

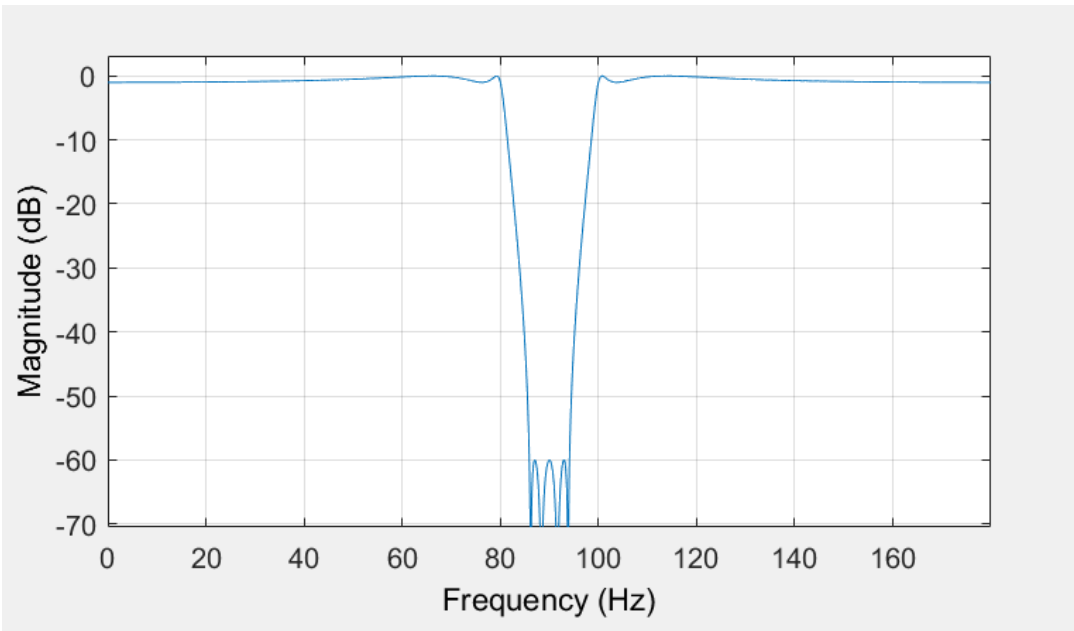
Filter Circle

組員：劉浩崙 B093011055

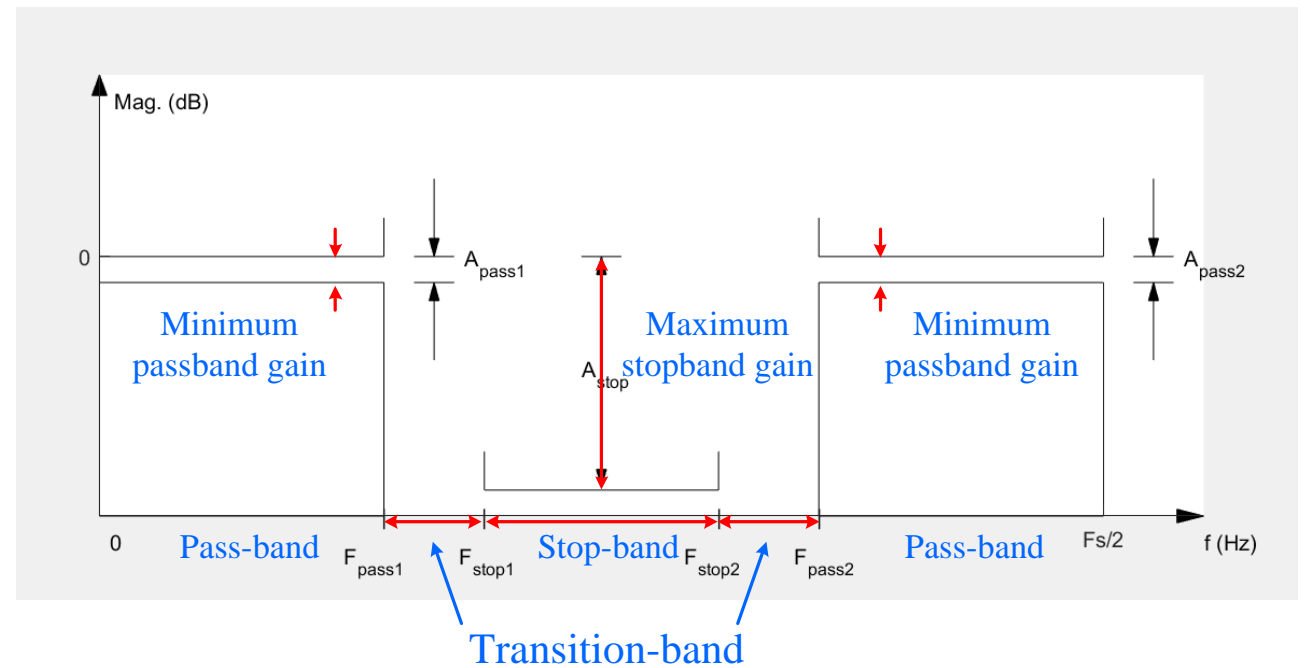
陳晉毅 B093011056

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



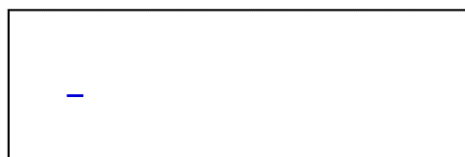
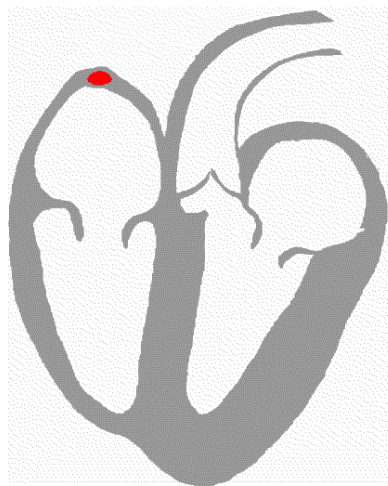
圖片來源：MATLAB Filter Designer



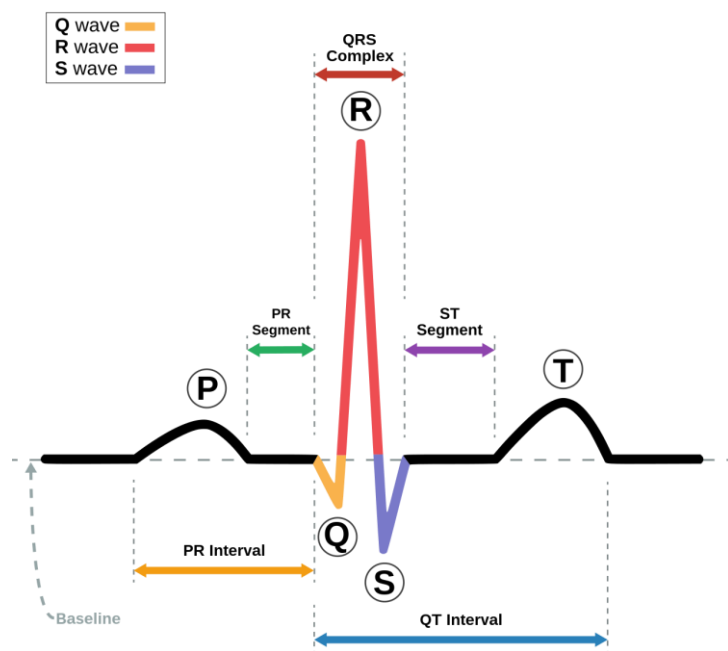
圖片來源：MATLAB Filter Designer

BS Filter應用-ECG 與 PLI

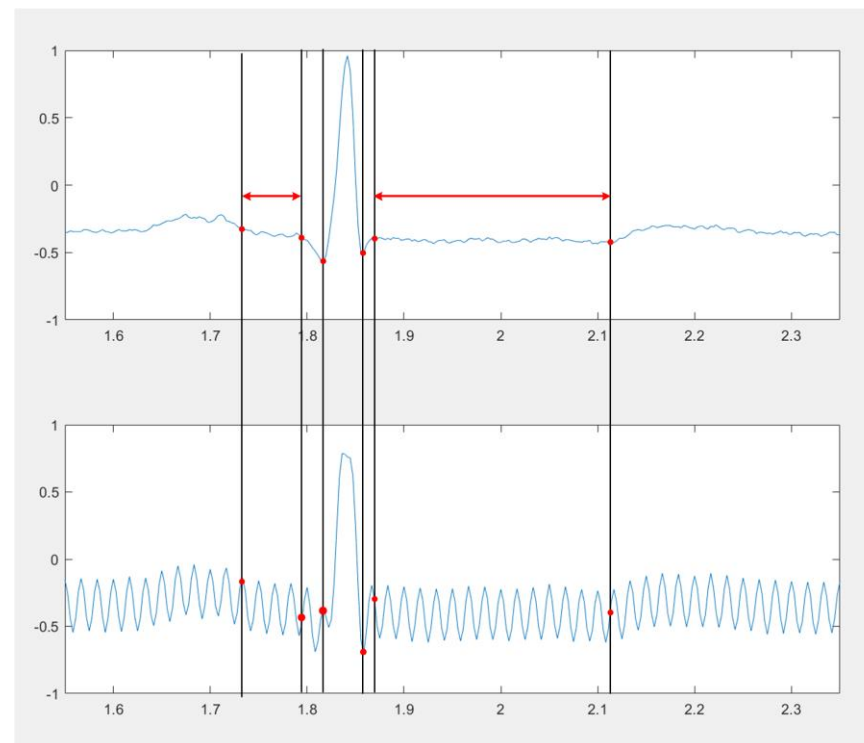
- 心電圖(Electrocardiography, ECG)訊號微弱，擷取訊號的傳輸線易受電源線的Power Line Interference (PLI)雜訊(60 Hz)汙染[1]
- 受雜訊污染的ECG訊號可能會影響醫師的判讀



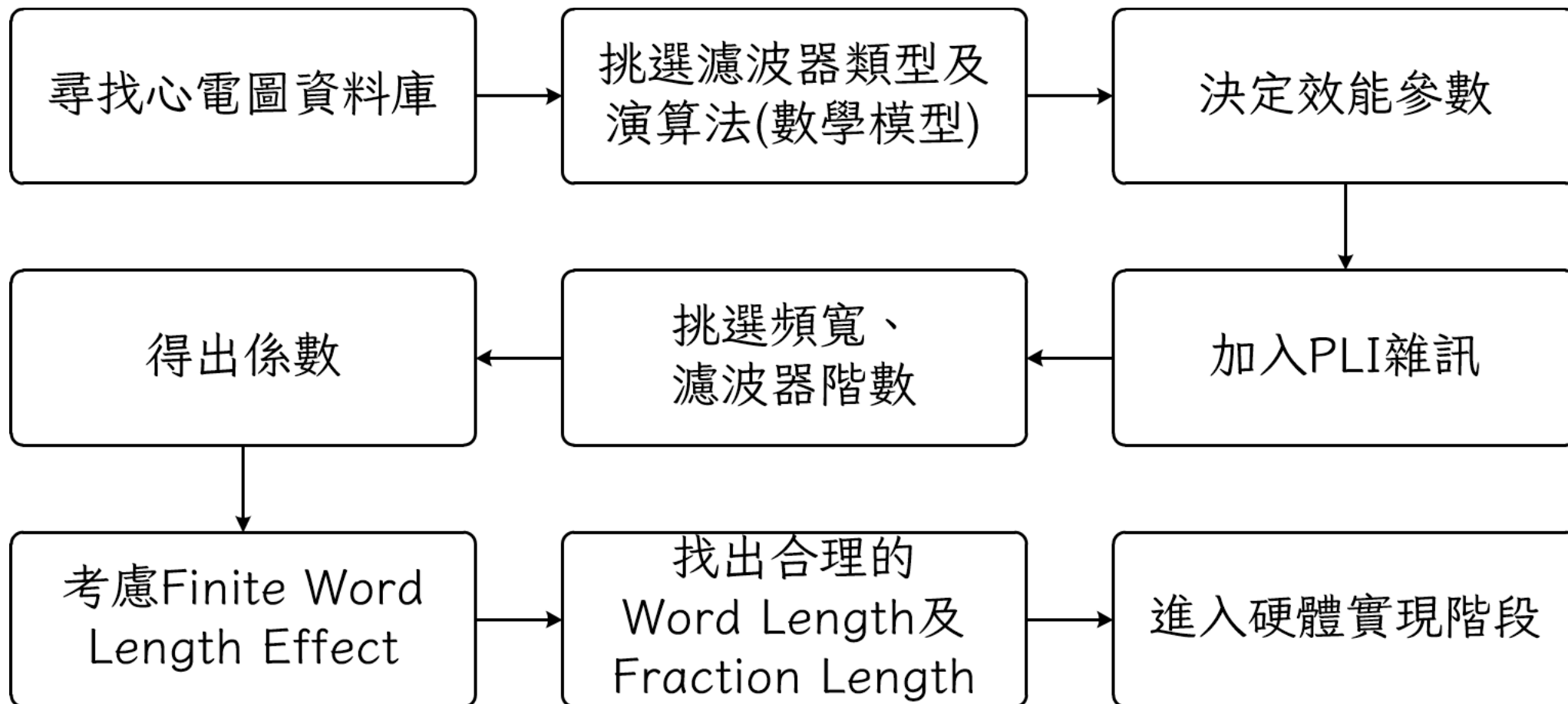
圖片來源：wiki-心電圖



圖片來源：wiki-心電圖

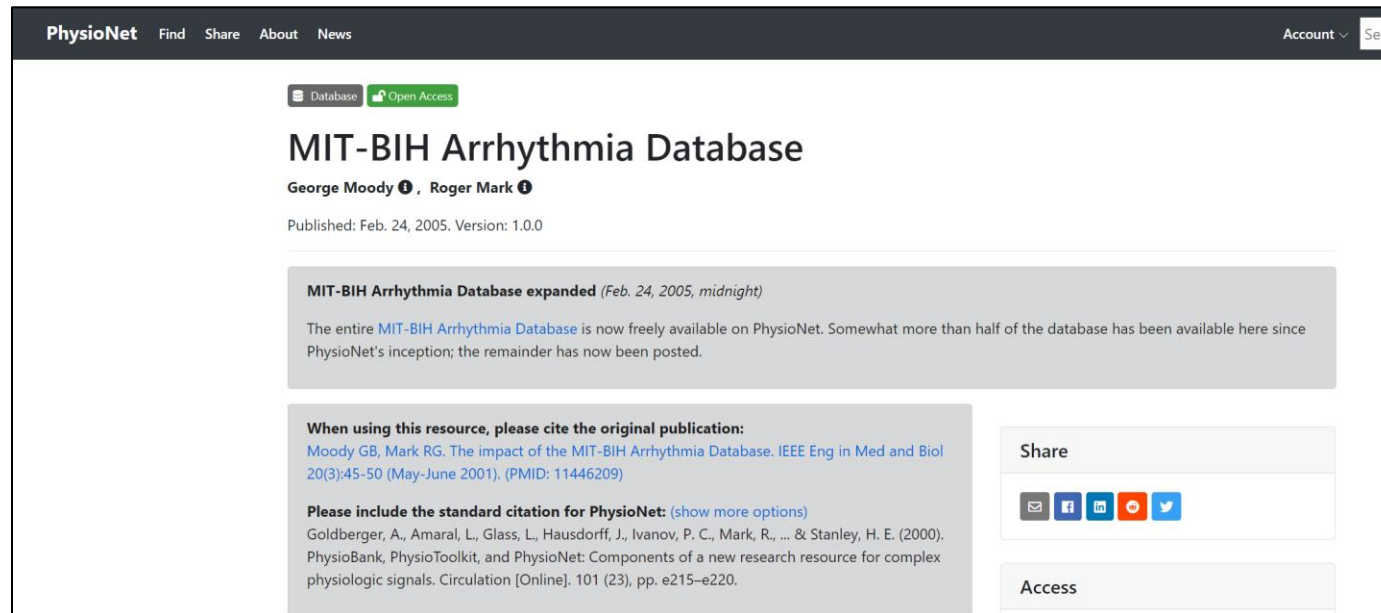


以ECG作為FC的設計範例



ECG資料來源及雜訊

- MIT-BIH資料庫 [2]
- ECG: 11bit ADC (0 V @ 1024); $f_s=360\text{Hz}$; precision $\pm 5\text{mV}$)
- PLI noise: $60\pm 0.2\text{ Hz}$ sine wave



The screenshot shows the MIT-BIH Arrhythmia Database page on the PhysioNet website. The page header includes the PhysioNet logo and navigation links (Find, Share, About, News). The main title is "MIT-BIH Arrhythmia Database" by George Moody and Roger Mark. It states the database was published on Feb. 24, 2005, and is version 1.0.0. A prominent announcement box states that the entire database is now freely available on PhysioNet. Below this, there is a section for citing the original publication and the standard citation for PhysioNet. On the right side, there are buttons for sharing the resource on various social media platforms and an "Access" button.

PhysioNet Find Share About News Account Search

Database Open Access

MIT-BIH Arrhythmia Database

George Moody, Roger Mark

Published: Feb. 24, 2005. Version: 1.0.0

MIT-BIH Arrhythmia Database expanded (Feb. 24, 2005, midnight)

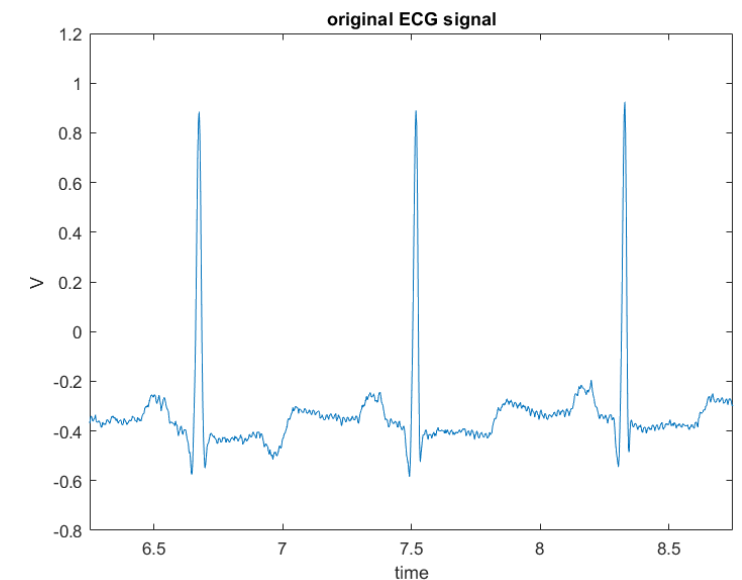
The entire MIT-BIH Arrhythmia Database is now freely available on PhysioNet. Somewhat more than half of the database has been available here since PhysioNet's inception; the remainder has now been posted.

When using this resource, please cite the original publication:
Moody GB, Mark RG. The impact of the MIT-BIH Arrhythmia Database. *IEEE Eng in Med and Biol* 20(3):45-50 (May-June 2001). (PMID: 11446209)

Please include the standard citation for PhysioNet: (show more options)
Goldberger, A., Amaral, L., Glass, L., Hausdorff, J., Ivanov, P. C., Mark, R., ... & Stanley, H. E. (2000). PhysioBank, PhysioToolkit, and PhysioNet: Components of a new research resource for complex physiologic signals. *Circulation [Online]*. 101 (23), pp. e215-e220.

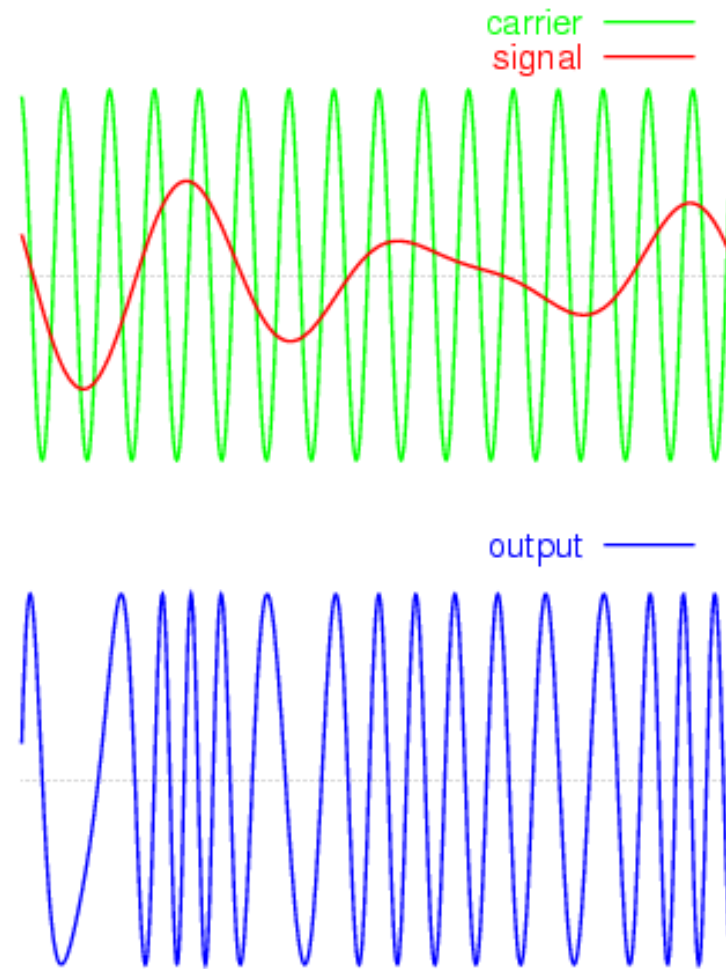
Share

Access



產生PLI雜訊

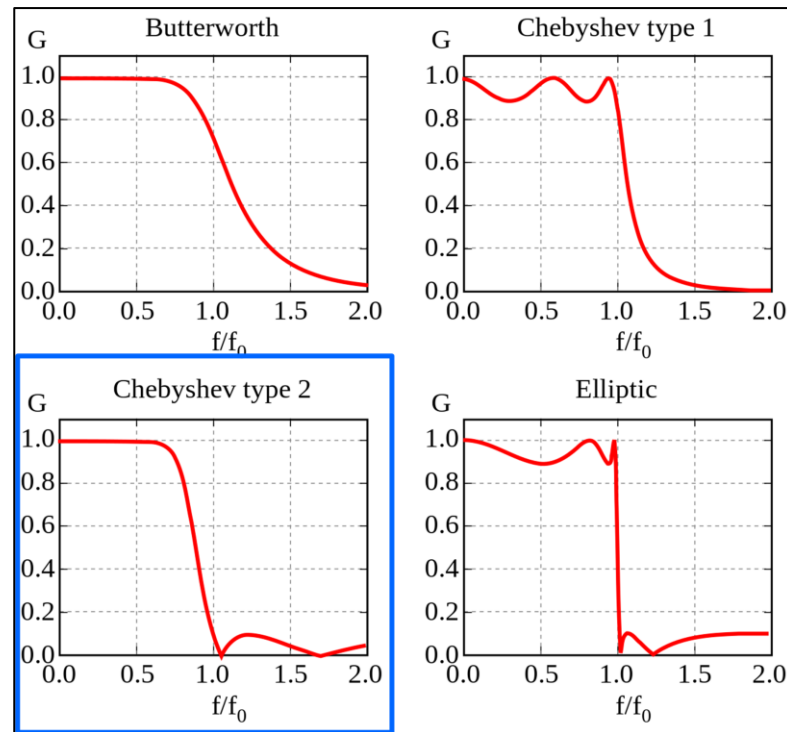
- $F_{\max} = 60.2 \text{ Hz}$
- $F_{\min} = 59.8 \text{ Hz}$
- 隨著時間會改變頻率的弦波
- 頻率調變



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]



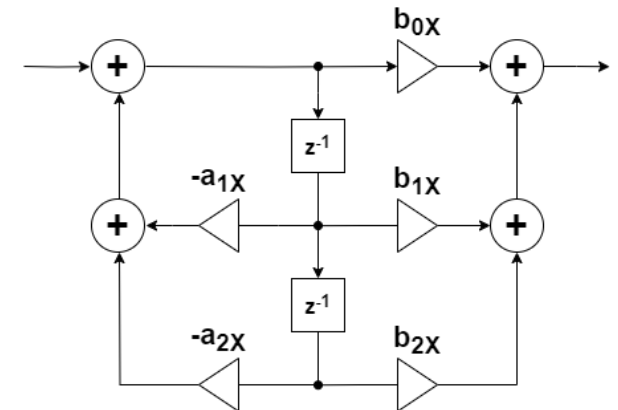
圖片來源：wiki - Chebyshev filter

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)

- $MAE = \frac{\sum_{i=1}^n |output_i - input_i|}{n}$
- $SNR = \frac{\sum_i |singal_out_i|^2}{\sum_i |noise_out_i|^2}$
- $Area = Section \times (2 \times DFF + 4 \times Adder + 5 \times Multiplier)$
 $DFF = WL$
 $Adder = 1.5 \times (2WL + 1)$
 $Multiplier = (1.5 \times 2WL)^2$

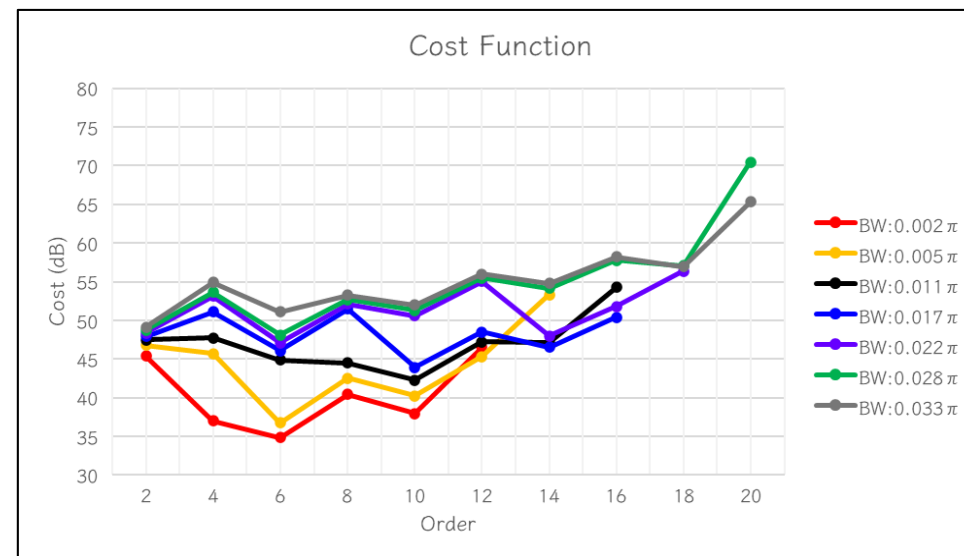
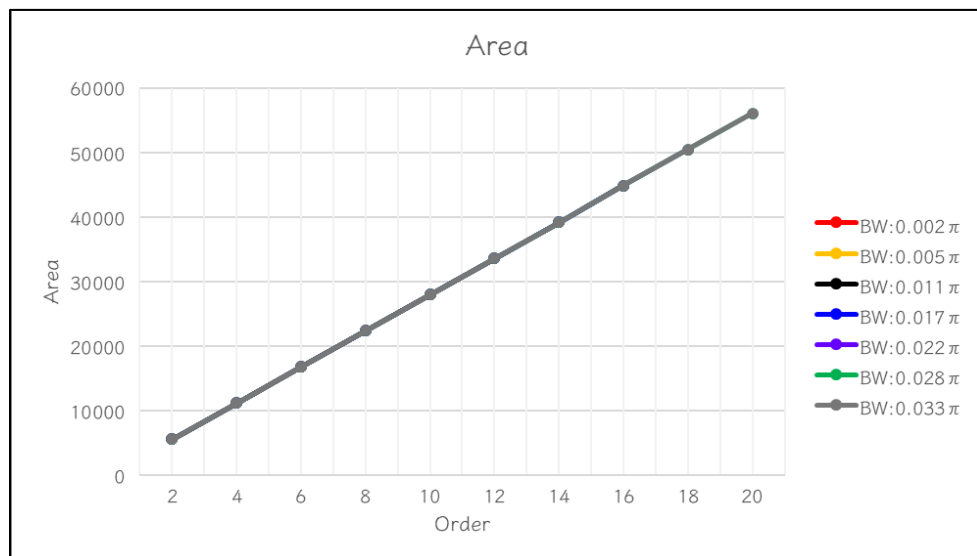
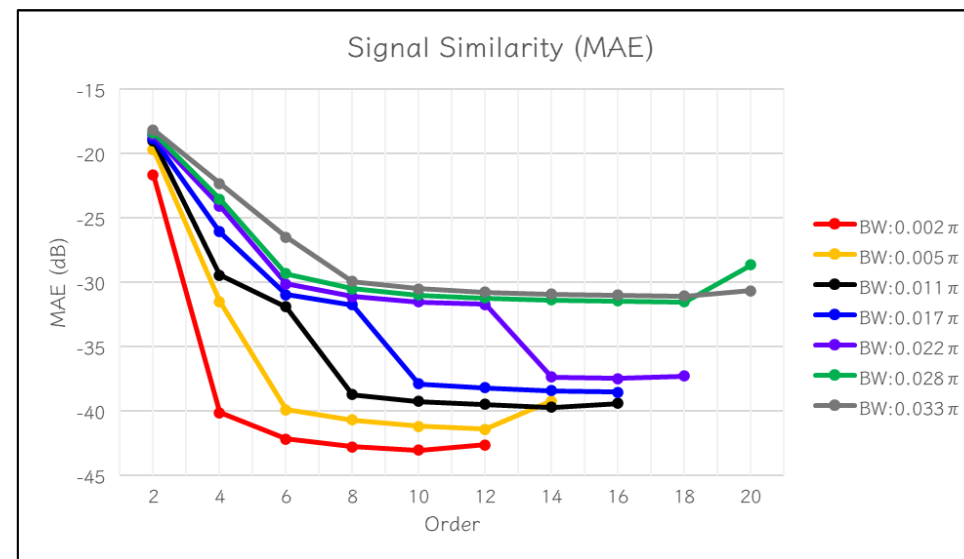
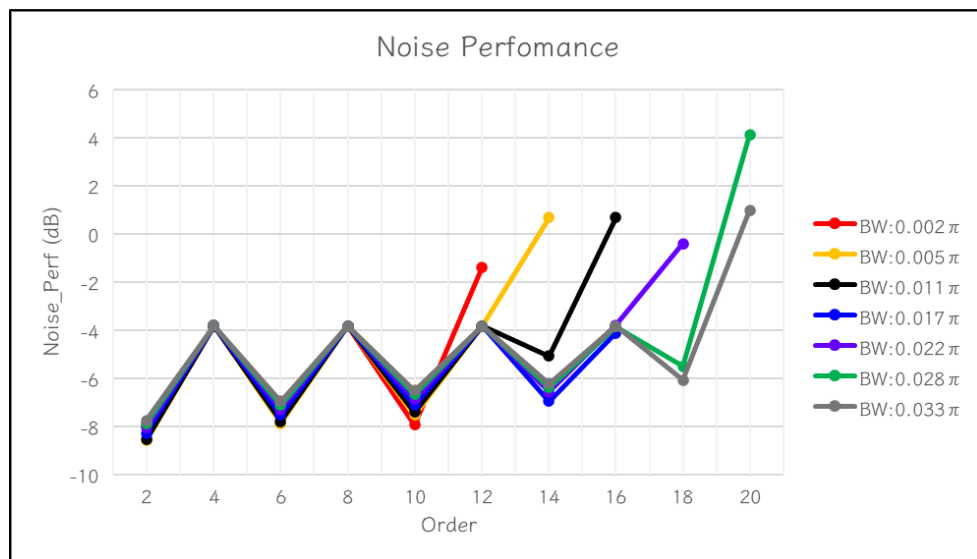


效能計算及Cost Function (2/2)

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

- $Cost = Area \times Noise_perf \times MAE^2$

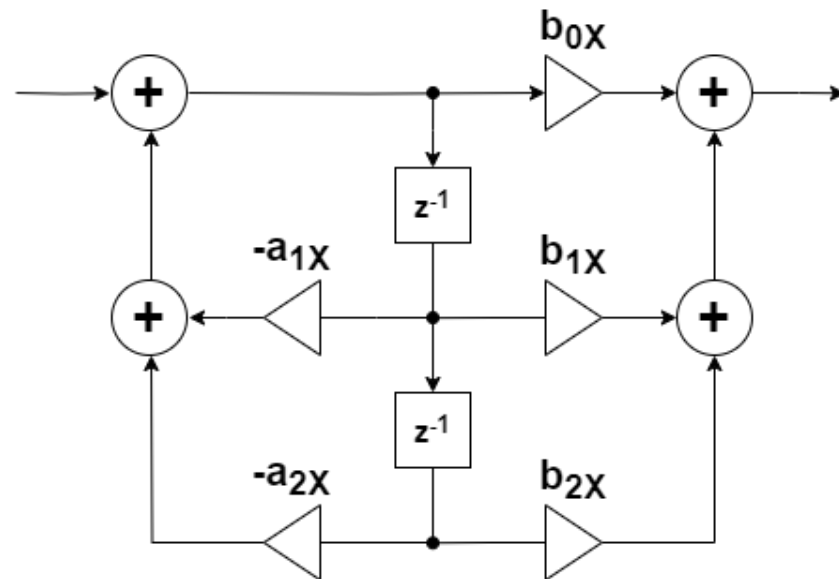
MATLAB模擬結果-不同頻寬及Order



6 Order Filter 設計結果

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

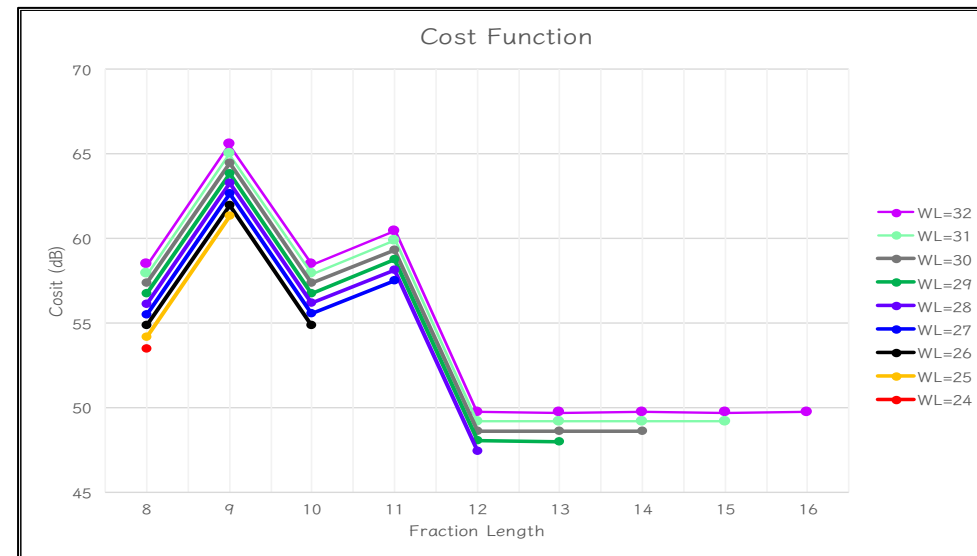
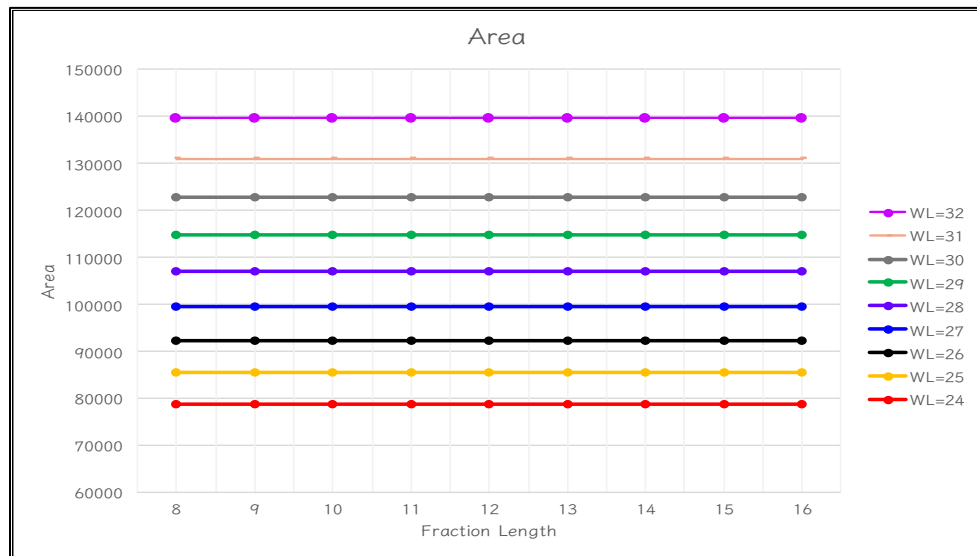
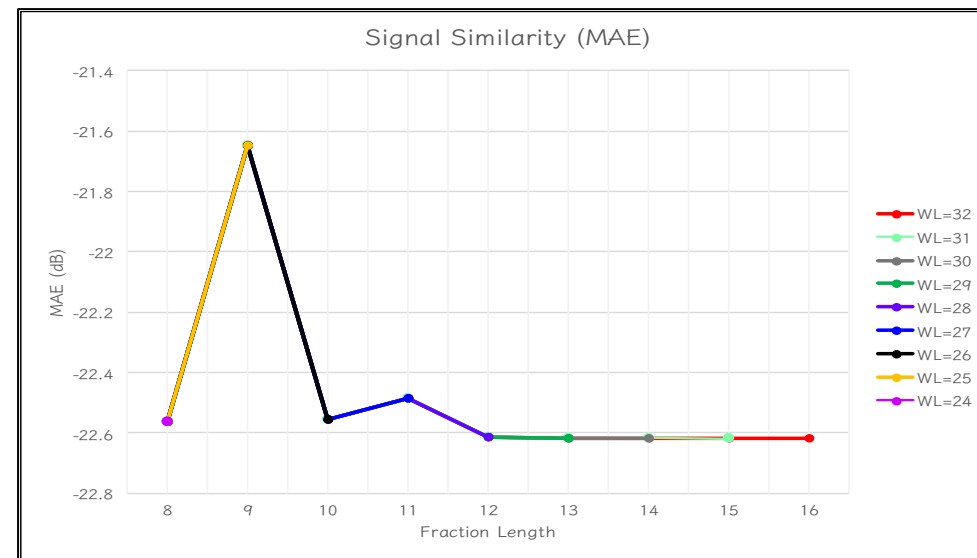
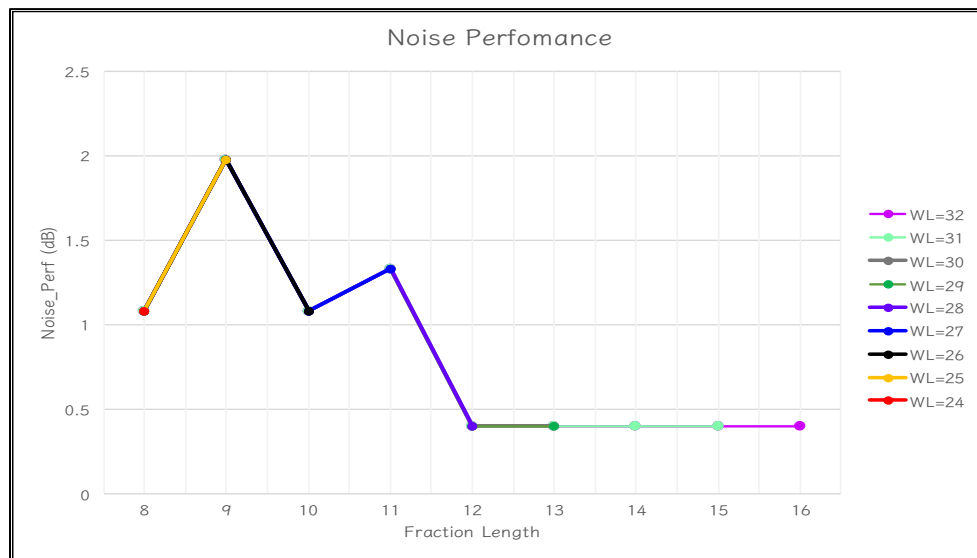
$$= \begin{bmatrix} 0.989019 & -0.99419 & 0.989019 & -0.95589 & 0.978156 \\ 0.989019 & -0.98384 & 0.989019 & -1.02179 & 0.978629 \\ 0.978616 & -0.97862 & 0.978616 & -0.97862 & 0.957232 \end{bmatrix}$$



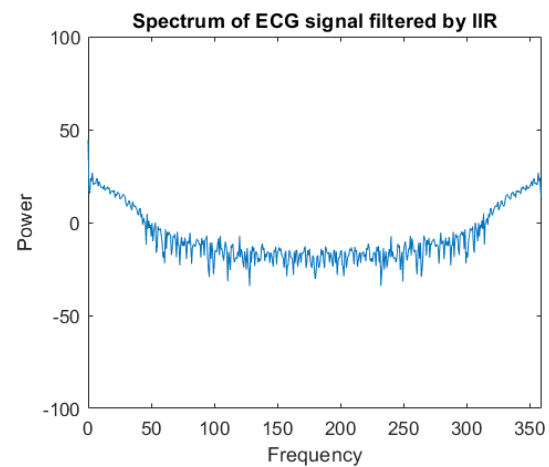
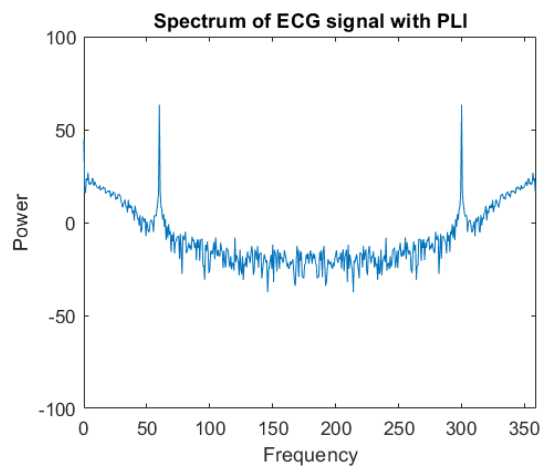
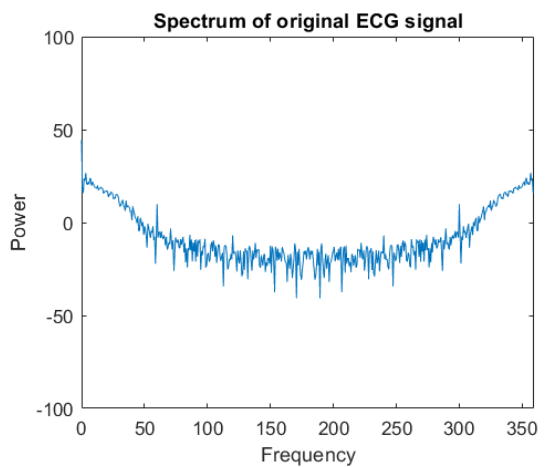
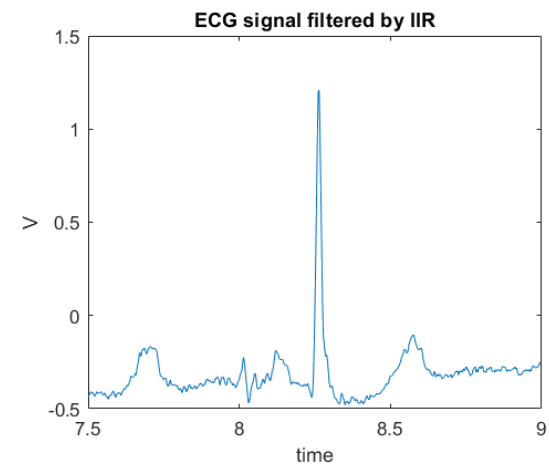
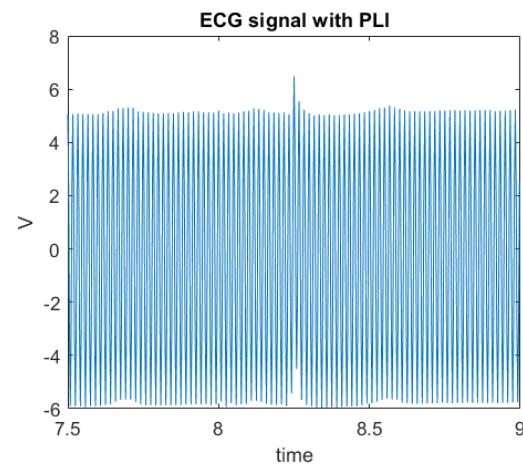
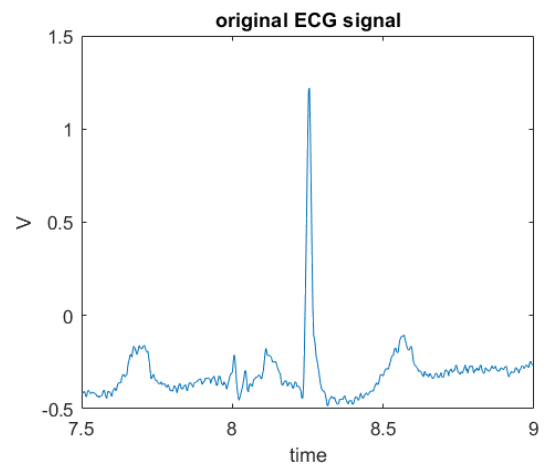
Word Length & Fraction Length

- 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)

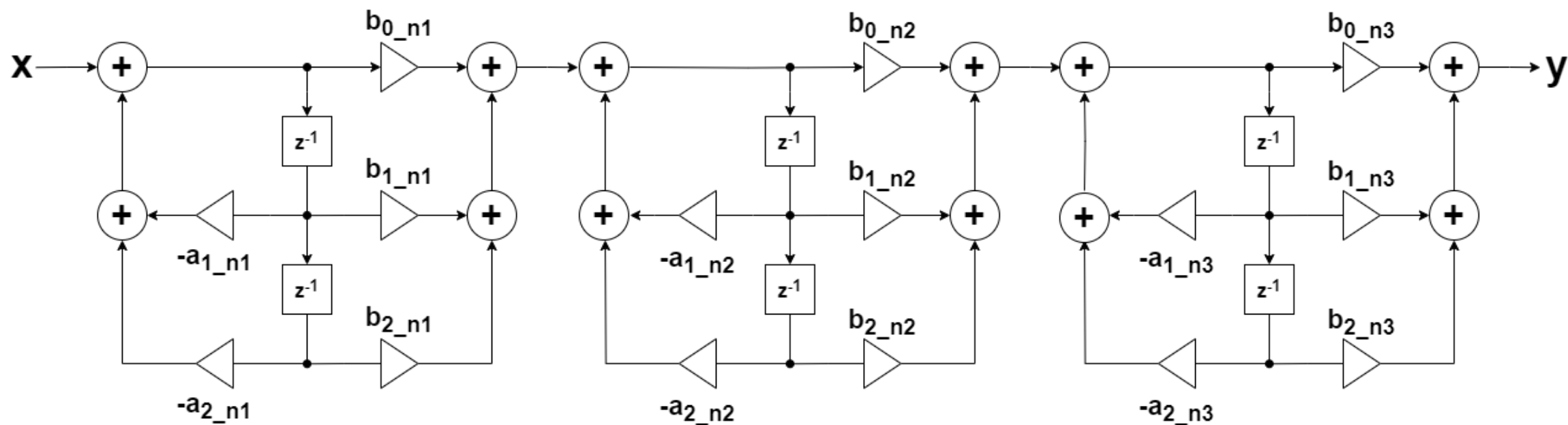


實際輸入ECG



濾波器架構

-IIR Cascaded Second-Order Sections Direct Form II

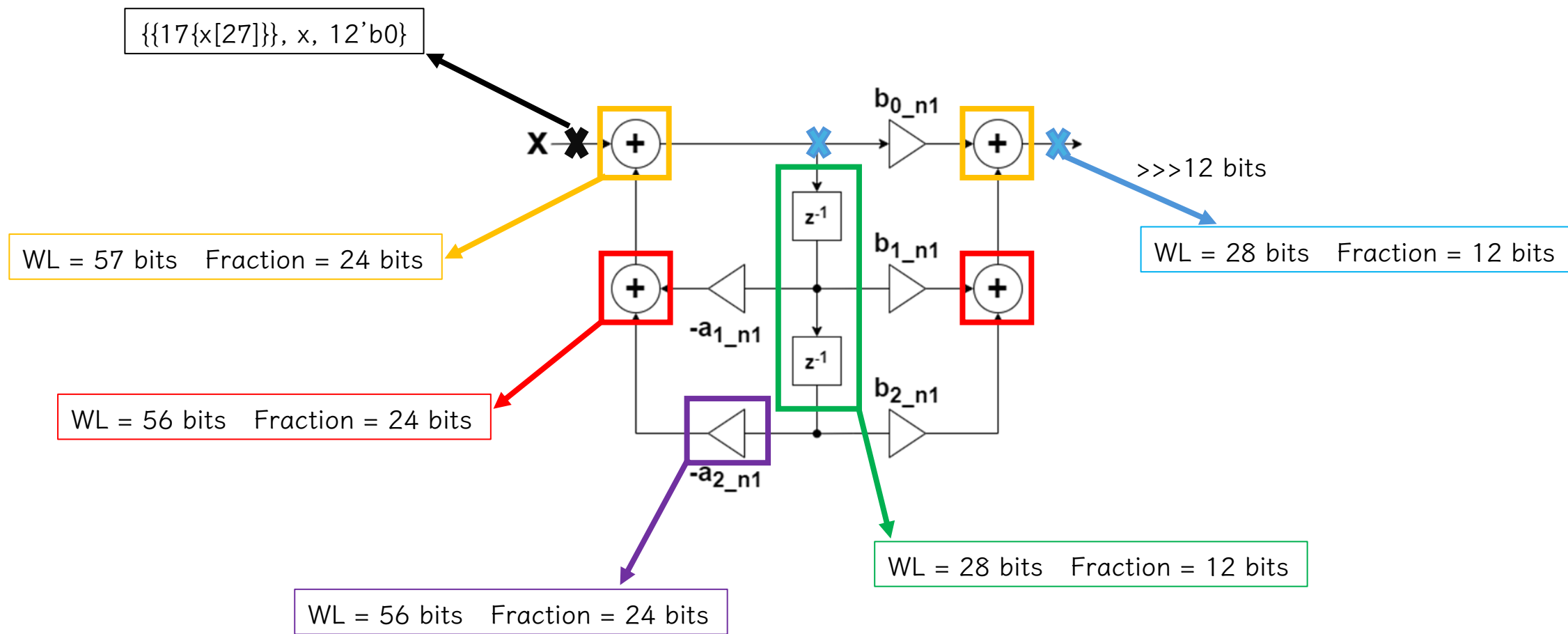


D flip-flop: WL=28
Fraction=12

濾波器係數: WL=28
Fraction=12

Input/Output: WL=28
Fraction=12

濾波器內部位元處理



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(μm^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(μm^2)

Area	

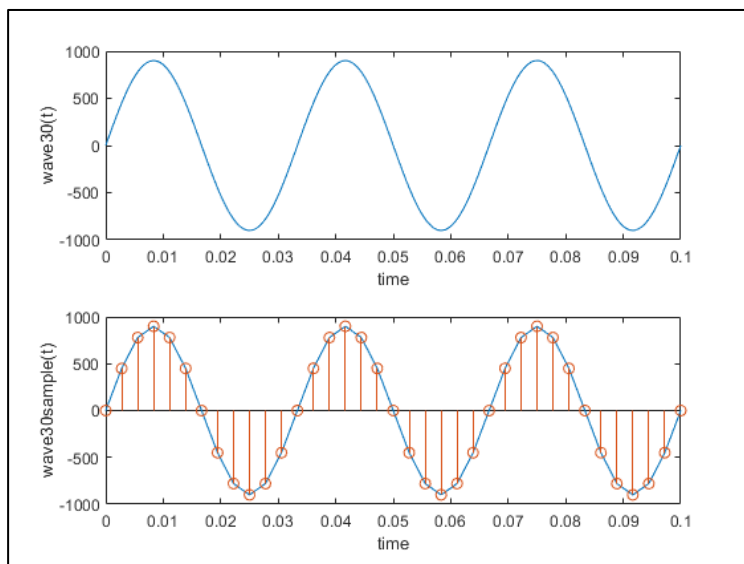
Combinational Area:	73034.030912
Noncombinational Area:	6372.039604
Buf/Inv Area:	5475.812318
Total Buffer Area:	1262.87
Total Inverter Area:	4212.95
Macro/Black Box Area:	0.000000
Net Area:	0.000000

Cell Area:	79406.070516
Design Area:	79406.070516

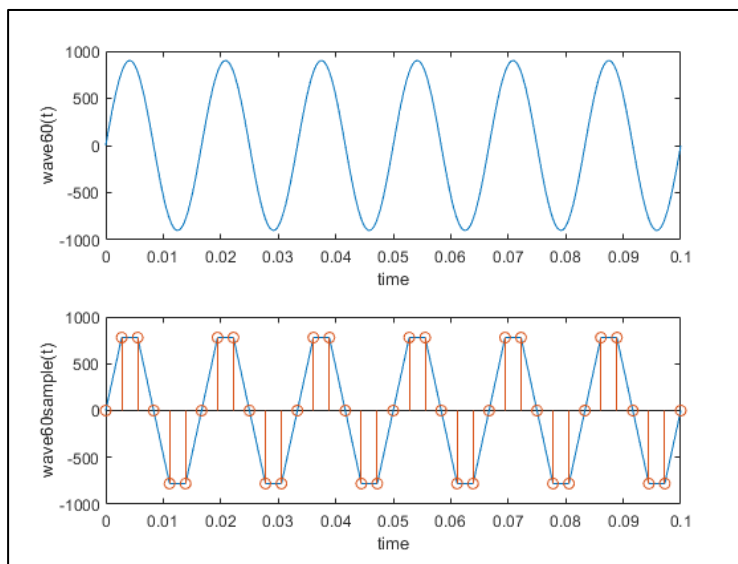
功能驗證(1/3)

- 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

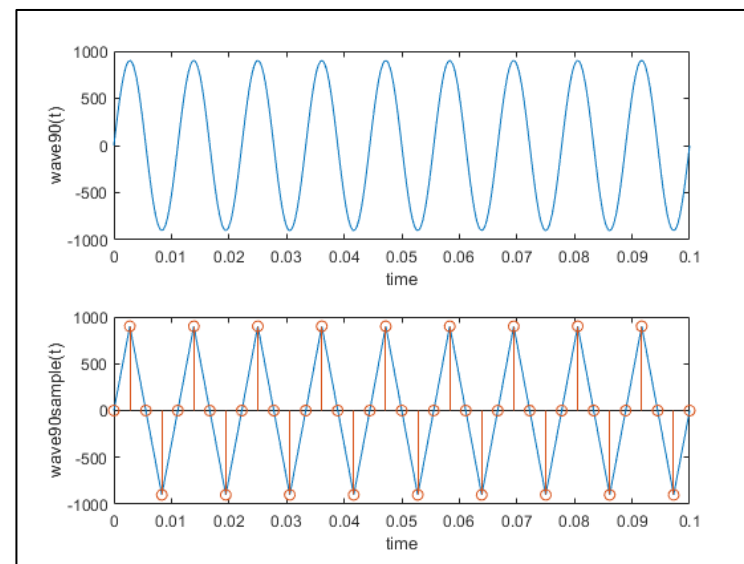
30 HZ



60 HZ



90 HZ

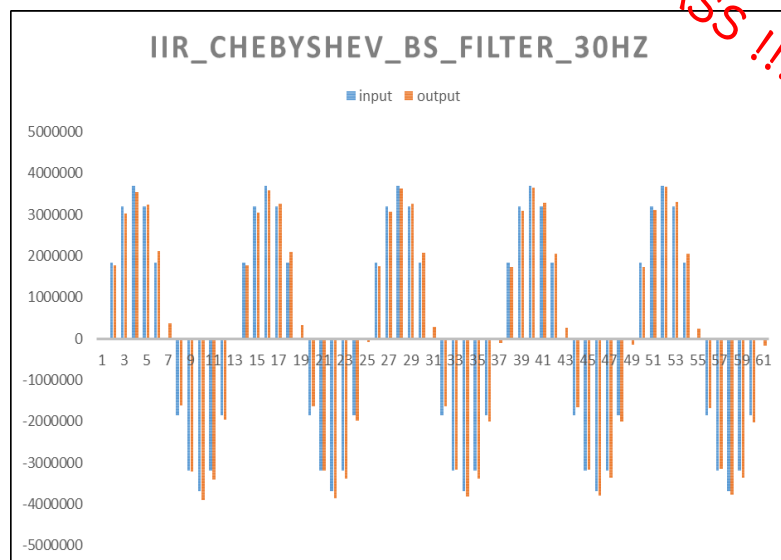


功能驗證(2/3)

- 模擬結果:

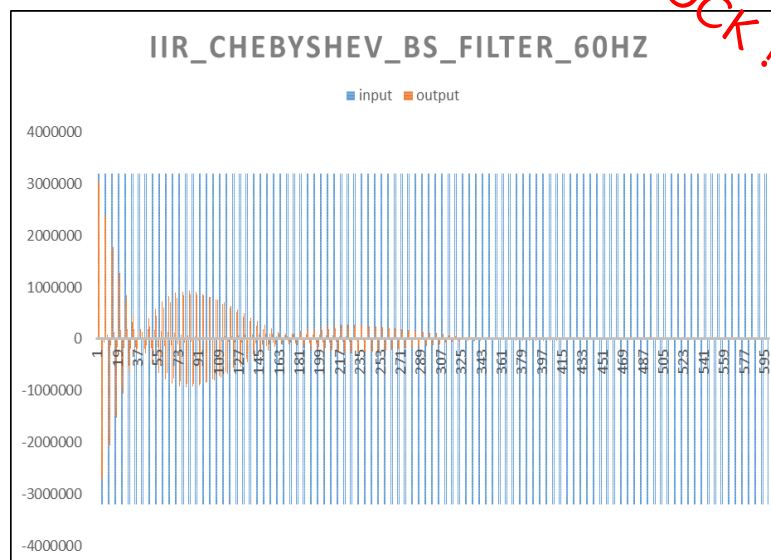
30 HZ

PASS !!!



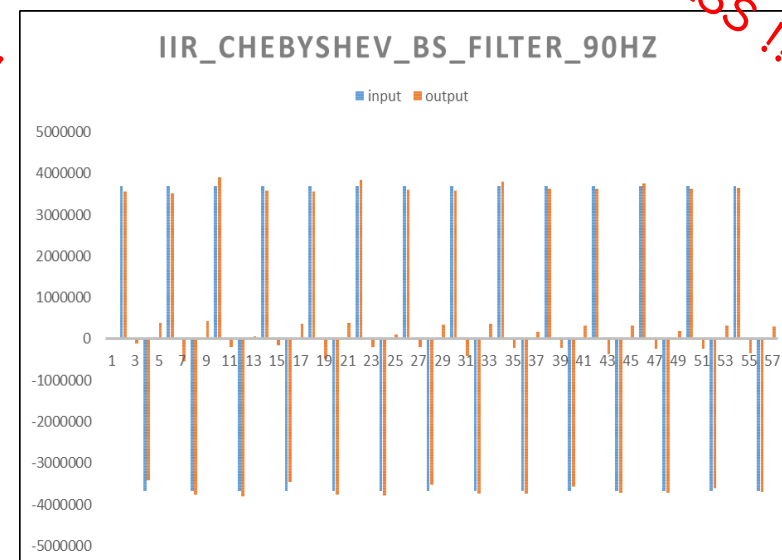
60 HZ

BLOCK !!!



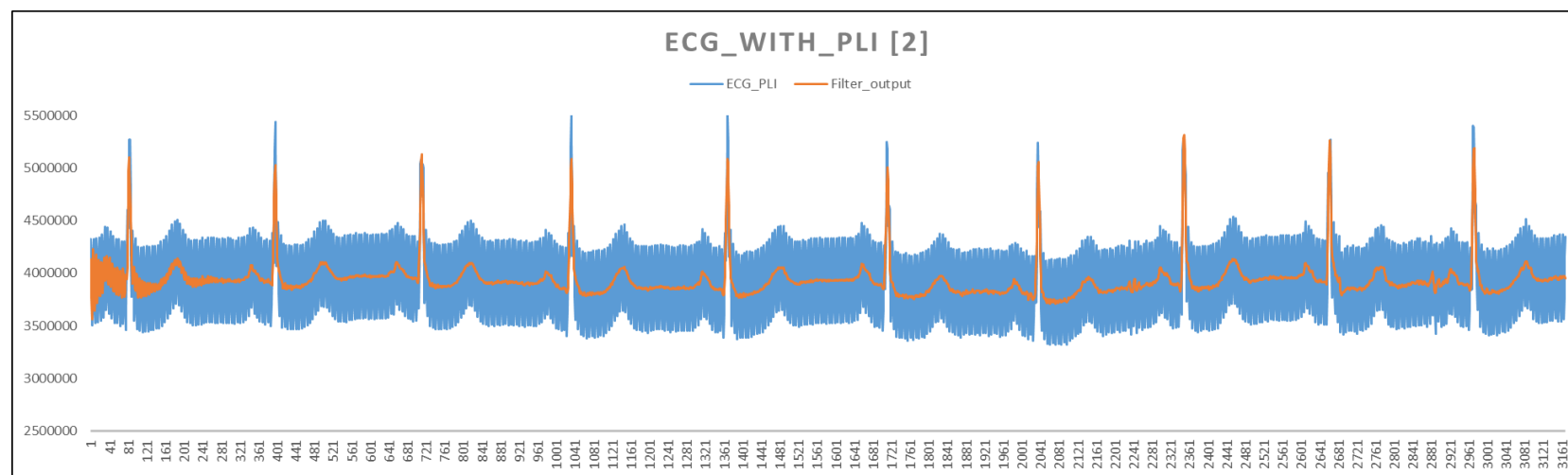
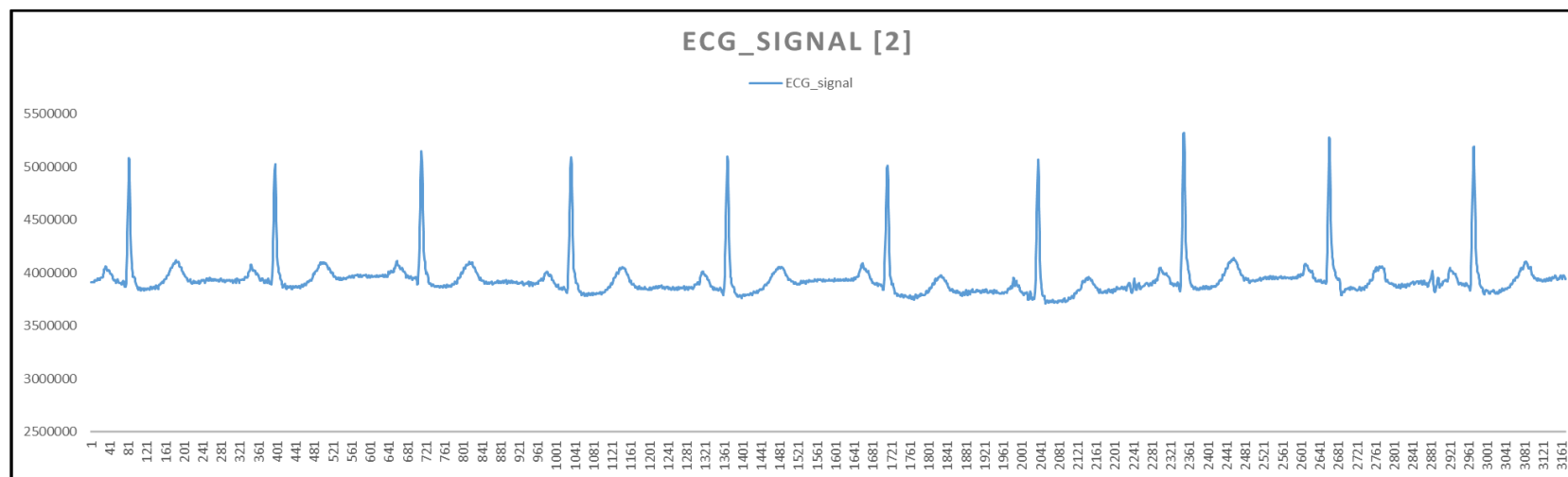
90 HZ

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