電子電路設計模擬與實習

實驗名稱：數位電路-動態參數測量

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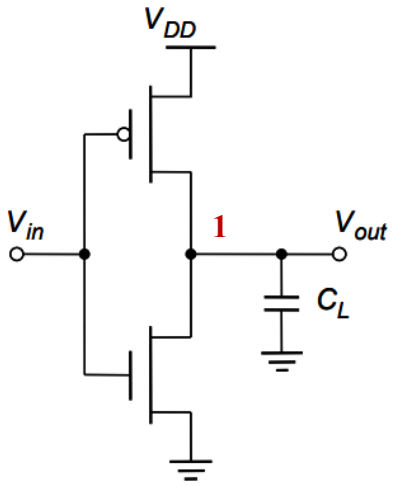
10. CMOS 反向器動態參數測量

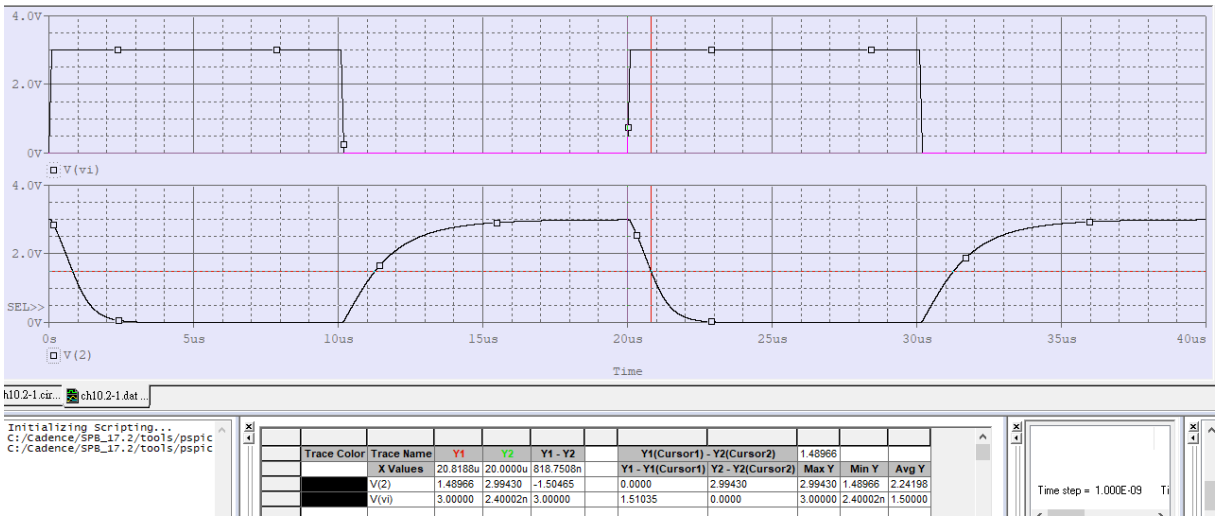
Lab 10-2. CMOS 反向器延遲時間分析

實驗電路圖：

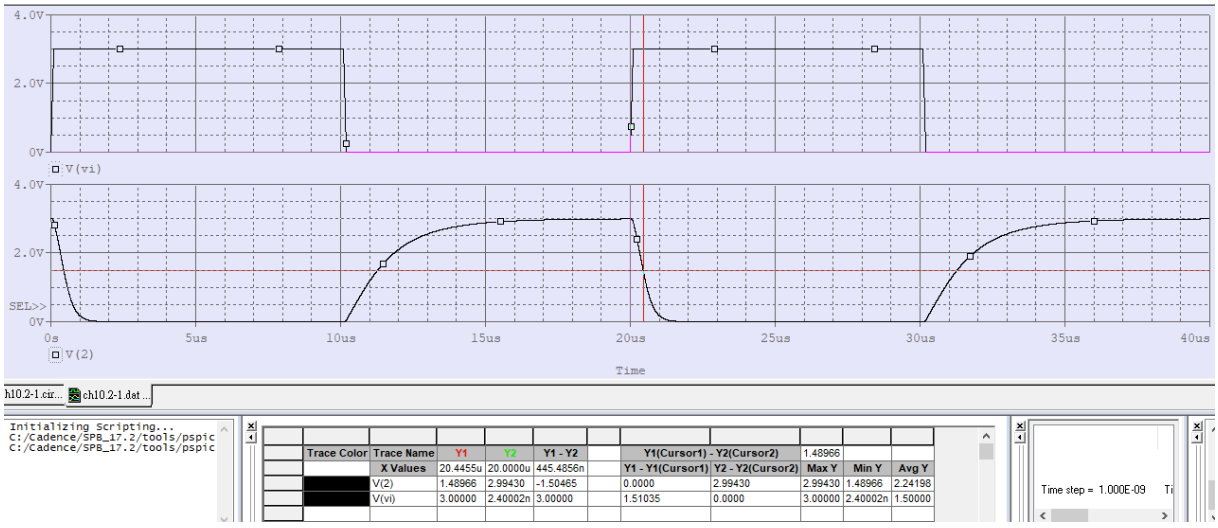


1. NMOS W/L 尺寸與 t_{pHL} 之關係

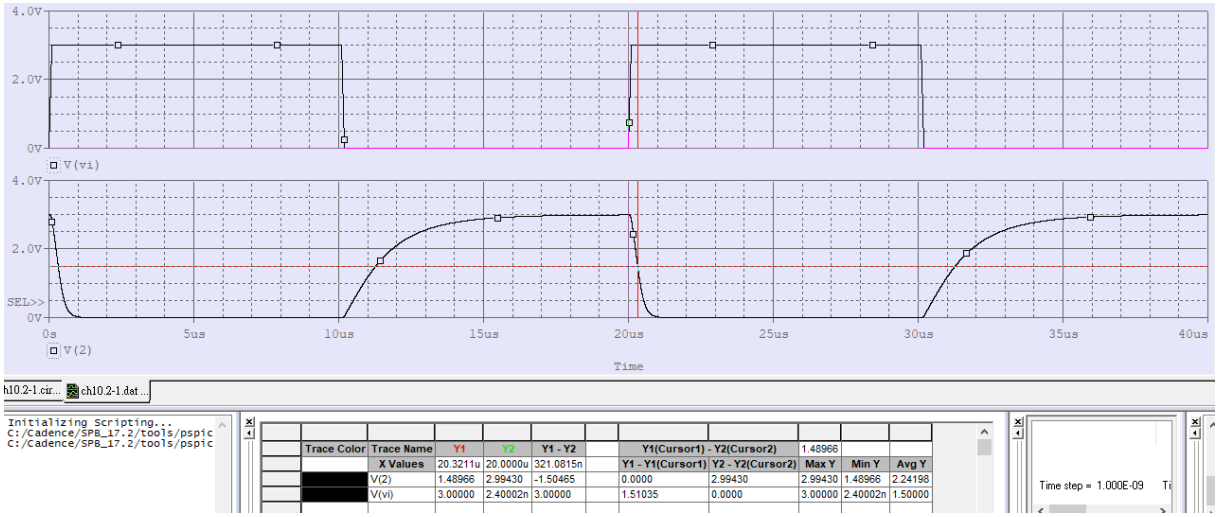
t_{pHL}	**NMOS W/L** (L=0.18μm)		
	1.5	3	4.5
PMOS W/L=3	0.8188μ	0.4455μ	0.3211μ



NMOS W/L = 1.5



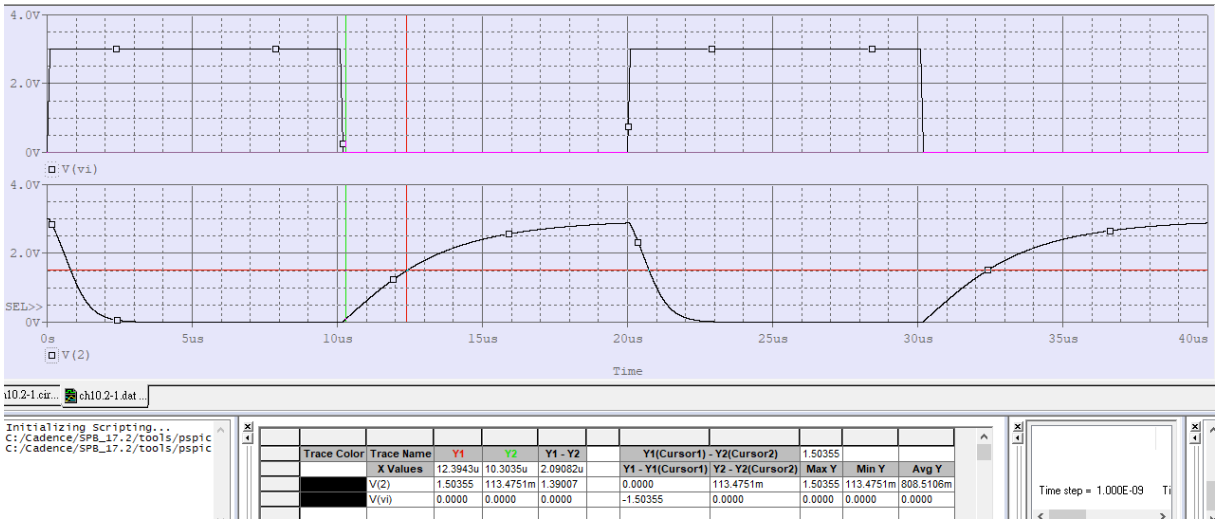
NMOS W/L = 3



NMOS W/L = 4.5

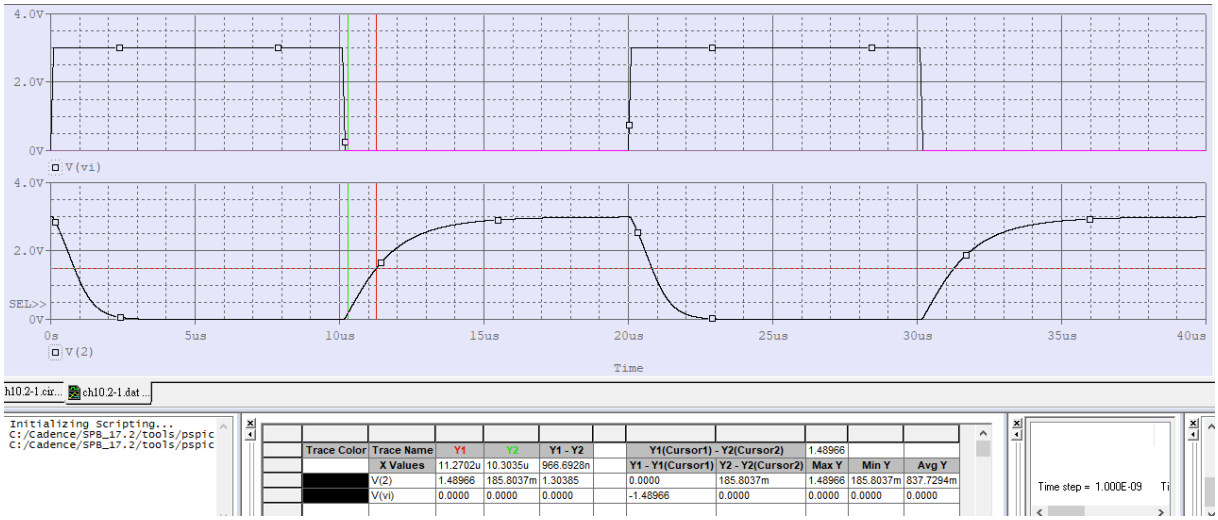
2. PMOS W/L 尺寸與 t_{pLH} 之關係

t_{pLH}	**PMOS W/L** (L=0.18um)		
	1. 5	3	4. 5
PMOS W/L=3	2.0908μ	0.9667μ	0.6115μ



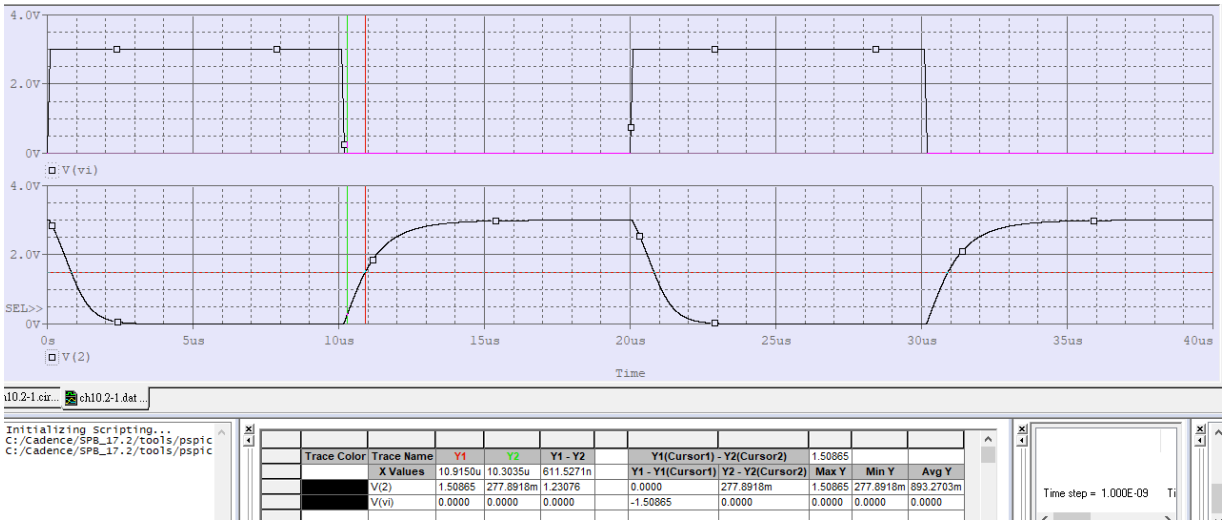
Trace Color	Trace Name	Y1	Y2	Y1 - Y2	Y1(Cursor1) - Y2(Cursor2)		1.50355		
	X Values	12.3943u	10.3035u	2.09082u	Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	V(2)	1.50355	113.4751m	1.39007	0.0000	113.4751m	1.50355	113.4751m	808.5106m
	V(vi)	0.0000	0.0000	0.0000	-1.50355	0.0000	0.0000	0.0000	0.0000

PMOS W/L = 1.5



Trace Color	Trace Name	Y1	Y2	Y1 - Y2	Y1(Cursor1) - Y2(Cursor2)		1.48966		
	X Values	11.2702u	10.3035u	966.6928n	Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	V(2)	1.48966	185.8037m	1.30385	0.0000	185.8037m	1.48966	185.8037m	837.7294m
	V(vi)	0.0000	0.0000	0.0000	-1.48966	0.0000	0.0000	0.0000	0.0000

PMOS W/L = 3

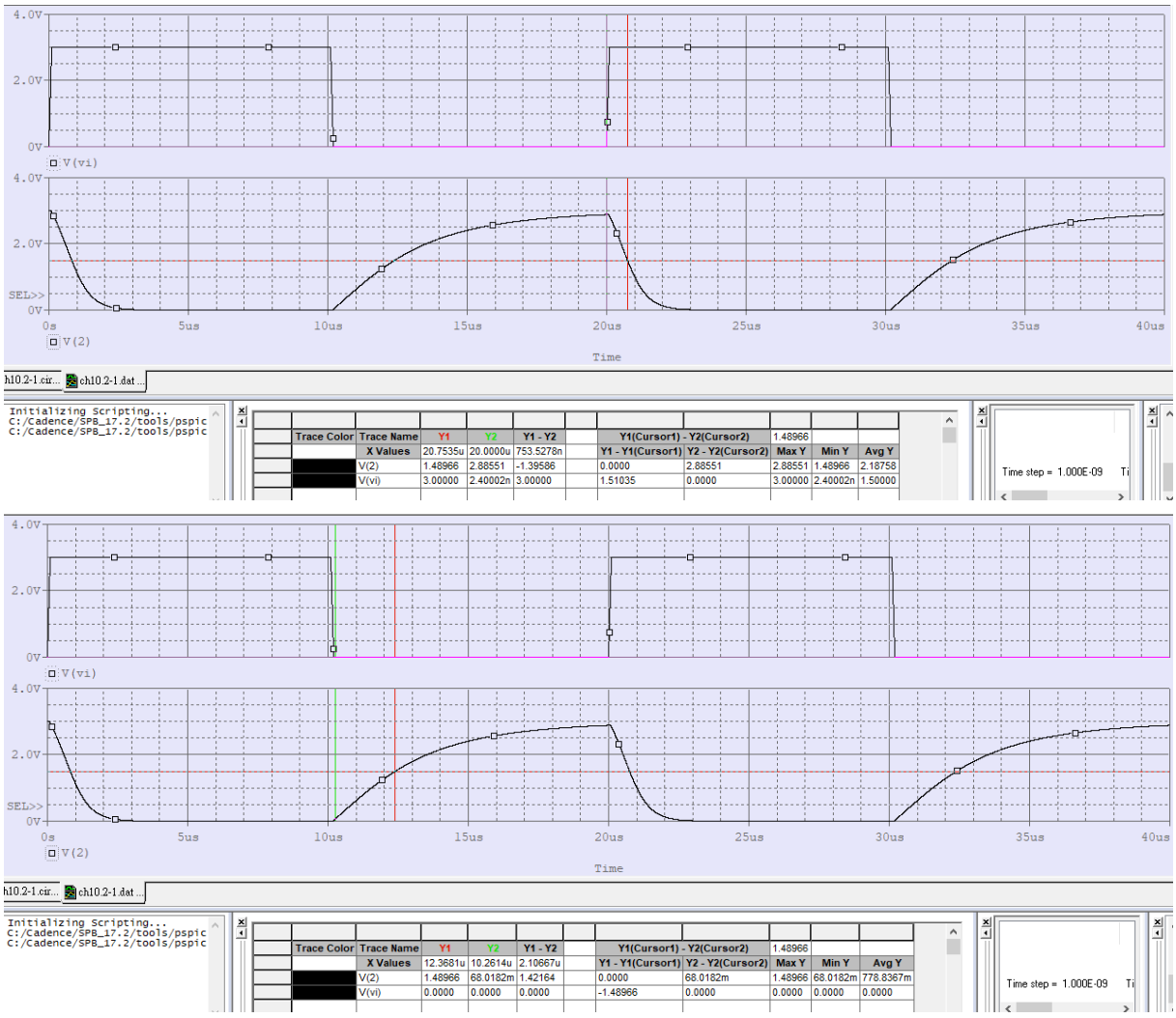


Trace Color	Trace Name	Y1	Y2	Y1 - Y2	Y1(Cursor1) - Y2(Cursor2)		1.50865		
	X Values	10.9150u	10.3035u	611.5271n	Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	V(2)	1.50865	277.8918m	1.23076	0.0000	277.8918m	1.50865	277.8918m	893.2703m
	V(vi)	0.0000	0.0000	0.0000	-1.50865	0.0000	0.0000	0.0000	0.0000

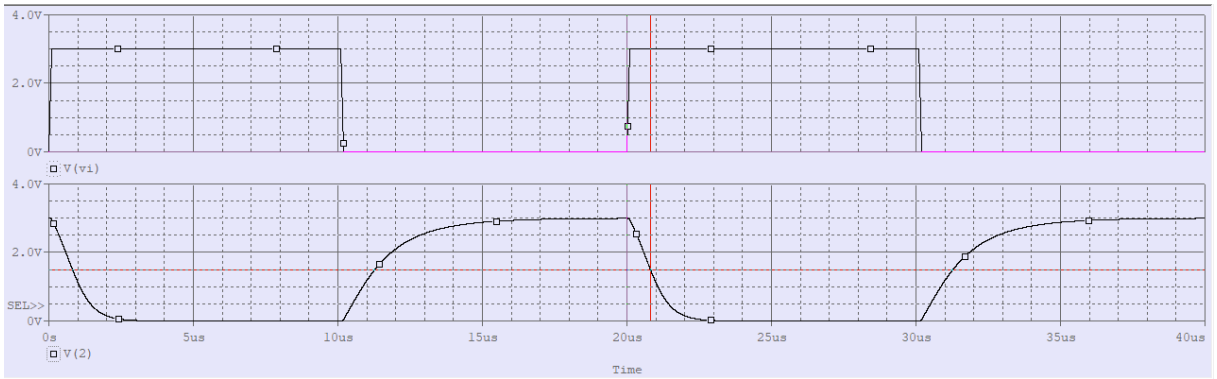
PMOS W/L = 4.5

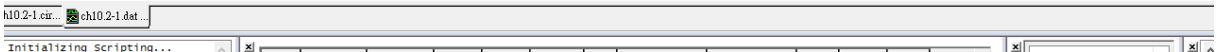
3. PMOS、NMOS W/L 的尺寸比(PMOS-to-NMOS ration)與 t_{pHL}、t_{pLH}之關係

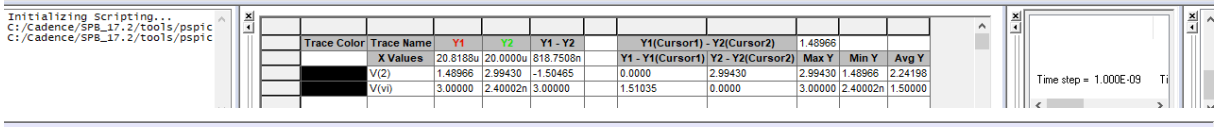
	PMOS-to-NMOS ration (L=0.18um)				
	1	2	3	4	5
t_{pHL}	0.7535µ	0.8188µ	0.8221µ	0.8223µ	0.8223µ
t_{pLH}	2.1067µ	1.0457µ	0.6862µ	0.4925µ	0.35µ



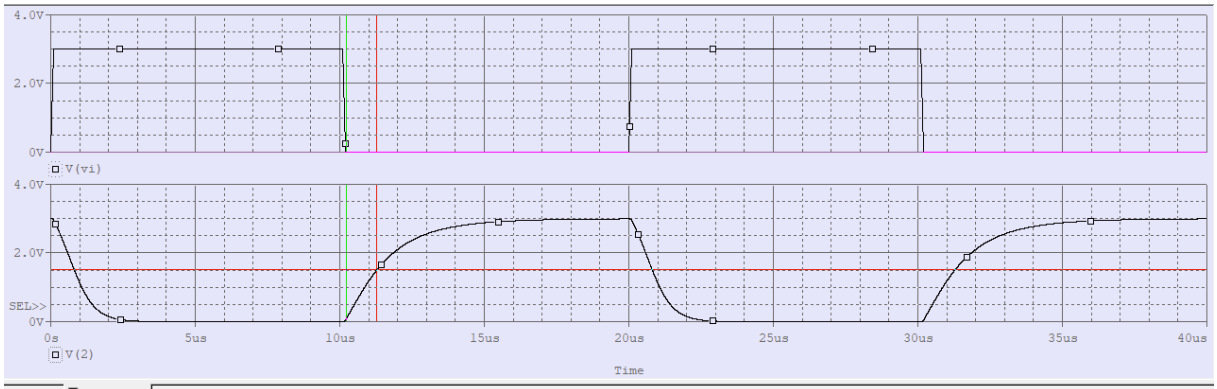
PMOS-to-NMOS ration = 1

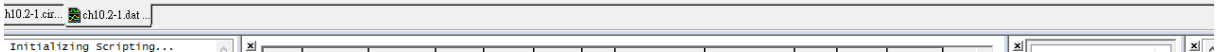


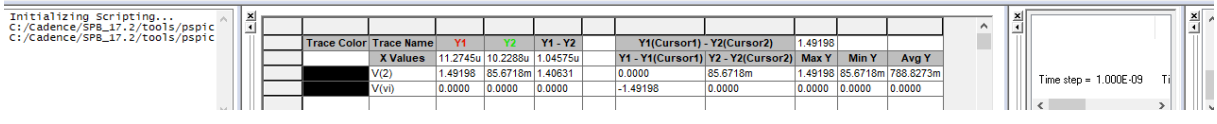




Trace Color	Trace Name	Y1	Y2	Y1 - Y2		Y1(Cursor1) - Y2(Cursor2)		1.48966		
	X Values	20.8188u	20.0000u	818.7508n		Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	V(2)	1.48966	2.99430	-1.50465		0.0000	2.99430	2.99430	1.48966	2.24198
	V(vi)	3.00000	2.40002n	3.00000		1.51035	0.0000	3.00000	2.40002n	1.50000

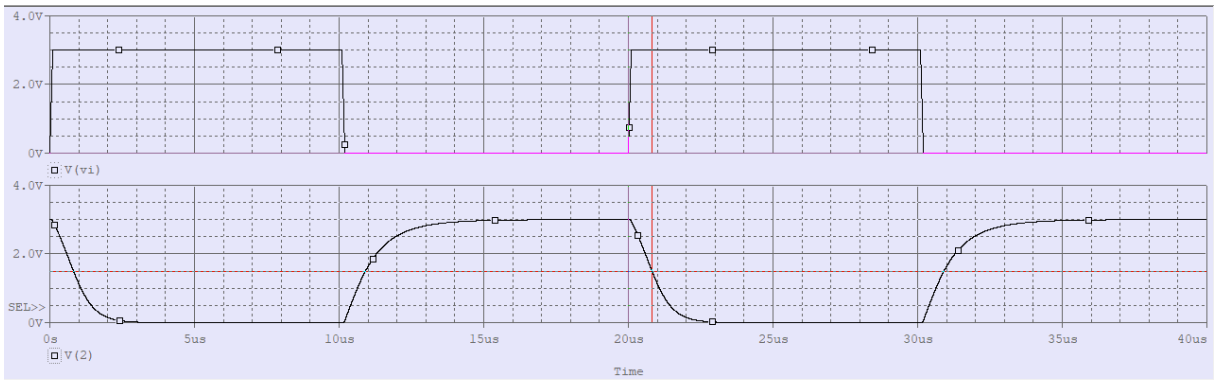


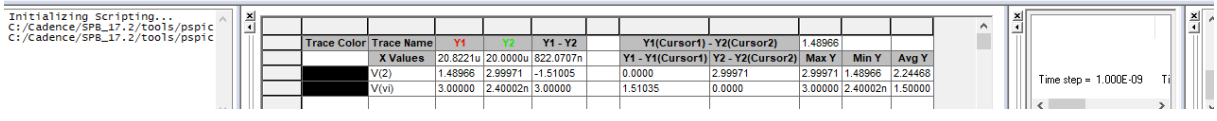




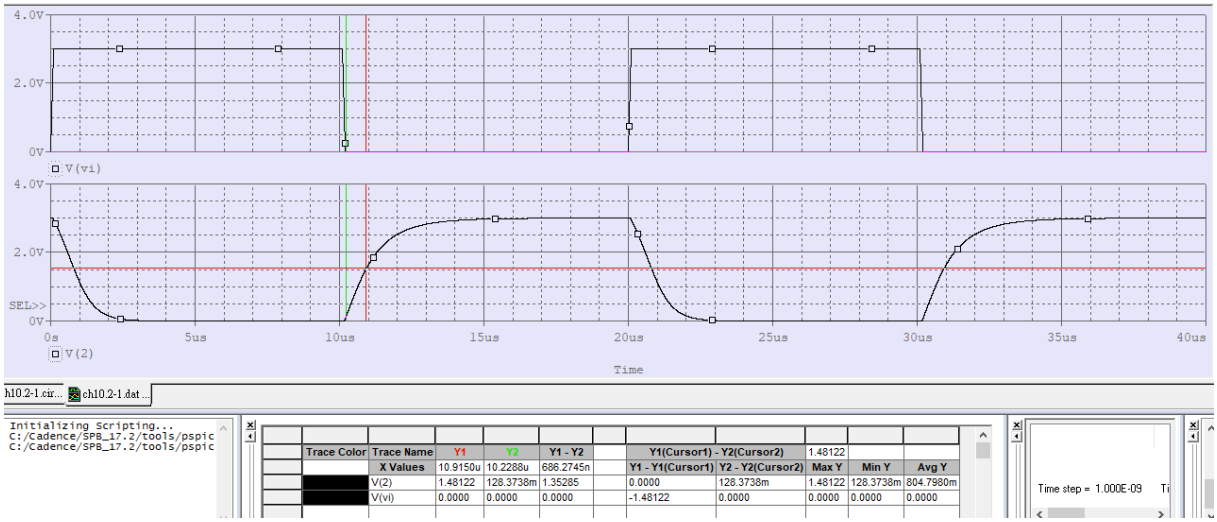
Trace Color	Trace Name	Y1	Y2	Y1 - Y2		Y1(Cursor1) - Y2(Cursor2)		1.49198		
	X Values	11.2745u	10.2288u	1.04575u		Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	V(2)	1.49198	85.6718m	1.40631		0.0000	85.6718m	1.49198	85.6718m	788.8273m
	V(vi)	0.0000	0.0000	0.0000		-1.49198	0.0000	0.0000	0.0000	0.0000

PMOS-to-NMOS ration = 2



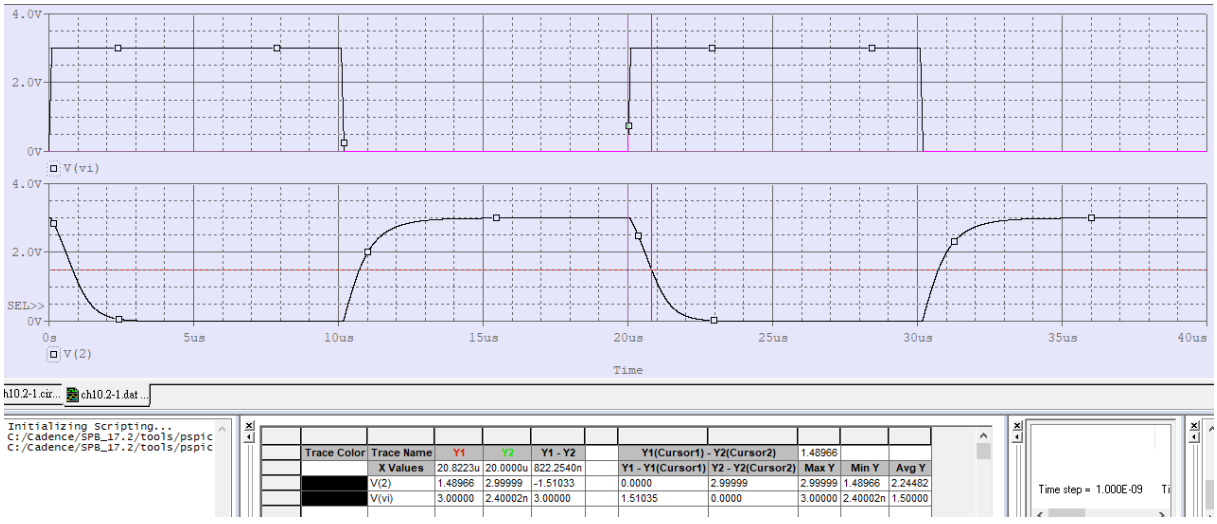


Trace Color	Trace Name	Y1	Y2	Y1 - Y2		Y1(Cursor1) - Y2(Cursor2)		1.48966		
	X Values	20.8221u	20.0000u	822.0707n		Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	V(2)	1.48966	2.99971	-1.51005		0.0000	2.99971	2.99971	1.48966	2.24468
	V(vi)	3.00000	2.40002n	3.00000		1.51035	0.0000	3.00000	2.40002n	1.50000

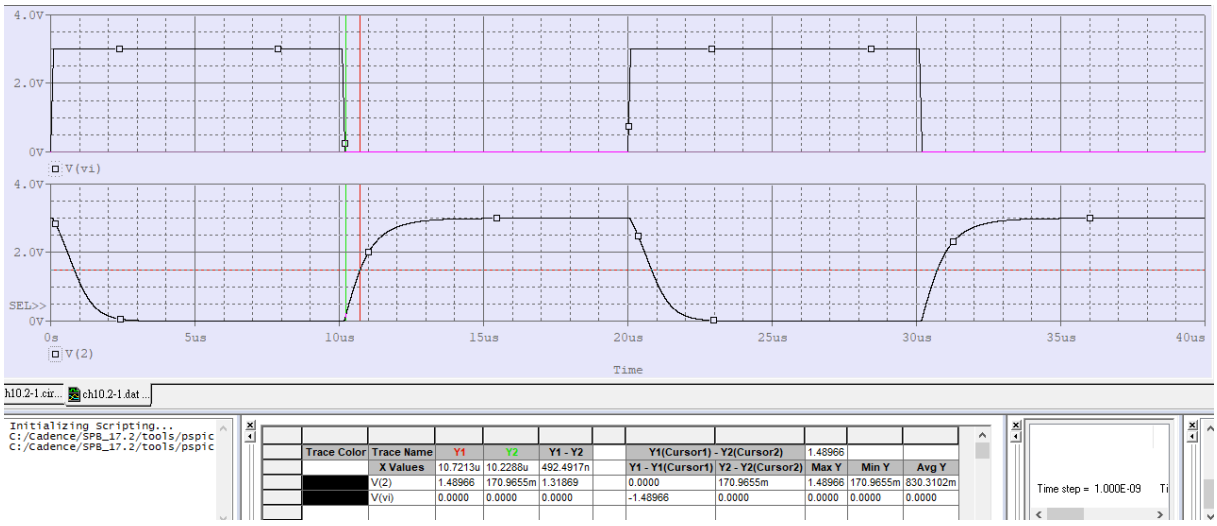


Trace Color	Trace Name	Y1	Y2	Y1 - Y2	Y1(Cursor1) - Y2(Cursor2)		1.48122		
	X Values	10.9150u	10.2288u	686.2745n	Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	V(2)	1.48122	128.3738m	1.35285	0.0000	128.3738m	1.48122	128.3738m	804.7980m
	V(vi)	0.0000	0.0000	0.0000	-1.48122	0.0000	0.0000	0.0000	0.0000

PMOS-to-NMOS ration = 3

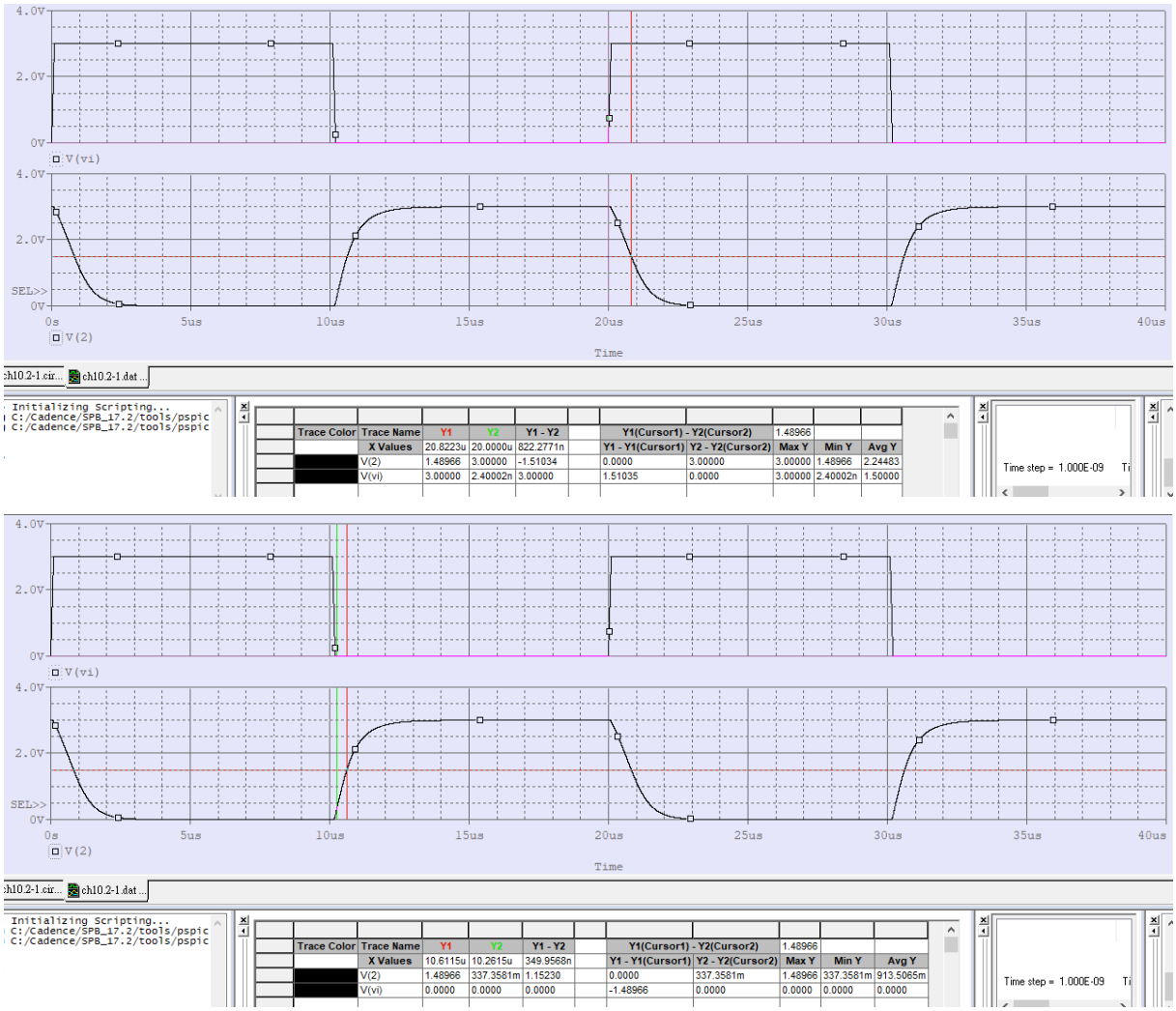


Trace Color	Trace Name	Y1	Y2	Y1 - Y2	Y1(Cursor1) - Y2(Cursor2)		1.48966		
	X Values	20.8223u	20.0000u	822.2540n	Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	V(2)	1.48966	2.99999	-1.51033	0.0000	2.99999	2.99999	1.48966	2.24482
	V(vi)	3.00000	2.40002n	3.00000	1.51035	0.0000	3.00000	2.40002n	1.50000



Trace Color	Trace Name	Y1	Y2	Y1 - Y2	Y1(Cursor1) - Y2(Cursor2)		1.48966		
	X Values	10.7213u	10.2288u	492.4917n	Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	V(2)	1.48966	170.9655m	1.31869	0.0000	170.9655m	1.48966	170.9655m	830.3102m
	V(vi)	0.0000	0.0000	0.0000	-1.48966	0.0000	0.0000	0.0000	0.0000

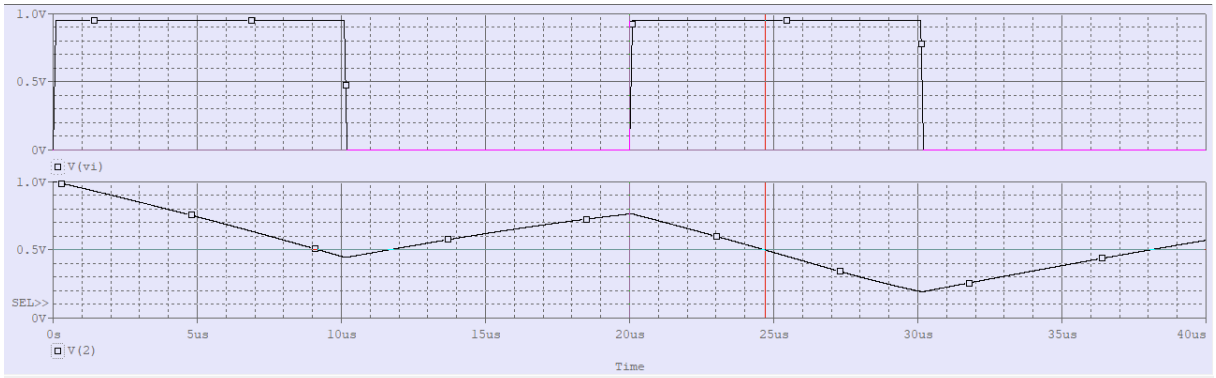
PMOS-to-NMOS ration = 4



PMOS-to-NMOS ration = 5

4. 電源電壓 V_{DD}與 t_{pHL}、t_{pLH}之關係。(NMOS W/L=1.5 及 PMOS W/L=3 (L=0. 18um))

	V_{DD}				
	1	2	3	4	5
t_{pHL}	4.7078μ	7.0459μ	5.0974μ	3.0844μ	2.1429μ
t_{pLH}	1.3959μ	1.0712μ	0.8441μ	0.487μ	0.3119μ



ch10.2-1.cir... ch10.2-1.dat ...

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Initializing Scripting...
C:/Cadence/SPB_17.2/tools/pspic
C:/Cadence/SPB_17.2/tools/pspic
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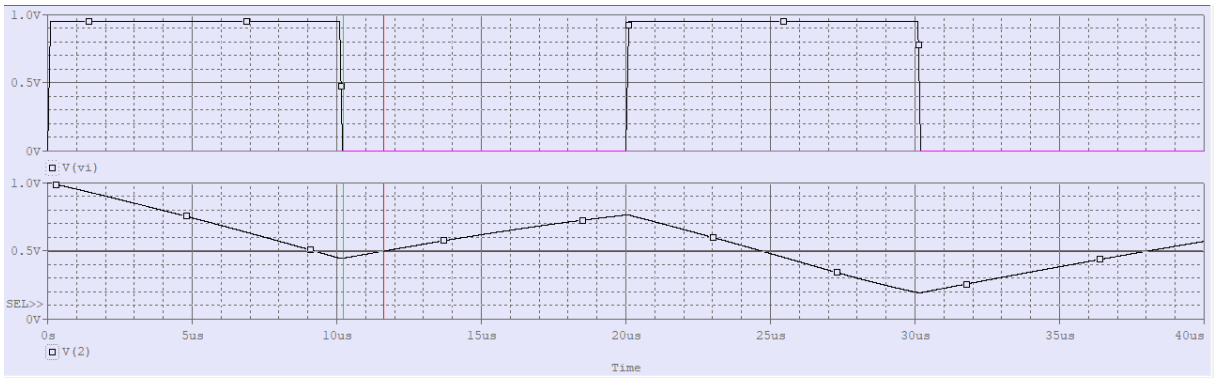
Trace Color	Trace Name	Y1	Y2	Y1 - Y2	Y1(Cursor1) - Y2(Cursor2)		499.6355m		
	X Values	24.7078u	20.0000u	4.70779u	Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	V(2)	499.6355m	764.9890m	-265.3534m	0.0000	764.9890m	764.9890m	499.6355m	632.3123
	V(vi)	950.0000m	760.0053p	950.0000m	450.3645m	0.0000	950.0000m	760.0053p	475.0000

Time step = 1.000E-09 Ti



ch10.2-1.cir... ch10.2-1.dat ...

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Initializing Scripting...
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C:/Cadence/SPB_17.2/tools/pspic
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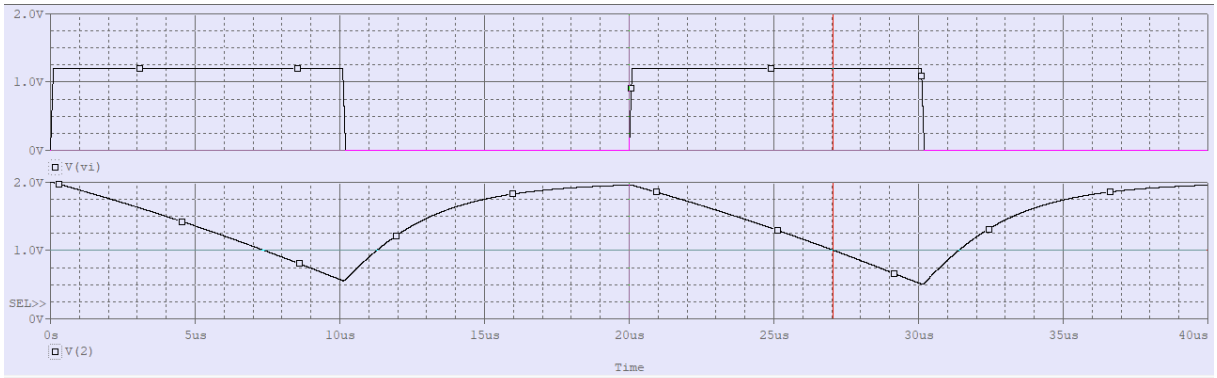
Trace Color	Trace Name	Y1	Y2	Y1 - Y2	Y1(Cursor1) - Y2(Cursor2)		500.1457m		
	X Values	11.6234u	10.2275u	1.39588u	Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	V(2)	500.1457m	447.7951m	52.3506m	0.0000	447.7951m	500.1457m	447.7951m	473.9704m
	V(vi)	0.0000	0.0000	0.0000	-500.1457m	0.0000	0.0000	0.0000	0.0000

Time step = 1.000E-09 Ti

$V_{DD} = 1$



ch10.2-1.cir... ch10.2-1.dat ...

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Initializing Scripting...
C:/Cadence/SPB_17.2/tools/pspic
C:/Cadence/SPB_17.2/tools/pspic
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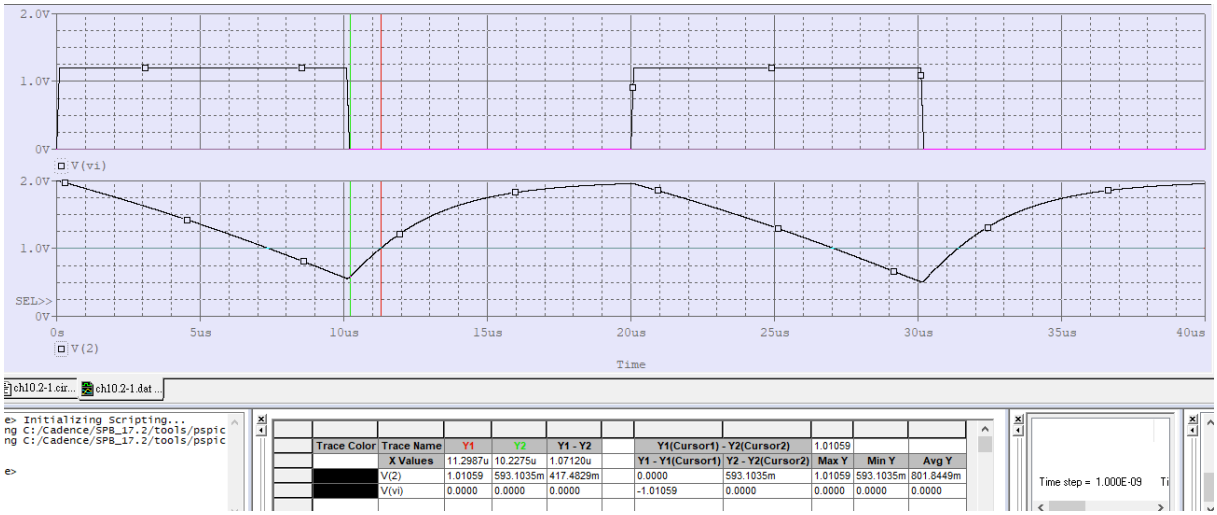
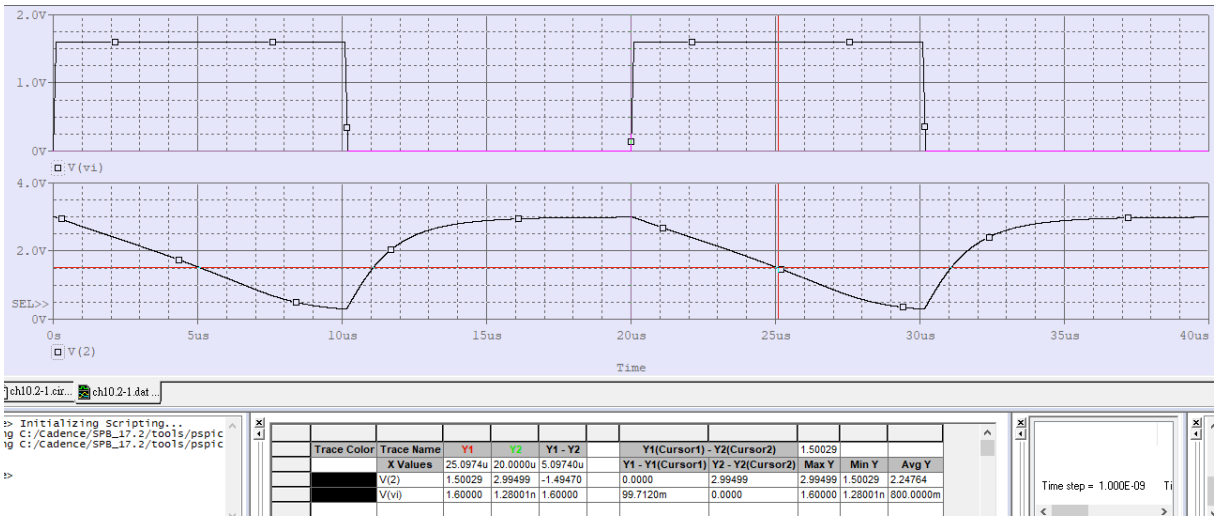
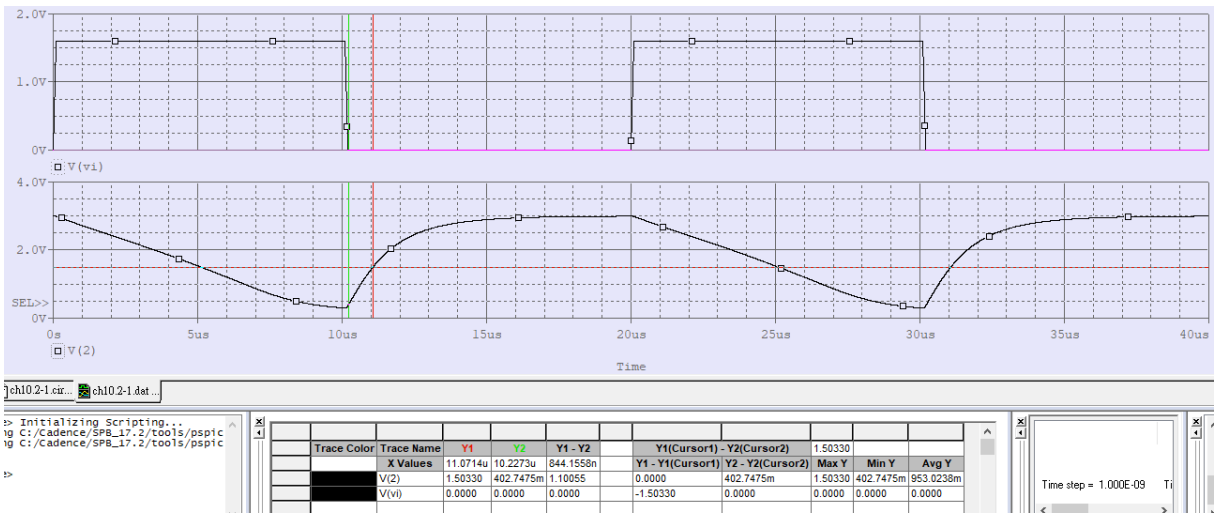
Trace Color	Trace Name	Y1	Y2	Y1 - Y2	Y1(Cursor1) - Y2(Cursor2)		1.00585		
	X Values	27.0459u	20.0000u	7.04588u	Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	V(2)	1.00585	1.96068	-954.8374m	0.0000	1.96068	1.96068	1.00585	1.48326
	V(vi)	1.20000	960.0068p	1.20000	194.1555m	0.0000	1.20000	960.0068p	600.0000m

Time step = 1.000E-09 Ti

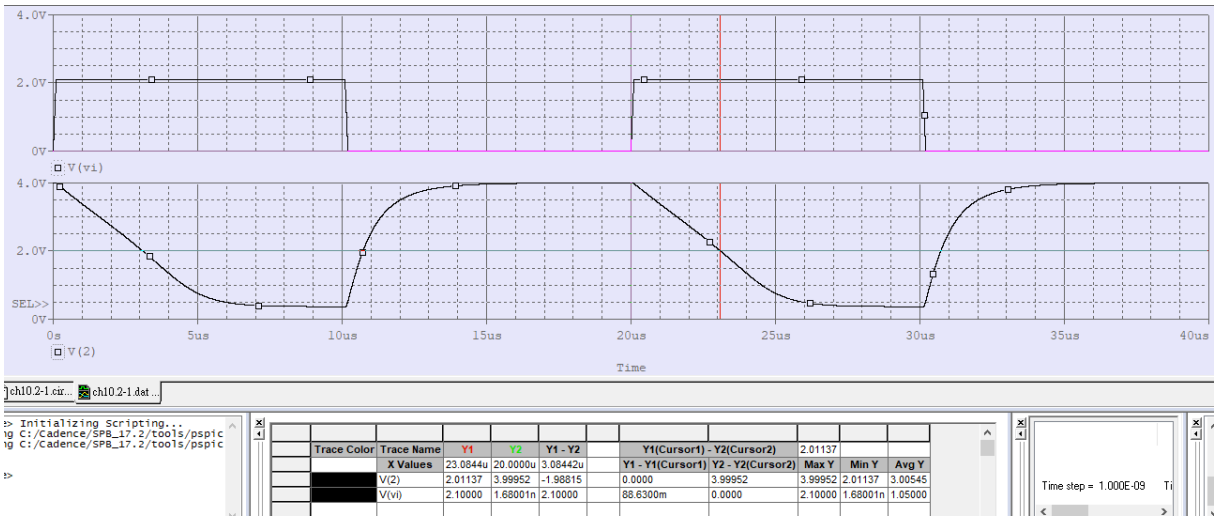

2.0V
1.0V
0V
V(vi)
2.0V
1.0V
SEL>>
0V
0s
5us
10us
15us
20us
25us
30us
35us
40us
V(2)
Time
ch10.2-1.cir...
ch10.2-1.dat...
e> Initializing Scripting...
ng C:/Cadence/SPB_17.2/tools/pspic
ng C:/Cadence/SPB_17.2/tools/pspic
e>
Trace Color | Trace Name | Y1 | Y2 | Y1 - Y2 | Y1(Cursor1) - Y2(Cursor2) | 1.01059
X Values | 11.2987u | 10.2275u | 1.07120u | Y1 - Y1(Cursor1) | Y2 - Y2(Cursor2) | Max Y | Min Y | Avg Y
V(2) | 1.01059 | 593.1035m | 417.4829m | 0.0000 | 593.1035m | 1.01059 | 593.1035m | 801.8449m
V(vi) | 0.0000 | 0.0000 | 0.0000 | -1.01059 | 0.0000 | 0.0000 | 0.0000 | 0.0000
Time step = 1.000E-09

$V_{DD} = 2$

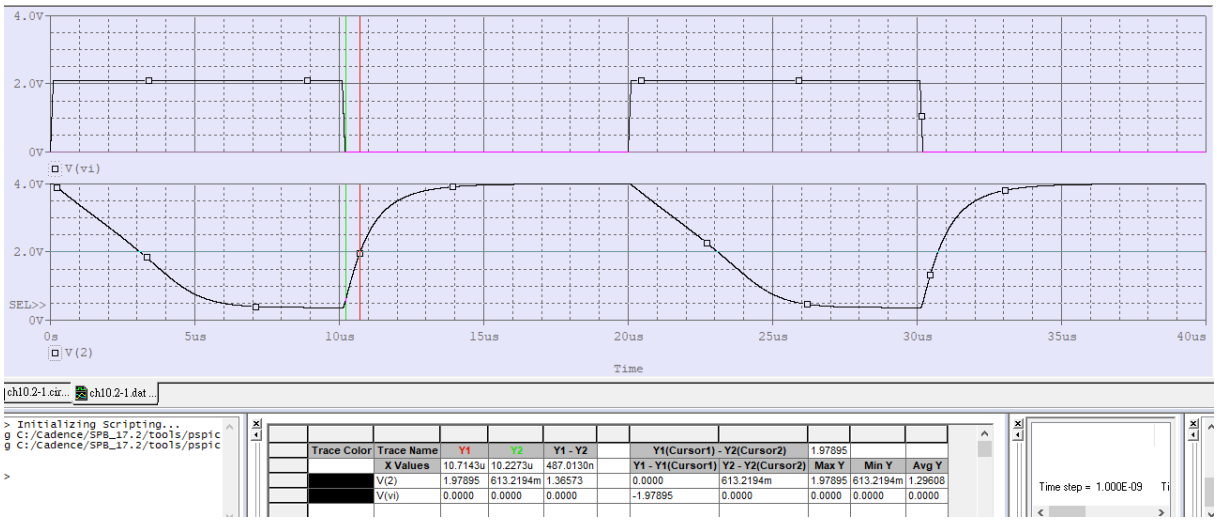

2.0V
1.0V
0V
V(vi)
4.0V
2.0V
SEL>>
0V
0s
5us
10us
15us
20us
25us
30us
35us
40us
V(2)
Time
ch10.2-1.cir...
ch10.2-1.dat...
e> Initializing Scripting...
ng C:/Cadence/SPB_17.2/tools/pspic
ng C:/Cadence/SPB_17.2/tools/pspic
e>
Trace Color | Trace Name | Y1 | Y2 | Y1 - Y2 | Y1(Cursor1) - Y2(Cursor2) | 1.50029
X Values | 25.0974u | 20.0000u | 5.09740u | Y1 - Y1(Cursor1) | Y2 - Y2(Cursor2) | Max Y | Min Y | Avg Y
V(2) | 1.50029 | 2.99499 | -1.49470 | 0.0000 | 2.99499 | 2.99499 | 1.50029 | 2.24764
V(vi) | 1.60000 | 1.28001n | 1.60000 | 99.7120m | 0.0000 | 1.60000 | 1.28001n | 800.0000m
Time step = 1.000E-09


2.0V
1.0V
0V
V(vi)
4.0V
2.0V
SEL>>
0V
0s
5us
10us
15us
20us
25us
30us
35us
40us
V(2)
Time
ch10.2-1.cir...
ch10.2-1.dat...
e> Initializing Scripting...
ng C:/Cadence/SPB_17.2/tools/pspic
ng C:/Cadence/SPB_17.2/tools/pspic
e>
Trace Color | Trace Name | Y1 | Y2 | Y1 - Y2 | Y1(Cursor1) - Y2(Cursor2) | 1.50330
X Values | 11.0714u | 10.2273u | 844.1558n | Y1 - Y1(Cursor1) | Y2 - Y2(Cursor2) | Max Y | Min Y | Avg Y
V(2) | 1.50330 | 402.7475m | 1.10055 | 0.0000 | 402.7475m | 1.50330 | 402.7475m | 953.0238m
V(vi) | 0.0000 | 0.0000 | 0.0000 | -1.50330 | 0.0000 | 0.0000 | 0.0000 | 0.0000
Time step = 1.000E-09

$V_{DD} = 3$

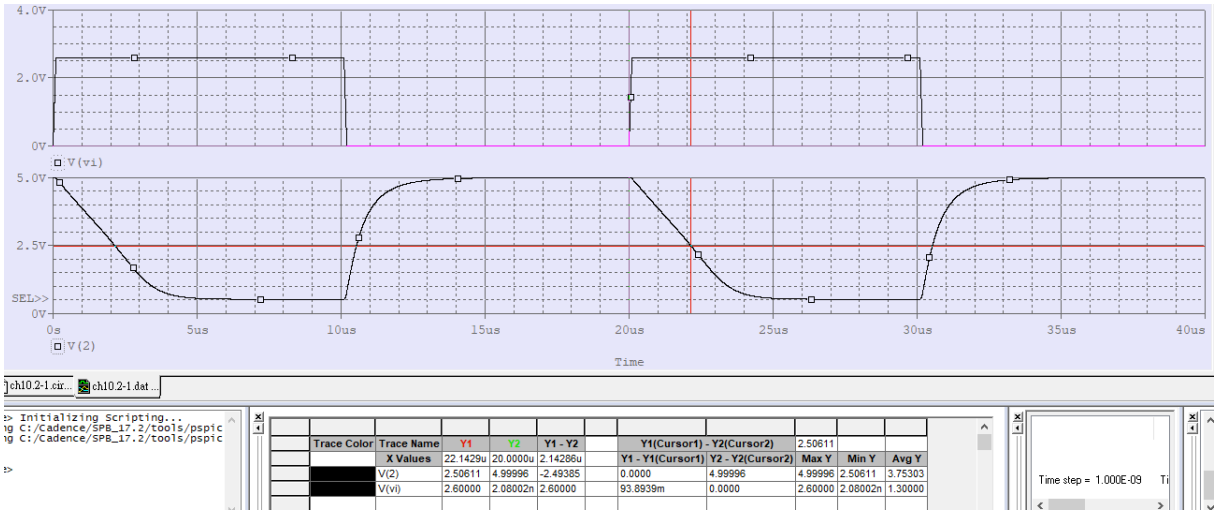


Trace Color	Trace Name	Y1	Y2	Y1 - Y2	Y1(Cursor1) - Y2(Cursor2)		2.01137		
	X Values	23.0844u	20.0000u	3.0844u	Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	V(2)	2.01137	3.99952	-1.98815	0.0000	3.99952	3.99952	2.01137	3.00545
	V(vi)	2.10000	1.68001n	2.10000	88.6300m	0.0000	2.10000	1.68001n	1.05000

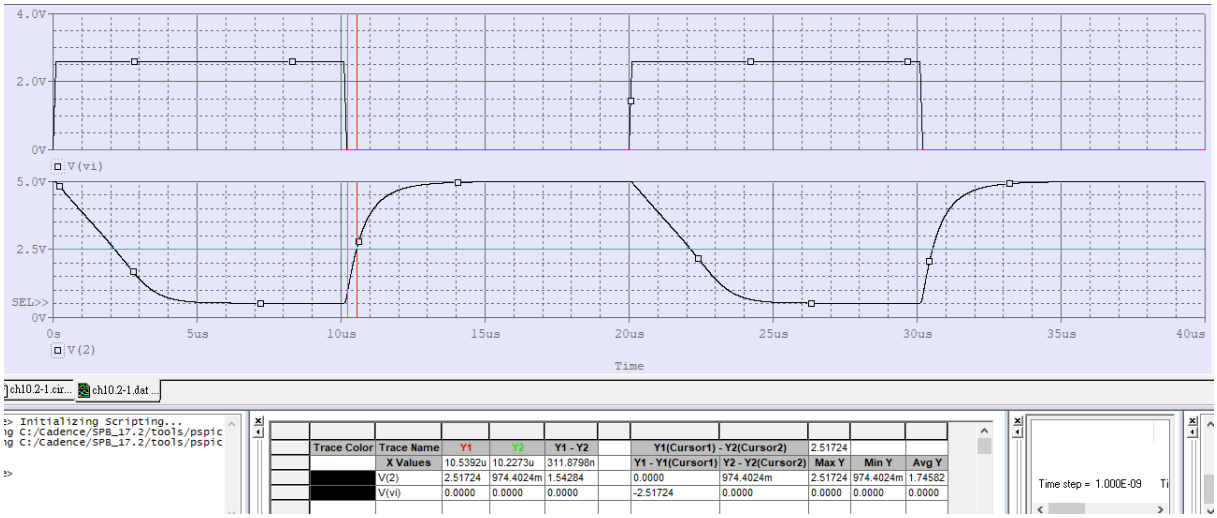


Trace Color	Trace Name	Y1	Y2	Y1 - Y2	Y1(Cursor1) - Y2(Cursor2)		1.97895		
	X Values	10.7143u	10.2273u	487.0130n	Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	V(2)	1.97895	613.2194m	1.36573	0.0000	613.2194m	1.97895	613.2194m	1.29608
	V(vi)	0.0000	0.0000	0.0000	-1.97895	0.0000	0.0000	0.0000	0.0000

$V_{DD} = 4$



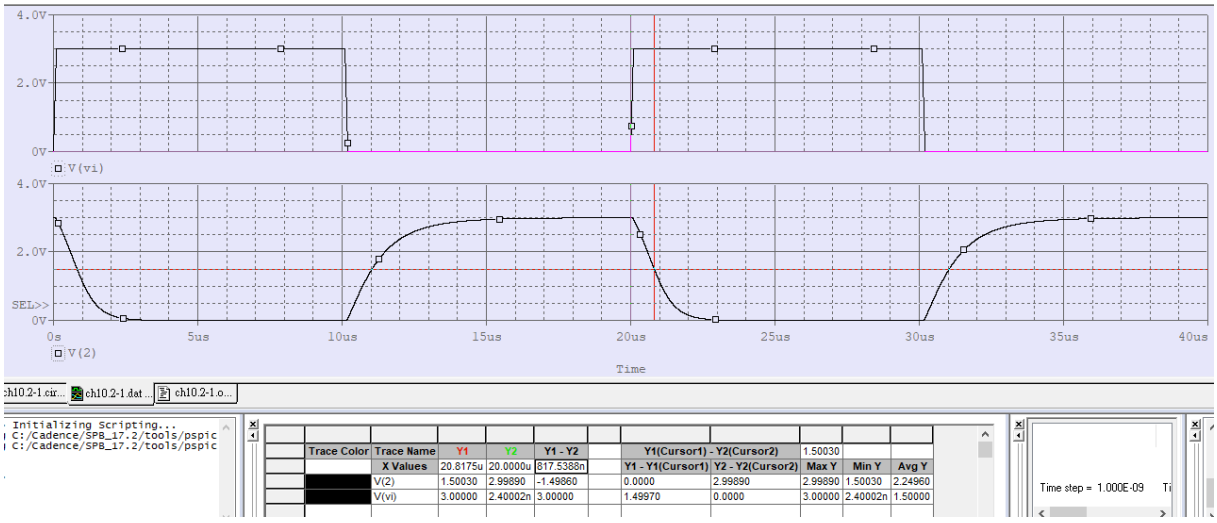
Trace Color	Trace Name	Y1	Y2	Y1 - Y2	Y1(Cursor1) - Y2(Cursor2)		2.50611		
	X Values	22.1429u	20.0000u	2.14286u	Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	V(2)	2.50611	4.99996	-2.49385	0.0000	4.99996	4.99996	2.50611	3.75303
	V(vi)	2.60000	2.08002n	2.60000	93.8939m	0.0000	2.60000	2.08002n	1.30000



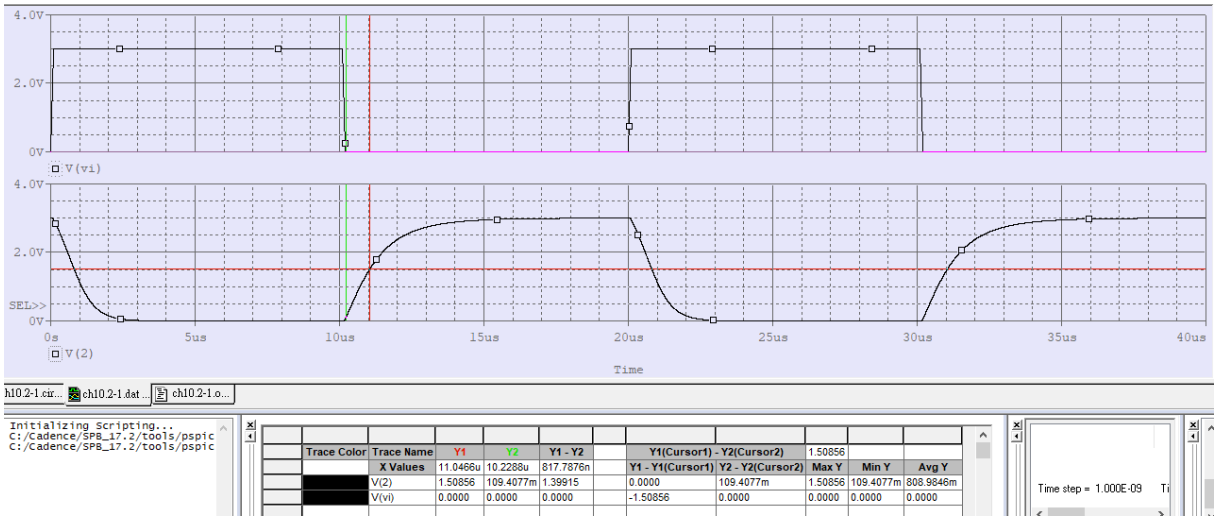
$\boldsymbol{V_{DD} = 5}$

5. 設計 (決定 PMOS、NMOS W/L 的尺寸比) 一 t_{pHL}、t_{pLH}相同之 CMOS 反向器 (假設 L = 0.18um，V_{DD} = 3V)

NMOS：L = 0.18um，W = 0.27um。PMOS：L = 0.18um，W = 0.69um。



$t_{pHL} = 817.5388ns$



Trace Color	Trace Name	Y1	Y2	Y1 - Y2		Y1(Cursor1) - Y2(Cursor2)		1.50856		
	X Values	11.0466u	10.2288u	817.7876n		Y1 - Y1(Cursor1)	Y2 - Y2(Cursor2)	Max Y	Min Y	Avg Y
	V(2)	1.50856	109.4077m	1.39915		0.0000	109.4077m	1.50856	109.4077m	808.9846m
	V(vi)	0.0000	0.0000	0.0000		-1.50856	0.0000	0.0000	0.0000	0.0000

$t_{pLH} = 817.7876\text{ns}$