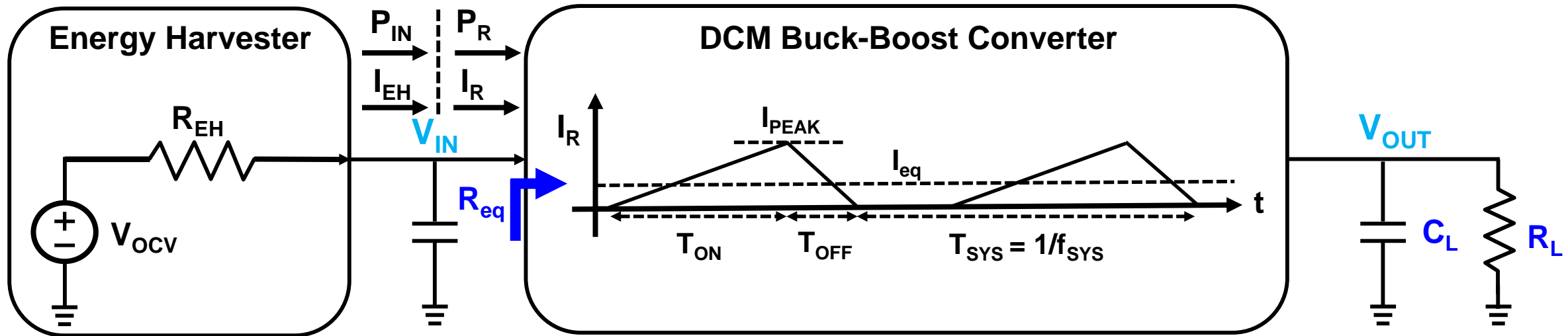


# **PBL - Implementation of MPPT**

# Concept

- From PBL part 1 conclusion:  
To achieve MPPT, the buck-boost converter should be well controlled to obtain the impedance matching :  $R_{EH} = R_{eq}$
- $$R_{eq} = V_{IN} / \left( \frac{0.5 * I_{PEAK} * T_{ON}}{T_{SYS}} \right)$$

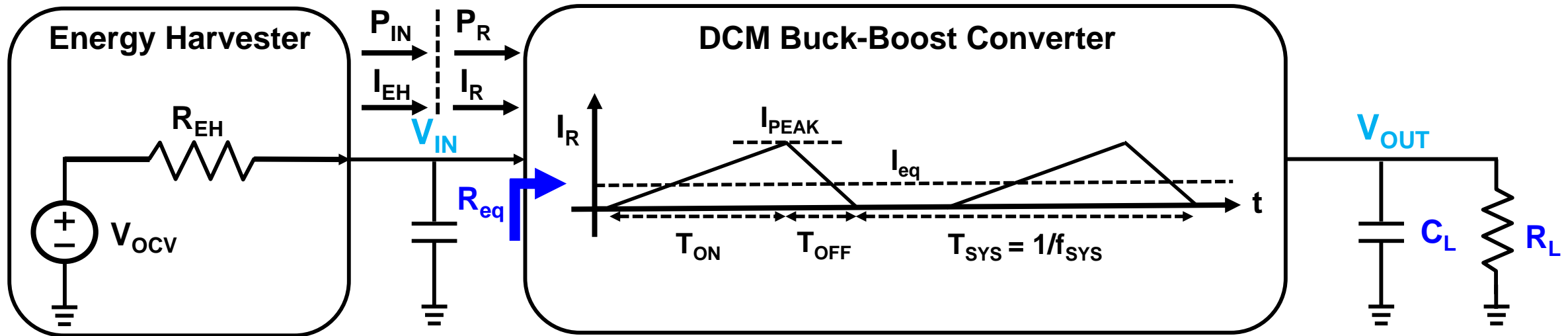


# Question



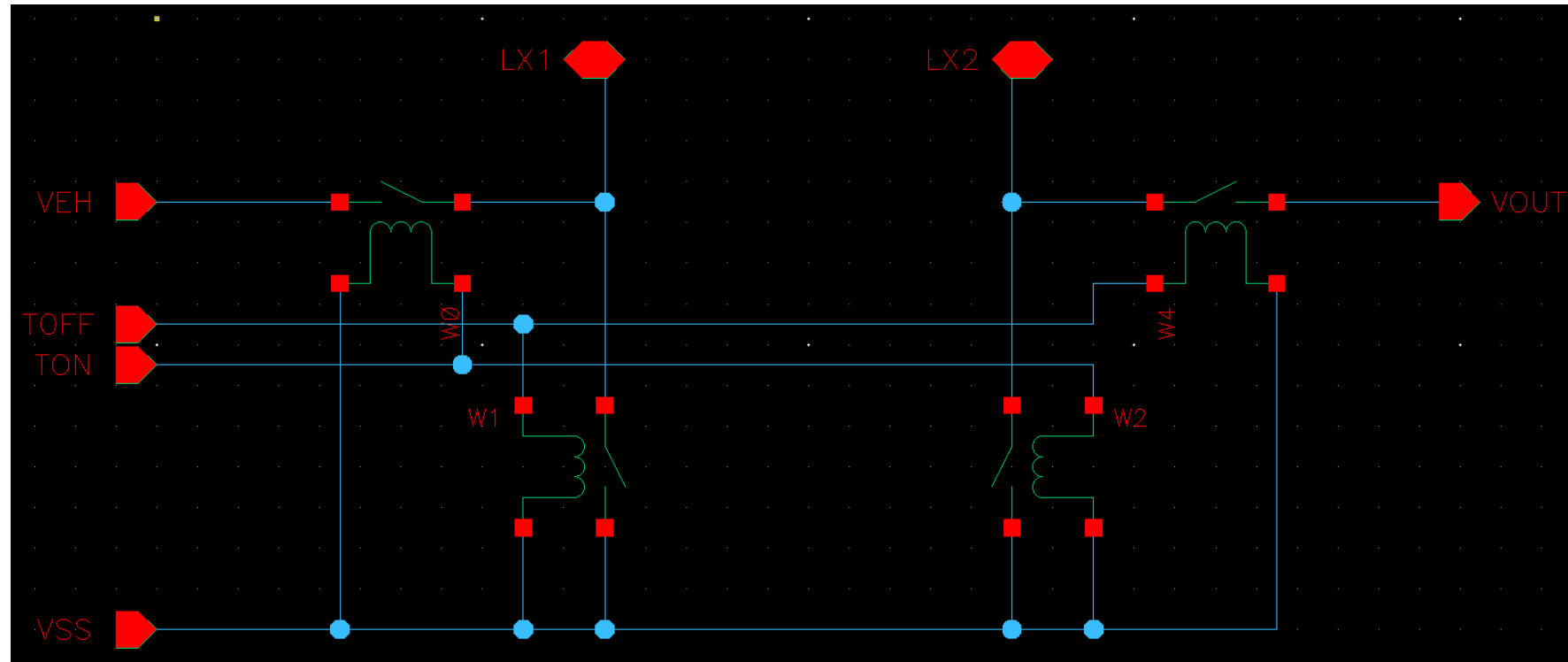
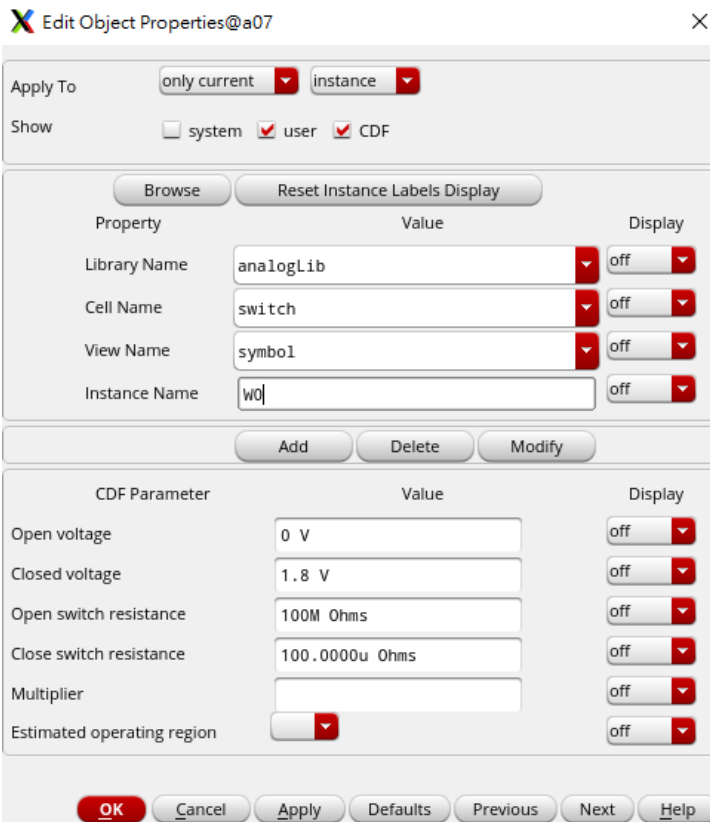
## Part1:

用理想開關實現 buck-boost converter，並觀察其不同 $R_{eq}$ 下的 $V_{IN}$ ，並記錄該 $V_{IN}$ 可提供給輸出的功率，對照所學。



# Schematic of Buck-Boost Converter

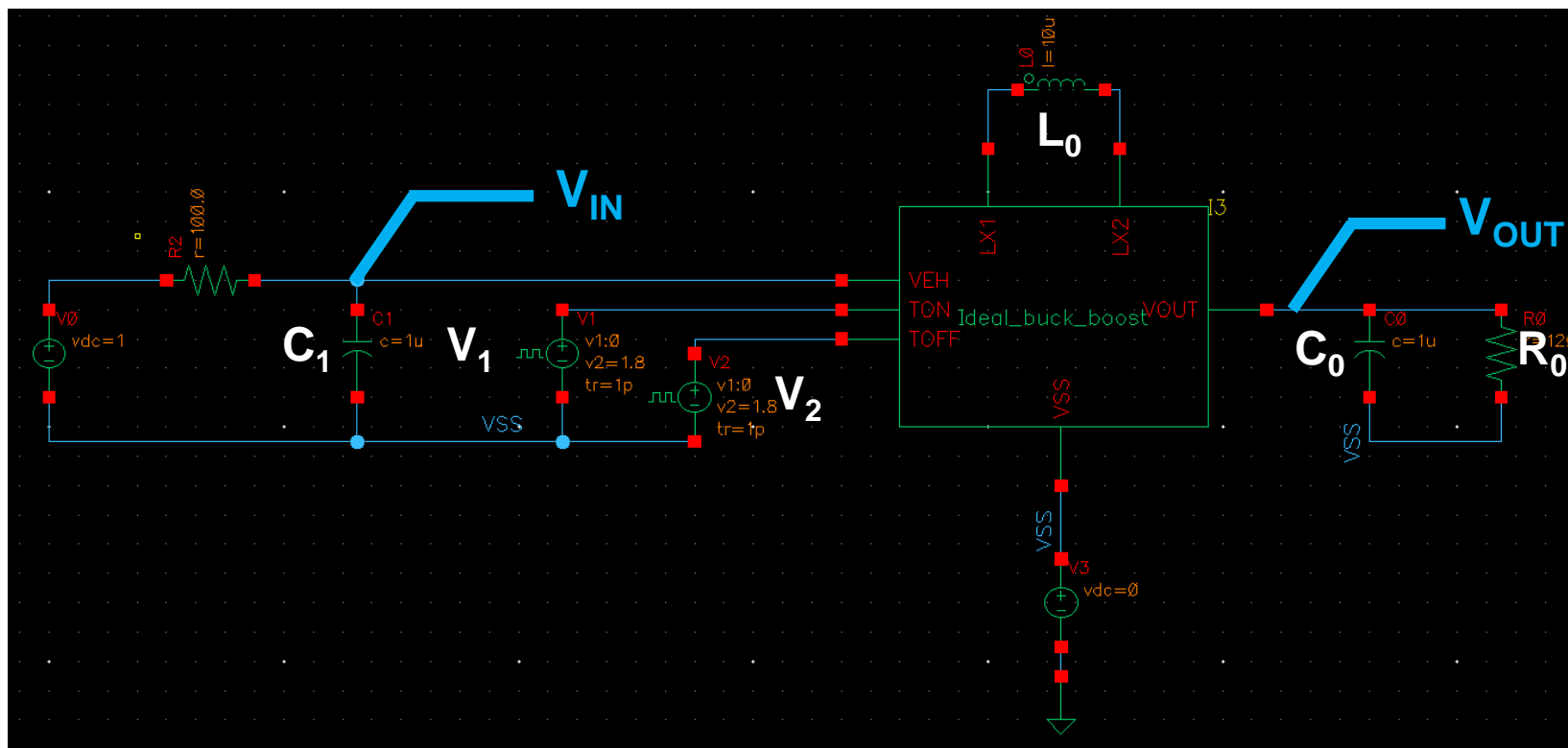
## Step 1: 建一個ideal buck-boost的schematic



# Circuit Simulation

## ■ Step 2:

建立testbench，使用1V串聯100ohm電阻作為energy harvester， $C_1$ 為輸入電容、 $V_1$ 為 $T_{ON}$ 訊號、 $V_2$ 為 $T_{OFF}$ 訊號、 $C_0$ 為輸出電容、 $R_0$ 為輸出負載



# Circuit Simulation

## Step 2各元件參數

$C_1$

$V_1$

$V_2$

$C_0$

$R_0$

$L_0$

Property

Value

Display

Library Name

analogLib

off

Cell Name

cap

off

View Name

symbol

off

Instance Name

C1

off

Add

Delete

Modify

CDF Parameter

Value

Display

Model name

off

Capacitance

1u F

off

Width

off

Length

off

Multiplier

off

Scale factor

off

OK

Cancel

Apply

Defaults

Previous

Next

Help

Property

Value

Display

Library Name

analogLib

off

Cell Name

vpulse

off

View Name

symbol

off

Instance Name

V1

off

Add

Delete

Modify

User Property

Master Value

Local Value

Display

Isignore

TRUE

off

CDF Parameter

Value

Display

Frequency name for 1/period

off

Noise file name

off

Number of noise/freq pairs

0

off

DC voltage

off

AC magnitude

off

AC phase

off

XF magnitude

off

PAC magnitude

off

PAC phase

off

Voltage 1

0 V

off

Voltage 2

1.8 V

off

Period

1/f s

off

Delay time

10u s

off

Rise time

1p s

off

Fall time

1p s

off

Pulse width

750.00n s

off

Temperature coefficient 1

off

Temperature coefficient 2

off

OK

Cancel

Apply

Defaults

Previous

Next

Help

Property

Value

Display

Library Name

analogLib

off

Cell Name

vpulse

off

View Name

symbol

off

Instance Name

V2

off

Add

Delete

Modify

User Property

Master Value

Local Value

Display

Isignore

TRUE

off

CDF Parameter

Value

Display

Frequency name for 1/period

off

Noise file name

off

Number of noise/freq pairs

0

off

DC voltage

off

AC magnitude

off

AC phase

off

XF magnitude

off

PAC magnitude

off

PAC phase

off

Voltage 1

0 V

off

Voltage 2

1.8 V

off

Period

1/f s

off

Delay time

10.750001u s

off

Rise time

1p s

off

Fall time

1p s

off

Pulse width

750.00n s

off

Temperature coefficient 1

off

Temperature coefficient 2

off

OK

Cancel

Apply

Defaults

Previous

Next

Help

Property

Value

Display

Library Name

analogLib

off

Cell Name

cap

off

View Name

symbol

off

Instance Name

C0

off

Add

Delete

Modify

CDF Parameter

Value

Display

Model name

off

Capacitance

1u F

off

Width

off

Length

off

Multiplier

off

Scale factor

off

Temp rise from ambient

off

Initial condition

off

Temperature coefficient 1

off

Temperature coefficient 2

off

Capacitor Area

off

Capacitor Perimeter

off

OK

Cancel

Apply

Defaults

Previous

Next

Help

Property

Value

Display

Library Name

analogLib

off

Cell Name

res

off

View Name

symbol

off

Instance Name

R0

off

Add

Delete

Modify

CDF Parameter

Value

Display

Model name

off

Resistance

120 Ohms

off

Length

off

Temp rise from ambient

off

Initial condition

off

Linear temp. coefficient

off

Quadratic temp. coeff.

off

Generate noise?

off

Scale factor

off

Number of Polynomial Coeffs

0

off

OK

Cancel

Apply

Defaults

Previous

Next

Help

Property

Value

Display

Library Name

analogLib

off

Cell Name

ind

off

View Name

symbol

off

Instance Name

L0

off

Add

Delete

Modify

CDF Parameter

Value

Display

Model name

off

Inductance

10u H

off

Resistance

0 Ohms

off

Multiplier

off

Temp rise from ambient

off

Initial condition

off

Linear temp. coefficient

off

Quadratic temp. coeff.

off

Generate noise?

off

Scale factor

off

Number of Polynomial Coeffs

0

off

OK

Cancel

Apply

Defaults

Previous

Next

Help

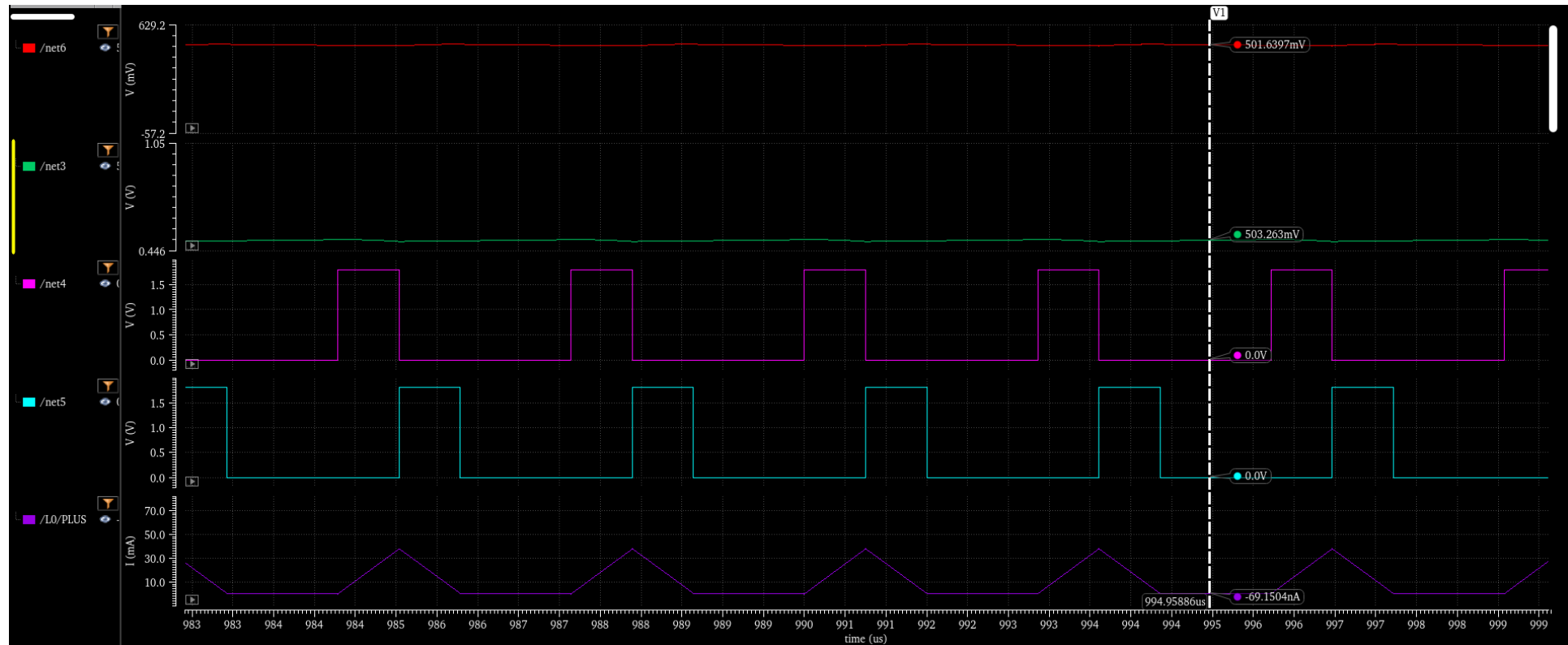
利用f改變 $R_{eq}$

利用R調整負載

# Circuit Simulation

## ■ Step 3 – Simulation:

1. 令  $f = 350\text{kHz}$ ,  $R_0 = 100\Omega$ , run transient analysis, 可以發現  $V_{\text{IN}}$  與  $V_{\text{OUT}}$  大致一樣, 約為  $0.5\text{V}$ , 此時 output power 為  $0.5 \times 0.5 / 100 = 2.5\text{mW}$



# Circuit Simulation

## ■ Step 3 – Simulation:

2. 將頻率增加(a)/減少(b)，並調整 $R_0$ 直到 $V_{IN}$ 與 $V_{OUT}$ 大致相同\*，將各參數填入下表，與頻率350kHz之數據做比較，何者的 $P_{OUT}$ 最大

| Frequency  | $R_0$        | $R_{eq}$ | $V_{IN}=V_{OUT}$ | $P_{OUT}$ |
|------------|--------------|----------|------------------|-----------|
| (a) 600kHz | $\Omega$     | $\Omega$ | V                | mW        |
| 350kHz     | 100 $\Omega$ | $\Omega$ | 0.5V             | mW        |
| (b) 100kHz | $\Omega$     | $\Omega$ | V                | mW        |

\*題目設定是 $\phi 1 (T_{ON}) = \phi 2 (T_{OFF})$ 。 $\phi 1$ 電感電流正比 $V_{IN}$ 、 $\phi 2$ 電感電流正比 $V_{OUT}$ ， $V_{IN}=V_{OUT}$ 才能open loop實現ZCD (若power是無法完全提供輸出，無法公平比較)

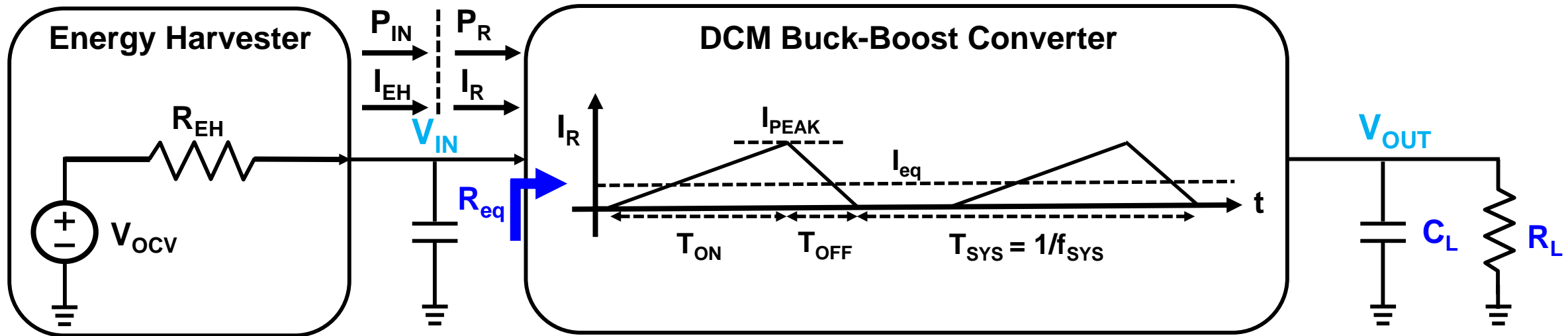


# Question



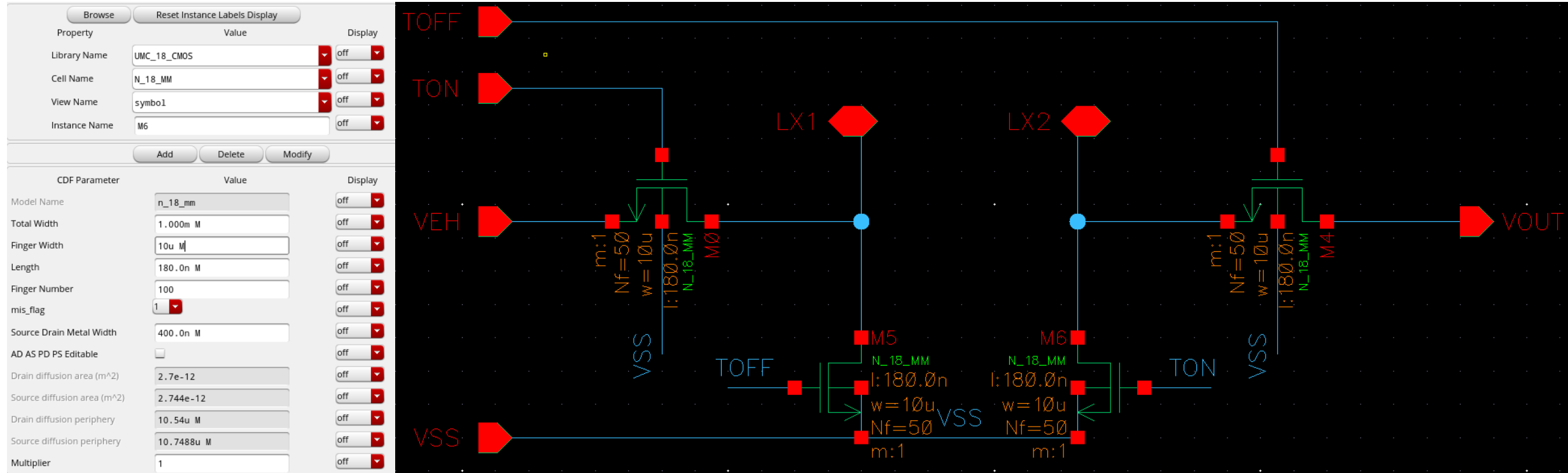
## Part 2:

以NMOS switch組成 buck-boost converter，並觀察其不同 $R_{eq}$ 下的 $V_{IN}$ ，並記錄該 $V_{IN}$ 可提供給輸出的power，對照Part 1



# Circuit Simulation

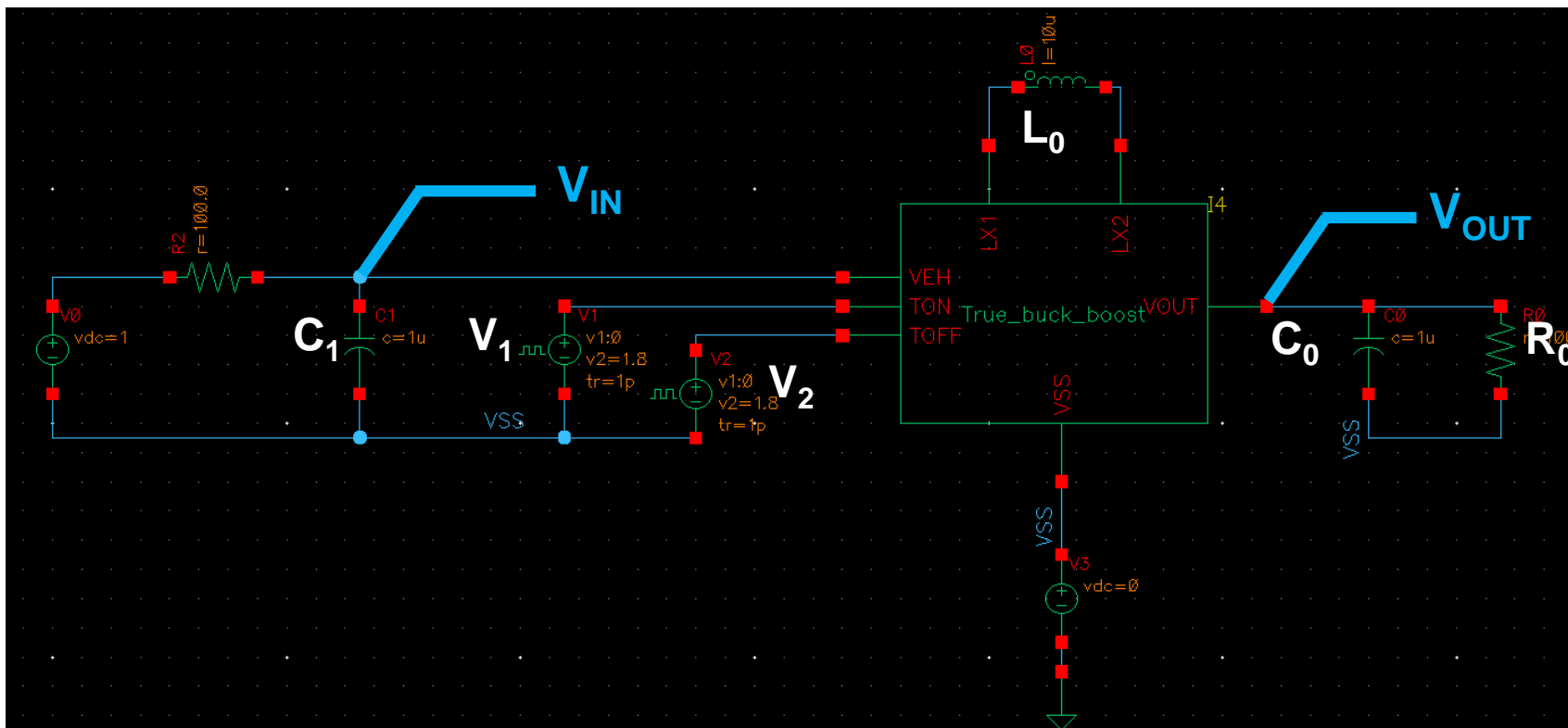
## Step 1: 建一個NMOS buck-boost的schematic



# Circuit Simulation

## ■ Step 2:

建立testbench，使用1V串聯100ohm電阻作為energy harvester， $C_1$ 為輸入電容、 $V_1$ 為 $T_{ON}$ 訊號、 $V_2$ 為 $T_{OFF}$ 訊號、 $C_0$ 為輸出電容、 $R_0$ 為輸出負載



# Circuit Simulation

## ■ Step 3:

以Part 1中350kHz case的設定跑模擬，(a)符不符合MPPT?(b)修改之使其正常傳輸能量且實現MPPT，並調整 $R_0$ 直到 $V_{IN}$ 與 $V_{OUT}$ 相近，將參數填入下表(c)請問輸出功率有何改變？

| $T_{ON}$ | $T_{ON}'$ | $T_{OFF}$ | $T_{OFF}'$ | $R_0$        | $R_0'$   | $P_{OUT}$ | $P_{OUT}'$ |
|----------|-----------|-----------|------------|--------------|----------|-----------|------------|
| 0.75us   | us        | 0.75us    | us         | 100 $\Omega$ | $\Omega$ | 2.5mW     | mW         |

# Circuit Simulation

## ■ Answer

- 電感電流非完全直線，因為實際上MOSFET會有 $R_{ON}$ ，因此 $T_{OFF}$ 會略小於 $T_{ON}$
- $V_{IN}$ 和 $V_{OUT}$ 跟原本ideal case不同:  $V_{IN}$ 變高表示 $R_{eq}$ 上升， $V_{OUT}$ 變低表示輸出的power下降
- 需先調整 $T_{ON}$ 讓 $V_{IN}$ 在MPP ( $T_{OFF}$ 先不改)
- 接著調整負載電阻讓 $V_{OUT} = V_{IN}$  (微調 $T_{OFF}$ 到零電流切換)
- 最後計算發現 $V_{IN} = V_{OUT}$ 時負載電阻為 $R_0'$ ，且 $R_0' > R_0$ ，表示提供給輸出的power減少

參考解答(Appendix Part 2)

Condition:  $V_{IN} = V_{OUT} = 0.5V$ ,  $f = 350kHz$



**Thanks for your attention!!**