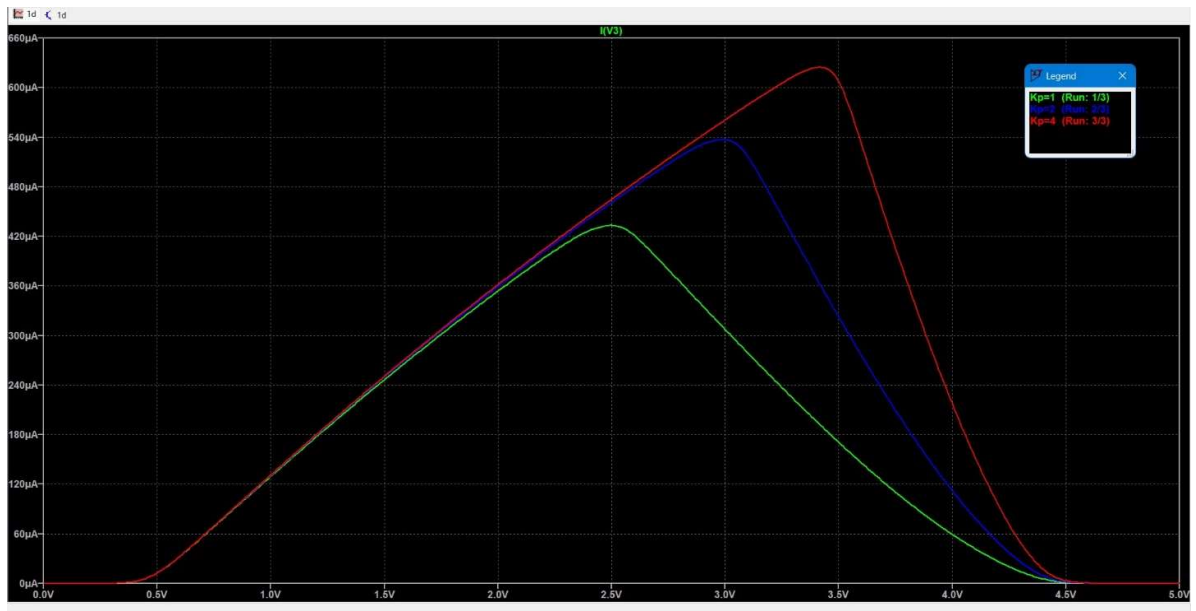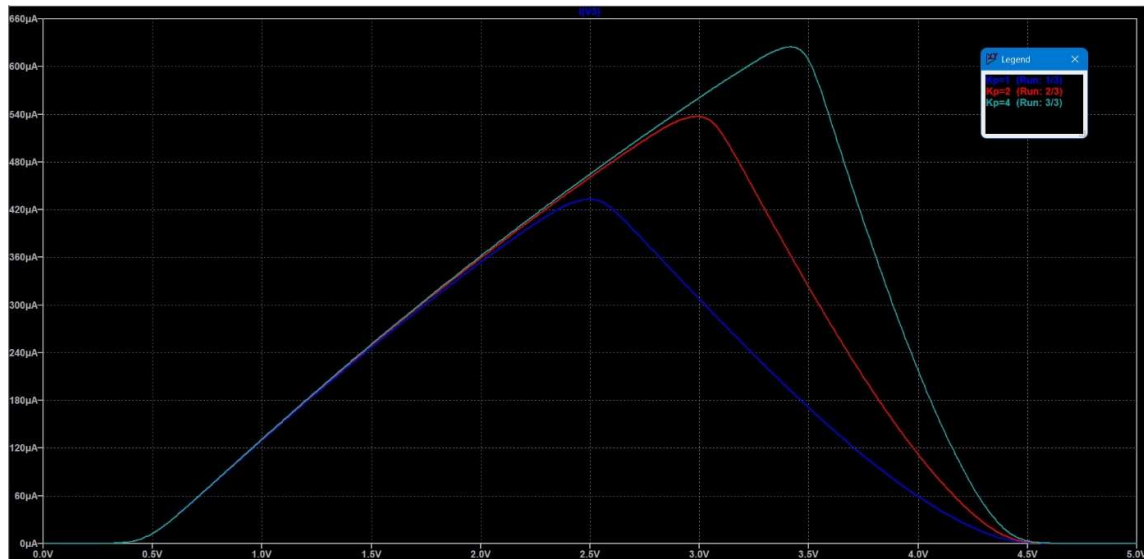

(ii)   When Kn is varied(Kn=1,2,4) and Kp is fixed

<u>Current drawn from the power supply when capacitor is connected at the output:</u>

(i)   When Kp is varied(Kp=1,2,4) and Kn is fixed

(ii)   When Kn is varied(Kn=1,2,4) and Kp is fixed