Department of Electronic and Telecommunication Engineering
University of Moratuwa

BM4111 - Medical Electronics and Instrumentation

Building an Instrumentation Amplifier - Part II

Practical Circuit Implementation and Evaluation

Group Members

P.M.N.S. Bandara	180066F
S.S. Hettiarachchi	180237G
H.D.M. Prematilaka	180497C

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Contents

Introduction and Post Analysis

The following observations were made while carrying out certain modifications to further enhance the performance of the instrumentation amplifier circuit implementations:

- A high pass filter with $R = 1M\Omega$ and $C = 1\mu F$ was added to the output of the instrumentation amplifiers to remove possible DC offsets.
- Using the MATLAB-based receiver class, a $50Hz$ notch filter was employed to suppress powerline interference.
- A bandpass filter (from $0.1Hz$ to $45Hz$) was included to limit the effect of external noise in the acquired signal.
- To test the functionality of the driven right leg (DRL) circuit, recordings were taken with and without the DRL circuit. It was realized that the DRL is essential to handle the effects of common mode voltage.
- A single-turn coil can be created by the lead wires and a nearby magnetic field could result in inductive coupling. Accordingly, the lead wires were twisted appropriately to negate the effects of inductive coupling. The optimal wire connections without loopy jumpers were attempted to further reduce possible inductive coupling.
- During the recordings, it was ensured that the laptop is not connected to the AC power supply to further minimize the effects of interference.
- Any relative movement between the electrodes and electrolytic gel would induce motion artefacts and thus, the subject was asked to keep the hands still to avoid such artefacts.
- Common mode interference is prominent when there is a reasonable electrode impedance mismatch. Accordingly, resistors and capacitors with lower tolerance values were used.
- Better results could have been observed if appropriate shielding techniques were used to suppress the effects of capacitive coupling.
- WiFi module of the Feather-board could be a source of interference that corrupts the incoming biological signal. Preferably, the Feather-board should be placed at a considerable distance away from INA and DRL circuits. However, since we had to implement the entire circuit on a single breadboard, the separation was not that significant.

Circuit Implementation 1: LM358 and LMP7701 based Instrumentation Amplifier

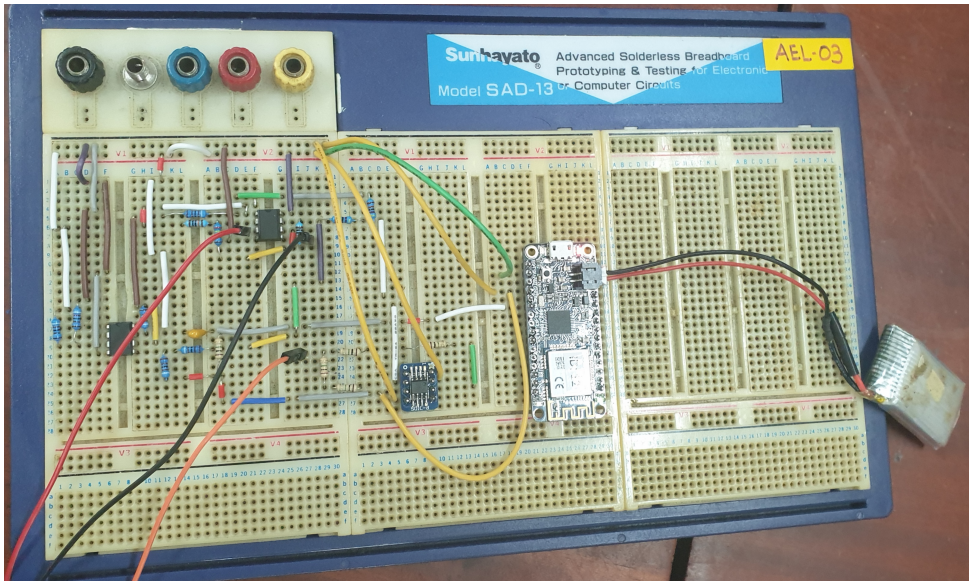

Figure 2.1: Implementation of Circuit 1

As anticipated through the initial calculations using CMRR, there is a significant common mode interference in this implementation (since this implementation had the worst CMRR which was $60dB$), mostly due to powerline interference.

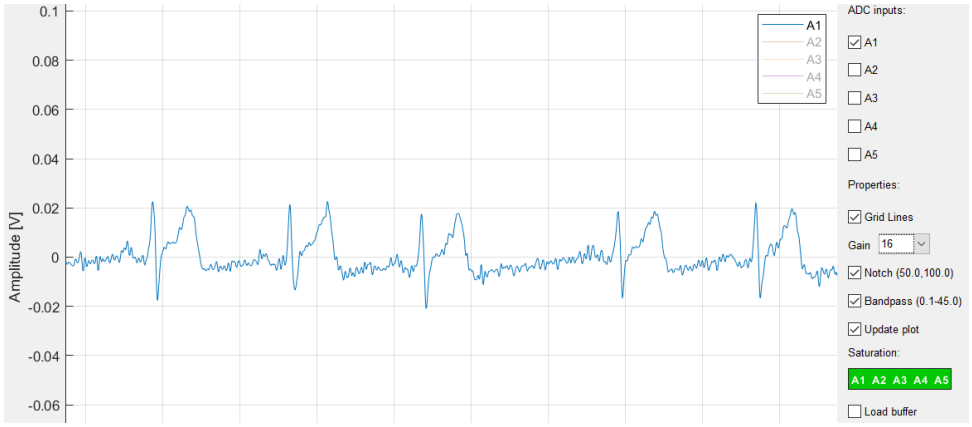

Figure 2.2: Recorded Signal from Circuit 1 after Filtering with Notch and Bandpass Filters

When the notch and bandpass filters were applied using MATLAB receiver class, the expected morphology of the ECG signal was able to be extracted, but with certain corrupted patterns/modifications such as having unexpected sharp dips and elevations within and/or after the local peaks of the ECG waveform such as the elevation of T-wave. This is possibly due to the IIR-based filter implementation in MATLAB which is typically a set of filters with non-linear phases.

Circuit Implementation 2: LMP7701 and LMP7702 based Instrumentation Amplifier

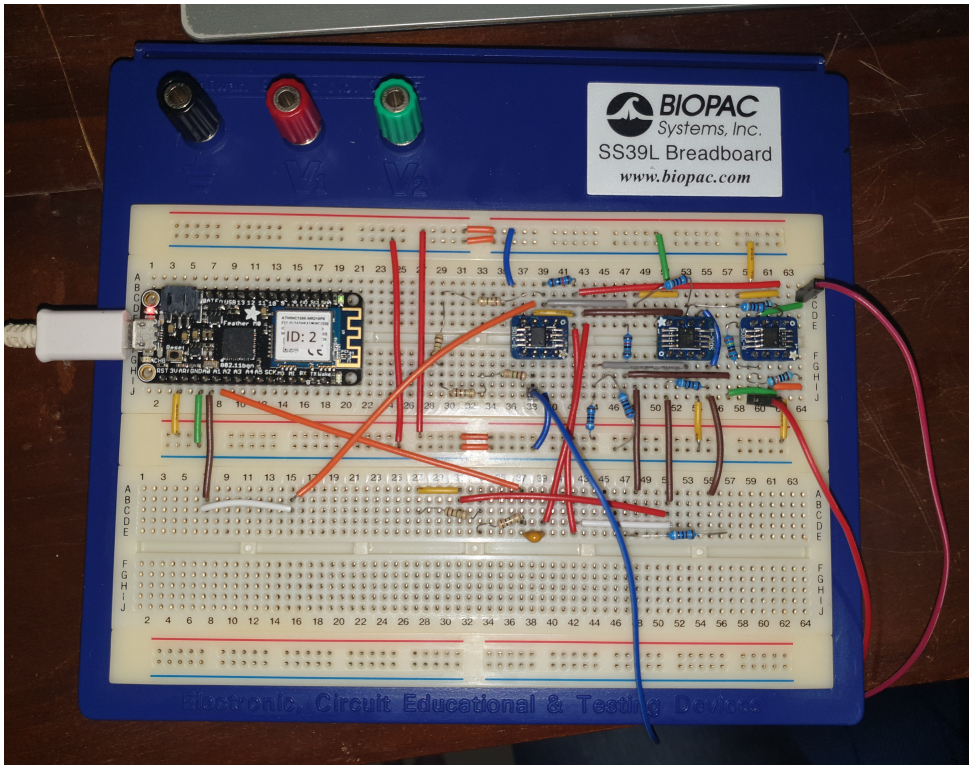

Figure 2.3: Implementation of Circuit 2

The only circuit-wise difference between the first and second circuits is the use of 2 LMP7702s in place of the LM358s. Other than this modification, the resistors, capacitors and circuit configurations are similar. Circuit implementation-2 produces better results compared to the first implementation owing to the superior CMRR of the LMP7702 (relative to the LM358's CMRR).

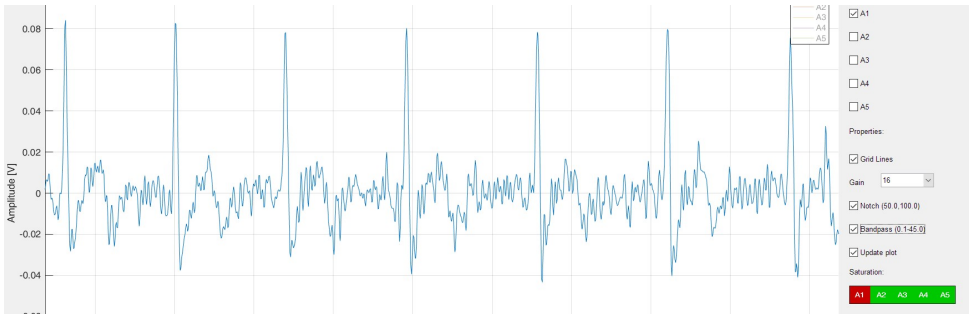

Figure 2.4: Recorded Signal from Circuit 2 after Filtering with Notch and Bandpass Filters

As we can observe from the above diagram, it is evident that the second implementation has managed to recover the characteristic shape of the ECG waveform. However, a considerable trace of noise is visible in the waveforms and the noise has dominated the PR and ST segments of the ECG signal.

Circuit Implementation 3: LMP7702 and AD8276 based Instrumentation Amplifier

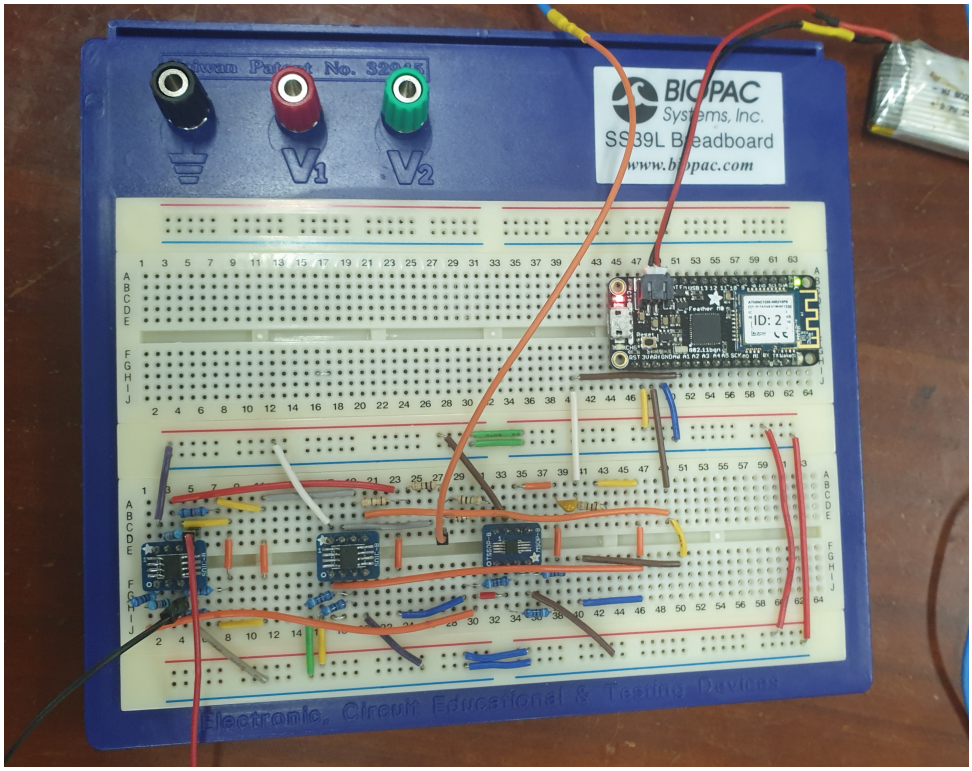

Figure 2.5: Implementation of Circuit 3

As per the initial calculations in the previous report, this implementation has the overall best performance among the three circuit implementations due to its built-in precise resistors of AD8276. Through our observations, we validated the same phenomenon.

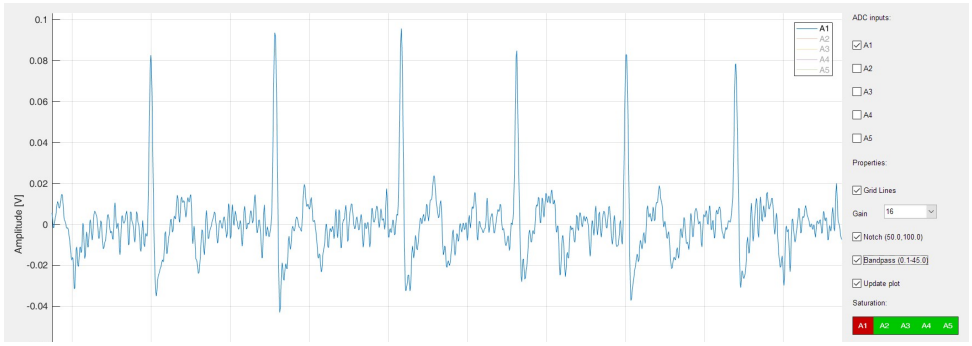

Figure 2.6: Recorded Signal from Circuit 3 after Filtering with Notch and Bandpass Filters

After the application of filters, the waveform seemed to be presenting the characteristic ECG pattern with lesser noise interference (still with traceable noise, especially in the PR and TP segments) than the previous circuit implementations, with fewer variations in the amplitude domain with respect to all ECG waveform segments. The noise in this implementation is assumed to be from the capacitive and inductive coupling from the circuit wire connections and with possible WiFi electromagnetic interference.