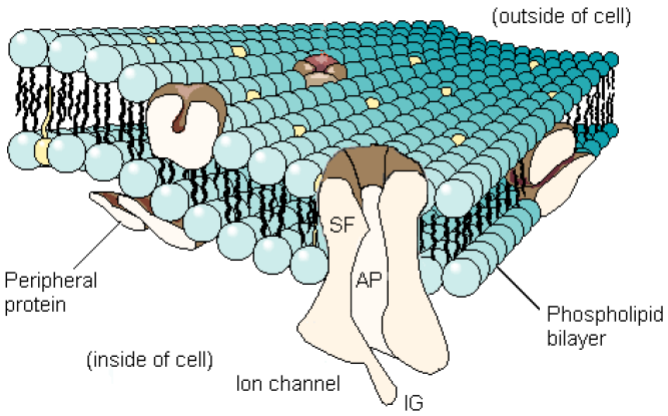
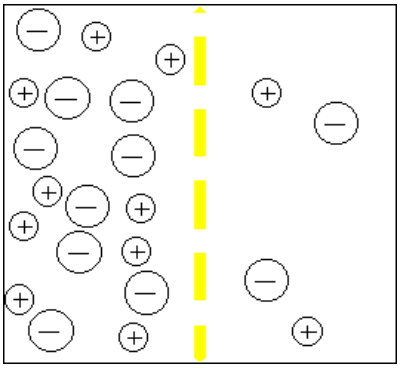
ECG SIGNAL ACQUISITION HARDWARE DESIGN

Origin of Bioelectric Signals

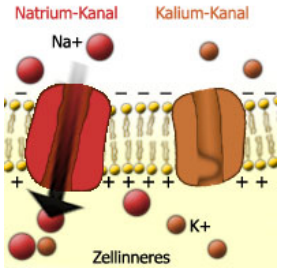


Cell membrane, channel proteins

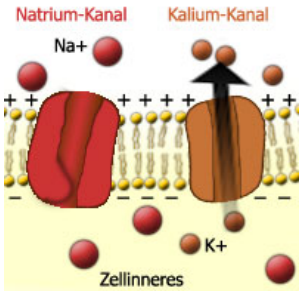


Electrical and chemical gradients at the semi-permeable cell membrane

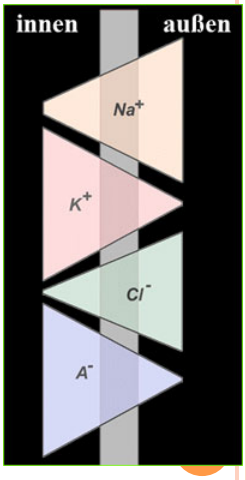
As a result, we get a membrane resting potential of about -70mV



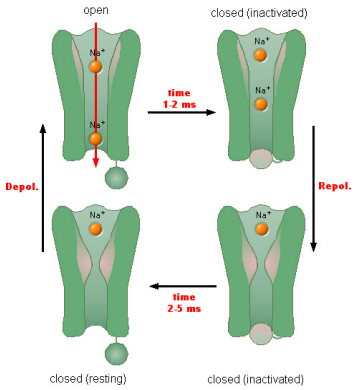
Depolarization
Sodium Cations
rush in



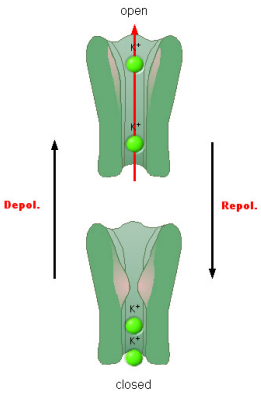
Hyperpolarization
Potassium Cations
rush out



Voltage- and Time dependent activation of Ion Channels: the physiological basis for action potentials



Sodium-Channel



Potassium- Channel

Bioelectric Signals

ECG Electro-Cardiogram, Heart activity
EMG Electro-Myogram, Muscle movement
EOG Electro-Oculogram, Eye movement
EEG Electro-Encephalogram
GSR Galvanic Skin Response

- Measured with electrodes:
  skin-electrode interface: Ions <--> Electrodes

Breathing, temperature, movement etc.

- Measured with other sensors / transducers:

NTC, LDR, piezo-crystal, hall-sensor, Accelerometer, Goniometer, …

>>>> ECG Electro-Cardiogram, Heart activity <<<<<<<<<<

EMG Electro-Myogram, Muscle movement

EOG Electro-Oculogram, Eye movement

EEG Electro-Encephalogram

GSR Galvanic Skin Response

- Measured with electrodes:
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Breathing, temperature, movement etc.

- Measured with other sensors / transducers:

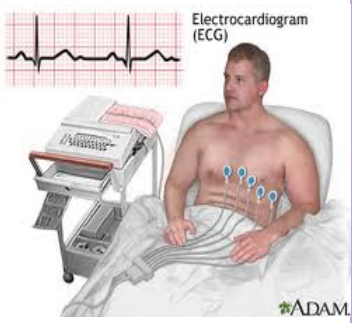
NTC, LDR, piezo-crystal, hall-sensor, Accelerometer, Goniometer, …

BACKGROUND

- ECG/EKG (electrocardiogram)

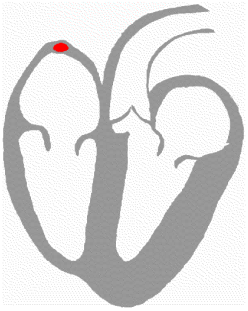
Records the heart's electrical activity:

- ✓ Heart beat rate
- ✓ Heart beat rhythm
- ✓ Heart strength and timing



BACKGROUND

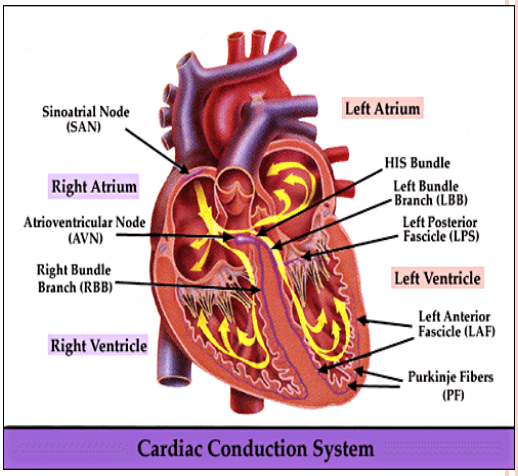
ECG works mostly by detecting and amplifying the tiny potential changes on the skin that are caused when the electrical signal in the heart muscle is charged and spread during each heart beat.



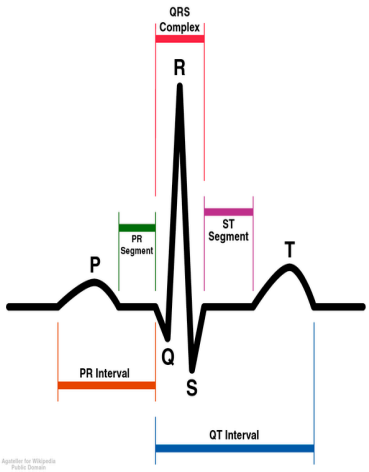
This is detected as tiny rises and falls in the voltage between two electrodes placed either side of the heart.

BACKGROUND

- **The heart's electrical system:**
  - Sinoatrial(SA) node
  - Atrioventricular(AV) node
  - His-Purkinje system



BACKGROUND



Schematic representation of normal ECG

P wave: signal spread from SA node to make the atria contract.

P-Q Segment: signal arrives AV node stay for a instant to allow the ventricle to be filled with blood.

Q wave :After the Bundle of His the signal is divided into two branches and run through the septum.

R,S wave: Left and right ventricle contraction are marked by the R,S wave.

T wave: ventricle relaxing

ECG SIGNAL

- ECG bio-signal typical specifications:
  - low differential voltage from 0.4 to 3 mV
  - high common-mode rejection ratio level
  - low frequency range
  - high noise

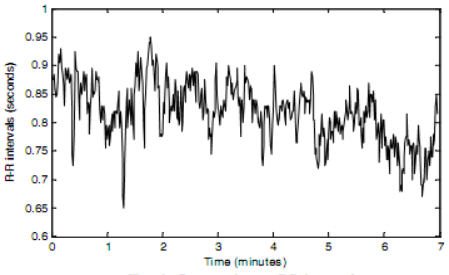
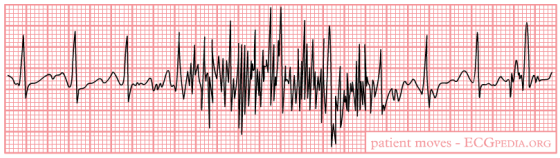


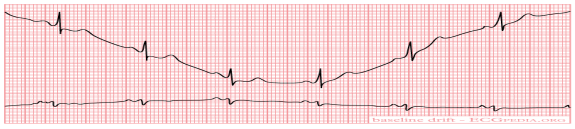
Fig. 6. Seven minutes RR intervals.

ECG SIGNAL

- Artifacts (disturbances) can have many causes. Common causes are:
- Movement



Sudden movement



Baseline drift

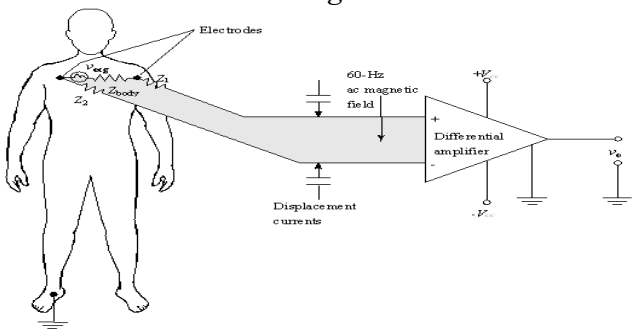
ECG SIGNAL

- **Electrical interference**

→From a nearby electrical appliance. A typical example is a 100 Hz background distortion from fluorescent lights. To be confused with atrial fibrillation.

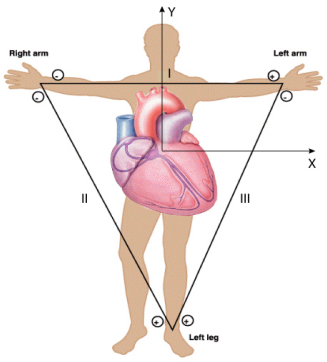
ECG ELECTRODE

- Lead
  - The signal recorded as the difference between two potentials on the body surface is called an "**ECG lead**". Each lead is said to look at the heart from a different angle.

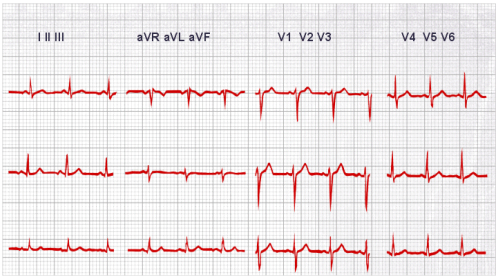


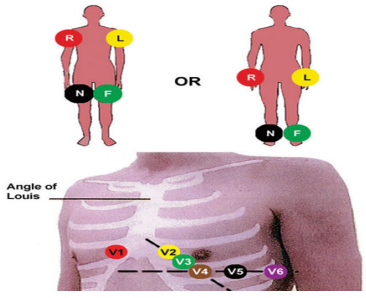
ELECTRODE

- Lead position



Lead III



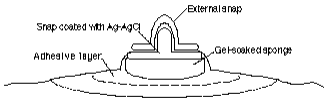


Lead 12

ECG ELECTRODE

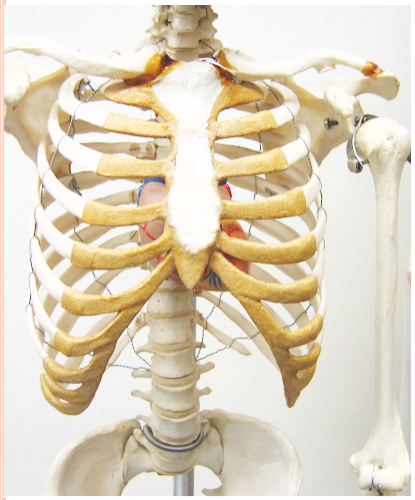
A typical surface electrode used for ECG recording is made of Ag/ AgCl, as shown on right Figure . The disposable electrodes are attached to the patients' skin and can be easily removed.

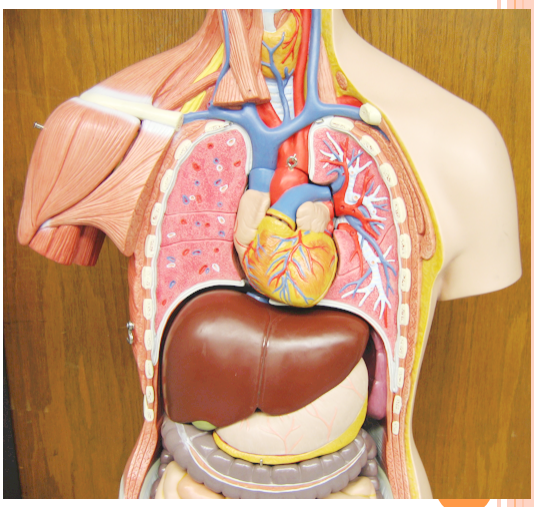
Wet, dry and insulating…



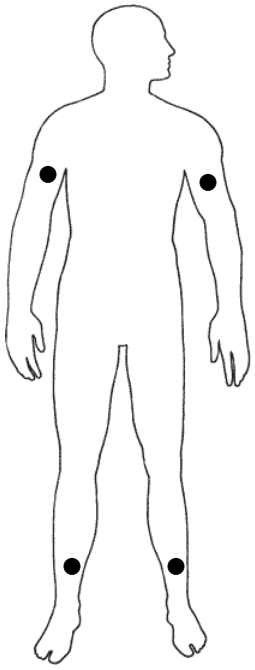
① **Limb Leads (Bipolar)**
② **Chest Leads (Unipolar)**
③ **Augmented Limb Leads (Unipolar)**

First, to make sure we know where the heart is …



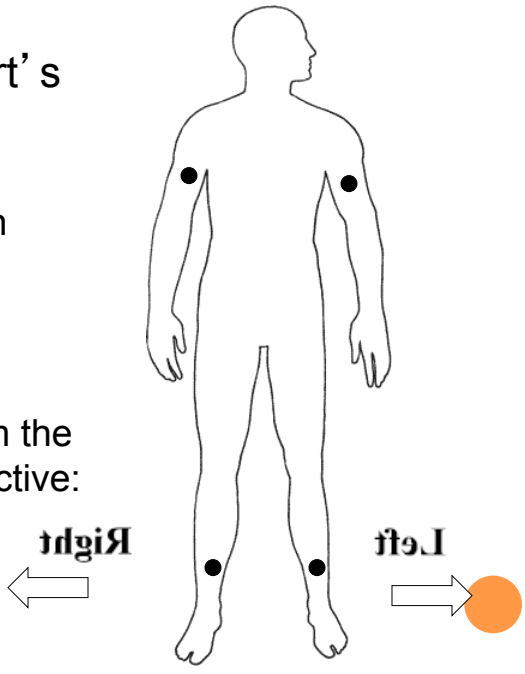


Sensing the heart's electrical activity via electrodes (contacts placed on the surface of the body)



Sensing the heart's electrical activity via electrodes (contacts placed on the surface of the body)

Note: anatomical orientation is from the subject's perspective:



The basic four limb electrodes:

right arm

left arm

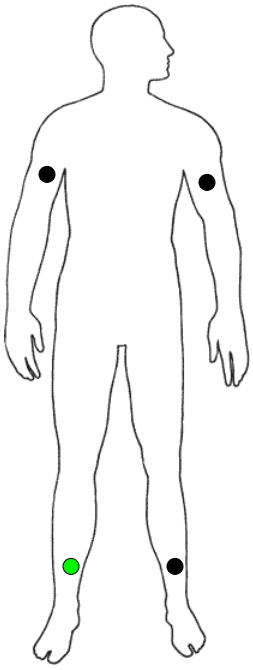
electrical polarity:

- neutral or ground
- negative
- positive

(manipulated by the EKG machine)

right leg

left leg



Lead I (toward left)

right arm

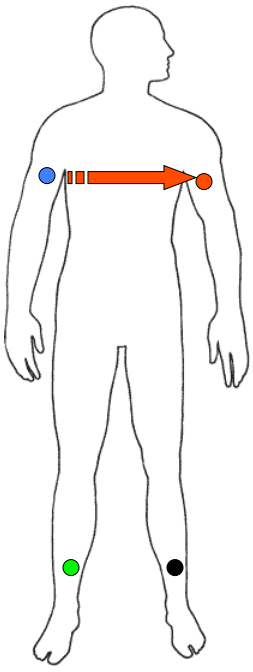
left arm

electrical polarity:

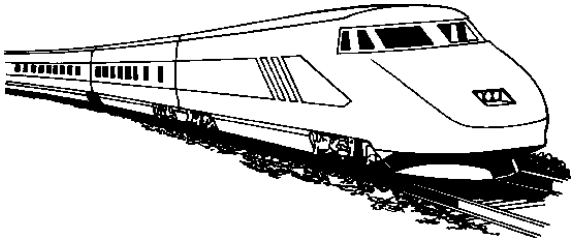
- neutral or ground
- negative
- positive

right leg

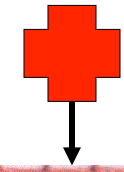
left leg

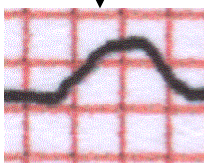


Interpreting the view from an electrode



for any given viewing (positive) electrode:



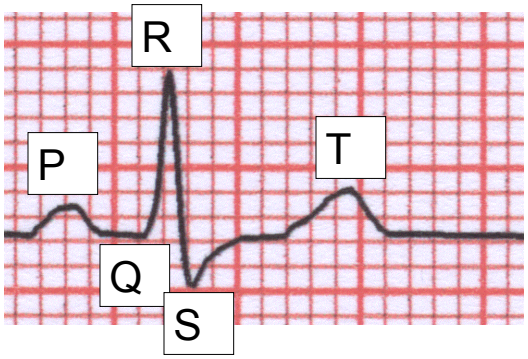


An approaching train of muscle fiber depolarizations (or repolarizations moving away)

is seen as an upward trace on the recording

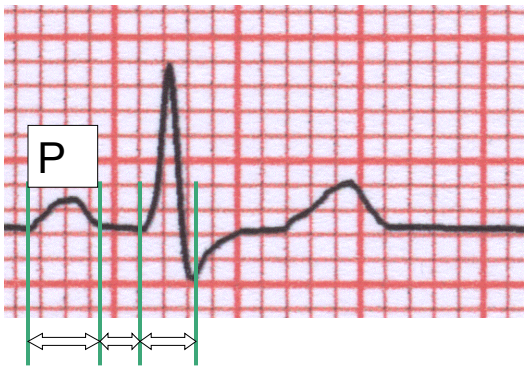
(opposite movement = downward trace)

Note: the normal average direction for the heart's electrical activity is from the upper right, in the right atrium, to the lower left.



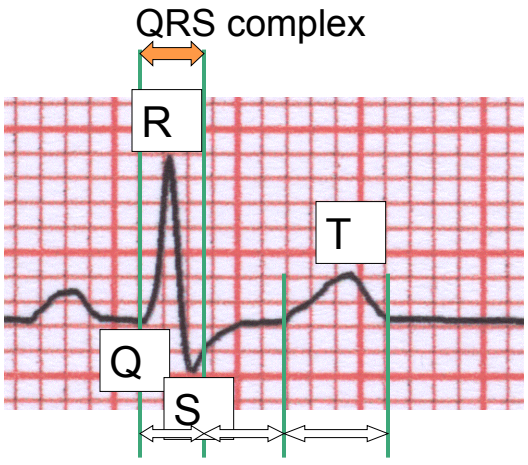
The main, typical waves of an EKG.

(This particular tracing does not show a Q wave, a downward wave just before the R wave.)



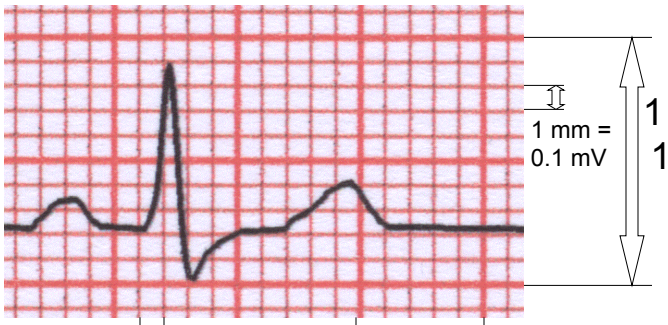
ATRIA: depol-pause-repol

(atrial repolarization is obscured by ventricular depolarization)

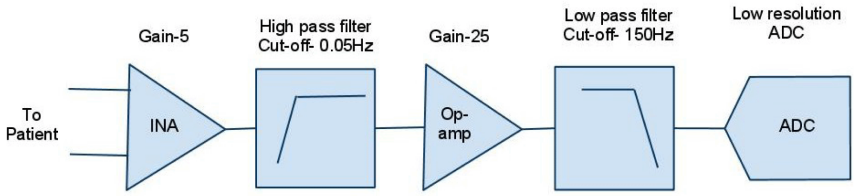


VENTRICLES: depol-pause-repolarize

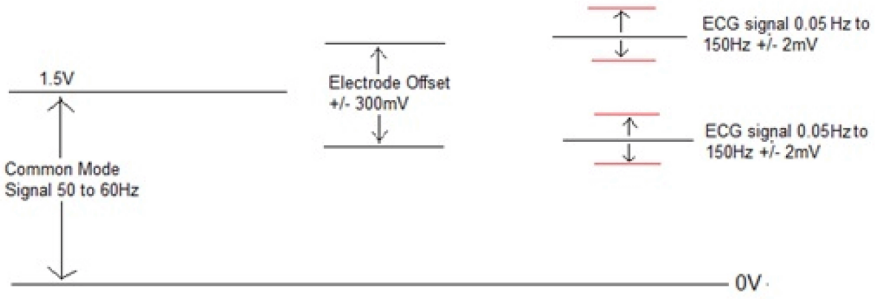
Standard calibration of EKG recordings



Electrocardiograph Block Diagram



Characteristics of ECG signals



the actual signal value will be ~0.4mV in an offset environment of 300mV.

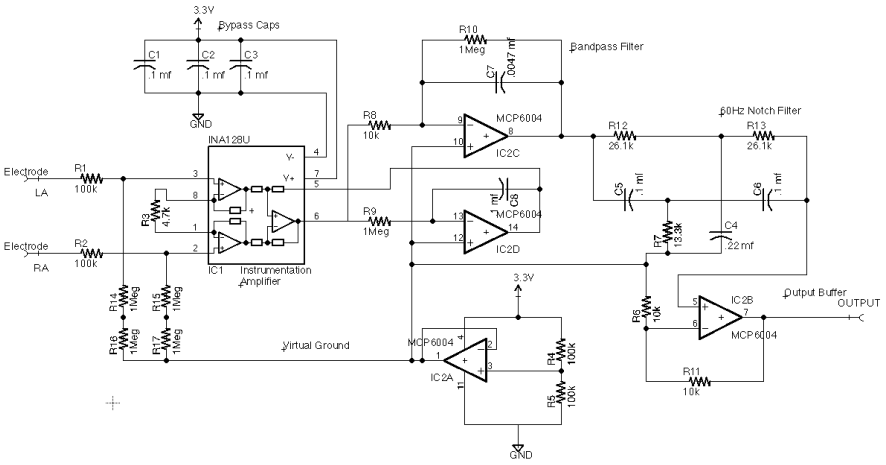
SOURCES OF NOISE IN ECG SIGNALS

- Baseline wander (low frequency noise)
- Power line interference (60Hz noise from power lines)
- Muscle noise (This noise is very difficult to remove as it is in the same region as the actual signal. It is usually corrected in software.)
- Other interference (i.e., radio frequency noise from other equipment)

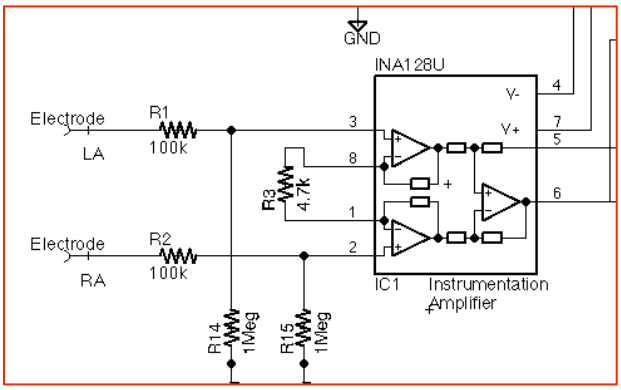
Removal of common mode noise

- Use instrumentation amplifiers with very high common mode rejection ratios on the order of 100dB
- Drive the patient body with an inverted common mode signal.
- Apply software algorithms after acquisition for the removal of noise

Our EKG Analog Front End Circuit

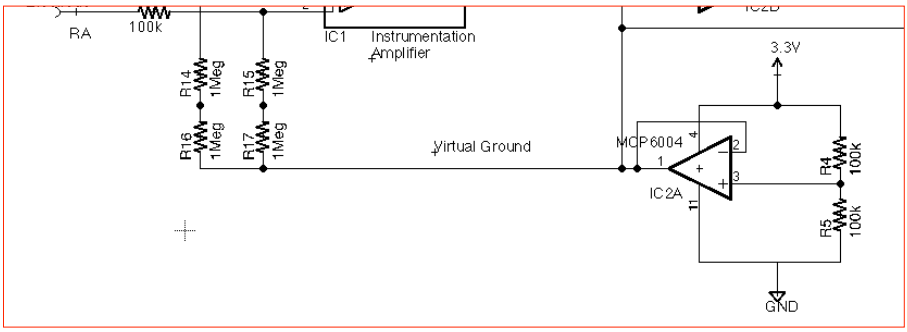


Instrumentation Amplifier



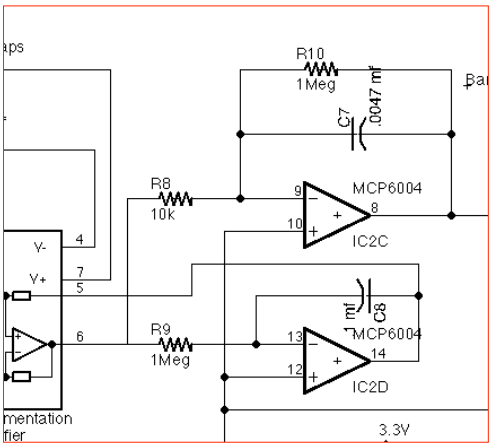
- High Common Mode Rejection– 120dB minimum
- Settable gain of 1 to 1000x, controlled by R3
- Low voltage, Single supply

Virtual Ground Circuit

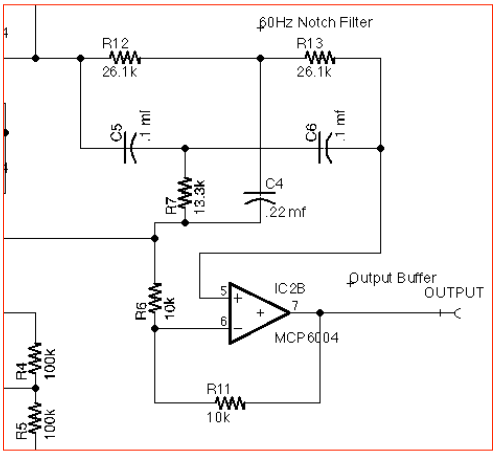


- Virtual Ground– 3.3v/2
- allows signals 0-3.3v swing

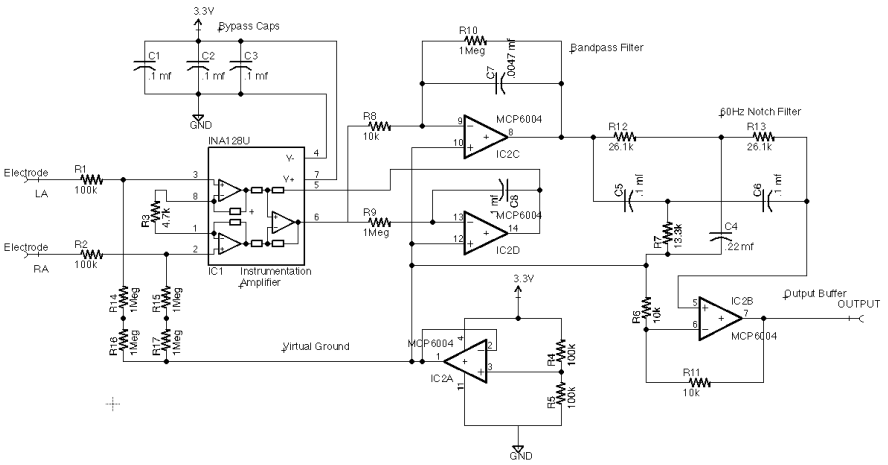
Band Pass filter ~1 Hz to ~40 Hz



60 Hz Notch filter and output buffer



Our EKG Analog Front End Circuit



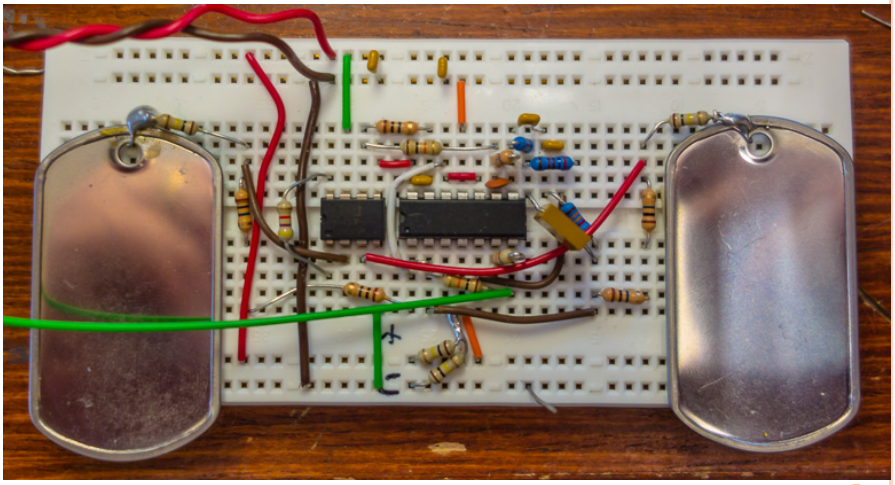
This Week's Lab 7

- Build an Analog Front End circuit for an ECG
- Test it
- Connect it to the FriendlyArm ADC

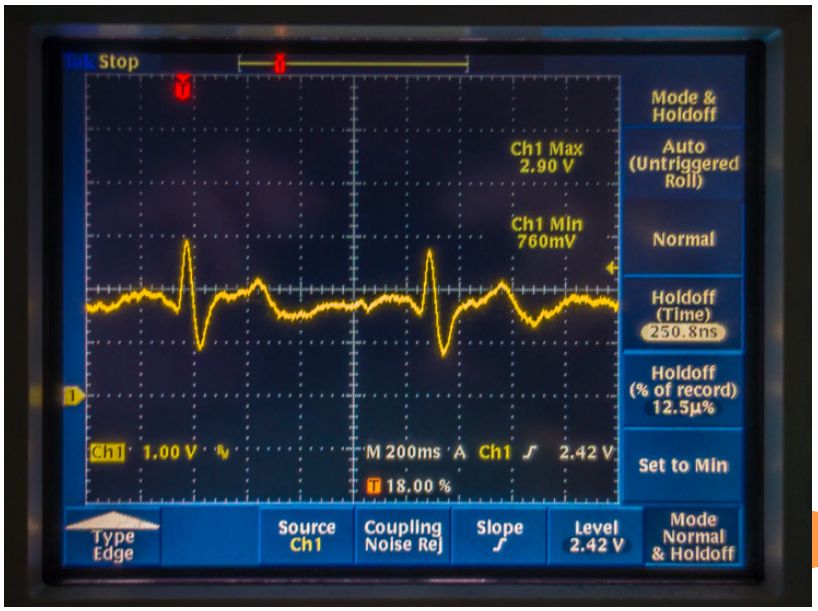
Next Week– display traces on LCD and calibrate To Standard Grid
Add digital processing to clean up signal

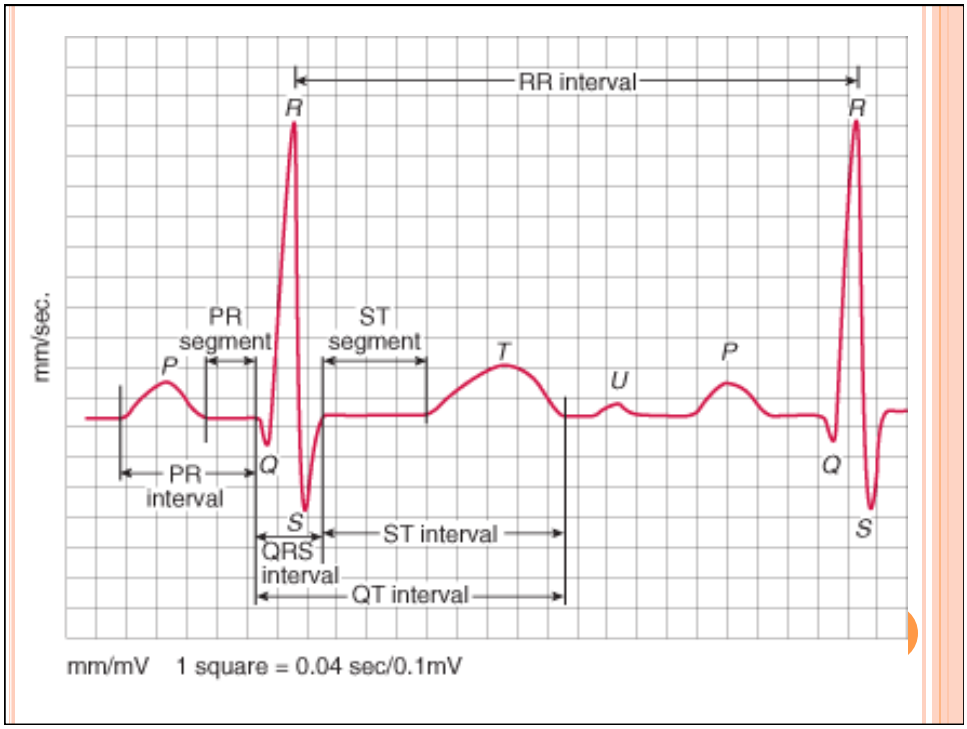
Final week– Add diagnostic signal processing routines

Our EKG Analog Front End Circuit



Our EKG Analog Front End Circuit




RR interval
R
R
PR
segment
ST
segment
P
T
U
P
Q
Q
S
S
PR
interval
ST interval
QRS
interval
QT interval
mm/sec.
mm/mV 1 square = 0.04 sec/0.1mV