Describe how you implemented the filter and convolutions to separate the mixed song. And how did you determine the filter size and cut-off frequency? (5%)

filter design:

TABLE 5.2	Equations for Ideal Impulse Responses for Standard Filters, Based on Cutoff Frequency f_c and Band Edge Frequencies f_1 and f_2	
Type of filter	$h_{ideal}(n),\ n \neq 0$	$h_{ideal}(0)$
Low-pass	$\frac{\sin(2\pi f_c n)}{\pi n}$	$2f_c$
High-pass	$-\frac{\sin(2\pi f_c n)}{\pi n}$	$1 - 2f_c$
Bandpass	$\frac{\sin(2\pi f_2 n)}{\pi n} - \frac{\sin(2\pi f_1 n)}{\pi n}$	$2(f_2 - f_1)$

```
for n = −N/2 to N/2
    if (n = 0) fltr(middle) = 1
    else fltr(n + middle) = sin(2*π*f_c*n)/(π*n)
fltr(middle) = 2*f_c
```

filter 的實作是參考 Unit4 投影片 p72 的公式及，不過為了加速運算，將 n 的 index 轉為 samplepts 的陣列表示。舉 low pass filter 為例：

samplepts :

-mid	-mid+1	...	-1	1	1	2	...	mid-1	mid

$$\text{low\_pass\_filter} = \frac{\sin\left(\boxed{\text{samplepts}} \times 2\pi f\_c\right)}{\boxed{\text{samplepts}} \times \pi}$$

convolutions:

$$\text{if } n \geq N$$

$$X = [x(n), x(n-1), x(n-2), \ldots, x(n-N+1)]$$

$$\text{else}$$

$$X = [x(n), x(n-1), \ldots, x(1), x(0), 0, \ldots, 0]$$

$$\text{filter} = [\text{filter}(0), \text{filter}(1), \ldots, \text{filter}(N-1)]$$

創建一個 X 如圖所示，其中 x 為 input signal，N 為 filter size。將 X 與 filter 內積 (np.dot)再取總和，即是 x 與 filter 的 convolution。
觀察發現 filter size 越大，band filter spectrum 在 cut-off frequency 處變動越大，最終選擇 filter size = 2001。
一開始參考 input signal 的 spectrum 決定 cut-off frequency。測試音檔後在微調 cut-off frequency（例如參雜到低音則調高 cut-off frequency。）

Compare the spectrum and shape of the filters.(5%)

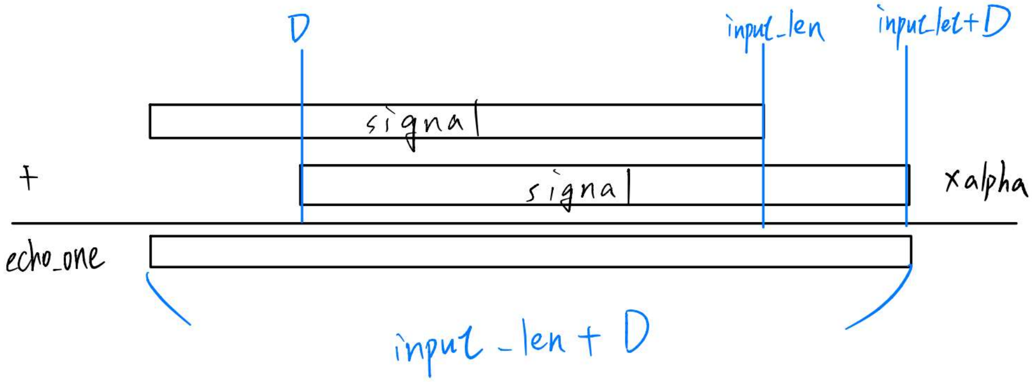
spectrum:
low pass 在 350hz 以下有值
band pass 在 400hz-750hz 有值
high pass 在 750 以上有值
shape:
low pass 在 middle 處有較寬的 concave
band pass 在 middle 處周遭的振幅較大
high pass 在 middle 處有較窄的 concave
（spectrum 及 filter 圖檔在跑好的 ipynb 檔裡）

Compare the differences between the signals before and after reducing the sampling rates.(5%)

band pass 及 low pass 聽不出差異，但 high pass 影響原本的音檔，原因是 sampling rate 未超過 nyquist frequency。

How did you implement one/multiple fold echo?(5%)

one fold



multiple fold