



## 馬達模型模擬

機電系統原理與實驗

國立台灣大學

機械工程學系



# Target

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- ◆ 利用Simulink建立直流馬達數學模型
- ◆ 了解馬達模型
- ◆ 對直流馬達模型進行回授控制





# Outline

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- ❑ Open loop
- ❑ Closed loop

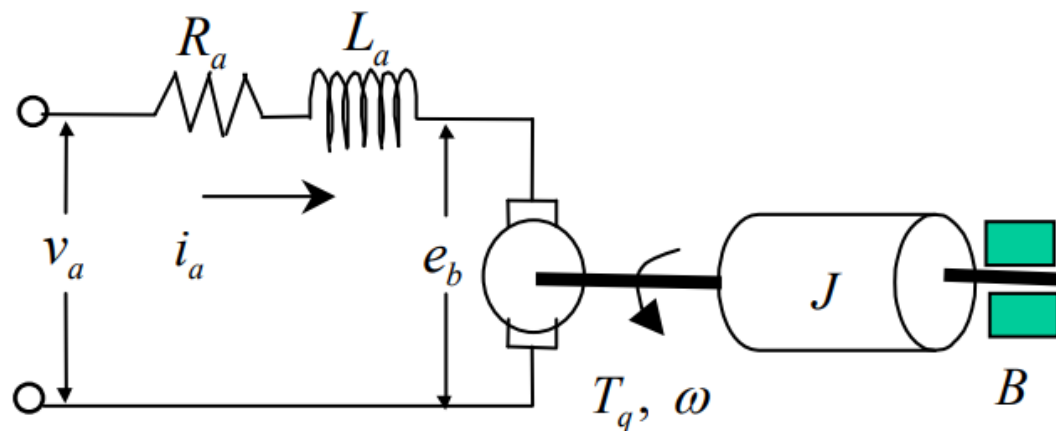




## 馬達模型模擬 Open loop

# 馬達模型係數

- $V_a$ : 電樞電壓
- $R_a$ : 電樞電阻
- $e_b$ : 反電動勢
- $J$ : 轉動慣量
- $\omega$ : 角速度
- $K_b$ : 反電動勢常數
- $i$ : 電樞電流
- $L_a$ : 電樞電感
- $B$ : 摩擦係數
- $T_q$ : 轉矩
- $K_t$ : 轉矩常數



直流馬達簡易模型

# 建立數學模型

## □ 由以下關係式建立數學模型

- ◆  $V_a(t) = R_a i_a(t) + L_a \frac{di_a(t)}{dt} + e_b(t)$
- ◆  $e_b(t) = K_b \omega(t)$
- ◆  $T_q(t) = K_t i_a(t)$
- ◆  $T_q(t) = J \frac{d\omega(t)}{dt} + B\omega(t)$

## □ 將上列各項取拉式轉換 整理合併

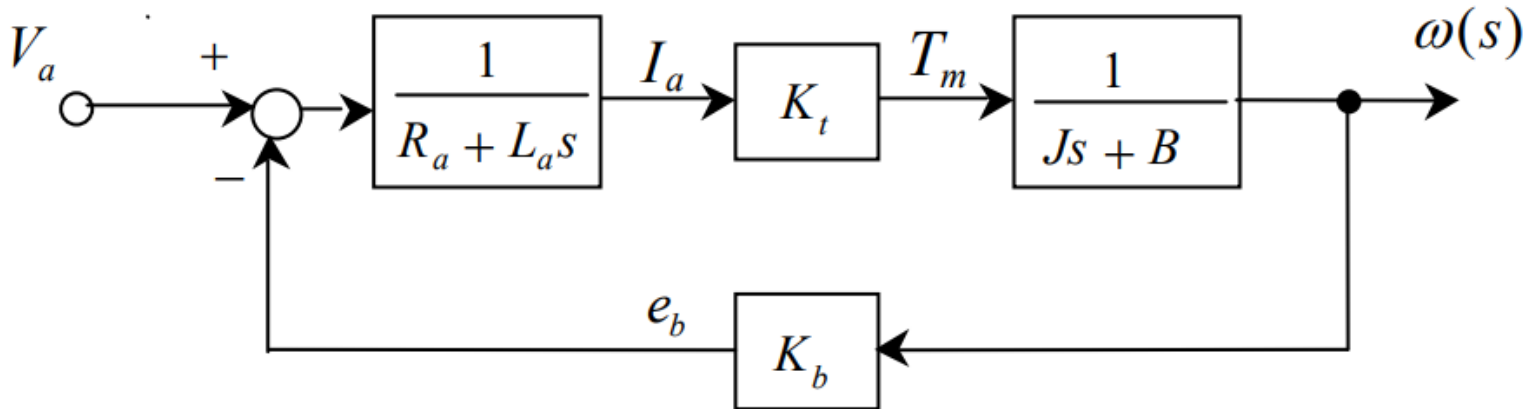
- ◆  $V_a(s) = (R_a + L_a s)I_a(s) + K_b \omega(s)$
- ◆  $T_q(s) = K_t I_a(s) = (Js + B)\omega(s)$
- ◆  $I_a(s) = \frac{Js+B}{K_t} \omega(s)$

# 建立數學模型

□ 整理後得到馬達轉移函數為

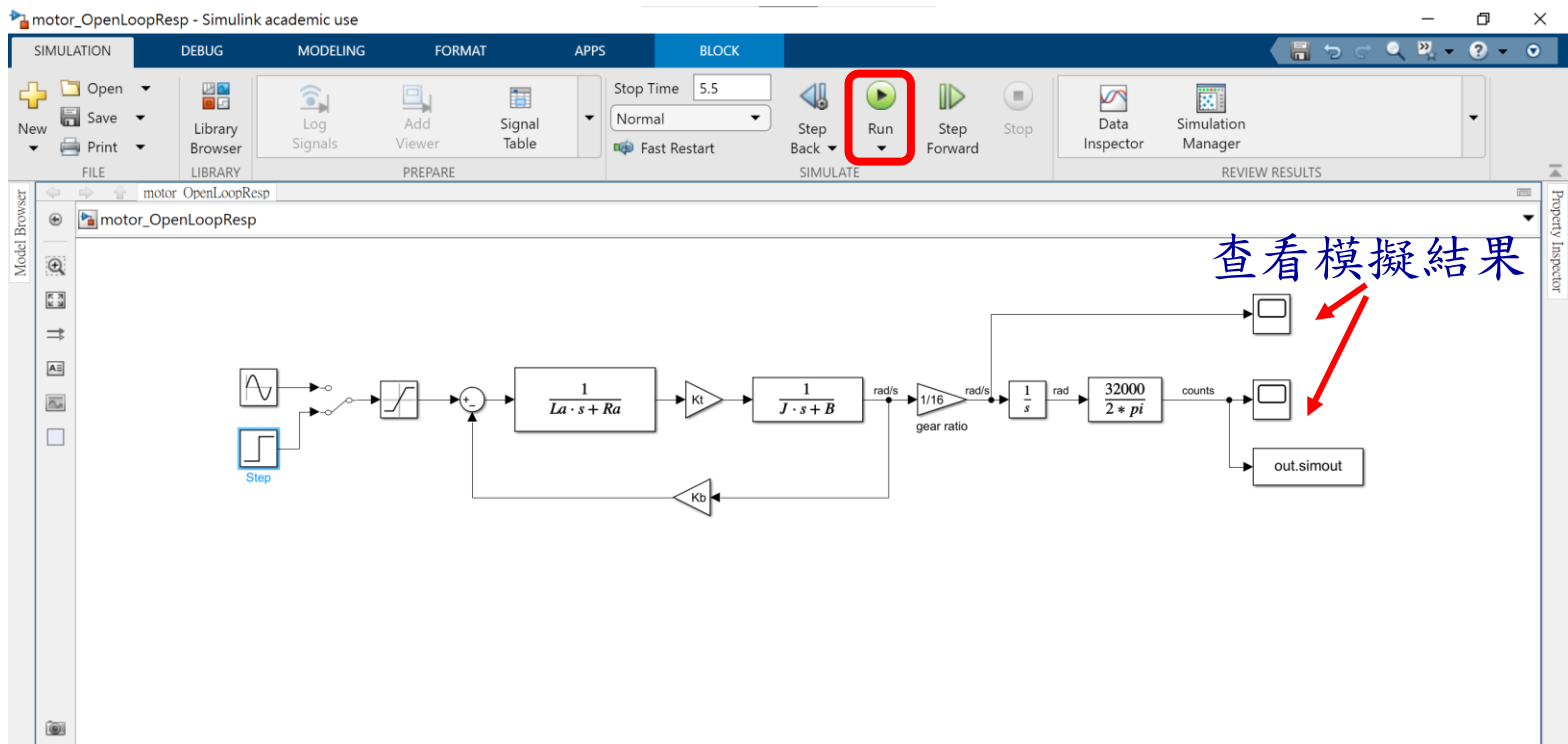
$$\square \frac{\omega(s)}{V_a(s)} = \frac{K_t}{(R_a + L_a s)(Js + B) + K_b K_t}$$

□ 製成方塊圖



# Simulink

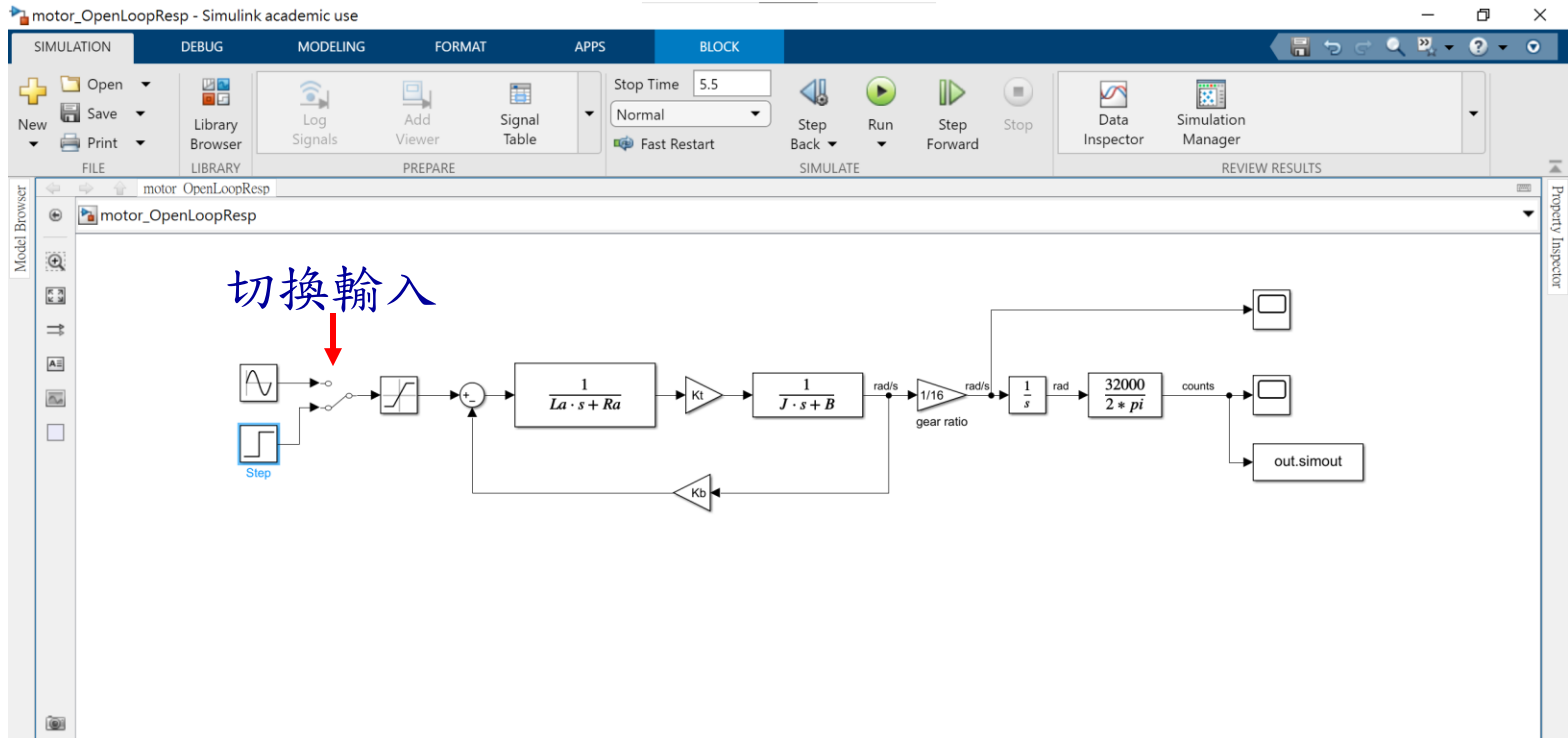
- ❑ 開啟 motor\_OpenLoopResp.slx
- ❑ Load 馬達參數 (parameters\_10.4volt.mat)
- ❑ 按下Run，從scope查看模擬結果





# Simulink

- 切换輸入
- 觀察不同輸入的響應



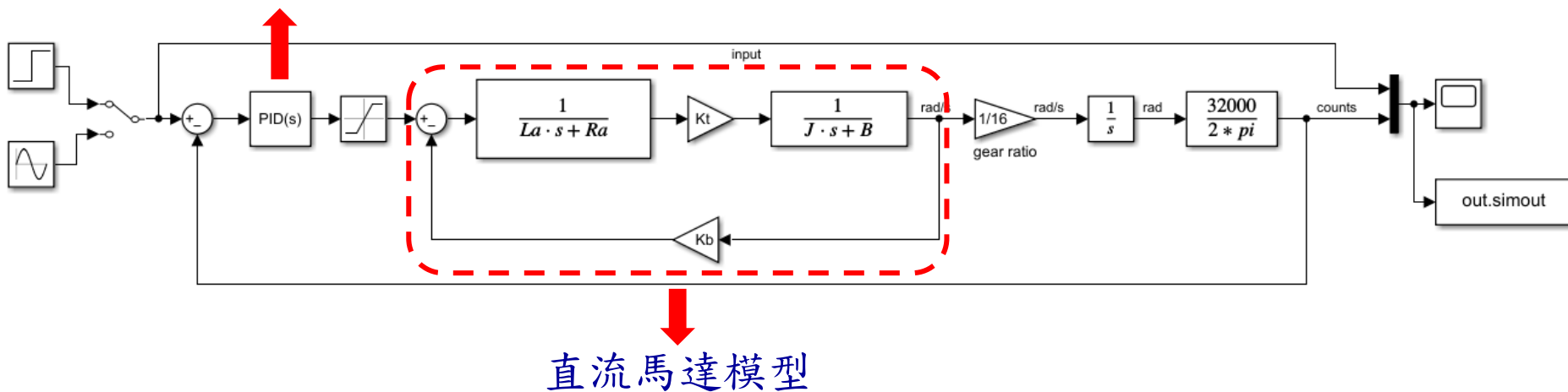


## 馬達模型模擬 Closed loop

# 建立模型

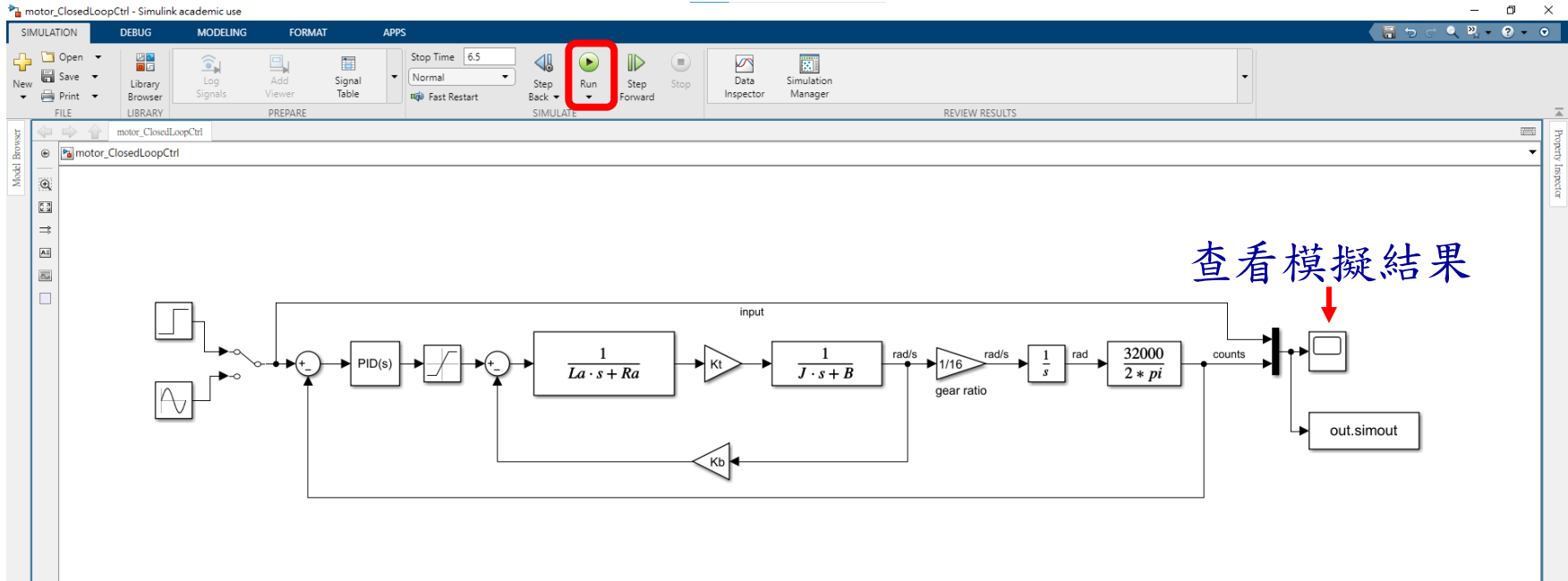
## 加入PID 進行回授控制

PID 控制器



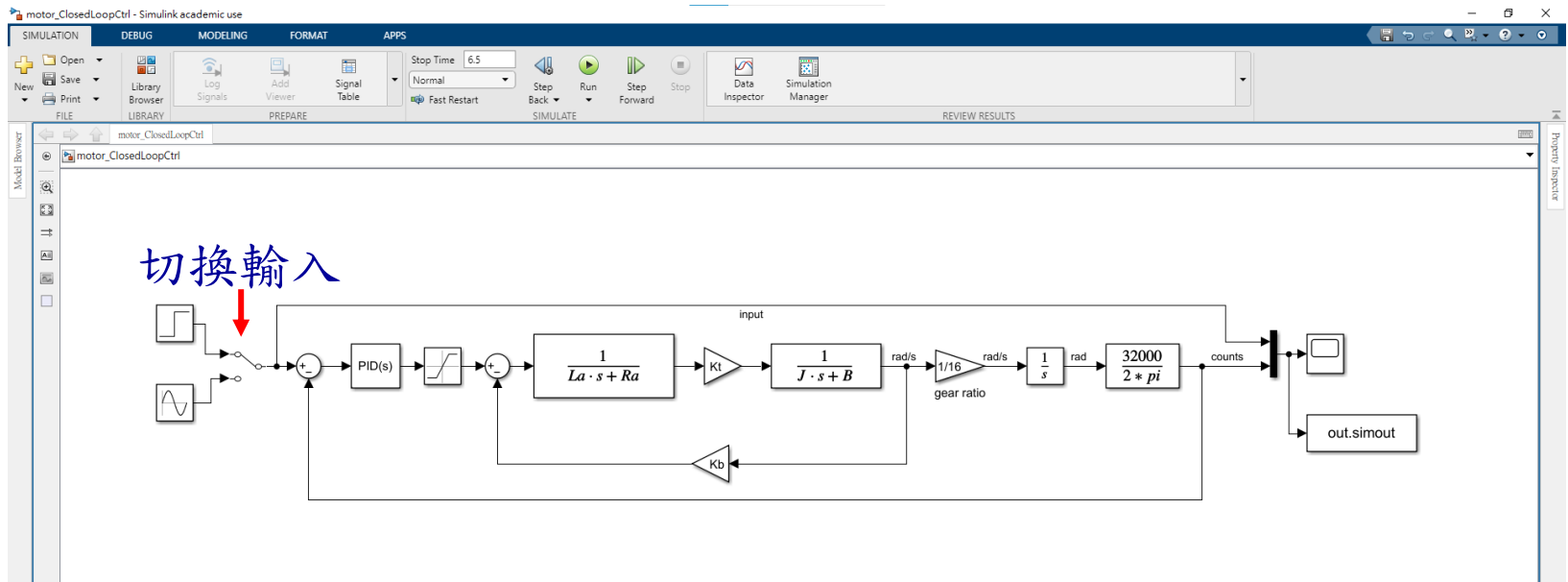
# Simulink

- ❑ 開啟 motor\_ClosedLoopCtrl.slx
- ❑ Load 馬達參數 (parameters\_10.4volt.mat)
- ❑ 按下Run，從scope查看模擬結果



# Simulink

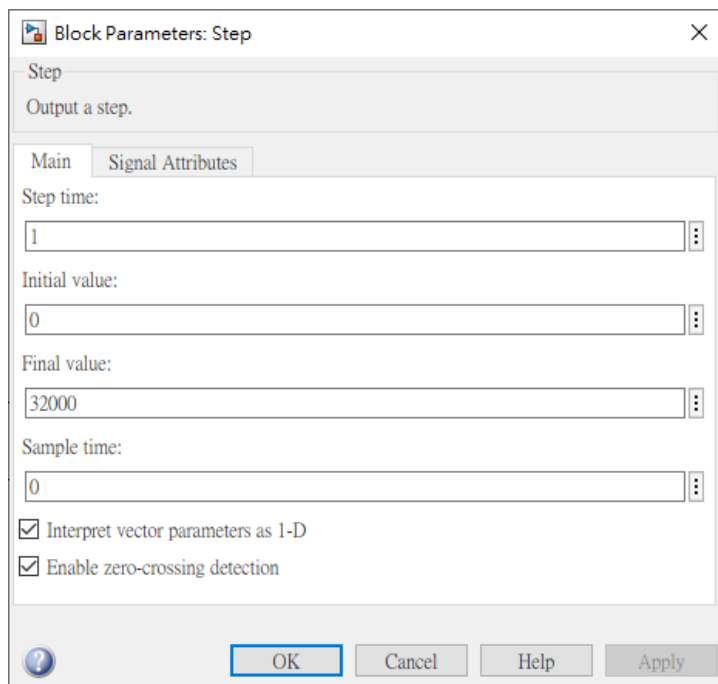
## 切换输入



# Simulink

## □ Step 和 Sine wave 輸入設定

### Step



Block Parameters: Step

Step

Output a step.

Main Signal Attributes

Step time:  
1

Initial value:  
0

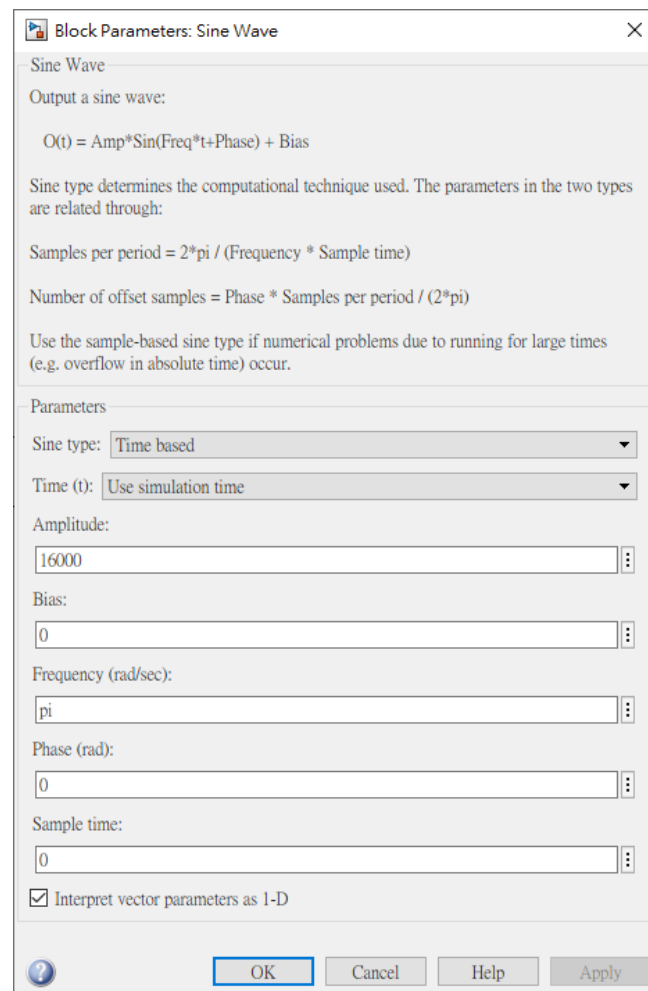
Final value:  
32000

Sample time:  
0

☒ Interpret vector parameters as 1-D  
☒ Enable zero-crossing detection

OK Cancel Help Apply

### Sine wave



Block Parameters: Sine Wave

Sine Wave

Output a sine wave:

$O(t) = \text{Amp} * \sin(\text{Freq} * t + \text{Phase}) + \text{Bias}$

Sine type determines the computational technique used. The parameters in the two types are related through:

Samples per period =  $2 * \pi / (\text{Frequency} * \text{Sample time})$

Number of offset samples =  $\text{Phase} * \text{Samples per period} / (2 * \pi)$

Use the sample-based sine type if numerical problems due to running for large times (e.g. overflow in absolute time) occur.

Parameters

Sine type: Time based

Time (t): Use simulation time

Amplitude:  
16000

Bias:  
0

Frequency (rad/sec):  
pi

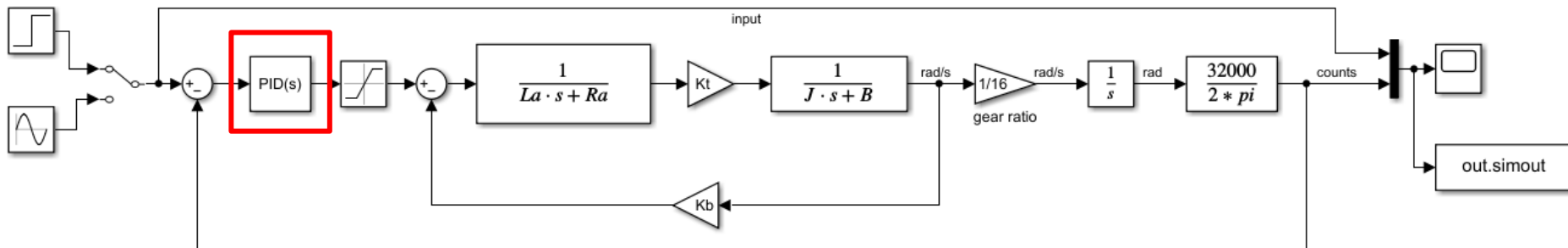
Phase (rad):  
0

Sample time:  
0

☒ Interpret vector parameters as 1-D

OK Cancel Help Apply

## □ 可以嘗試調整PID參數



Block Parameters: PID Controller

PID 1dof (mask) (link)

This block implements continuous- and discrete-time PID control algorithms and includes advanced features such as anti-windup, external reset, and signal tracking. You can tune the PID gains automatically using the 'Tune...' button (requires Simulink Control Design).

Controller: **PID** Form: **Parallel**

Time domain:

☒ Continuous-time

☐ Discrete-time

Discrete-time settings

Sample time (-1 for inherited): **-1**

Compensator formula

$$P + I \frac{1}{s} + D \frac{N}{1 + N \frac{1}{s}}$$

Main Initialization Output Saturation Data Types State Attributes

Controller parameters

Source: **internal**

Proportional (P): **0.0000001**

Integral (I): **0**

Derivative (D): **0**

☒ Use filtered derivative

Filter coefficient (N): **100**

Automated tuning

Select tuning method: **Transfer Function Based (PID Tuner App)** **Tune...**

☒ Enable zero-crossing detection

OK Cancel Help Apply

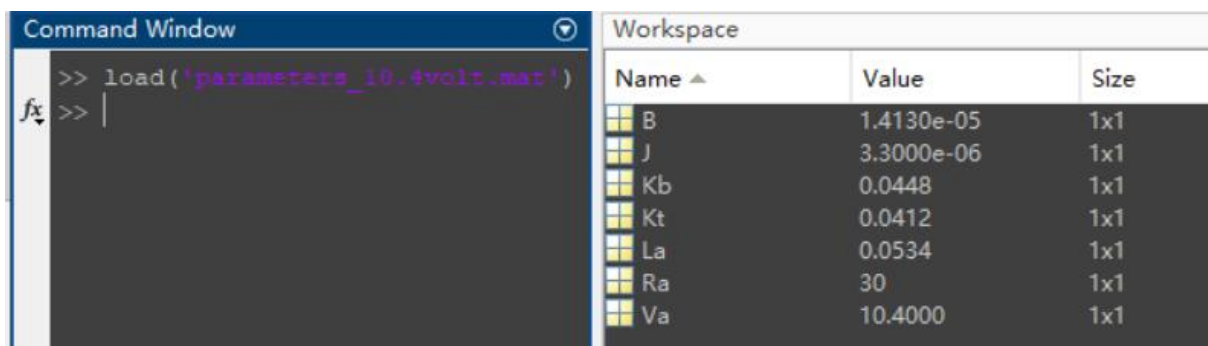


## 補充



## Notice

- 馬達參數是額外建立的
- 在使用simulink檔案前，請先在matlab的Comment Window輸入**`load('parameters_10.4volt.mat')`**，將馬達參數讀進Workspace中

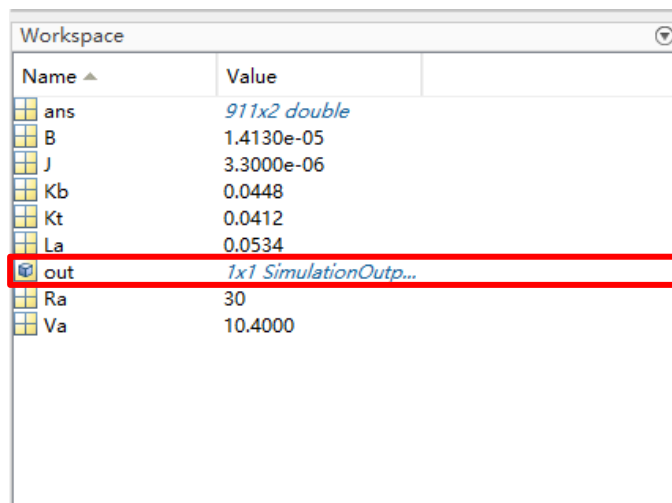


The screenshot shows the MATLAB Command Window and Workspace. The Command Window displays the command `load('parameters_10.4volt.mat')` being executed. The Workspace window shows a table of variables loaded from the file.

Name	Value	Size
B	1.4130e-05	1x1
J	3.3000e-06	1x1
Kb	0.0448	1x1
Kt	0.0412	1x1
La	0.0534	1x1
Ra	30	1x1
Va	10.4000	1x1

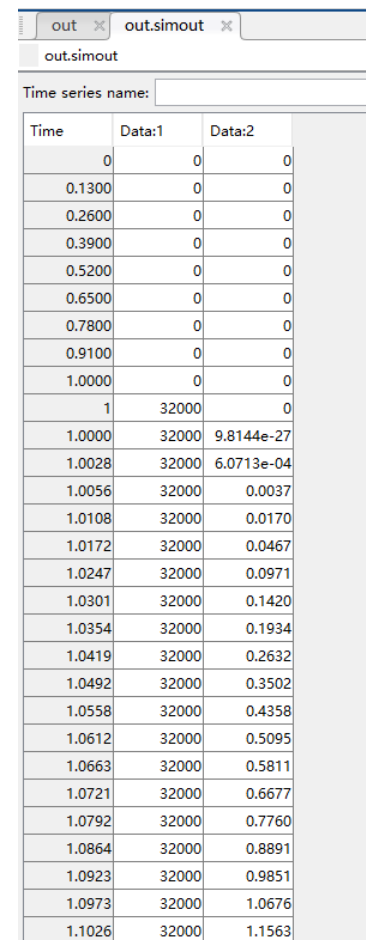
# 補充

- ❑ 馬達響應圖除了直接從scope查看，也可以從 matlab的 workspace中取得數據再自行繪圖
- ❑ 變數名稱為 out
- ❑ out.simout
  - ◆ Time: 時間
  - ◆ Data1: 輸入訊號
  - ◆ Data2: 輸出訊號



Workspace

Name ^	Value
ans	911x2 double
B	1.4130e-05
J	3.3000e-06
Kb	0.0448
Kt	0.0412
La	0.0534
out	1x1 SimulationOutp...
Ra	30
Va	10.4000



out x out.simout x

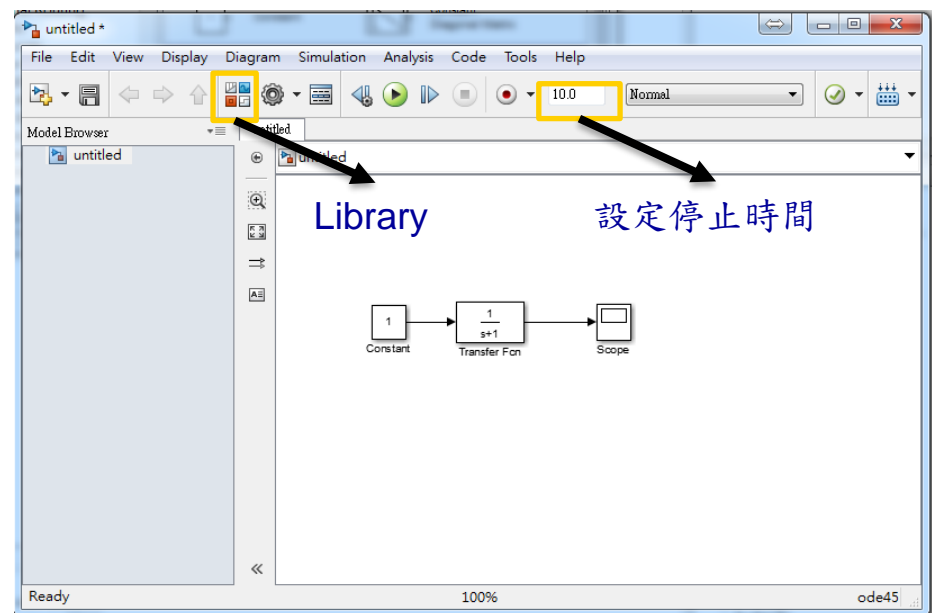
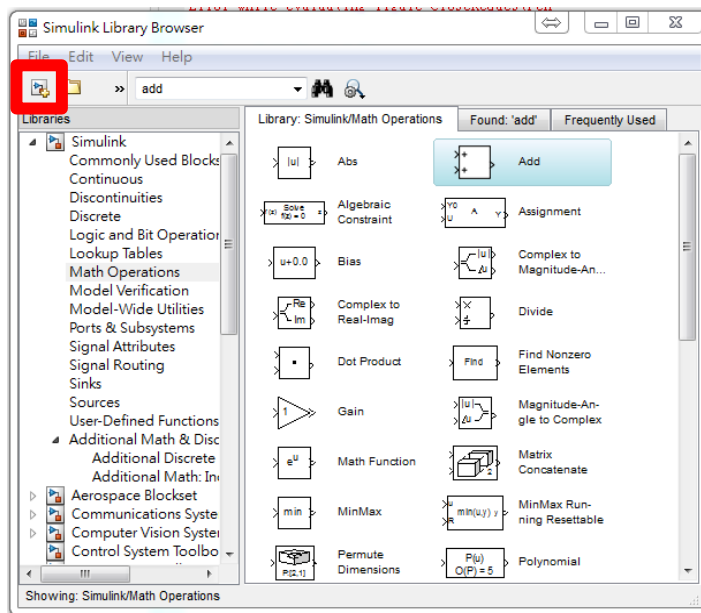
out.simout

Time series name:

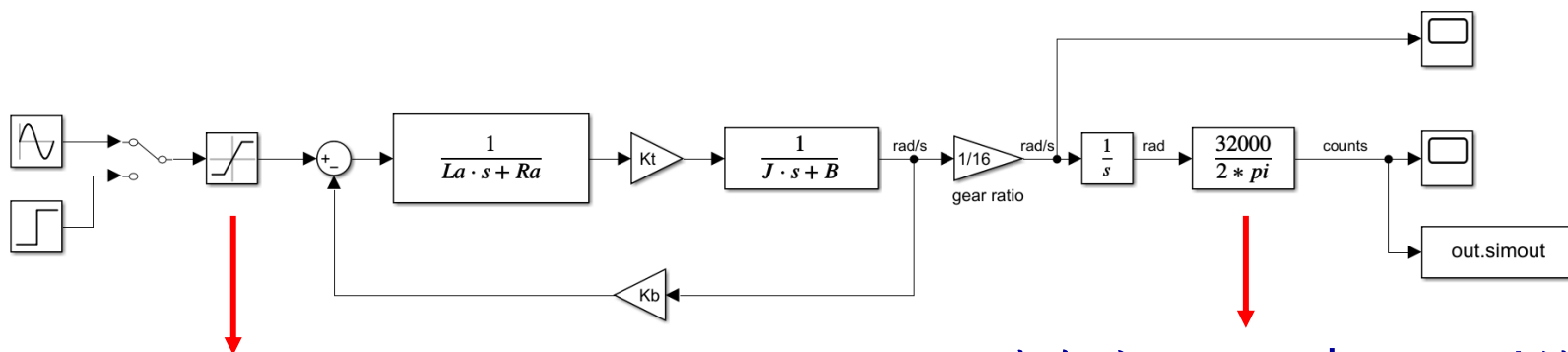
Time	Data:1	Data:2
0	0	0
0.1300	0	0
0.2600	0	0
0.3900	0	0
0.5200	0	0
0.6500	0	0
0.7800	0	0
0.9100	0	0
1.0000	0	0
1	32000	0
1.0000	32000	9.8144e-27
1.0028	32000	6.0713e-04
1.0056	32000	0.0037
1.0108	32000	0.0170
1.0172	32000	0.0467
1.0247	32000	0.0971
1.0301	32000	0.1420
1.0354	32000	0.1934
1.0419	32000	0.2632
1.0492	32000	0.3502
1.0558	32000	0.4358
1.0612	32000	0.5095
1.0663	32000	0.5811
1.0721	32000	0.6677
1.0792	32000	0.7760
1.0864	32000	0.8891
1.0923	32000	0.9851
1.0973	32000	1.0676
1.1026	32000	1.1563

## ❑ Simulink Library

- ◆ 利用 Search 找到自己要用的東西
- ◆ Transfer fun. / constant / add 已足夠建立一簡單系統



# 補充



Saturation :

考慮到實際上L298N輸出電壓  
上限，因此在輸出電壓設置  
saturation

馬達角度和encoder count轉換：  
encoder 轉一圈 32000 count