Contents

1 Filters

1.1 Requirements

- Band-pass filter, consisting of a high-pass and a low-pass filter.
  - High-pass blocks DC offsets
  - Low-pass high-frequency components not a part of the ECG signal
- 50 Hz twin notch filter
  - Filters out mains noise

Given that normal ECG signals range from 0.01 Hz to 100 Hz (Li et al., 2017), we may calculate the required circuit using equation (1). By having $C = 1\,\mu\text{F}$, we find R:

$$F_c = \frac{1}{2\pi RC} \tag{1}$$

$$R_{low} = \frac{1}{2\pi 10^{-6} 10^{2}} \simeq 1.6\,\text{k}\Omega$$
$$R_{high} = \frac{1}{2\pi 10^{-6} 10^{-2}} \simeq 16\,\text{M}\Omega$$
$$R_{notch} = \frac{1}{2\pi 10^{-6} 50} \simeq 3\,\text{k}\Omega$$

Given the limitation in the range of resistors available, the following were chosen: $2\,\text{k}\Omega$ and $1\,\text{M}\Omega$, corresponding to a signal range of 0.2 Hz to 80 Hz. While much shorter than what is required, the utilised oscilloscope is not able to register values below 0.2 Hz, and F_c refers to where $\frac{V_{out}}{V_{in}} = -3\,\text{dB}$. As we are dealing with non-ideal filters, there will still be a strong enough signal in the important range. Finally, this also implies that the tolerances of the resistors are largely ignored, as those are expected to be minimal sources of error compared to all other factors, including our circuit's configuration.

1.2 Characterisation

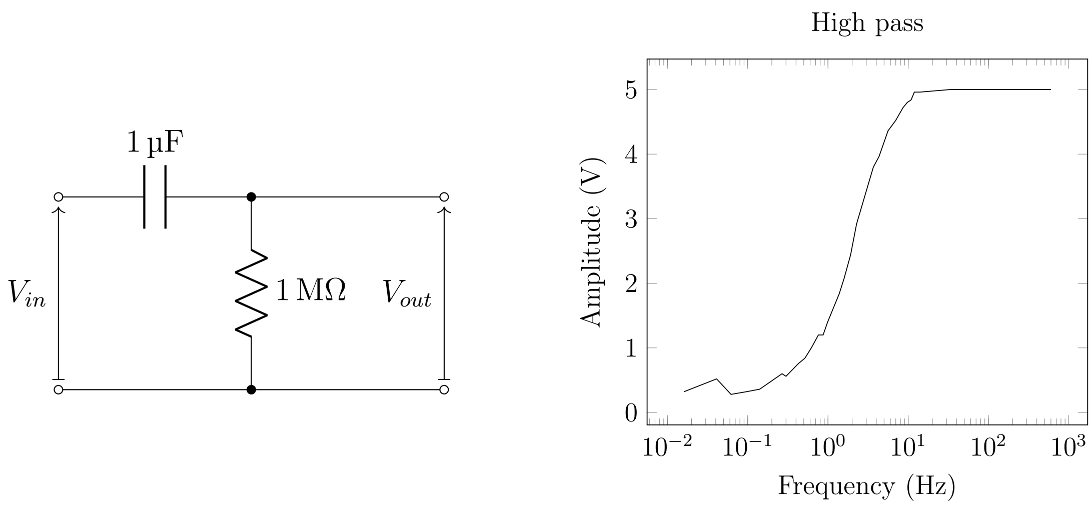


Figure 1: Circuit and characterisation of high pass filter.

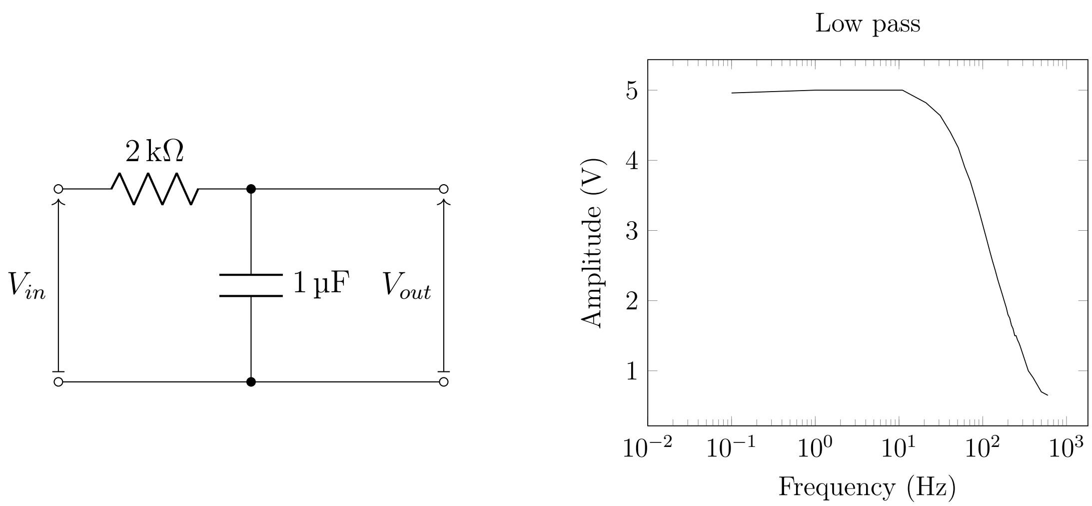
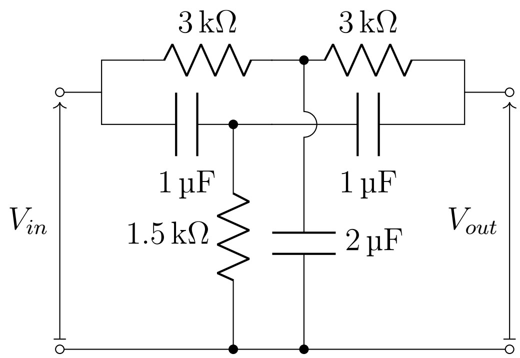


Figure 2: Circuit and characterisation of low pass filter.



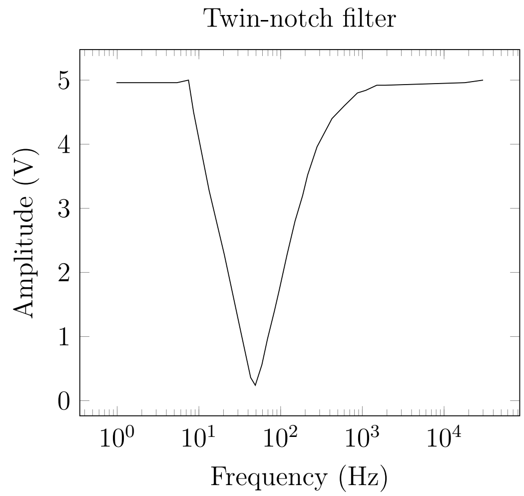


Figure 3: Circuit and characterisation of twin notch filter.

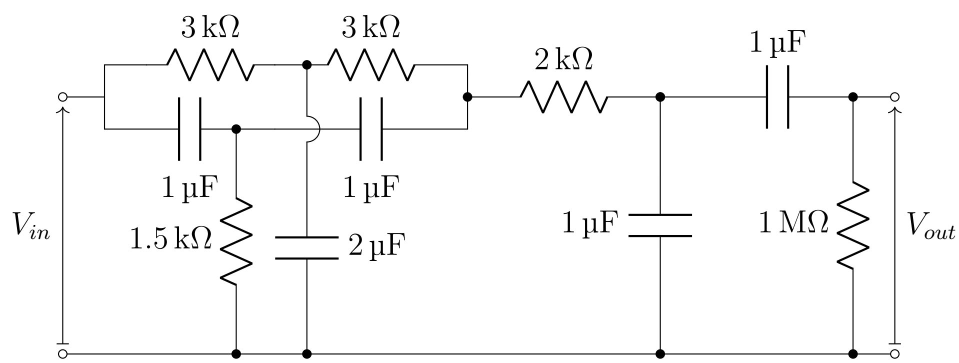


Figure 4: Combined filter circuit.

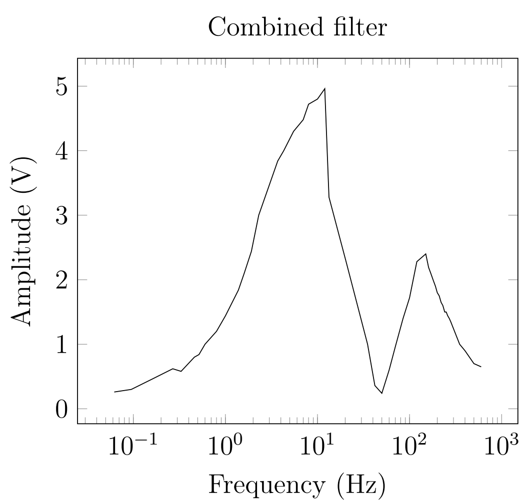


Figure 5: Combined filter characterisation.

2 Analysis

Please see Appendix, Table 2 for PR values and classification of each patient.

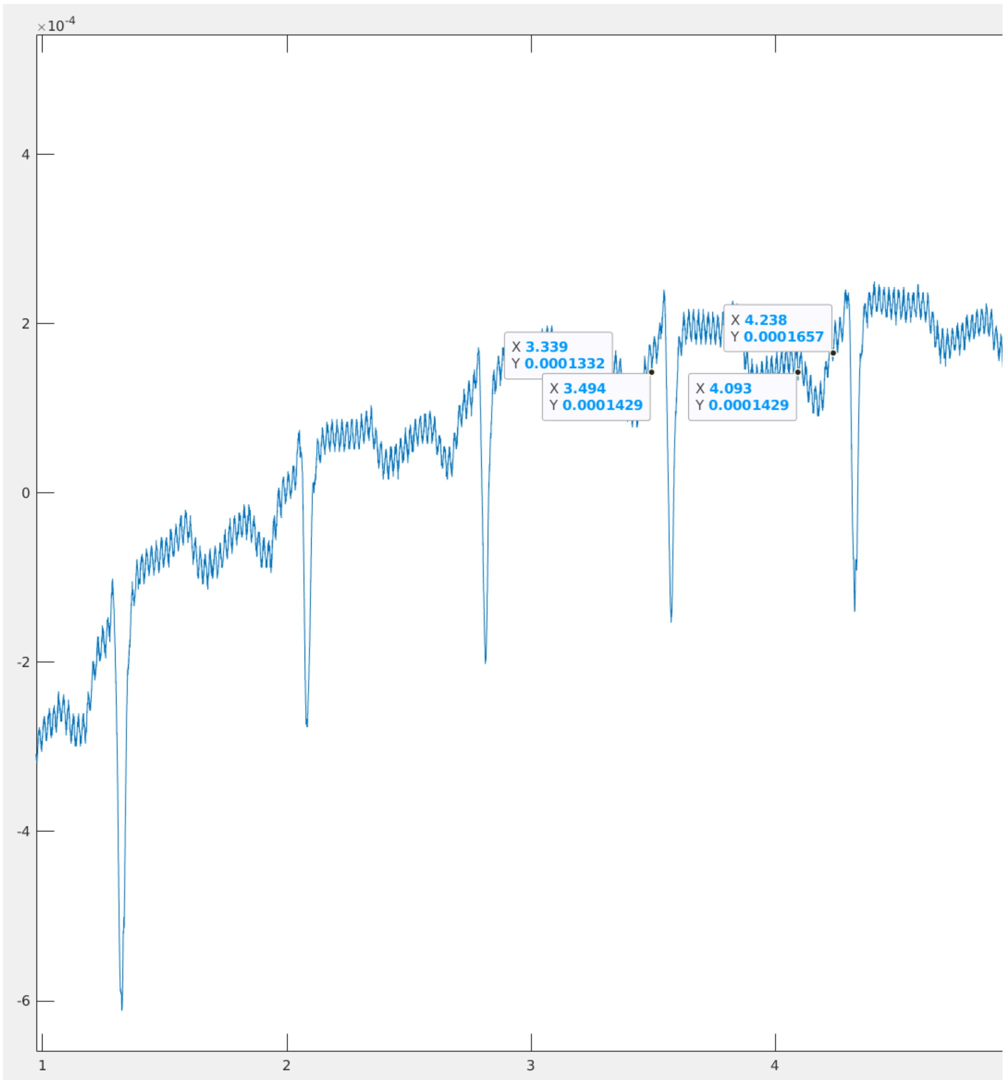


Figure 6: Using Matlab to estimate PR length. Notice the amount of noise, increasing uncertainty. Code in Appendix, Listing 1.

From which we may calculate:

$$\begin{aligned} \text{Sensitivity} &= \frac{2}{6} = 33.33\% \\ \text{Specificity} &= \frac{19}{24} = 79.16\% \end{aligned} \tag{2}$$

	Definitive Diagnosis	
Diagnostic test	Abnormal	Normal
Abnormal	2	5
Normal	4	19

Table 1: Comparison between gold standard and analysis using analogue filter circuit.

These results imply that 30% ($\frac{9}{30}$) of all patients would be given an incorrect diagnosis. Ethically a clinician could not present a diagnosis made solely with this circuit – especially given that it only caught first-degree heart block (FDHB) in $\frac{1}{3}$ of cases. Given the expectation that this filter arrangement was poor, this inaccuracy is unsurprising, but at the same time it is encouraging that true negatives were caught 79% of the time – perhaps making this valuable purely in supporting a negative diagnosis. Analogue circuits are, nevertheless, valuable for their simplicity and accomplishing the reduction of interference, which this circuit has (to some extent) successfully done.

Alternatively, one supplements the use of analogue circuits with digital filtering. There are several algorithms that attempt to perform the task – some more successful than others (García et al., 2018). Even filters with the ability to produce adaptive filtration, varying with the dynamic range of an ECG, have relatively low complexity – though they require hard-to-obtain external references (García et al., 2018). Indeed, this is a field in continuous development, and ultimately both analogue and digital filtration has to be used in conjunction.

3 Appendix

Listing 1: Import data and generate plots

```
clear;clc;
data=zeros(30,1); time=zeros(30,1);
for i = 1:30
    [data{i}, time{i}] = ECG_prac(i);
    plot(time{i}, data{i}(:,1));
    print(['./plots/patient_' num2str(i) '.eps'], '-depsc');
end
```

Listing 2: Specificity and Sensitivity

```
clc;clear;
load('gold.mat', 'gold');
data=[0 1 1 1 1 0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0 0 0];
results=zeros(2);
for i = 1:30
    if(data(i) == 1 && gold(i) == 1)
        results(1,1) = results(1,1)+1;
    elseif(data(i) == 1 && gold(i)==0)
        results(1,2) = results(1,2)+1;
    elseif(data(i) == 0 && gold(i)==1)
        results(2,1) = results(2,1)+1;
    elseif(data(i) == 0 && gold(i)==0)
        results(2,2) = results(2,2)+1;
    end
end

sickPeople = numel(gold(gold==1));
healthyPeople = numel(gold(gold==0));
```

Patient No.	PR Interval 1	PR Interval 2	PR Interval 3	Average	Status
1	0.182	0.180	0.181	0.181	Normal
2	0.309	0.427	0.406	0.381	PR $\geq$ 200 ms
3	0.620	0.620	0.621	0.620	PR $\geq$ 200 ms
4	0.399	0.324	0.302	0.342	PR $\geq$ 200 ms
5	0.279	0.300	0.178	0.252	PR $\geq$ 200 ms
6	0.183	0.213	0.133	0.176	Normal
7	0.182	0.220	0.150	0.184	Normal
8	0.200	0.183	0.156	0.180	Normal
9	0.132	0.122	0.121	0.125	Normal
10	0.250	0.162	0.182	0.198	Normal
11	0.475	0.459	0.559	0.498	PR $\geq$ 200 ms
12	0.181	0.198	0.165	0.181	Normal
13	0.181	0.183	0.201	0.188	Normal
14	0.128	0.161	0.120	0.136	Normal
15	0.090	0.138	0.132	0.120	Normal
16	0.180	0.112	0.158	0.150	Normal
17	0.219	0.202	0.180	0.200	PR $\geq$ 200 ms
18	0.172	0.199	0.182	0.184	Normal
19	0.113	0.143	0.144	0.133	Normal
20	0.202	0.181	0.130	0.171	Normal
21	0.118	0.141	0.138	0.132	Normal
22	0.088	0.089	0.093	0.090	Normal
23	0.159	0.280	0.131	0.133	Normal
24	0.124	0.087	0.112	0.280	Normal
25	0.200	0.200	0.260	0.220	PR $\geq$ 200 ms
26	0.086	0.179	0.113	0.126	Normal
27	0.159	0.147	0.191	0.166	Normal
28	0.127	0.179	0.142	0.149	Normal
29	0.200	0.159	0.201	0.187	Normal
30	0.169	0.132	0.179	0.160	Normal

Table 2: Consecutive PR intervals, average and patient classification

References

Jianqiang Li, Genqiang Deng, Wei Wei, Huihui Wang, and Zhong Ming. Design of a real-time ECG filter for portable mobile medical systems. *IEEE Access*, 5:696–704, 2017. ISSN 2169-3536.

Manuel García, Miguel Martínez-Iniesta, Juan Ródenas, José J Rieta, and Raúl Alcaraz. A novel wavelet-based filtering strategy to remove powerline interference from electrocardiograms with atrial fibrillation. *Physiological measurement*, 39(11):115006, 2018. ISSN 09673334.