Electrocardiography (ECG) project

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INTRODUCTION

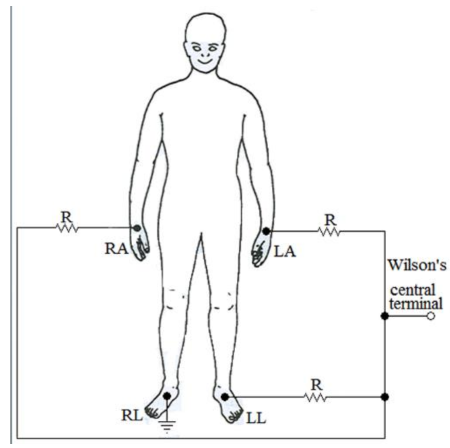
Electrocardiography (ECG) is the recording of heart's electrical activity by placing electrodes at specific points on the surface of the body. The electrical activity is produced by polarization and depolarization of the cell membrane during heartbeat. These appear as tiny electrical signals on the skin which can be detected and amplified by the ECG. Electrocardiogram (ECG) is the electrical representation of the contractile activity of the heart over time, which can be easily recorded using noninvasive electrodes on the chest or limbs. Long-term recording and analysis of ECG is useful and necessary for those who suffer cardiovascular diseases, so that the patient and doctors can continuously monitor the status of cardiac activity. ECG Amplitude range is 1mV -5 mV, Frequency range 0.05 Hz-150 Hz.

Electrodes

We use Dry surface electrodes, applied directly on the skin, can record biopotentials without the need of removing fat and sweat or even applying electrolytic gel.

This type of electrode has very high input impedance encapsulated with the metal sensor, and it is also named active electrode. The input impedance, electronically enhanced, ensures lower sensitivity to the impedance of the skin interface.

The minimum Number of electrodes that can be used is 3 electrodes located on limb and there is a reference electrode



Instrumentation Amplifier

We use The AD620 is a low cost, high accuracy instrumentation amplifier, offer high

CMRR, Wide power supply range (±2.3 V to ±18 V)

To get R_G we use this Equation → ***R_G = 49.9K / (Gain – 1*).**

When Gain =8 $\quad$ R_G=6.98k ohm $\quad$ CMRR=100db

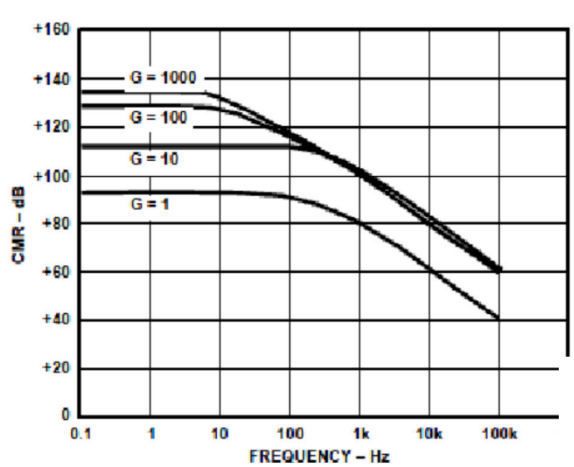
Filters

Filter response **is Butterworth filter.**

High pass fitter

A high-pass filter typically has a **cutoff frequency around 0.05 Hz**. This allows frequencies above this threshold, which carry the diagnostic information of the ECG signal, to pass through for analysis**.**

Removing **Baseline Drift**, ECG readings measure tiny electrical signals from the heart. One challenge is baseline wander caused by respiration (breathing). This slow voltage fluctuation sits at a low frequency and can obscure the ECG



signal. A high-pass filter effectively **blocks these slow-moving signals**, allowing the essential high-frequency components of the ECG to pass through undistorted.

We use 3 orders of high pass filter (2 orders is active, 1order is passive)

$$f_c = \frac{1}{2\pi\tau} = \frac{1}{2\pi RC},$$

Assume if R=100K Ohm so C=3.2uF

Low pass fitter

Low-pass filters allow lower-frequency signals to pass through and block any frequencies above a certain threshold, which **is typically set at 150 Hz** because the clinically relevant info in the ECG falls below that.

the low-pass filter ensures that the focus remains on the clinically relevant components of the ECG signal, such as the P wave, QRS complex, T wave.

We use 6 orders of low pass filter (4 orders is active, 2order is passive)

$$f_c = \frac{1}{2\pi\tau} = \frac{1}{2\pi RC},$$

Assume if C=100nF so R=10610.3oham ~=10k ohm

Notch filter

We use notch filter to Targeting Specific Frequency Unlike high-pass and low-pass filters that target a range of frequencies, a notch filter zeroes in on a very narrow band of frequencies. In ECG applications, this band is centered around the local power line frequency, **which is either 50 Hz or 60 Hz depending on the region**.

Notch filter can eliminate power line interference, Power lines emit electromagnetic interference that can contaminate the ECG signal. This interference often falls within the same frequency range as the ECG itself, making it difficult to remove with simpler filters The notch filter canceling out this specific narrowband of noise from the power lines.

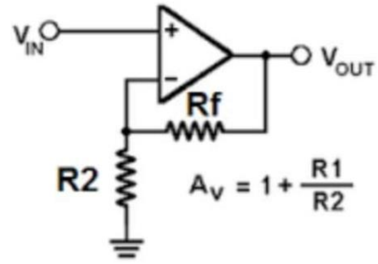
$$\boxed{f_N = \frac{1}{4\pi RC}}$$

Assume if C=10uF so R=160 ohm

Gain stage

The electrical signals generated by the heart are very weak. The gain stage acts as an amplifier,
boosting the amplitude (strength) of the ECG signal to a level suitable for processing and display.

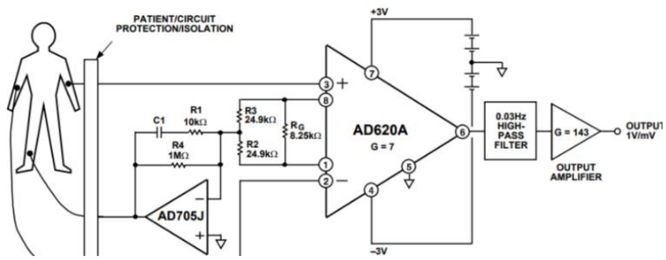
Using noninverting amplifier by gain=6



$$Vout = (1 + \frac{Rf}{R2})Vin$$

The Driven-Right-Leg (DRL) circuit

The DRL circuit utilizes the patient's right leg as a reference point. It essentially drives the voltage of the right leg to match the common-mode interference affecting all the other electrodes.

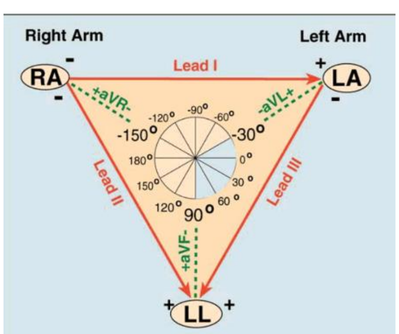


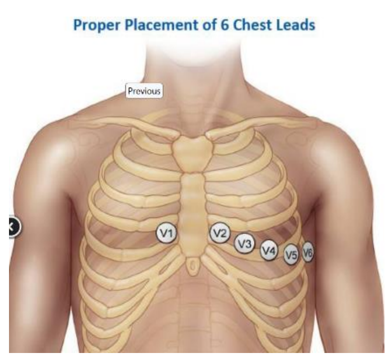
By actively driving the right leg voltage to mimic the common-mode noise, the DRL circuit effectively cancels it out. Imagine subtracting the common noise from each electrode's signal. This subtraction significantly reduces the interference in the final ECG recording.

Lead Selector

The lead selector acts like a switch, allowing you to choose which specific lead's electrical activity you want to view on the ECG display.

There is standard 12-lead ECG provides a comprehensive picture of the heart's electrical activity by recording its signals from various angles. These different angles are achieved through the placement of electrodes on the chest, arms, and legs.





Bipolar limb leads (frontal plane):

- Lead I: RA (-) to LA (+) (Right Left, or lateral)
- Lead II: RA (-) to LL (+) (Superior Inferior)
- Lead III: LA (-) to LL (+) (Superior Inferior)

Augmented unipolar limb leads (frontal plane):

- Lead aVR: RA (+) to [LA & LL] (-) (Rightward), calculated as (-RA + LA + LL)/3
- Lead aVL: LA (+) to [RA & LL] (-) (Leftward), calculated as (RA + LA + LL)/3
- Lead aVF: LL (+) to [RA & LA] (-) (Inferior), calculated as (RA - LA + LL)/3

Unipolar (+) chest leads (horizontal plane):

- Leads V1, V2, V3: (Posterior Anterior)
- Leads V4, V5, V6:(Right Left, or lateral

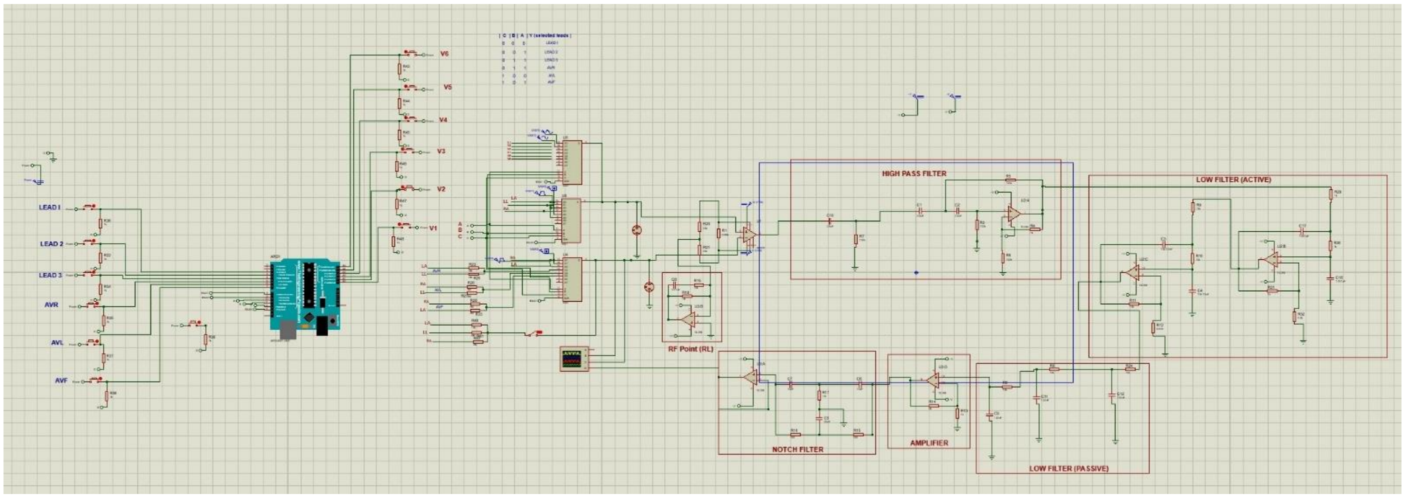
We achieving this selection by 3 multiplexer 6x1

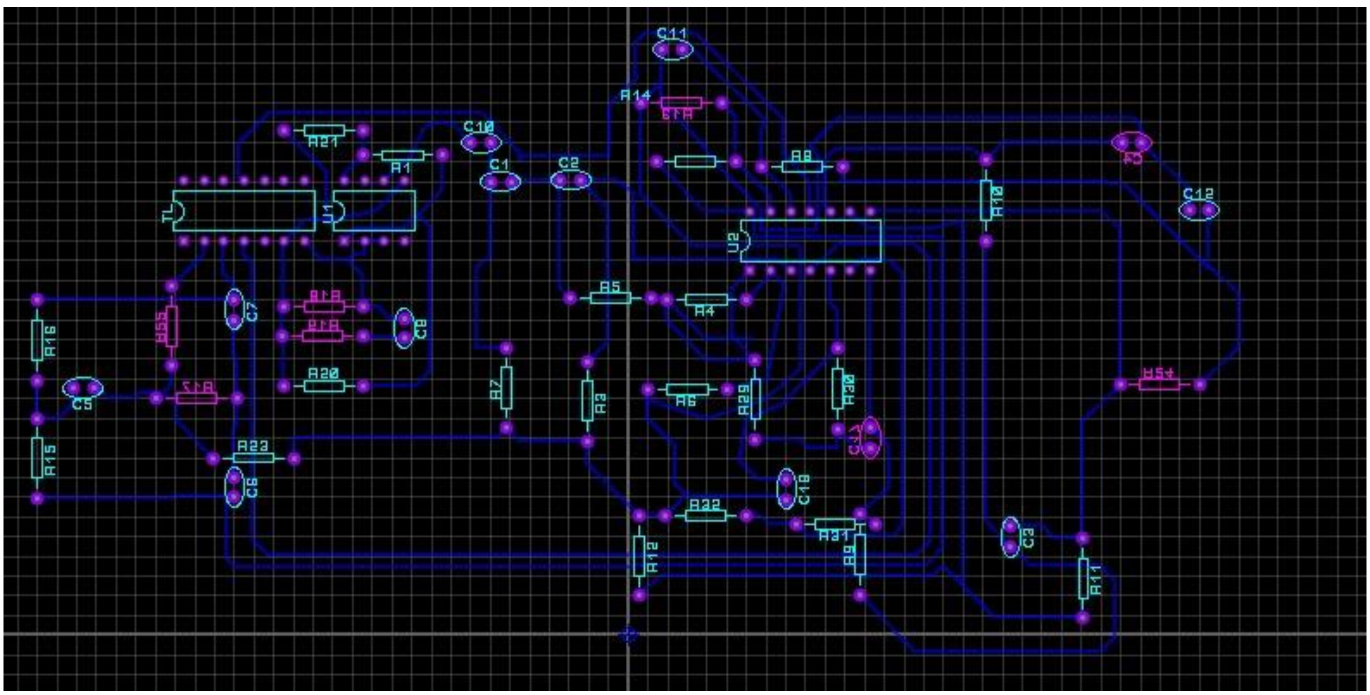
LEAD	A	B	C
I	0	0	0
II	1	0	0
II	0	1	0
aVR	1	1	0
aVL	0	0	1
aVF	1	0	1

LEAD	A	B	C
V_1	0	0	0
V_2	1	0	0
V_3	0	1	0
V_4	1	1	0
V_5	0	0	1
V_6	1	0	1

Total Gain Calculation:

- gain stage * instrumentation amplifier gain * band pass filter Amplification = 6 * 8 *2 = 96
- gain stage * band pass filter Amplification = 12


LEAD I
LEAD 2
LEAD 3
AVR
AVL
AVF
V6
V5
V4
V3
V2
V1
HIGH PASS FILTER
LOW FILTER (ACTIVE)
RF Point (RL)
NOTCH FILTER
AMPLIFIER
LOW FILTER (PASSIVE)


C11
R14
R21
C10
R1
C1
C2
R8
R10
C12
U1
U2
R5
R4
R16
C7
C8
R20
R7
R3
R6
R29
R30
C5
R15
R23
C6
R32
C18
R31
R12
C3
R11