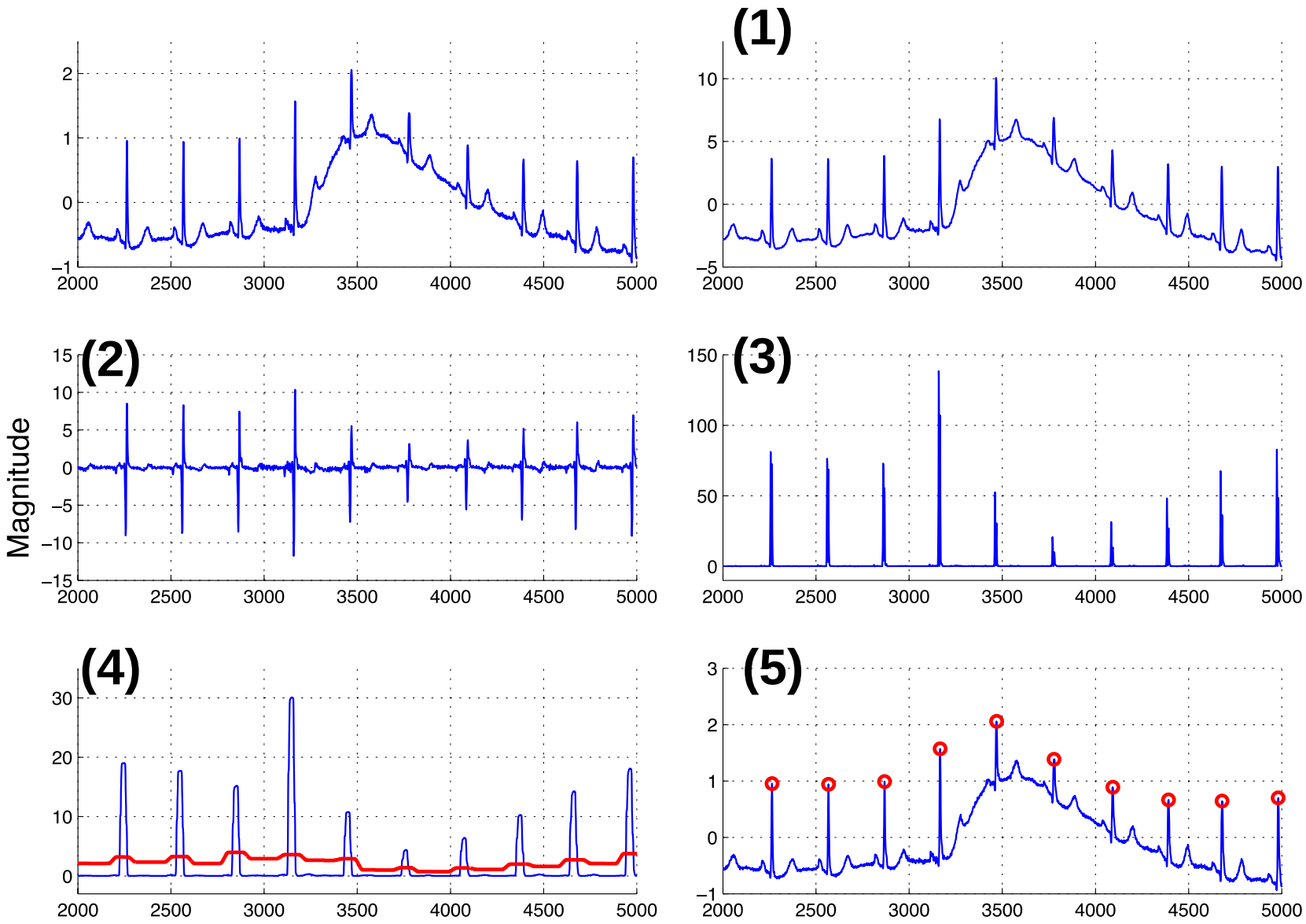
數位訊號處理實驗
Digital Signal Processing Laboratory
Lab 4
Heart Rate Estimation

Task 1

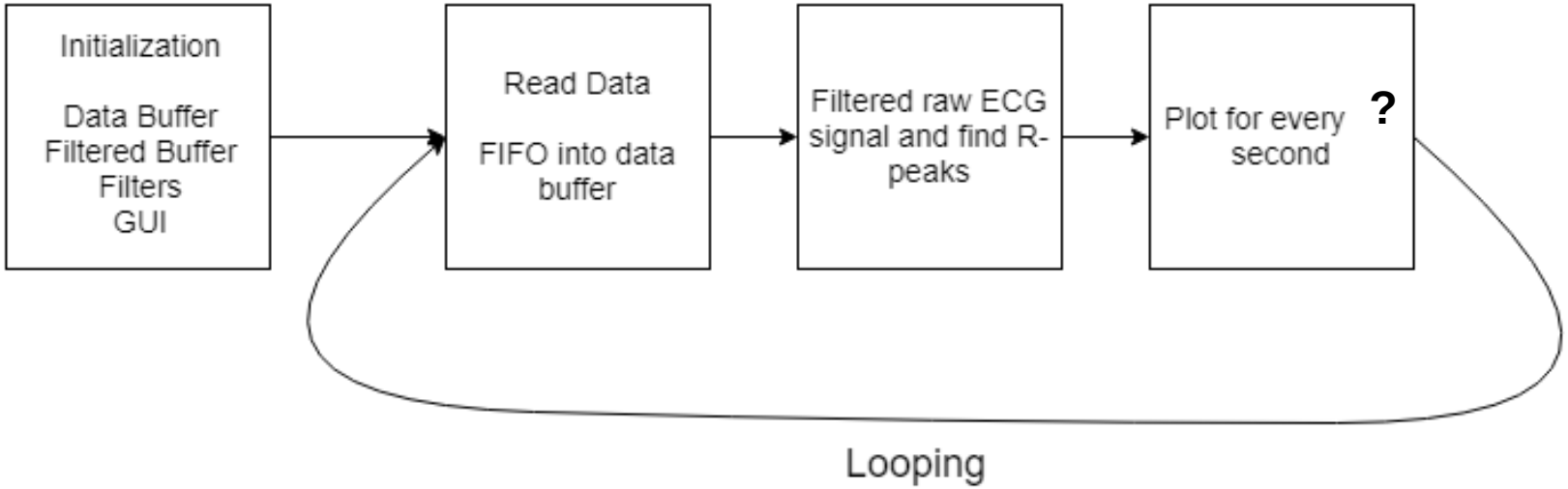
- Detect the R wave from your recorded ECG signals.

Pre-Processing of ECG Signals to Locate R Peaks (3/3)



Task 3

- Implement the pre-processing of the ECG signals(Lab 3) and R-peak detection in real time and display the processed ECG signals (i.e., noise-reduced 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
  - **The evaluation will depend on the average of the elapsed time for 100 loops of your signal processing and display (see ShortIntro2MatlabProfiler.pdf)**


Initialization
Data Buffer
Filtered Buffer
Filters
GUI
Read Data
FIFO into data buffer
Filtered raw ECG signal and find R-peaks
Plot for every second
?
Looping

Notes on Real Time Implementation: Time Profiling of Each Step

- **Sampling rate for data acquisition (Arduino side)**
- **Data transfer rate (Arduino to PC)**
- **FIFO handling**
- **Pre-processing: notch filtering (filter order), high pass filtering (filter order), squaring and flattening (LPF order), thresholding**
- **Peak finding**
- **Display**

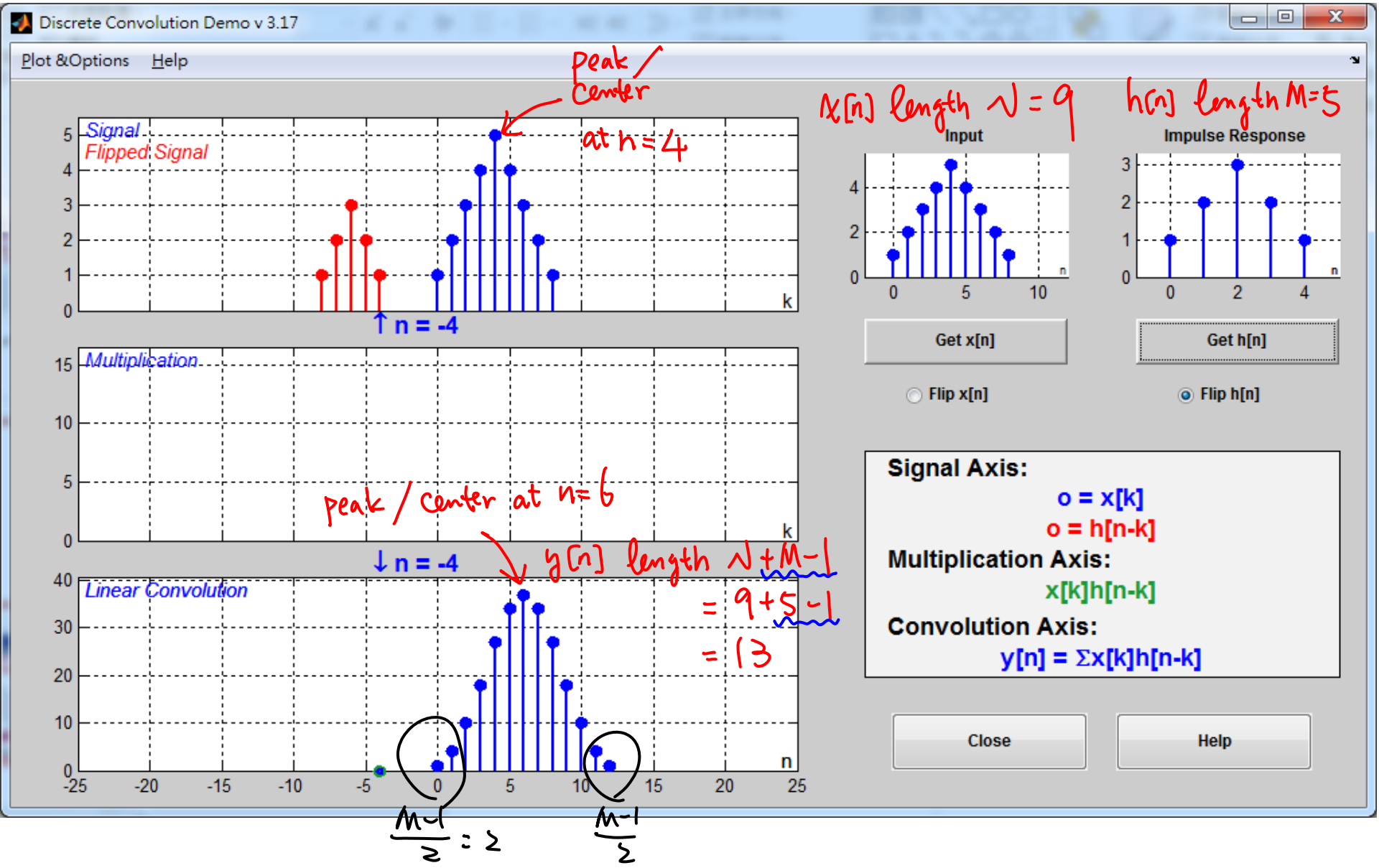
(See ShortIntro2MatlabProfiler.pdf, DisplayWithCorrectTiming.mov and DisplayWithIncorrectTiming.mov)

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.



peak / center at n = 4

x[n] length N = 9

h[n] length M = 5

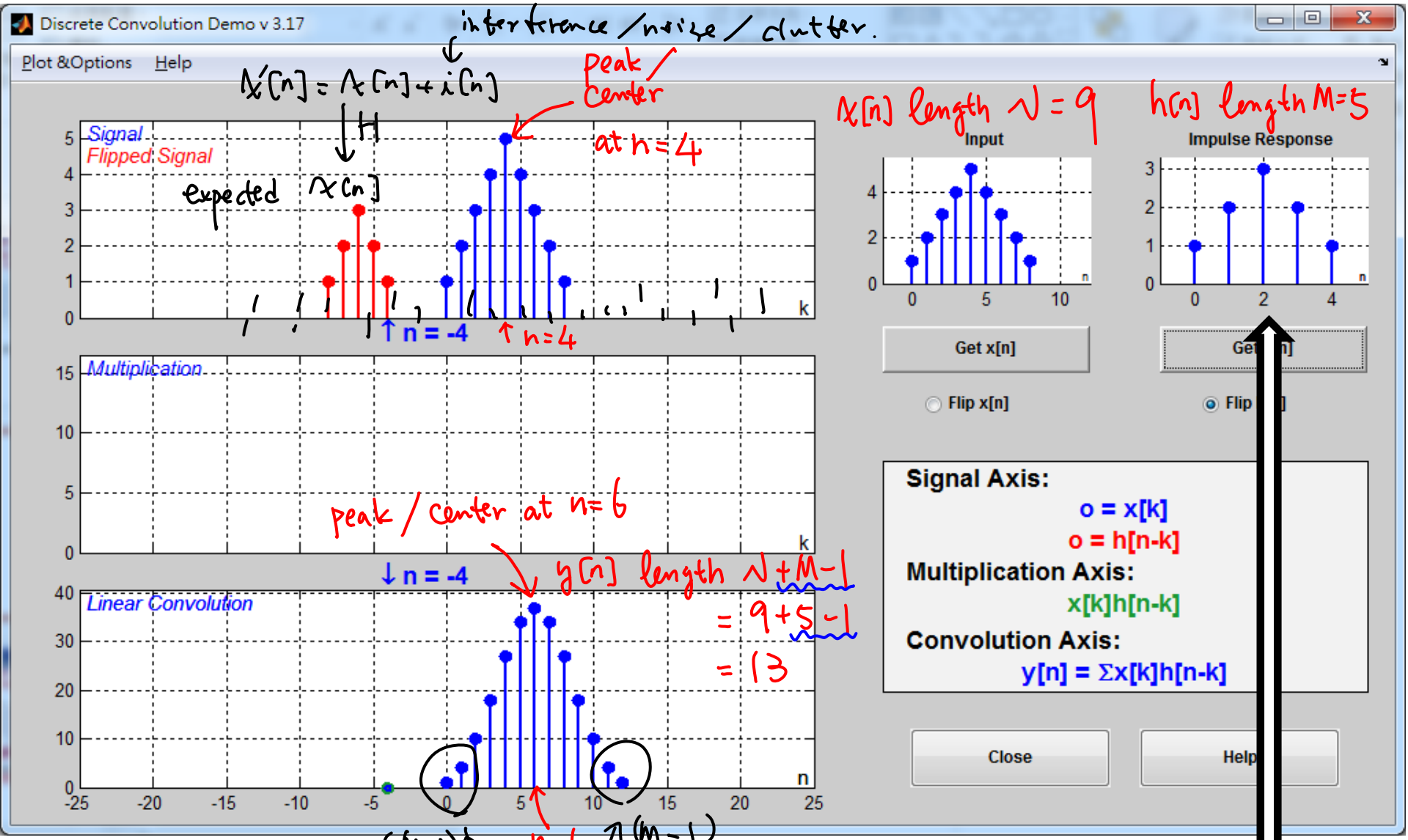
peak / center at n = 6

y[n] length N + M - 1 = 9 + 5 - 1 = 13

$\frac{M-1}{2} = 2$

$\frac{M-1}{2}$

y[n] vs x[n] ⇒ extra M-1 points



Linear phase FIR filter

y[n] vs x[n] ⇒ ① extra M-1 points ⇒ distortion

↳ x[n] ② delay (M-1)/2

Group delay (你希望M是奇數還是偶數?)

```
>> x = [ 1 2 3 4 5 4 3 2 1];
>> h = [ 1 2 3 2 1];
>> y = conv(x,h);
>> y_same = conv(x,h,'same');
>> figure
>> subplot(2,1,1)
>> stem([0:(length(x)+length(h)-1)-1], y);
>> subplot(2,1,2)
>> stem([0:length(x)-1], y_same);
>> axis([0 12 0 40])
>> title('y')
>> title('remove group delay')
```