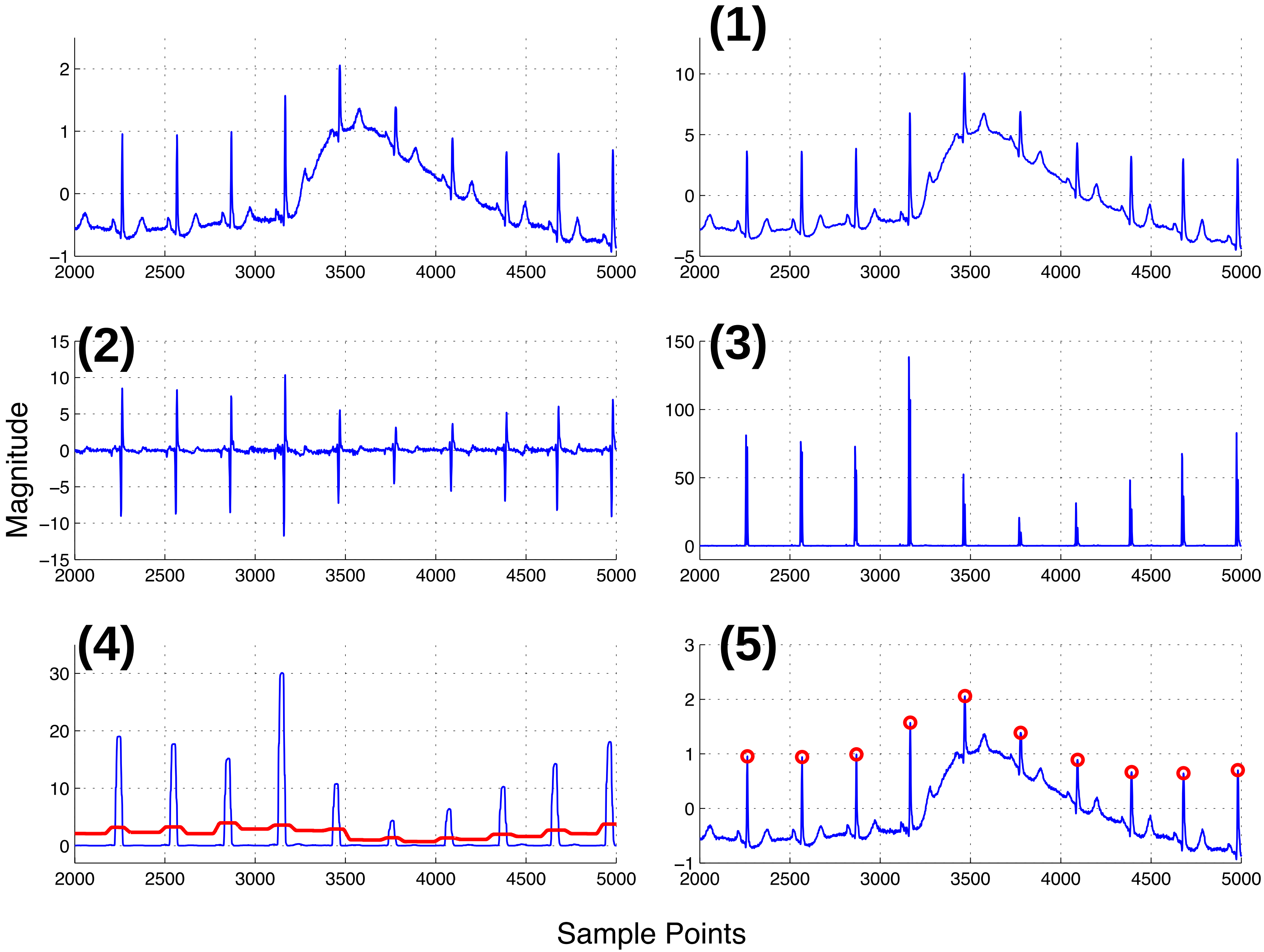
數位訊號處理實驗
Digital Signal Processing Laboratory
Lab 4
Heart Rate Detection

Task 1

- Detect the R wave from your recorded ECG signals.

Pre-Processing of ECG Signals (3/3)



Task 3 (See Your TAs' Demo)

- Implement the pre-processing of the ECG signals(Lab 3) and R-peak detection in real time and display the processed ECG signals and the R-peaks in real time.
  - Better modularize your signal processing flow. That is, please make each block as a function and then perform function calls.
  - Note that you can implement your signal processing modules in PC or in Arduino.
  - Can you display "Heart Rate" (Inverse of the RR interval) in real time?
  - Can you "beep" for each R peak

Task 2

- Find the R-peaks in MIT-BIH database.

(You have to take care "**group delay**" introduced by your linear phase FIR filtering in order to obtain the almost the same R-peak time as provided by the MIT-BIH database)

  - Detailed description about the provided data, please see the Lab 4 on the LMS e-learning system.
  - Please draw a table in your report. The first column is the name of the data set, the 2nd column is TP, the 3rd column is FN, and the 4th column is FP.
  - Please justify how you estimate your TP, FN, and FP and the precision when matching your results with the ground truth.

數位訊號處理概論
Introduction to Digital Signal Processing: Topic 7 Design of FIR and IIR Filters (Part of Textbook Chap 10 and Chap 11)

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Recall:
For Example:
Ideal Low Pass Filter with Linear Phase

$$H_{\mathrm{lp}}(e^{j\omega}) = \begin{cases} e^{-j\alpha\omega}, & |\omega| < \omega_c \\ 0, & \omega_c < |\omega| \le \pi \end{cases} \quad (10.21)$$

$$h_{\mathrm{lp}}[n] = \frac{\sin \omega_c (n-\alpha)}{\pi (n-\alpha)}. \quad (10.22)$$

all pass filter.

$\omega_c = \pi$, $\alpha = n_d$, α: delay.

$\Rightarrow h_{lp}[n] = \delta(n - n_d)$

$x[n] \rightarrow \boxed{h_{lp}[n]} \rightarrow x(n - n_d)$

Recall: Group Delay: Amplitude Response and Angle Response

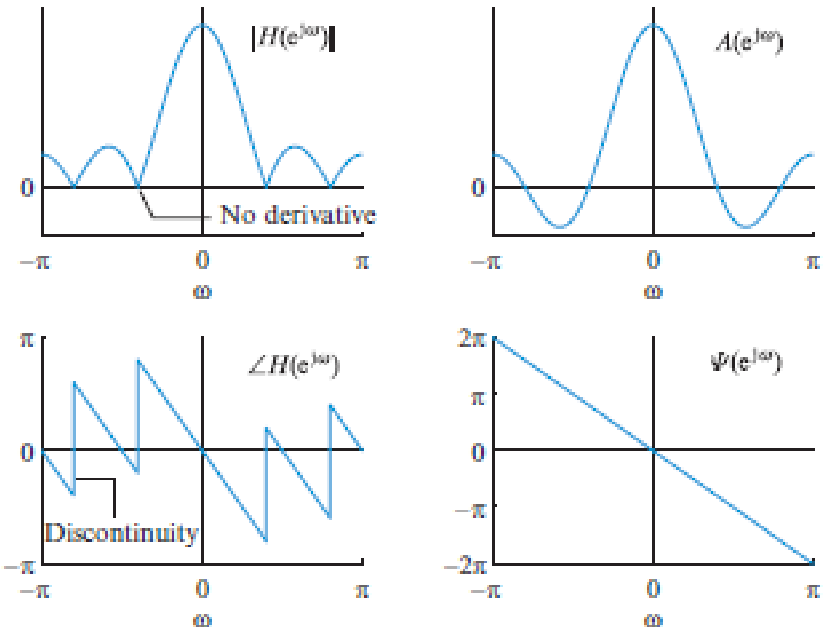


Figure 10.3 The differences between the magnitude and amplitude response representations of the frequency response function.

Group delay $$\tau_{gd}(\omega) = -\frac{d\Psi\left(e^{j\omega}\right)}{d\omega} \quad (10.44)$$

Recall: Linear Phase System vs. Group Delay

$$H_{\mathrm{lp}}(\mathrm{e}^{\mathrm{j}\omega}) = \begin{cases} \mathrm{e}^{-\mathrm{j}\alpha\omega}, & |\omega| < \omega_c \\ 0. & \omega_c < |\omega| \le \pi \end{cases}$$

Group delay = ?

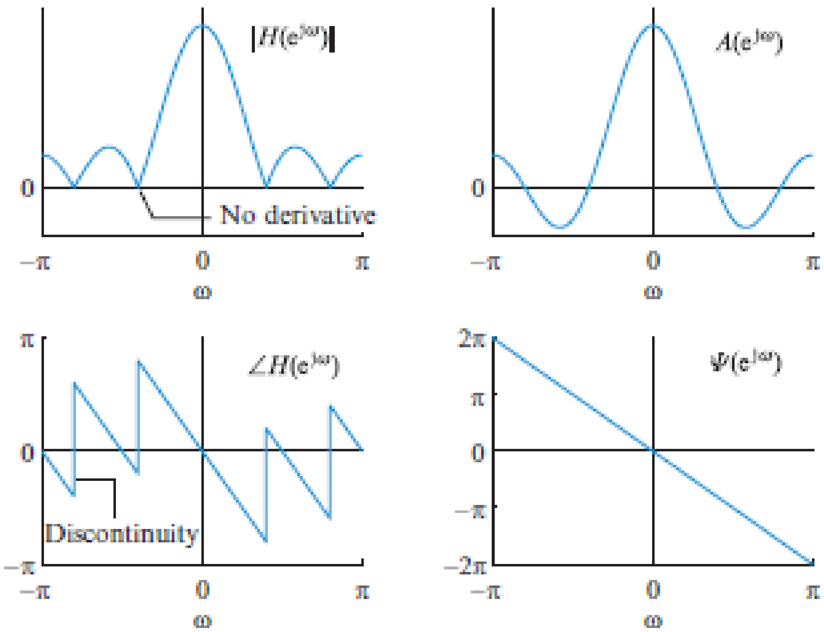


Figure 10.3 The differences between the magnitude and amplitude response representations of the frequency response function.

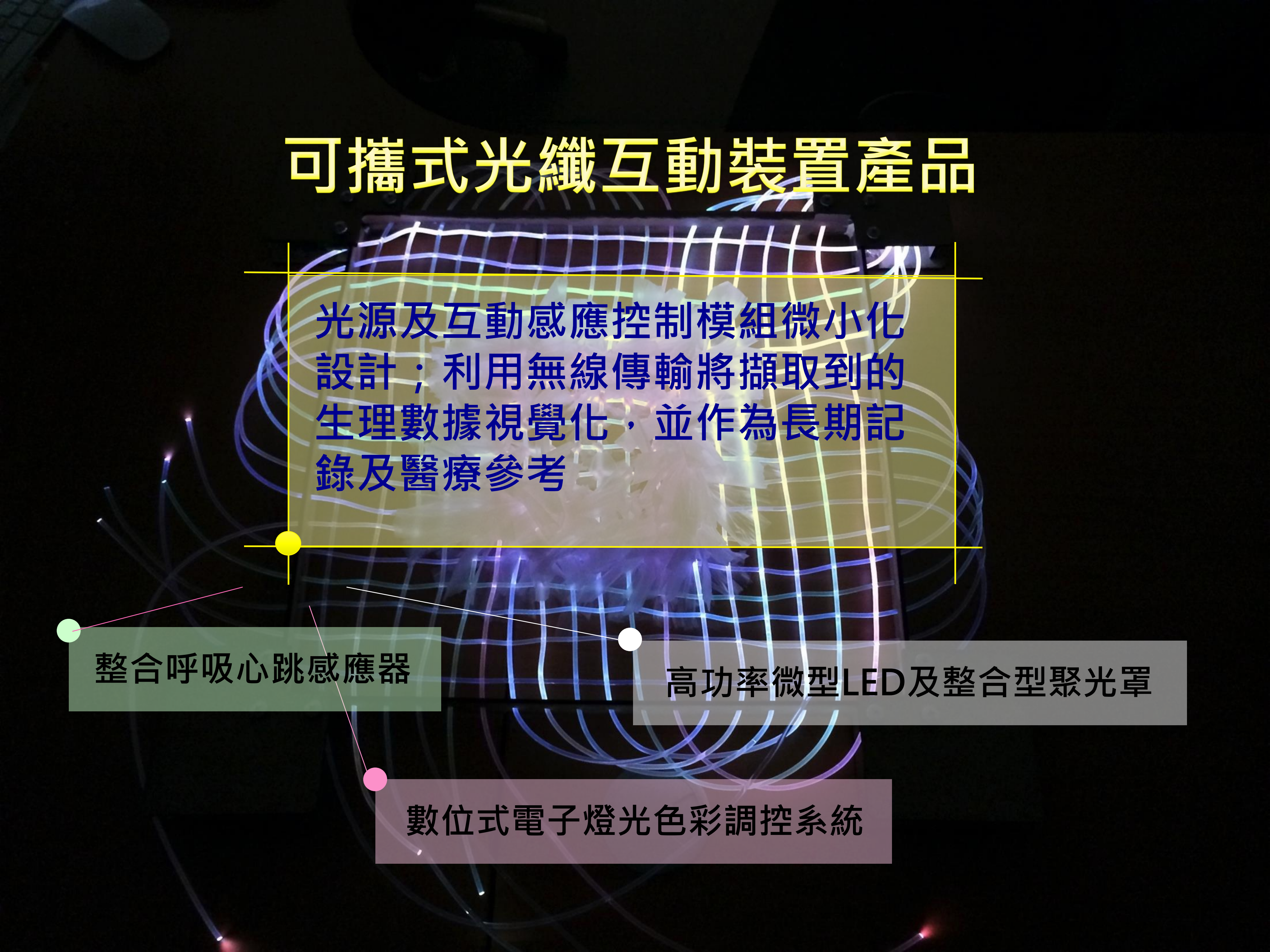
Table 10.1 Properties of impulse response sequence $h[n]$ and frequency response function $H(e^{j\omega}) = A(e^{j\omega})e^{j\Psi(e^{j\omega})}$ of FIR filters with linear phase.

Type	$h[k]$	M	$A(e^{j\omega})$	$A(e^{j\omega})$	$\Psi(e^{j\omega})$
I	even	even	$\sum_{k=0}^{M/2} a[k]\cos\omega k$	even–no restriction	$-\frac{\omega M}{2}$
II	even	odd	$\sum_{k=1}^{\frac{M+1}{2}} b[k]\cos\left[\omega\left(k-\frac{1}{2}\right)\right]$	even $A(e^{j\pi})=0$	$-\frac{\omega M}{2}$
III	odd	even	$\sum_{k=1}^{M/2} c[k]\sin\omega k$	odd $A(e^{j0})=0$ $A(e^{j\pi})=0$	$\frac{\pi}{2}-\frac{\omega M}{2}$
IV	odd	odd	$\sum_{k=1}^{\frac{M+1}{2}} d[k]\sin\left[\omega\left(k-\frac{1}{2}\right)\right]$	odd $A(e^{j0})=0$	$\frac{\pi}{2}-\frac{\omega M}{2}$

Table 10.2 Unified representation and uses of FIR filters with linear phase.

Type	M	$Q(e^{j\omega})$	$P(e^{j\omega})$	$H(e^{j\omega})=0$	Uses
I	even	1	$\sum_{k=0}^{M/2} \tilde{a}[k]\cos\omega k$		LP, HP, BP, BS, multiband filters
II	odd	$\cos(\omega/2)$	$\sum_{k=0}^{\frac{M-1}{2}} \tilde{b}[k]\cos\omega k$	$\omega=\pi$	LP, BP
III	even	$\sin\omega$	$\sum_{k=0}^{M/2} \tilde{c}[k]\cos\omega k$	$\omega=0,\pi$	differentiators, Hilbert transformers
IV	odd	$\sin(\omega/2)$	$\sum_{k=0}^{\frac{M-1}{2}} \tilde{d}[k]\cos\omega k$	$\omega=0$	differentiators, Hilbert transformers

Potential Final Projects


可攜式光纖互動裝置產品
光源及互動感應控制模組微小化設計；利用無線傳輸將擷取到的生理數據視覺化，並作為長期記錄及醫療參考
整合呼吸心跳感應器
高功率微型LED及整合型聚光罩
數位式電子燈光色彩調控系統

內外時鐘 Clock Inside Out

作品所傳遞的訊息是「外在與內在世界時間的差異與層次」，當觀眾配戴著生理感應器看到時鐘時，就進入了有別於外在世界的時間和空間，雖然時針和分針仍然隨著世界的時間在運轉，但秒針是依著觀眾的心跳節奏前進，隨著觀眾的呼吸速度亮暗。

Link “Heart Rate” with “Audio” or/and “Video” Play