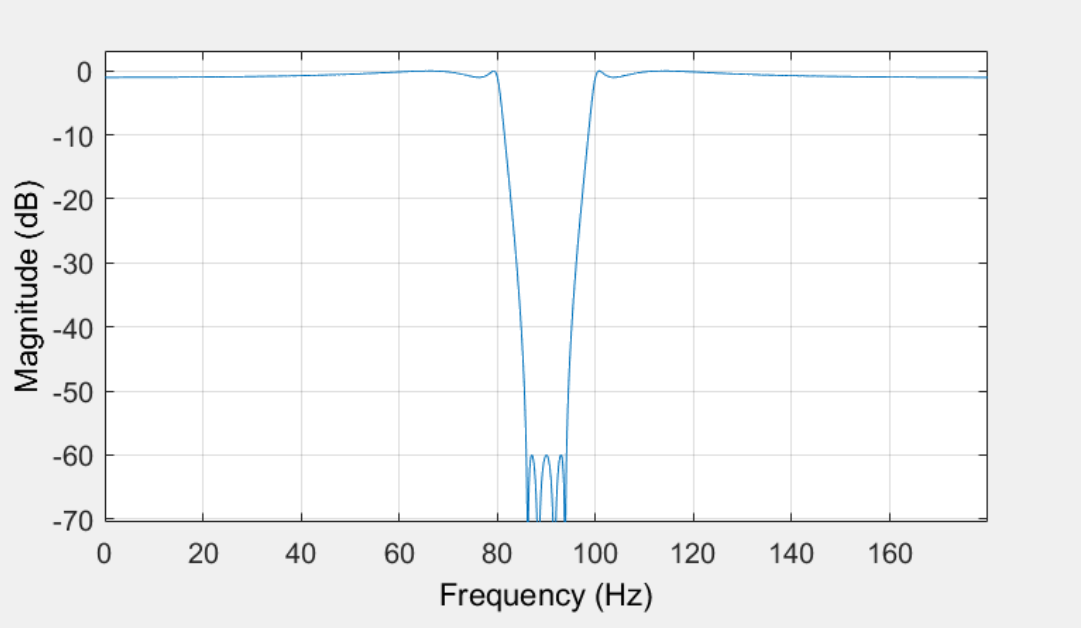
Filter Circle

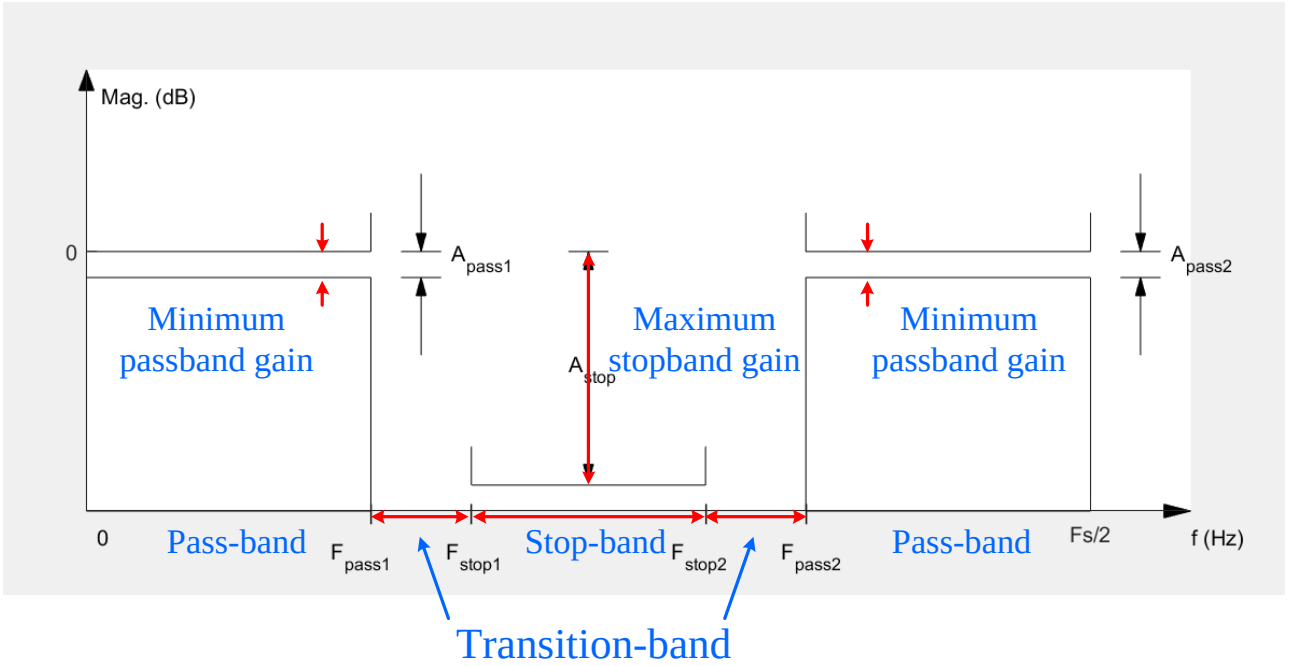
組員: 劉浩崴 B093011055
陳晉毅 B093011056

Band Stop Filter

- 濾除特定範圍的訊號
- 應用場合：主要雜訊出現在特定頻率



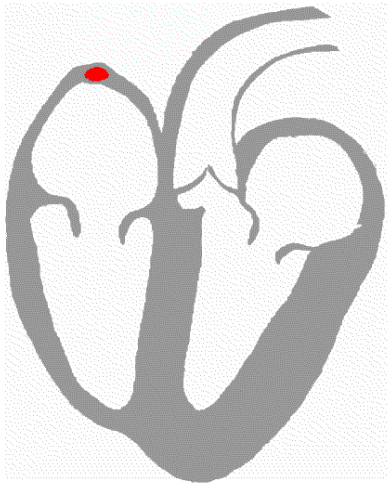
圖片來源：MATLAB Filter Designer



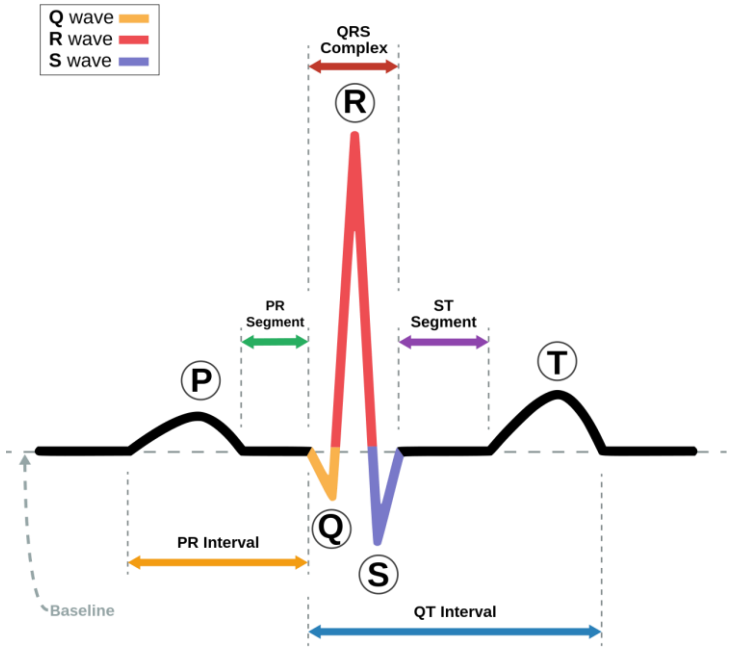
圖片來源：MATLAB Filter Designer

BS Filter應用-ECG 與 PLI

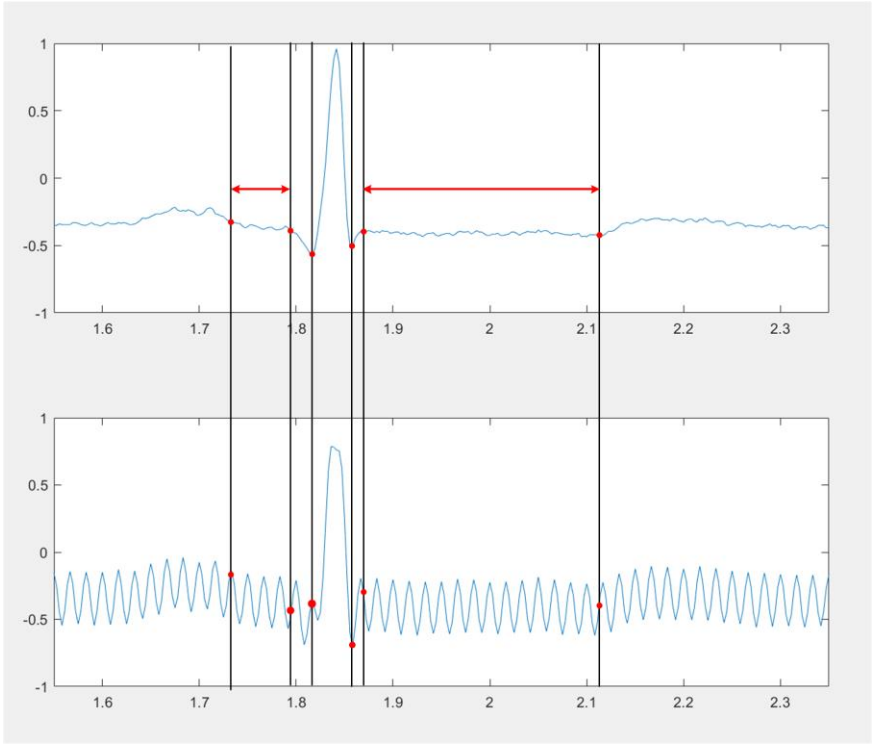
- 心電圖(Electrocardiography, ECG)訊號微弱，擷取訊號的傳輸線易受電源線的Power Line Interference (PLI)雜訊(60 Hz)汙染[1]
- 受雜訊污染的ECG訊號可能會影響醫師的判讀



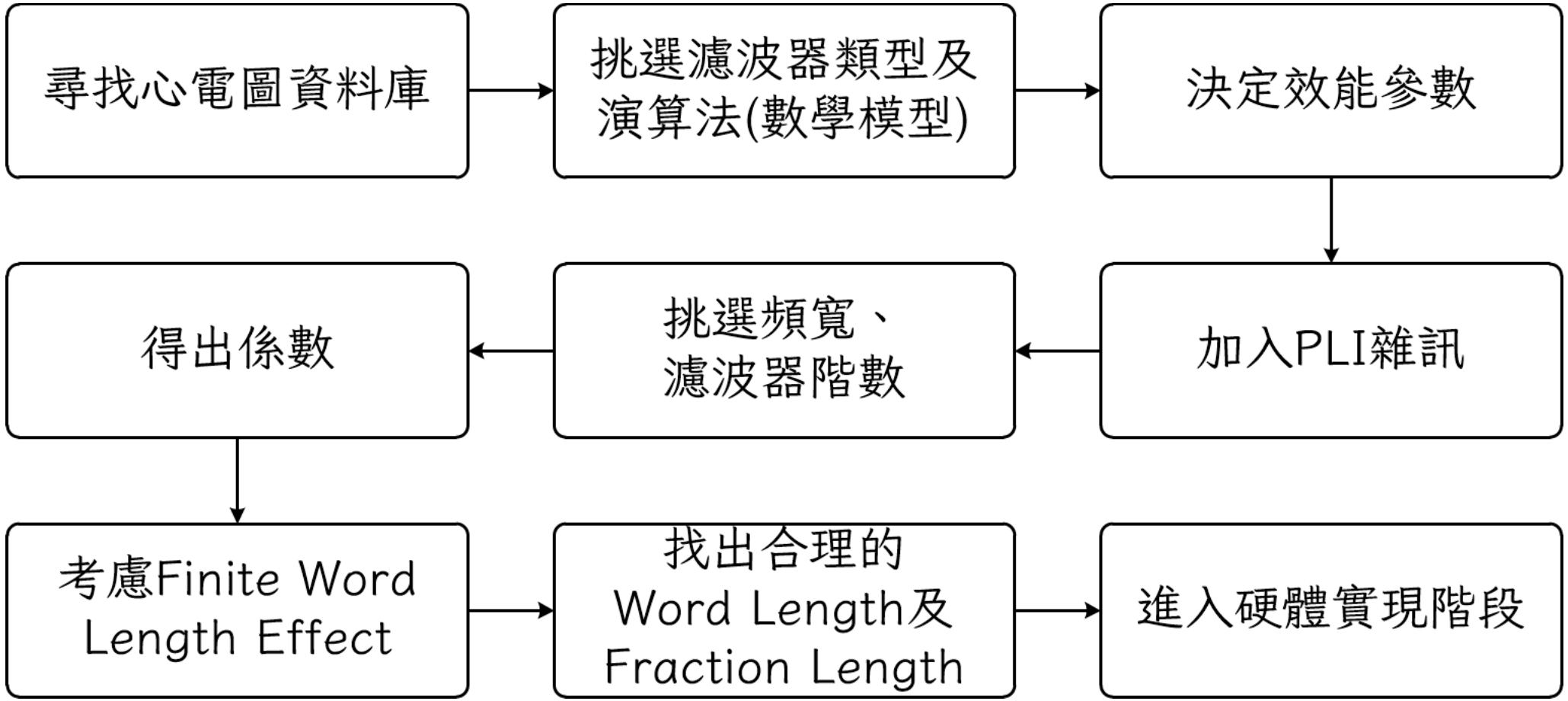
圖片來源：wiki-心電圖



圖片來源：wiki-心電圖

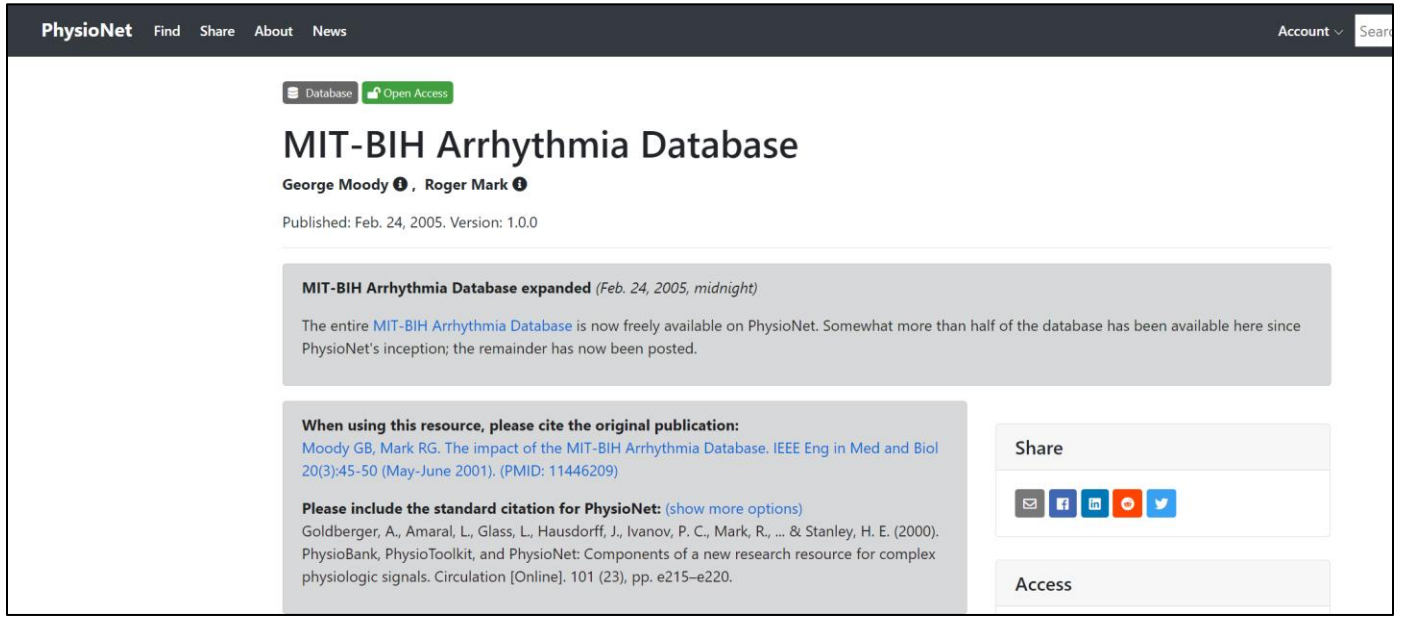


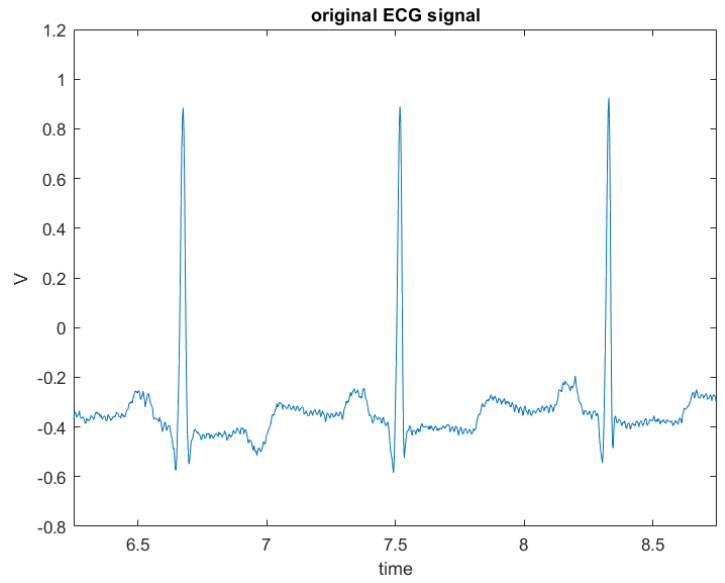
以ECG作為FC的設計範例



ECG資料來源及雜訊

- MIT-BIH資料庫 [2]
- ECG: 11bit ADC (0 V @ 1024); fs=360Hz；precision ± 5mV)
- PLI noise: 60±0.2 Hz sine wave

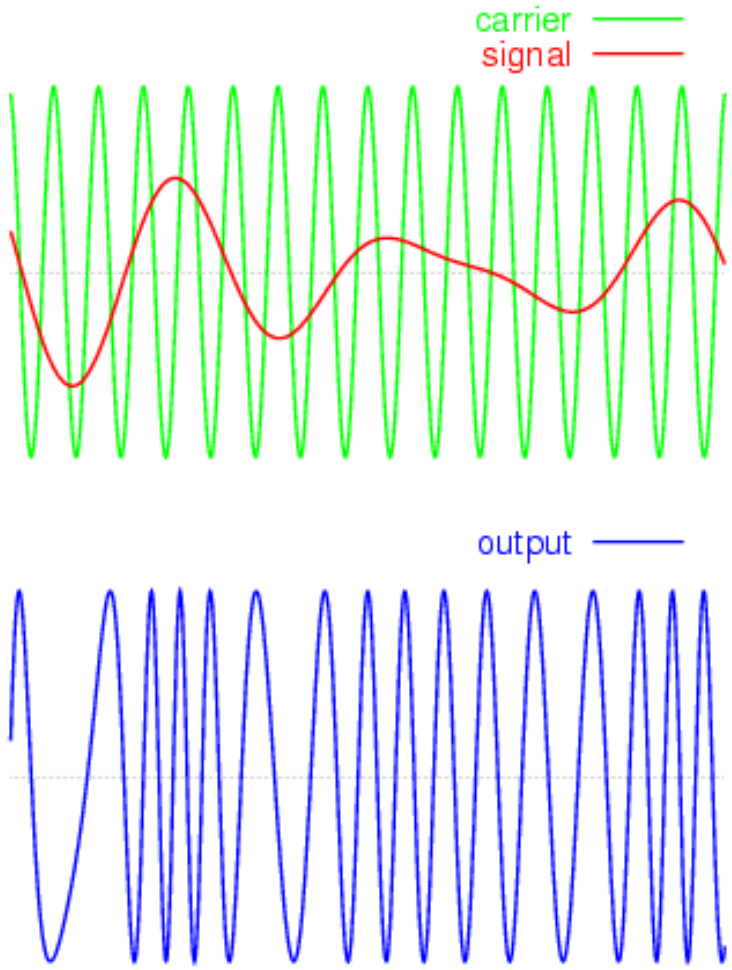




[2] G. B. Moody and R. G. Mark, "The impact of the MIT-BIH Arrhythmia Database," *IEEE Engineering in Medicine and Biology Magazine*, vol. 20, no. 3, pp. 45-50, May/June, 2001.

產生PLI雜訊

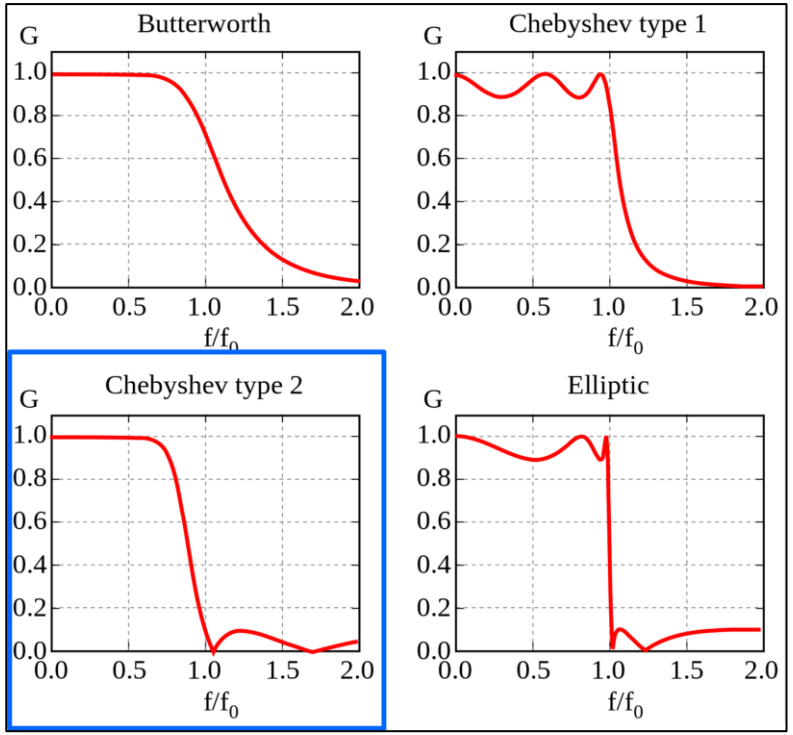
- F_{max} = 60.2 Hz
- F_{min} = 59.8 Hz
- 隨著時間會改變頻率的弦波
- 頻率調變



圖片來源：wiki -頻率調變

濾波器形式及架構

- FIR濾波器
  - 優：沒有回授、電路好實現
  - 缺：有phase delay 、階數要高才會有好的效能
- IIR濾波器
  - 優：較小的階數即有好的效能，因此計算時間(delay)小
  - 缺：有Group Delay、有回授
- IIR結果較好 [3]
- 考量後使用Chebyshev II [4]



圖片來源：wiki - Chebyshev filter

效能及成本指標

- 衡量訊號相似度：Mean Absolute Error (MAE)
- 衡量雜訊量：Signal-to-Noise Ratio (SNR)
- 衡量成本：Area

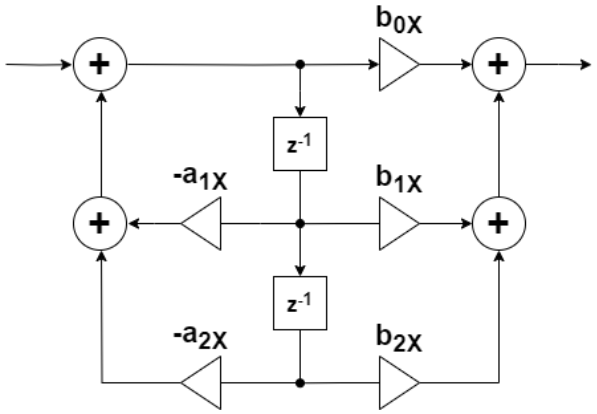
效能計算及Cost Function (1/2)

- $\mathrm{MAE} = \frac{\sum_{i=1}^{n} |output_i - input_i|}{n}$

- $SNR = \frac{\sum_i |\, singal\_out_i \,|^2}{\sum_i |\, noise\_out_i \,|^2}$

- $Area = Section \times (2 \times DFF + 4 \times Adder + 5 \times Multiplier)$

$$DFF = WL$$
$$Adder = 1.5 \times (2WL + 1)$$
$$\mathrm{M}ultiplier = (1.5 \times 2WL)^2$$

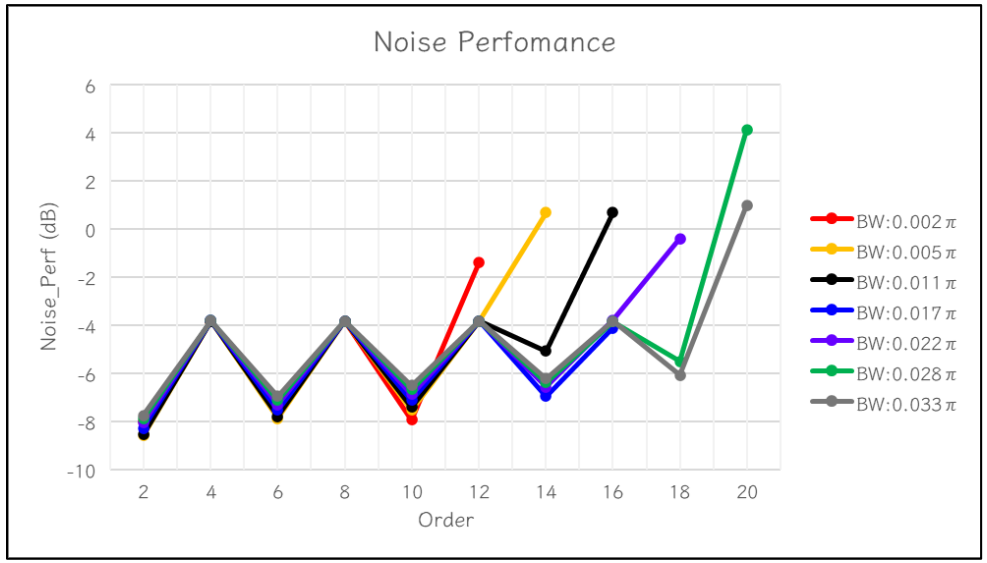


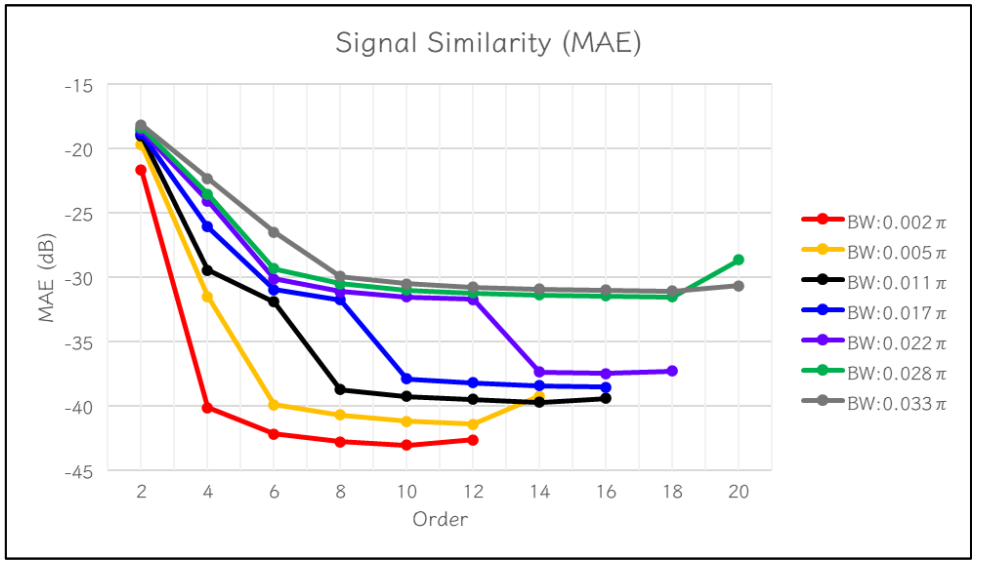
效能計算及Cost Function (2/2)

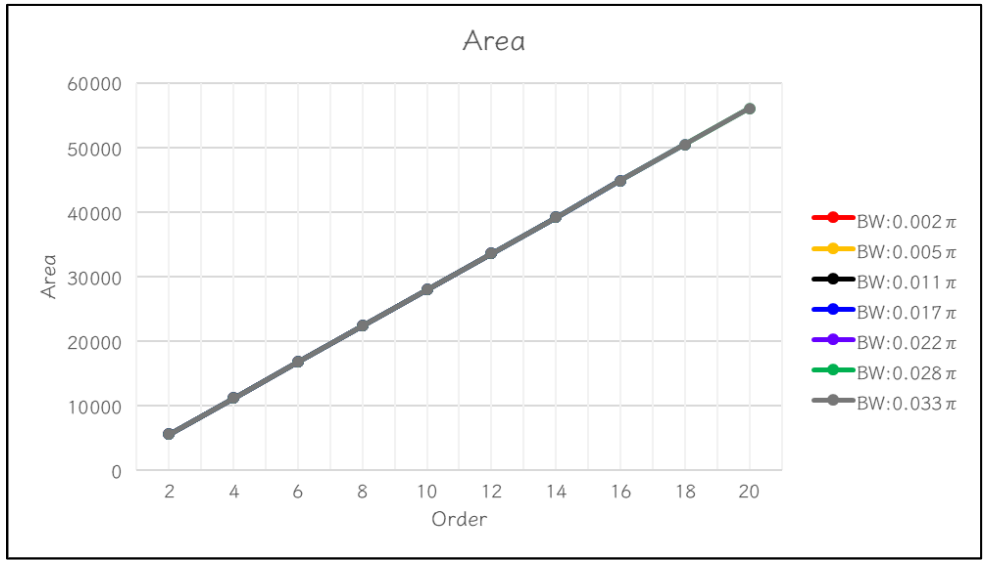
- $\mathrm{N}oise\_perf = f(x) = \begin{cases} e^{\frac{40}{SNR}}, & SNR < 40\ dB \\ \frac{40}{SNR}, & 40dB \leq SNR \leq 100dB \\ \frac{40}{100}, & SNR \geq 100\ dB \end{cases}$

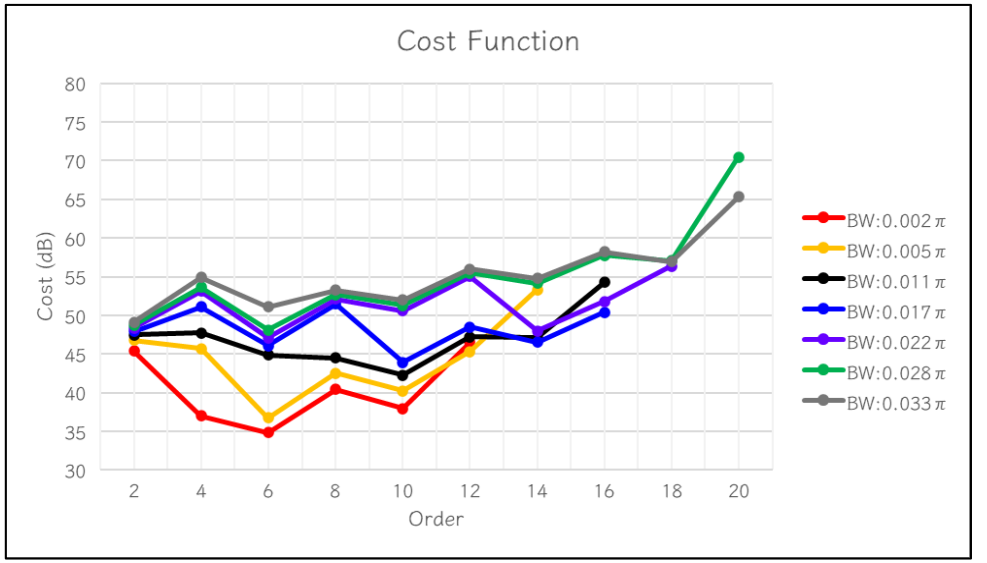
- $Cost = Area \times \mathrm{N}oise\_perf \times MAE^2$

MATLAB模擬結果-不同頻寬及Order





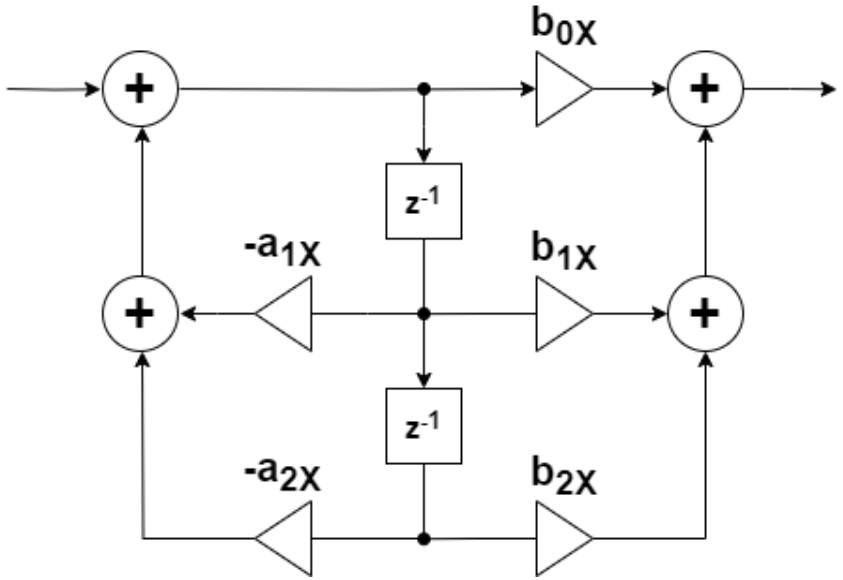




6 Order Filter 設計結果

- $\begin{bmatrix} b_{01} & b_{11} & b_{21} & a_{11} & a_{21} \\ b_{02} & b_{12} & b_{22} & a_{12} & a_{22} \\ b_{03} & b_{13} & b_{23} & a_{13} & a_{23} \end{bmatrix}$

$$= \begin{bmatrix} 0.989019 & -0.99419 & 0.989019 & -0.95589 & 0.978156 \\ 0.989019 & -0.98384 & 0.989019 & -1.02179 & 0.978629 \\ 0.978616 & -0.97862 & 0.978616 & -0.97862 & 0.957232 \end{bmatrix}$$



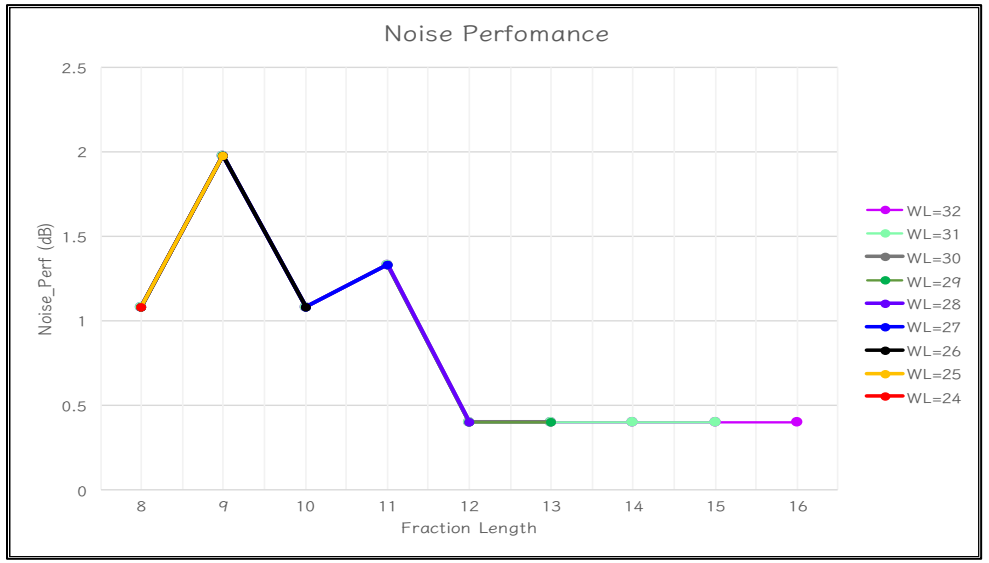
Word Length & Fraction Length

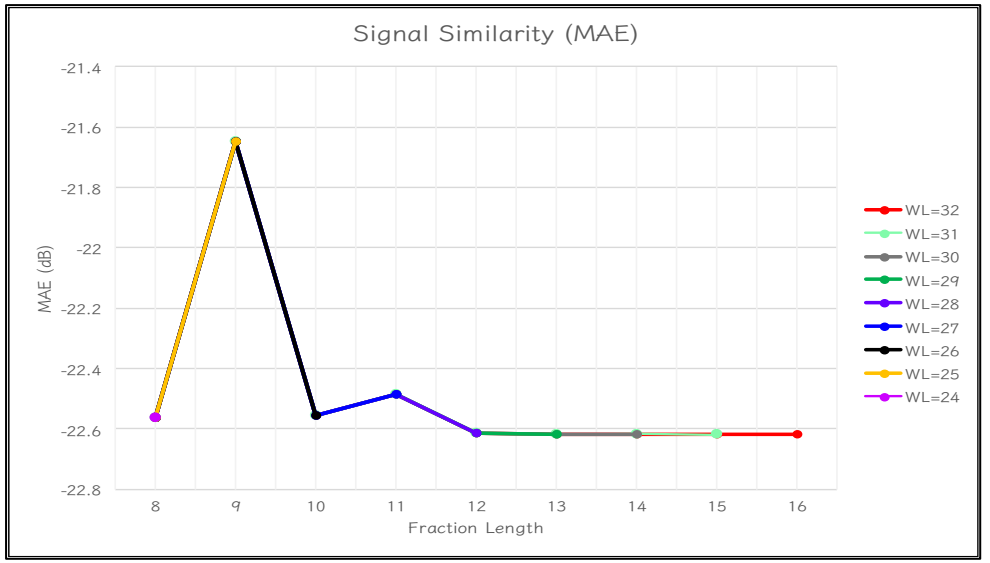
- 以DFF、係數為核心考慮Word Length
- 以worst case design間接決定運算單元的Word Length

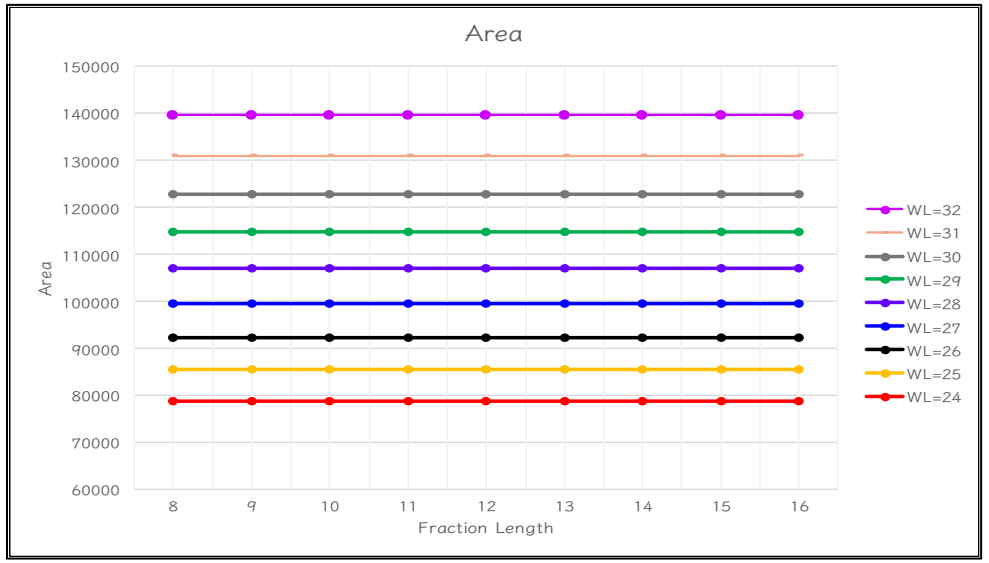
- Integer Length: 影響Dynamic Range。
  本次應用中，決定波形是否失真。

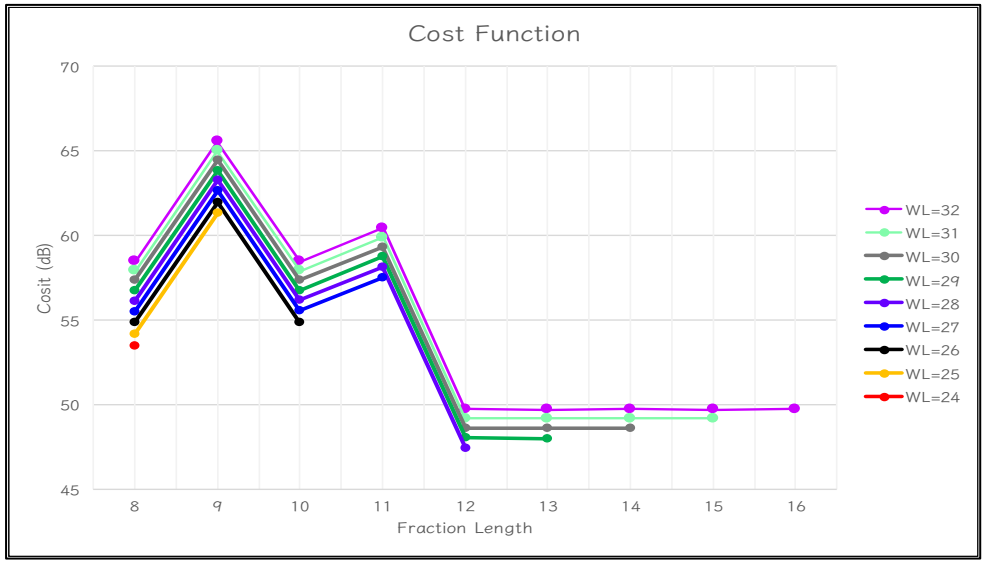
- Fraction Length: 影響精準度。
  本次應用中，影響輸出的MAE、Noise。

MATLAB模擬-WL (可處理ADC全電壓)

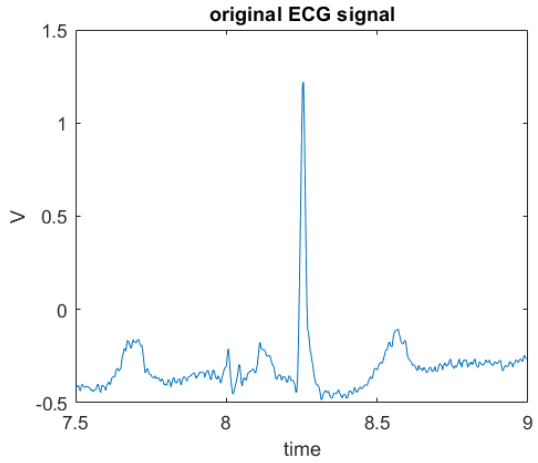


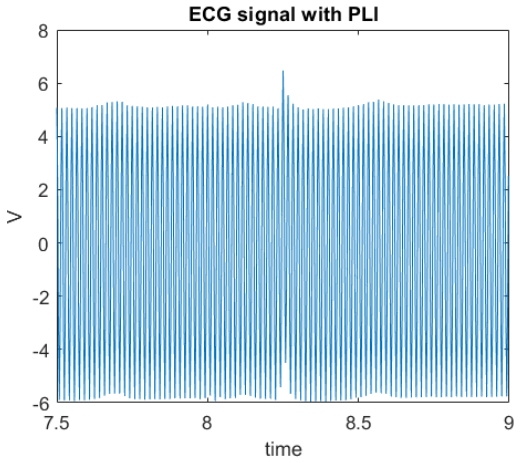


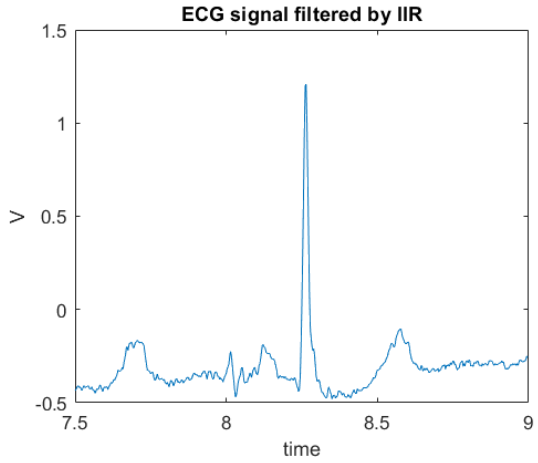


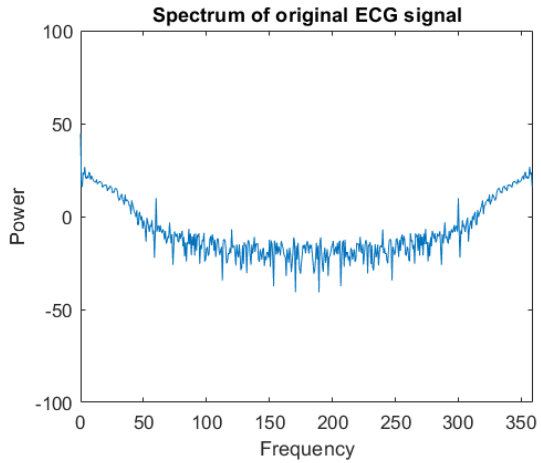


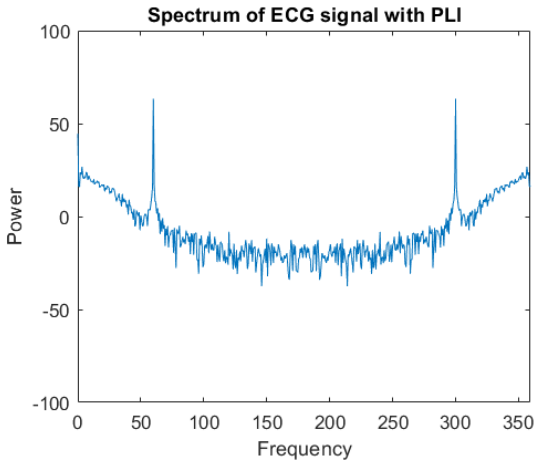
實際輸入ECG

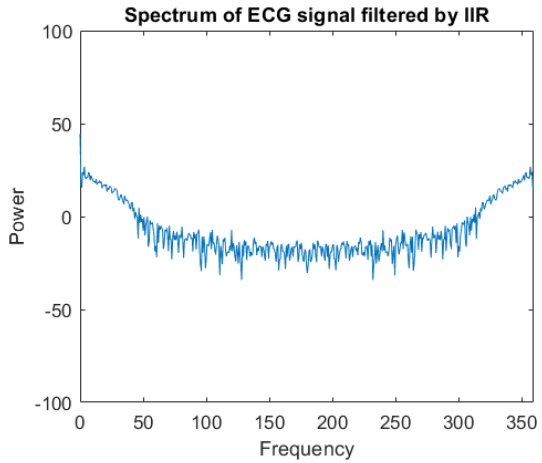

original ECG signal
V
time


ECG signal with PLI
V
time


ECG signal filtered by IIR
V
time

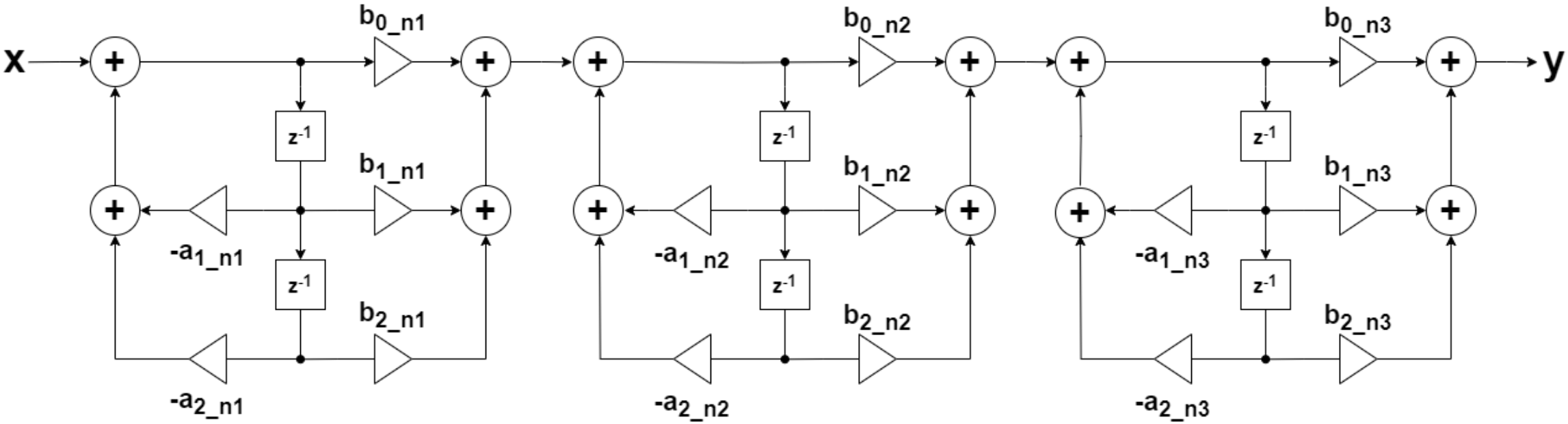

Spectrum of original ECG signal
Power
Frequency


Spectrum of ECG signal with PLI
Power
Frequency


Spectrum of ECG signal filtered by IIR
Power
Frequency

濾波器架構

-IIR Cascaded Second-Order Sections Direct Form II

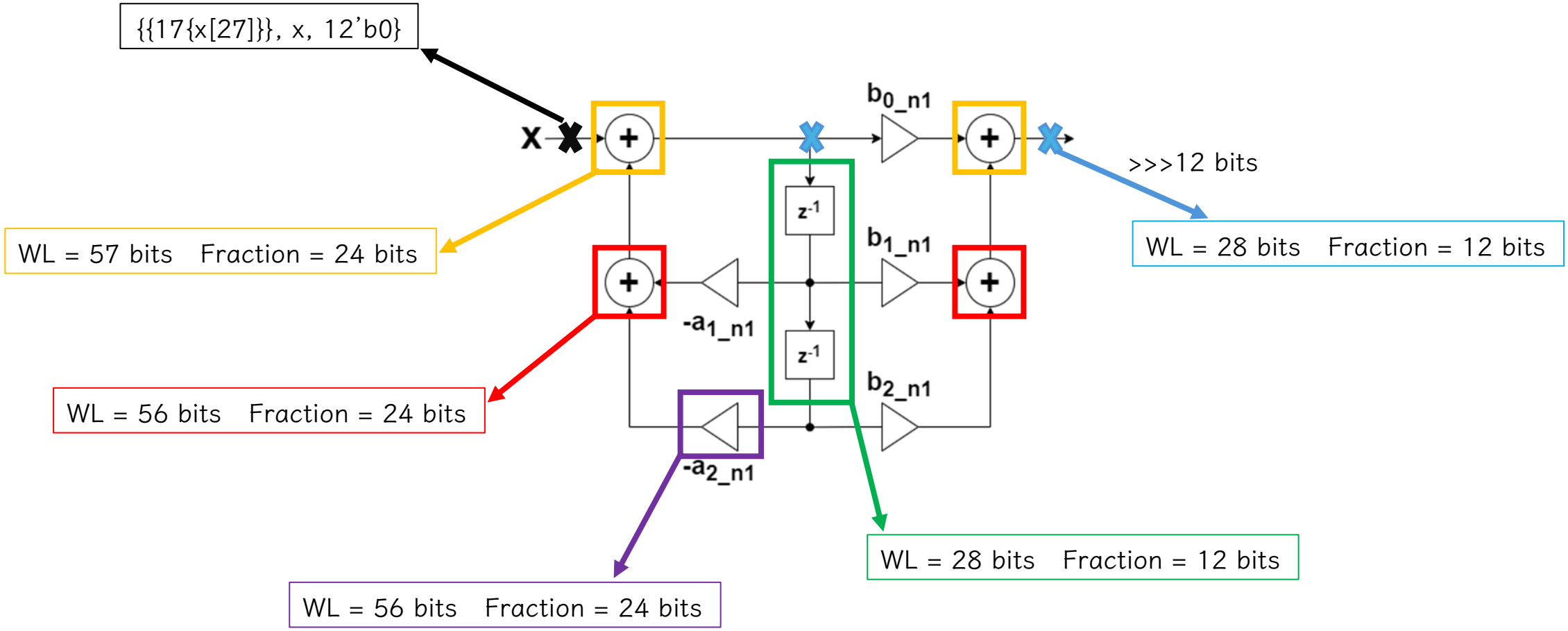


D flip-flop: WL=28
Fraction=12

濾波器係數: WL=28
Fraction=12

Input/Output: WL=28
Fraction=12

濾波器內部位元處理


{{17{x[27]}}, x, 12'b0}
X
b_{0_n1}
b_{1_n1}
b_{2_n1}
$-a_{1\_n1}$
$-a_{2\_n1}$
z^{-1}
z^{-1}
>>>12 bits
WL = 57 bits Fraction = 24 bits
WL = 28 bits Fraction = 12 bits
WL = 56 bits Fraction = 24 bits
WL = 28 bits Fraction = 12 bits
WL = 56 bits Fraction = 24 bits

邏輯合成結果

- 使用製程: tsmc 130(nm)

操作頻率: 360(Hz)
合成面積: 66383.618387(um^2)

```
Area
-----------------------------------
Combinational Area:    60110.027963
Noncombinational Area:  6273.590424
Buf/Inv Area:           1928.246370
Total Buffer Area:           183.32
Total Inverter Area:        1744.93
Macro/Black Box Area:      0.000000
Net Area:                  0.000000
-----------------------------------
Cell Area:             66383.618387
Design Area:           66383.618387
```

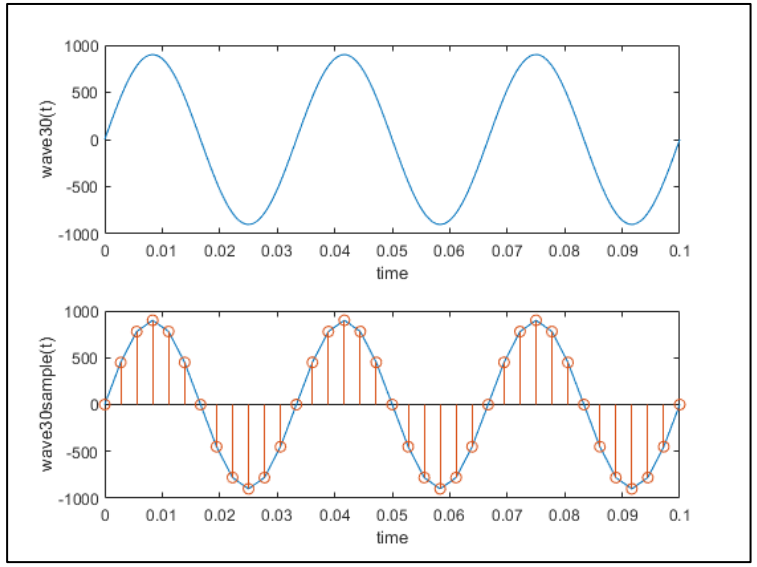
最大操作頻率: 50 (MHz)
合成面積: 79406.070516(um^2)

```
Area
-----------------------------------
Combinational Area:    73034.030912
Noncombinational Area:  6372.039604
Buf/Inv Area:           5475.812318
Total Buffer Area:          1262.87
Total Inverter Area:        4212.95
Macro/Black Box Area:      0.000000
Net Area:                  0.000000
-----------------------------------
Cell Area:             79406.070516
Design Area:           79406.070516
```

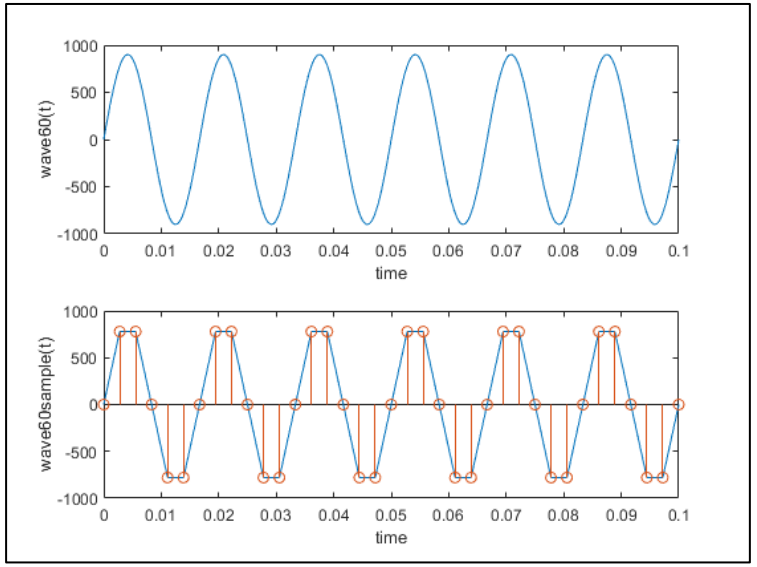
功能驗證(1/3)

- 使用MATLAB分別產生30、60、90 Hz的弦波並以360 Hz的採樣頻率進行採樣
- 將採樣的數值進行量化 => WL = 28 bits Fraction = 12 bits
- 執行TB模擬

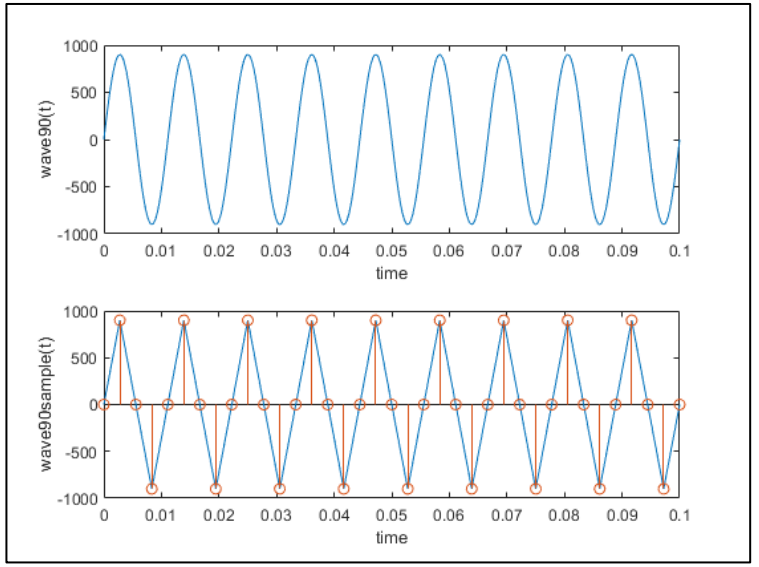
30 HZ



60 HZ



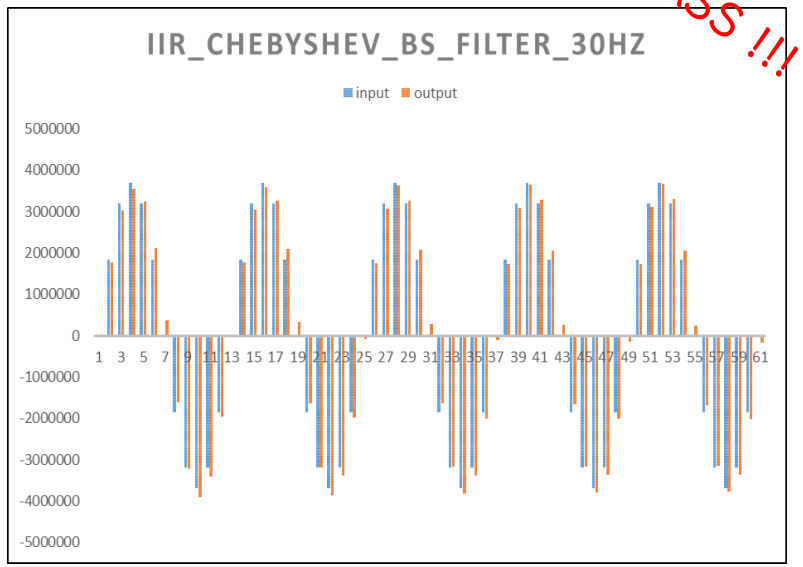
90 HZ



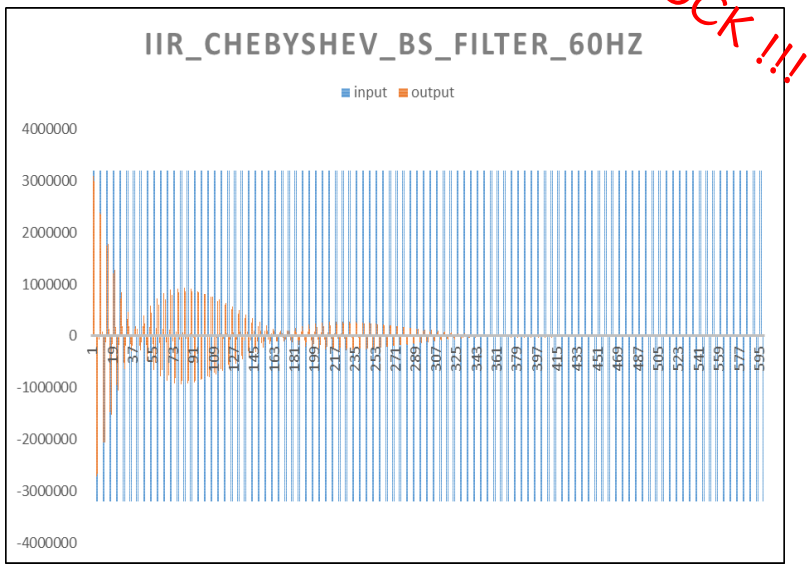
功能驗證(2/3)

- 模擬結果:

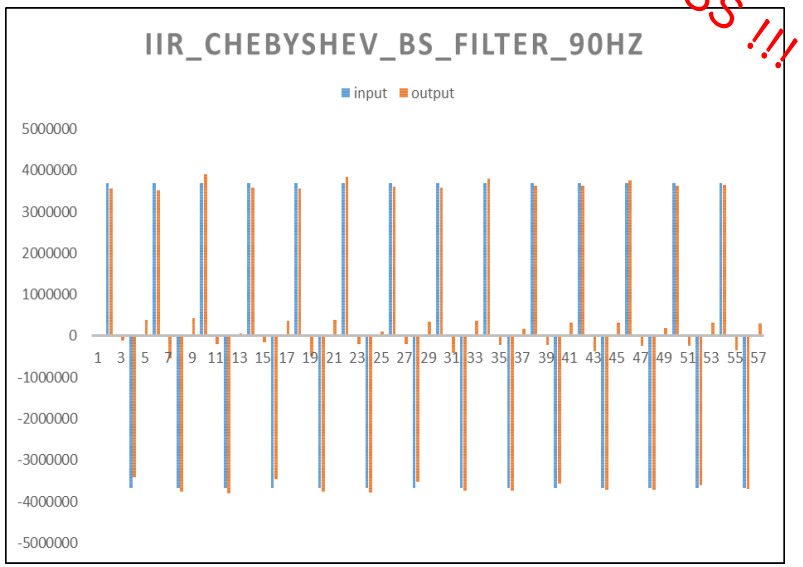
30 HZ PASS !!!



60 HZ BLOCK !!!

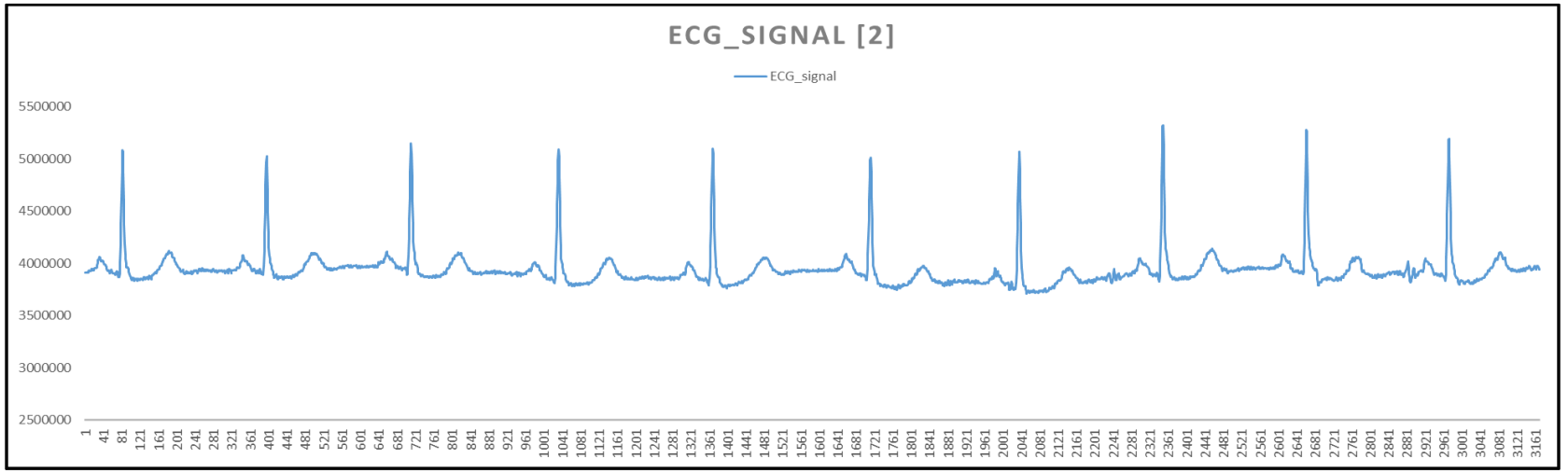


90 HZ PASS !!!

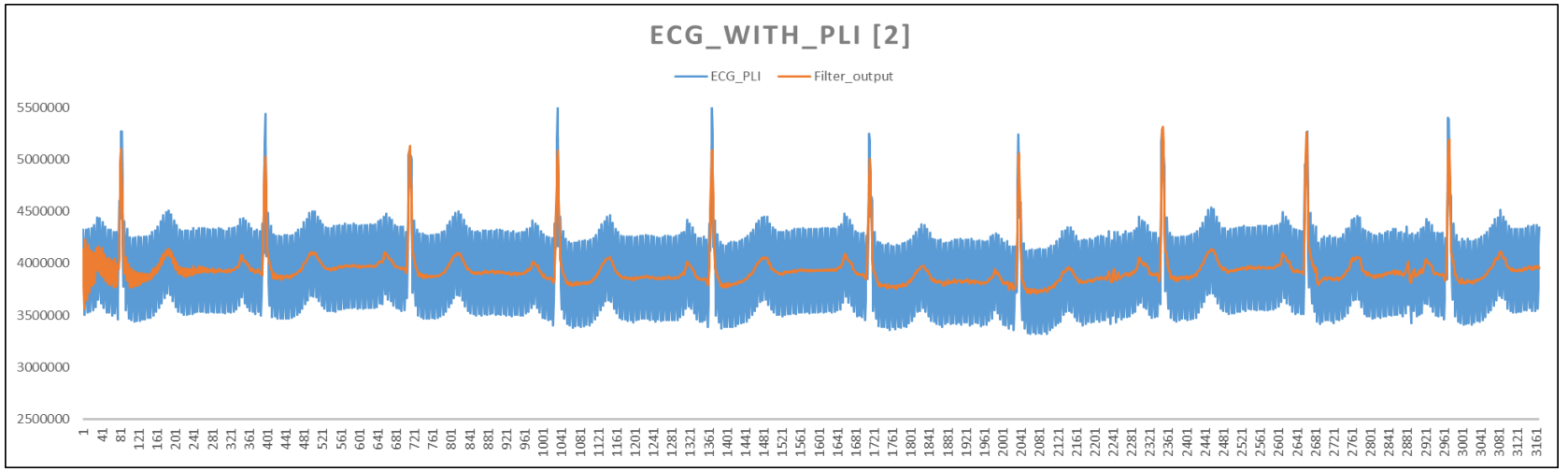


功能驗證(3/3)

- 將含有雜訊的ECG訊號進行採樣、量化並輸入至濾波器



PLI 雜訊濾除 !!!



參考文獻

[1] T. Sharma and K. K. Sharma, “ Power line interference removal from ECG signals using wavelet transform based component-retrieval,” *International Conference on Advances in Computing, Communications and Informatics (ICACCI)*, pp. 95-101, 2016.

[2] G. B. Moody and R. G. Mark, “The impact of the MIT-BIH Arrhythmia Database,” *IEEE Engineering in Medicine and Biology Magazine*, vol. 20, no. 3, pp. 45-50, May/June, 2001.

[3] S. Saxena, R. Jais and M. K. Hota, “Removal of Powerline Interference from ECG Signal using FIR, IIR, DWT and NLMS Adaptive Filter,” *International Conference on Communication and Signal Processing (ICCSP)*, pp. 0012-0016, 2019.

[4] S. Natarajan, “Comparison and Implementation of Different Types of IIR Filters for Speech Signal Analysis,” *International Journal of Engineering Research & Technology (IJERT)*, vol. 6(2), pp. 550 – 555, 2017.

The End