Exercise 4 Voltage Scaling

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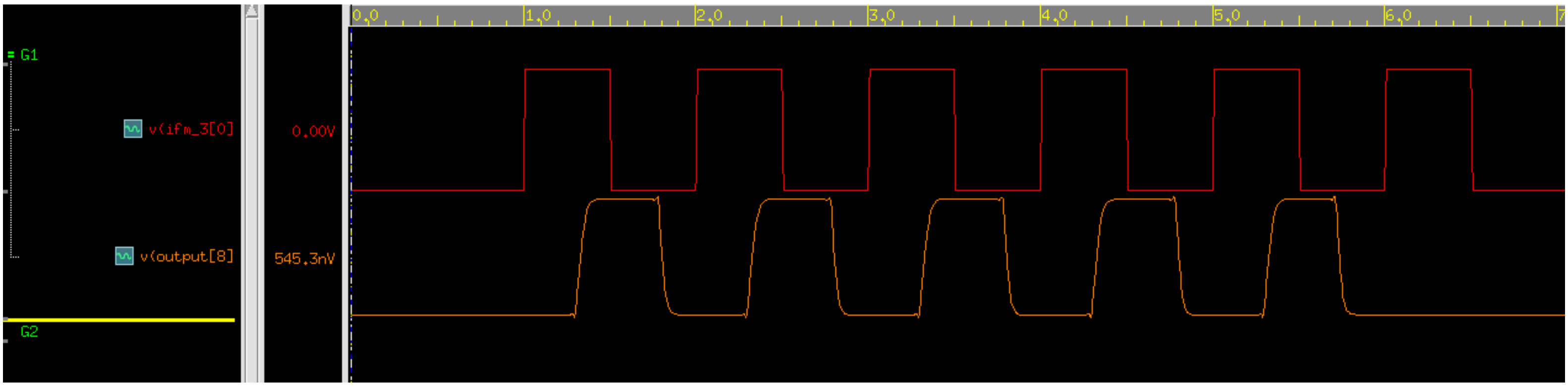
Critical path:

```
Startpoint: IFM_3[0] (input port)
Endpoint: Output[8] (output port)
Path Group: default
Path Type: max
```

從 report 中可以看出 critical path 需要通過 IFM_3[0]到 Output[8]，因此我的 pattern 設計中的前 10 組為只讓 IFM_3[0]在 0 和 1 之間變動並使輸出在 256 的上下變動使 Output[8]會跟著 IFM_3[0]進行變化;而後面的 20 組則是隨機產生的 pattern 為了使測出來的 average power 可以更準一點。



此圖為 Output[8]跟著 IFM_3[0]進行變化。

Find the optimal energy-delay product with different voltage

Energy = power*delay

Energy-Delay Product = Energy*delay

(1) VDD = 0.7V

```
****** transient analysis tnom=  25.000 temp=  25.000 ******
tr_critical=-177.3409p  targ=   2.3277n   trig=   2.5050n
tf_critical= 800.5076p  targ=   2.8055n   trig=   2.0050n
critical_delay= 311.5834p
pwr=  89.8181u  from=   0.                to=  16.0000n

          ***** job concluded
******
```

Energy = 89.8181*311.5384 = 27,981.52($\mathrm{x}10^{-18}$J)

Energy-Delay Product = 27,981.52*311.5834 = 8,718.58

($\mathrm{x}10^{-27}$J*s)

(2) VDD = 0.65V

```
****** transient analysis tnom=  25.000 temp=  25.000 ******
tr_critical=-134.6358p  targ=   2.3704n   trig=   2.5050n
tf_critical= 839.3840p  targ=   2.8444n   trig=   2.0050n
critical_delay= 352.3741p
pwr=  75.6127u  from=   0.                to=  16.0000n

          ***** job concluded
******
```

Energy = 75.6127*352.3741 = 26,643.96($\mathrm{x}10^{-18}$J)

Energy-Delay Product = 26,643.96*352.3741 = 9,388.30

($\mathrm{x}10^{-27}$J*s)

(3) VDD = 0.6V

```
****** transient analysis tnom=  25.000 temp=  25.000 ******
tr_critical= -75.0798p  targ=   2.4299n   trig=   2.5050n
tf_critical= 895.8796p  targ=   2.9009n   trig=   2.0050n
critical_delay= 410.3999p
pwr=  62.8394u  from=   0.                to=  16.0000n

          ***** job concluded
******
```

Energy = 62.8394*410.3999 = 25,789.28 ($\mathrm{x}10^{-18}$J)

Energy-Delay Product = 25,789.28*410.3999 = 10,583.92

($\times 10^{-27}$J*s)

(4) VDD = 0.55V

```
****** transient analysis tnom=  25.000 temp=  25.000 ******
tr_critical=  14.8903p  targ=   2.5199n   trig=   2.5050n
tf_critical= 979.7169p  targ=   2.9847n   trig=   2.0050n
critical_delay= 497.3036p
pwr=  51.4196u  from=   0.               to=  16.0000n

          ***** job concluded
******
```

Energy = 51.4196*497.3036 = 25,571.15 ($\times 10^{-18}$J)

Energy-Delay Product = 25,571.15*497.3036 = 12,716.62

($\times 10^{-27}$J*s)

(5) VDD = 0.5V

```
****** transient analysis tnom=  25.000 temp=  25.000 ******
tr_critical= 158.3075p  targ=   2.6633n   trig=   2.5050n
tf_critical=   1.1147n  targ=   3.1197n   trig=   2.0050n
critical_delay= 636.4976p
pwr=  41.2310u  from=   0.               to=  16.0000n

          ***** job concluded
******
```

Energy = 41.2310*636.4976 = 26,243.43 ($\times 10^{-18}$J)

Energy-Delay Product = 26,243.43*636.4976 = 16,703.88

($\times 10^{-27}$J*s)

(6) VDD = 0.45V

```
****** transient analysis tnom=  25.000 temp=  25.000 ******
tr_critical= 413.9151p  targ=   2.9189n   trig=   2.5050n
tf_critical=   1.3559n  targ=   3.3609n   trig=   2.0050n
critical_delay= 884.9162p
pwr=  32.1596u  from=   0.               to=  16.0000n

          ***** job concluded
******
*******************************
```

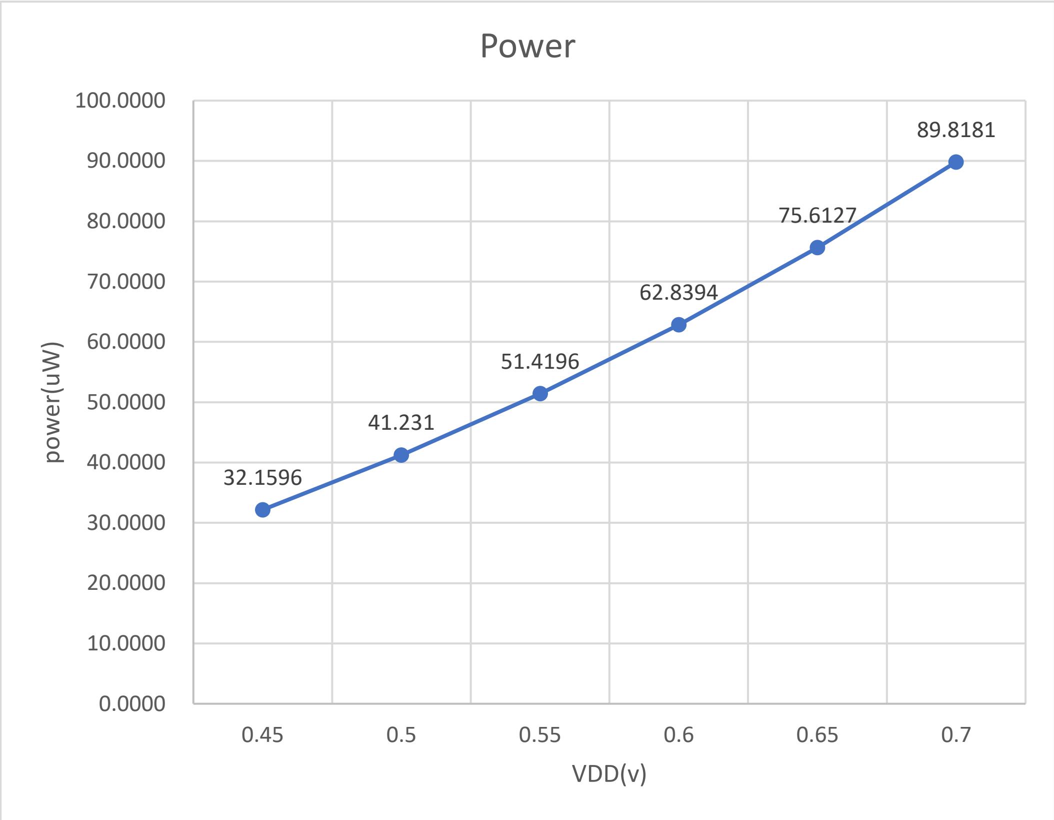
Energy = 32.1596*884.9162 = 28,458.55 (x10^{-18}J)

Energy-Delay Product = 28,458.55*884.9162 = 25,183.43

(x10^{-27}J*s)

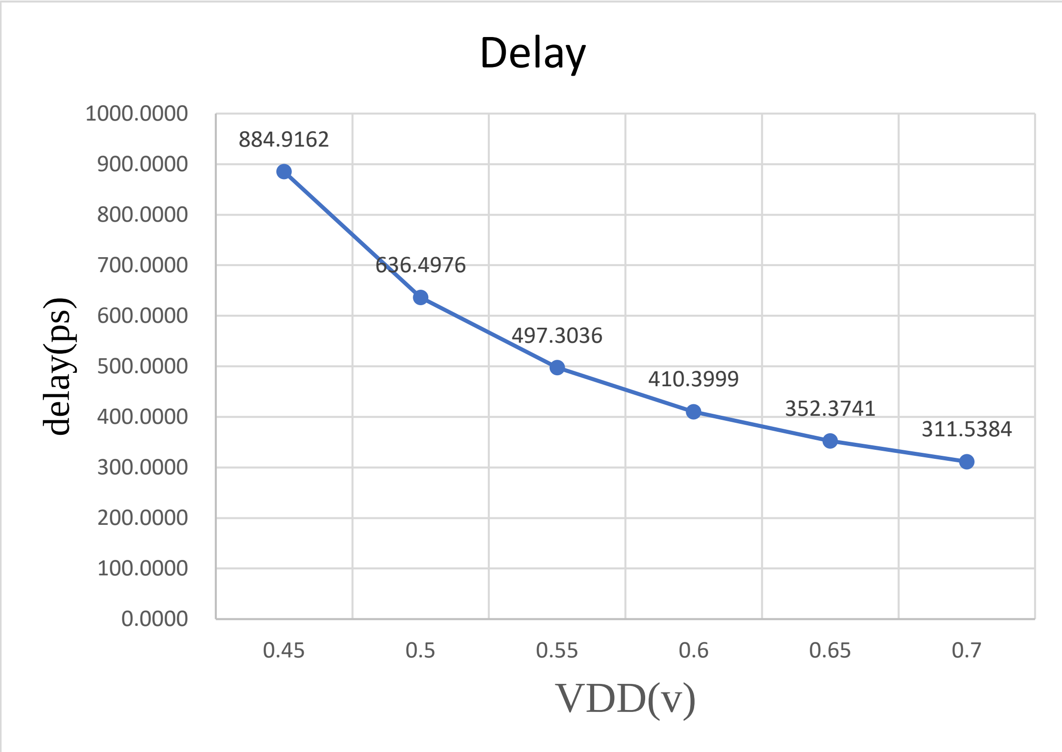
Plot Curve:

(1)Power



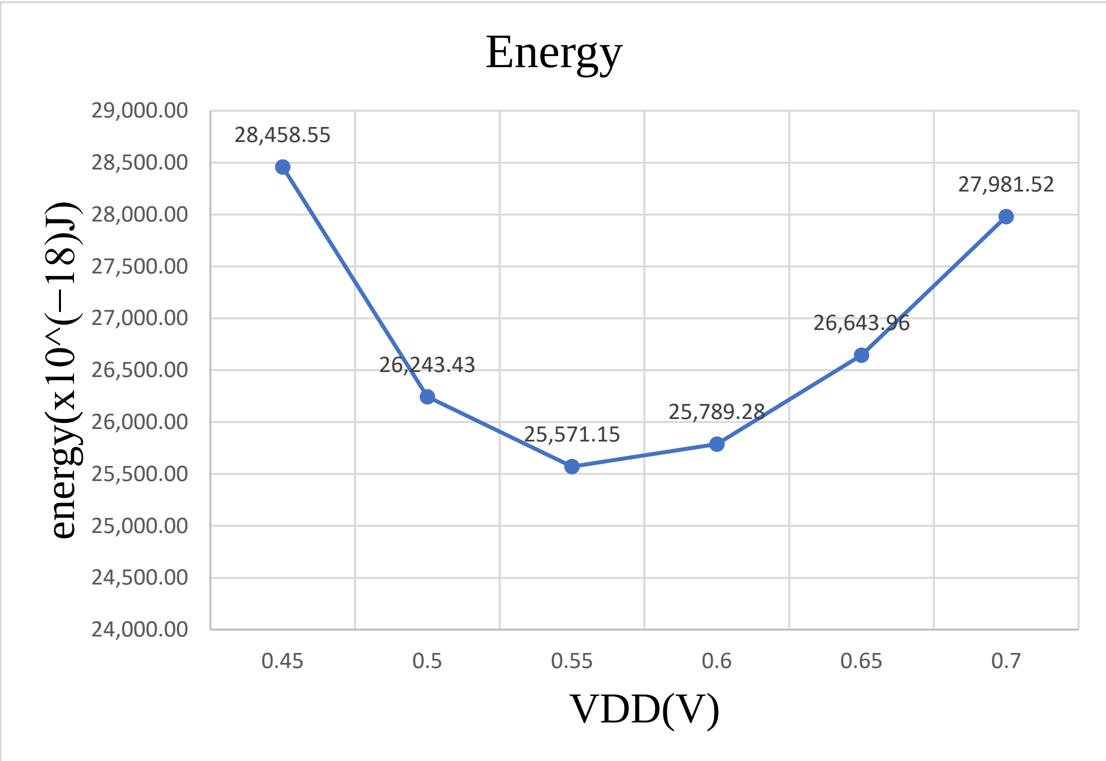
可以看出 power 和 VDD 大小成正比。

(2)Delay



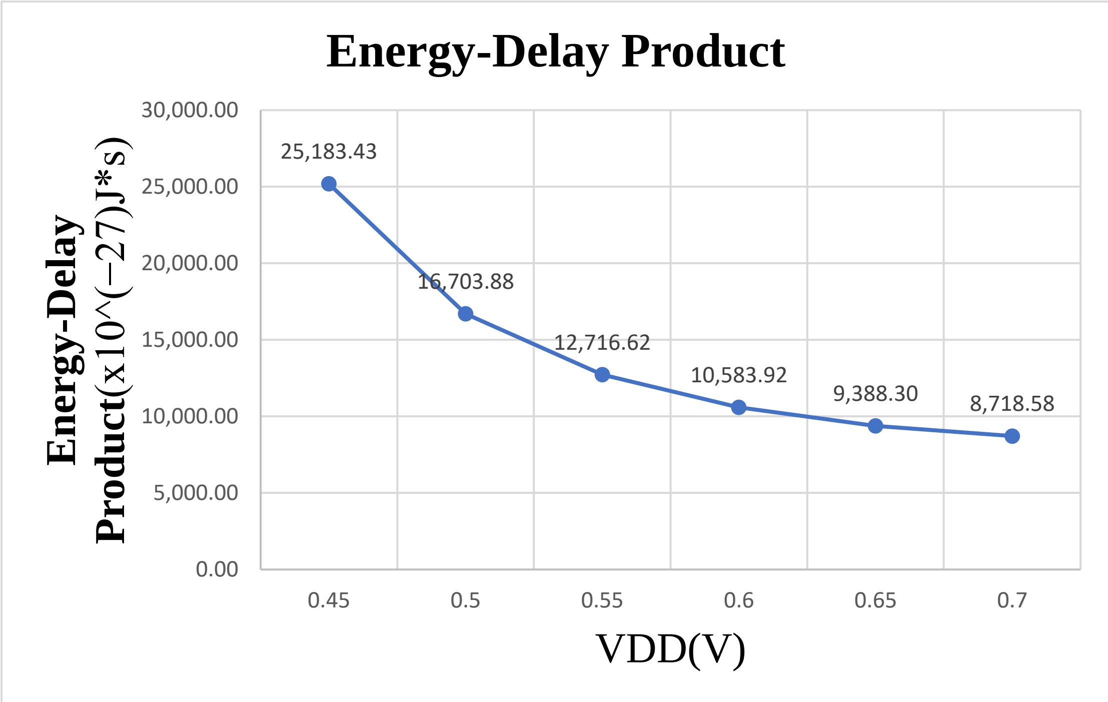
可以看出 delay 和 VDD 大小成反比。

(3)Energy



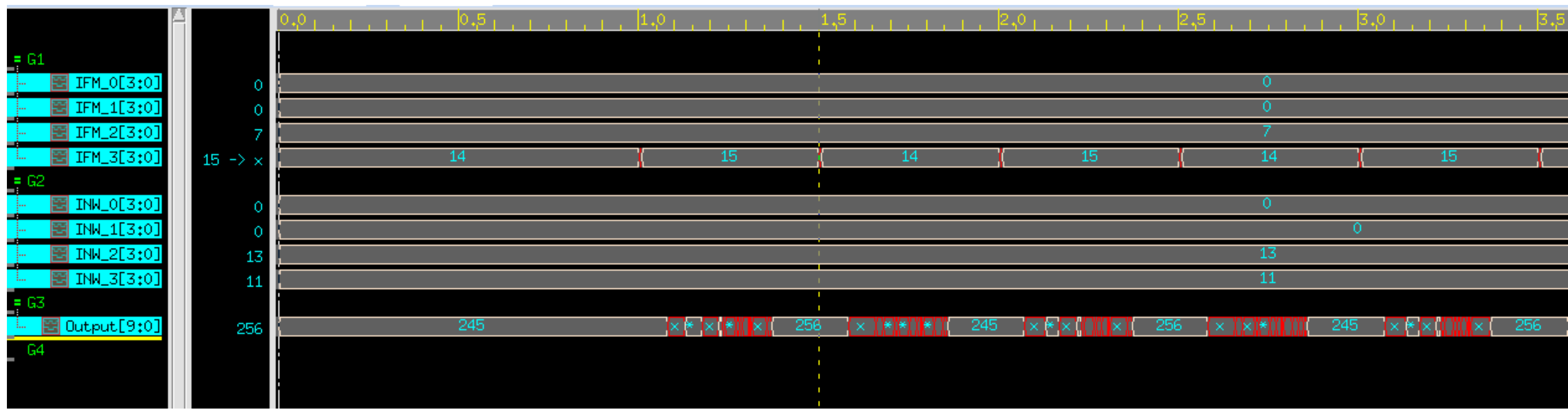
可以看出 energy 在 VDD = 0.55V 時有最小值。

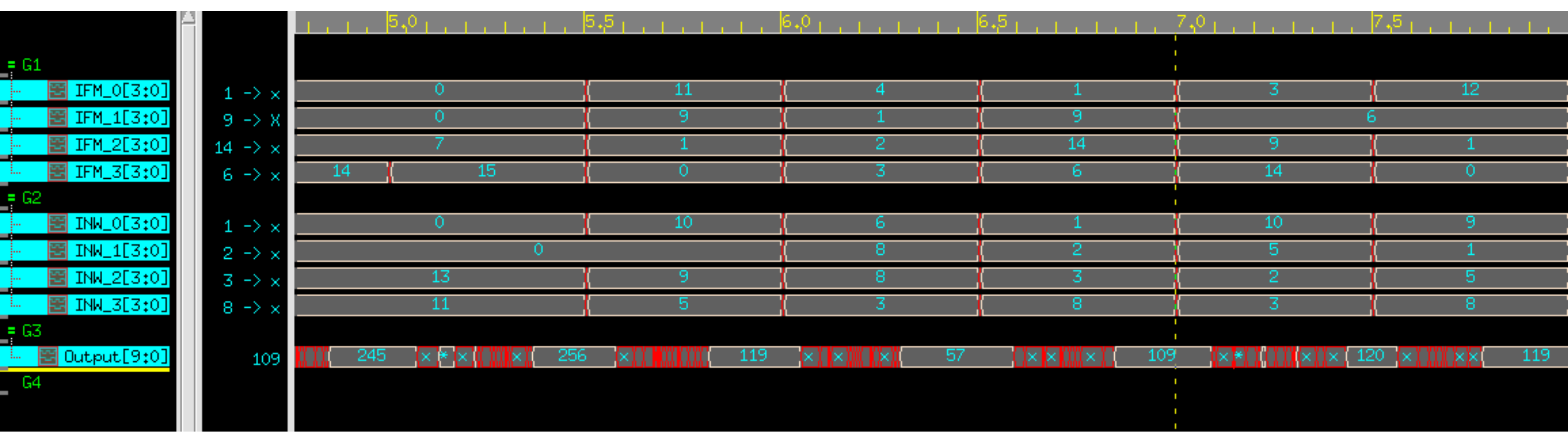
(4)Energy-Delay Product

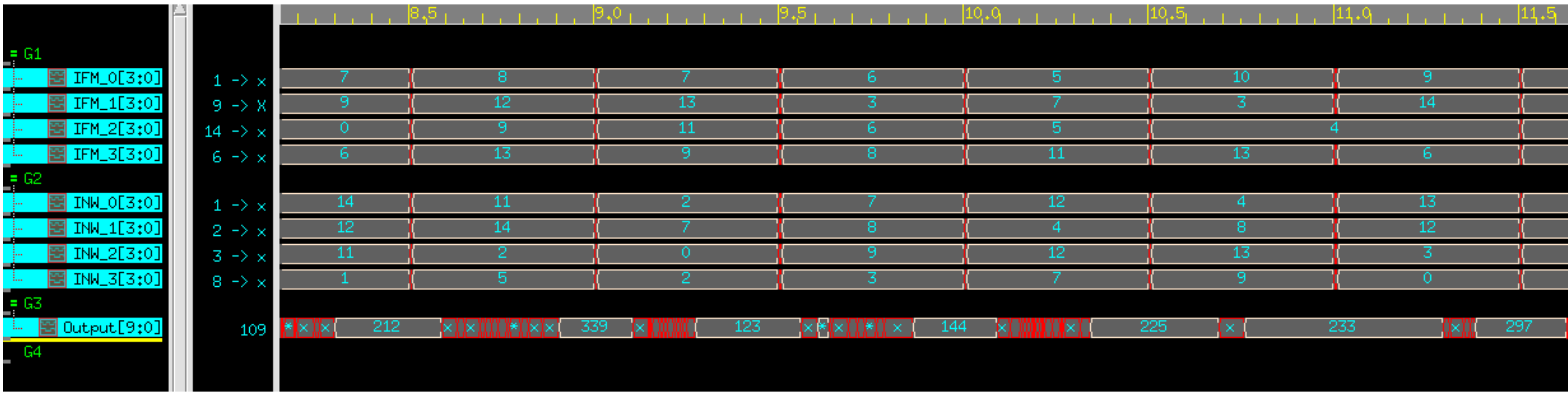


可以看出 Energy-Delay Product 和 VDD 大小成反比。

Provide the waveform with the correct function in your report (import .tr0 to nWave)







由以上的圖中可以看出 2x2 convolution 的功能都有正常計算和運作。