ECG Monitor Developing Report

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Introduction

ECG monoitor is a medical equipment designed to monitor the heart beating of a patient. It detects the electrical signal on the patient's skin and always display it on a screen, which can reflect the electrical activity of the heart over a period. Alexander Muirhead is reported to have attached wires to a feverish patient's wrist to obtain a record of the patient's heartbeat in 1872 at St Bartholomew's Hospital, which should be the oldest version of ECG. Then Augustus Waller used a Lippmann capillary electrometer and a projector to successfully record to heartbeat in real time. An initial breakthrough came when Willem Einthoven who was awarded the Nobel Prize in Medicine used the string galvanometer he invented in 1901 to record the heartbeat. And he assigned the letters P, Q, R, S, and T to the various deflections. He also described the electrocardiographic features of a number of cardiovascular disorders. Nowadays, engineers have developed 12-lead ECG that are widely used in hospital. **Figure 1** shows a typical ECG result in one peroid [1].

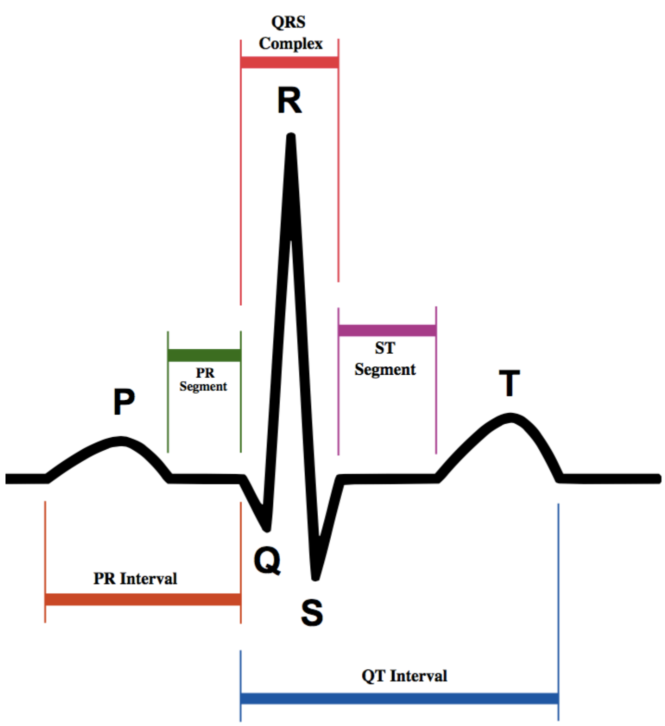

Figure 1 A typical ECG result in one peroid

The reason why people want to make ECG is obvious. People wanted to record the heartbeat. And when they made it, they found some relationships between heart diseases and the patients' ECG. So ECG has been strongly developed and widely uesd in monitoring sepecially for Intensive Care Unit. The reason why we want to do it is that in this way we can understand how a typical medical equipment works and how it is developed deeply. Futhermore, we can learn some enginerring and signal processing knowledge, which is the base of biomedical engineering.

Heartbeat can result heart muscle depolarizing, a very tiny electrical signal on skin, that can be detected by electrodes. So the basic idea is to get the electrical signal on skin by electrodes and then process it by amplify and filter and finally display it.

The new trends for ECG can be divided into three parts. One is that engineers try to develop smaller ECG monitor so that people can wear it all the time and almost with no feeling. Another one locates at the ECG data transmission, engineers hope data can be transmitted to the hospital immediately. The third one is doctors and computer scientists want to develop new algorithms to detect more diseases from ECG results with high efficiency and accuracy. The problems on these areas are difficiulties in power supply for small device, data transfer from the samll device and data privacy, disease dignosis. So we still need to make efforts on these aspects and related areas.

Methods

In Biomedical Engineering Class at SUSTC, we use "SUSTC_ECG_DEMO_V2.0-PCB" to finish the anolog part of this project. **Figure 2** shows the circuit diagram of the board. The PCB contains five parts: Power supply, Instrumentation Amplifier, Bandpass Filter, 50Hz-Notch Filter, and Noninverting Ampilfer. The reason why we choose this design is that it can produce a good and stable ECG and it contains the basic part of a ECG circuit board. And it is not very complex so that we can finish it.

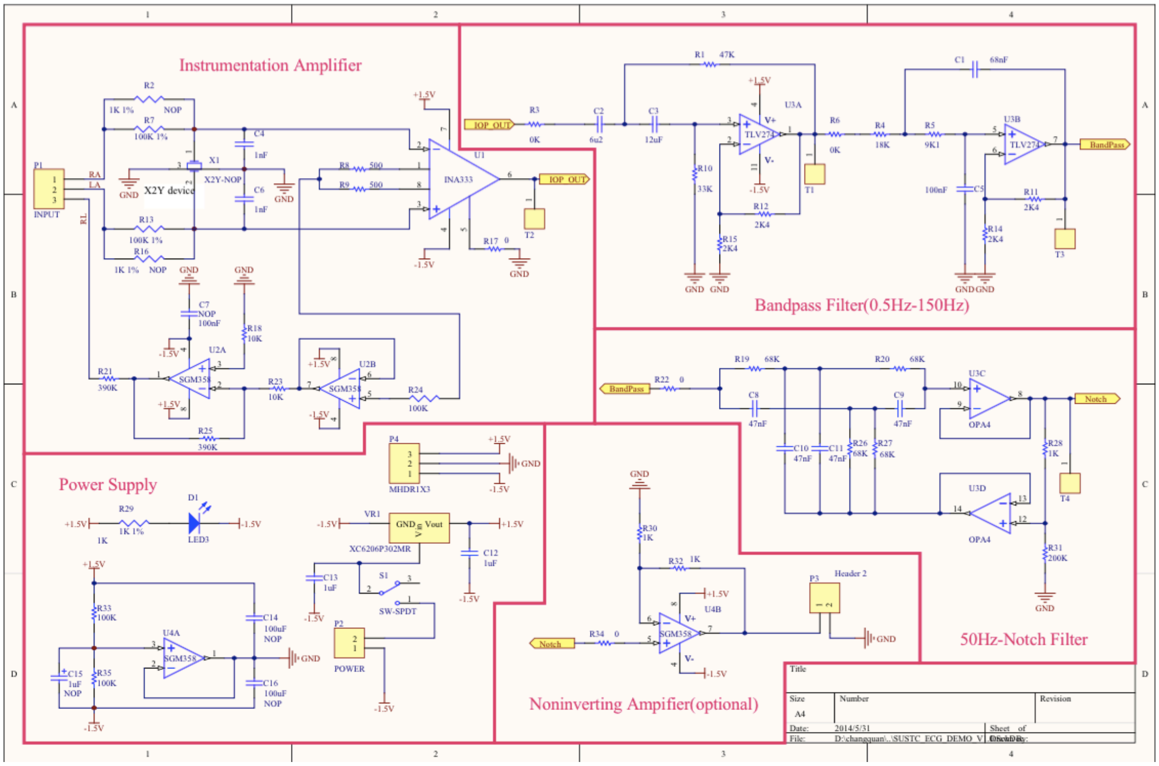

Figure 2 The Circuit Diagram of SUSTC_ECG_DEMO_V2.0-PCB [2]

The functions for each part are explained here. Power supply is designed to connect the battery so we can power the board and use it conveniently. It can also be powered by a plower supply instrument. Instrumentation amplifier contains a differential amplifier and a right leg drive circuit. Input at the differential amplifier is the entrance for the signal gotten by the electrodes. It amplifies the difference between two electrodes for following process. Right leg drive circuit is designed to balance the noise at two electrodes so that remove the noise to some extends. Bandpass filter is used to filter the very high and very low signals that is not the ECG signal. 50Hz-Notch Filter is used to filter the 50Hz City Power frequency interference, which is very strong and annoying. Non inverting Amplifier is used to amply the signal we get to a better amplitude.

We used waveform generator (RIGOL DG1032Z), oscilloscope (RIGOL DS1074Z), DC power supply (RIGOL DP832) multimeter, welding sets, and TINA-TI to debug our circuit. The debug method can be simply described one part at a time. Firstly, when I soldered a component, I check the connection by multimeter. And I soldered all parts independently. Then Use multimeter to debug the power supply part. After that, I used waveform generator and oscilloscope to debug the other four parts by inputing a signal and testing the output. After all parts were passed the test, I soldered all parts together. And then test the whole system by input the very small input and also by measuring my ECG. And I also changed the resister in 50Hz-Notching Filter and before this I had used the TINA-TI to simulate the results.

At first, I did not notice that we should use 50K for R31 as we designed and I had used 200K as the PCB circuit showed. I found the lowest output is 0.112Vpp when input is 2Vpp. And I had tried my best to find four capacitors of the nearest capacitance. But the result was almost the same. I also noticed that when using 200K, when input frequency is 47 or 53, the output is the same as input. So the Q value should be very high. But it's hard to find the idea lowest output frequency. Then someone told me that we should use 50K for R31 as teacher told us. Then I changed it. And I found that the lowest output is 0.42Vpp when input is 2Vpp at 51.4Hz. And the Q factor should be decreased so we can test that point. So I guess that resistor is related to change the Q factor of the twin-T filter. To verify this hypothesis, I have searched on the internet to find how to calculate the Q factor value. But it's too complicated. Then I think I can simulate the situation with Tina-TI. So I do it. And the result is shown in **Figure 3**. The result is interesting. The minimum Gain(-6) is much lower than that of R31=50K whose minimum Gain is about -16(can be found in Lab5_PrelabGS_ 2015.docx). And the Q factor is 34.28, which is much larger than that of R31=50K (11.77). So it's normal that I encountered the problem when using 200K. In addition, The result I got using 50K, the minimum Gain is about -14. It's very close to the simulation result(-16).

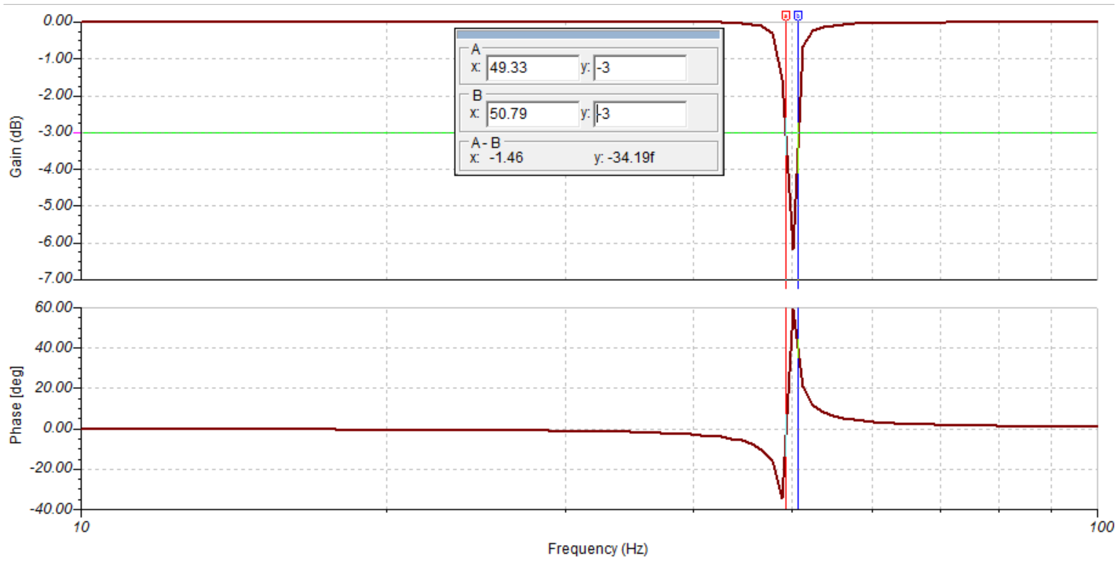

Figure 3 The simulation for twin-T circuit with R31=200K

After I succesfully tested the whole circuit by signal from Waveform generator. I spent a lot of time to debug it on testing my ECG. At first, there was no any signal no matter how I tried. Then I used my circuit to test another person. Then I noticed a possible ECG signal by chance. After that, I relized that we should clamp the electrodes on hands so that they could touch the atteries. I used ethanol to wash my skin and applied saline water onto it. Then the signal became more stable. And I also noticed that when I put my hands on pans, the 50Hz frequency interference became much smaller. Then I got my ECG showing below.

Results

The final ECG results are shown in **Table 1 Heat Rate results** and **Figure 4 ECG signal got from SUSTC_ECG_DEMO_V2.0-PCB**. It's a very good wave that shows the ECG waveform clearly. But it still contains some 50Hz noise.

Table 1 Heat Rate results

	1	2	3	Average
Cycle(ms)	880	825	850	851.67
Heart Rate(bpm)	68.1	72.7	70.6	70.5

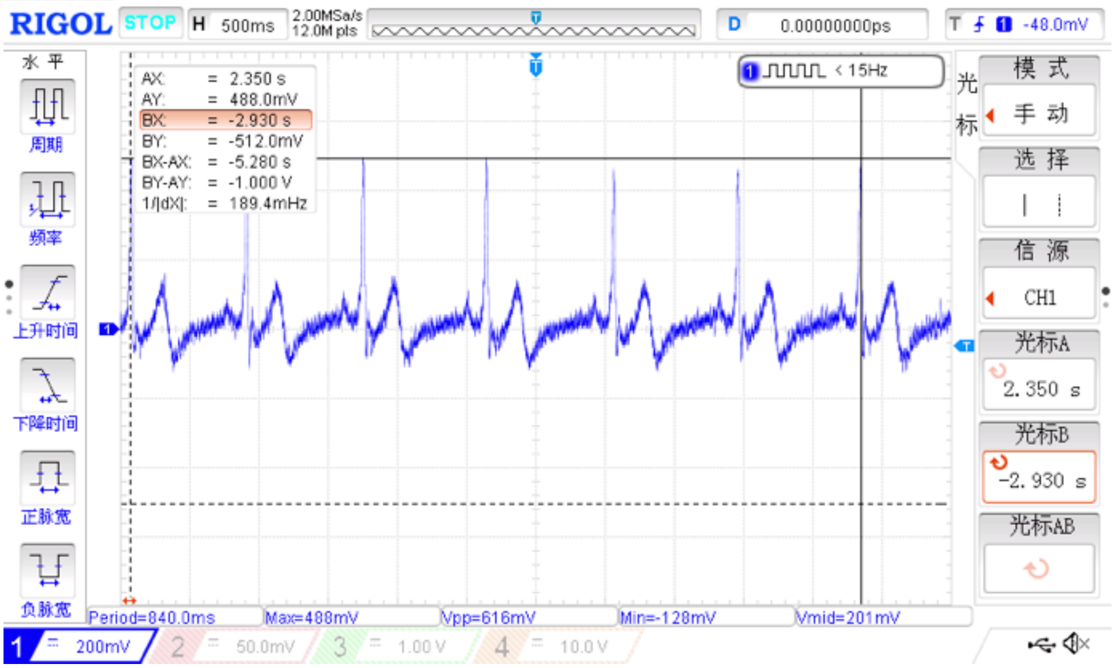

Figure 4 ECG signal got from SUSTC_ECG_DEMO_V2.0-PCB

The instrumentation amplifier circuit test results are shown in Table 2.

Table 2 Instrumentation amplifier circuit test results

Input Vpp	Output Vmax	Output Vmin	G_{in}
20mV	1.02V	-1.0V	101

I used the following strategy to test the right leg drive circuit. Use wave generator to produce a 50mVpp square wave with 20% duty cycle. Input the wave at Pin5 of U2B. Test the output at Pin3 of P1 by oscilloscope. The output Vpp is 1.96V with 80% duty cycle. Then use a sin wave to test it. Input:50mVpp, Output Vpp is 1.96V and the wave is also a sin wave. So it is an inverting amplifier circuit and the tested Gain is -39.2.

The Bandpass filter's testing results are shown in **Table 3** and **Figure 5**.

Table 3 Bandpass filter's testing results

Frequency(Hz)	V_i p-p (V)	V_op-p (V)	measured gain	measured gain in dB
10	0.5	2.02	4.04	12.1276273
30	0.5	2.02	4.04	12.1276273
50	0.5	2.02	4.04	12.1276273
80	0.5	1.90	3.8	11.59567193
100	0.5	1.78	3.56	11.02899996
120	0.5	1.62	3.24	10.2109002
130	0.5	1.52	3.04	9.657471672
140	0.5	1.42	2.84	9.066366801
150	0.5	1.34	2.68	8.562695881
160	0.5	1.24	2.48	7.889033617
170	0.5	1.14	2.28	7.15869694
180	0.5	1.06	2.12	6.526717219
200	0.5	0.94	1.88	5.483156985
240	0.5	0.68	1.36	2.670778167
280	0.5	0.5	1	0
320	0.5	0.42	0.84	-1.514414279
5	0.5	2.02	4.04	12.1276273
4	0.5	2.02	4.04	12.1276273
3	0.5	1.98	3.96	11.95390372
2	0.5	1.90	3.8	11.59567193
1.8	0.5	1.86	3.72	11.4108588
1.6	0.5	1.82	3.64	11.22202767
1.4	0.5	1.74	3.48	10.83158488
1.2	0.5	1.62	3.24	10.2109002
1.0	0.5	1.46	2.92	9.307657029
0.96	0.5	1.42	2.84	9.066366801

0.9	0.5	1.34	2.68	8.562695881
0.8	0.5	1.22	2.44	7.747796527
0.6	0.5	0.86	1.72	4.710568938
0.4	0.5	0.42	0.84	-1.514414279
0.2	0.5	0.14	0.28	-11.05683937

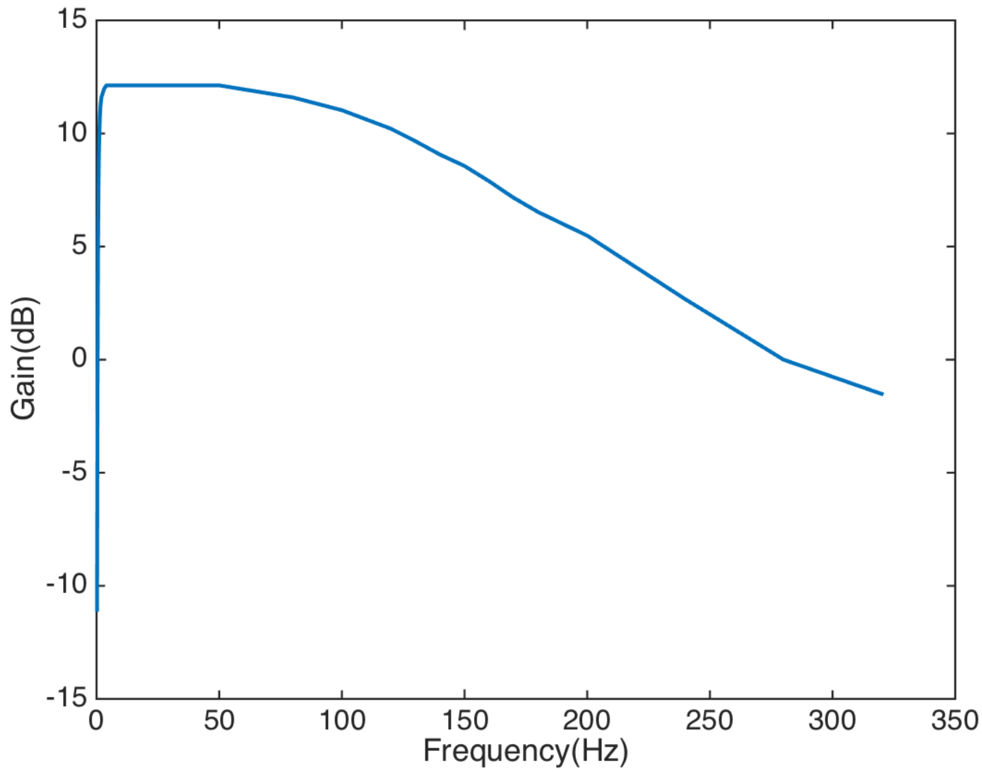

Figure 5 The amplitude-frequency response curve for Bandpass filter

The -3dB frequency = 0.96Hz and 140Hz. Bandwidth = 139.04Hz; The Center Frequency = 70.48Hz. Q factor = 0.507.

The 50Hz Notch filter's testing results are shown in **Table 4** and **Figure 6**.

Table 4 50Hz Notch filter's testing results

Frequency(Hz)	**V_i p-p (V)**	**V_op-p (V)**	**measured gain**	**measured gain in dB**
0.5	2	2.02	1.01	0.086427476
10	2	2.02	1.01	0.086427476

20	2	2.02	1.01	0.086427476
30	2	2.02	1.01	0.086427476
40	2	2.00	1	0
45	2	1.94	0.97	-0.264565315
48	2	1.76	0.88	-1.110346557
49	2	1.58	0.79	-2.047458174
49.6	2	1.42	0.71	-2.974833026
50	2	1.22	0.61	-4.2934033
51	2	0.58	0.29	-10.75204004
51.4	2	0.42	0.21	-13.55561411
52	2	0.58	0.29	-10.75204004
53.8	2	1.42	0.71	-2.974833026
55	2	1.66	0.83	-1.618438152
60	2	1.94	0.97	-0.264565315
70	2	2.00	1	0
80	2	2.02	1.01	0.086427476
100	2	2.02	1.01	0.086427476

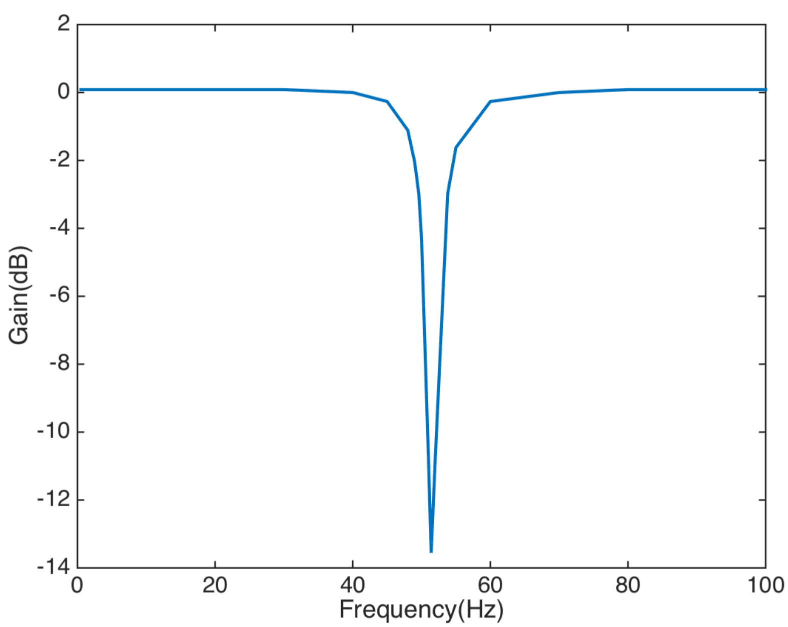

Figure 6 The amplitude-frequency response curve for 50Hz Notch filter

The -3dB frequency = 49.6Hz and 53.8Hz. Bandwidth = 4.2Hz; The Center Frequency = 51.7Hz. Q factor = 12.3.

Discussion

It did not take me a lot of time to debug the whole analog part for amplify the signal generated from the waveform generator. I think this should owe to the habit that "when I soldered a component, I check the connection by a multimeter". So checking your work immediately is very important. When something is wrong, you should keep all others the same and change one factor to see the results. When I found there was no signal for my heart beat at first. I changed the input into Waveform generator and tested it again. However, the output was normal. So I was sure that it's the electrodes connection problem. And finally I found some tricks mentioned in Methods part and made it. Another thing is that one should never give up. In a project, there are always many problems, you should solve them one by one with systematic strategies.

For the 50Hz Notch Filter part, I did not choose four capacitors as near as possible from many capacitors. I thought in that way, we waste many. Maybe I should do like that to make the circuit better. Another part we can improve is that we can arrange the wire into a way that they introduce the smallest noise. We should do control experiment for that. And we can find a better environment to perform the test so that the noise is at a very low state.

Next, what I am going to do is to finish the improvements mentioned above. And then finish to digital part and connect the two parts together.

References

[1] https://en.wikipedia.org/wiki/Electrocardiography

[2] SUSTC_ECG_DEMO_V2.0-PCB.pdf given by teacher