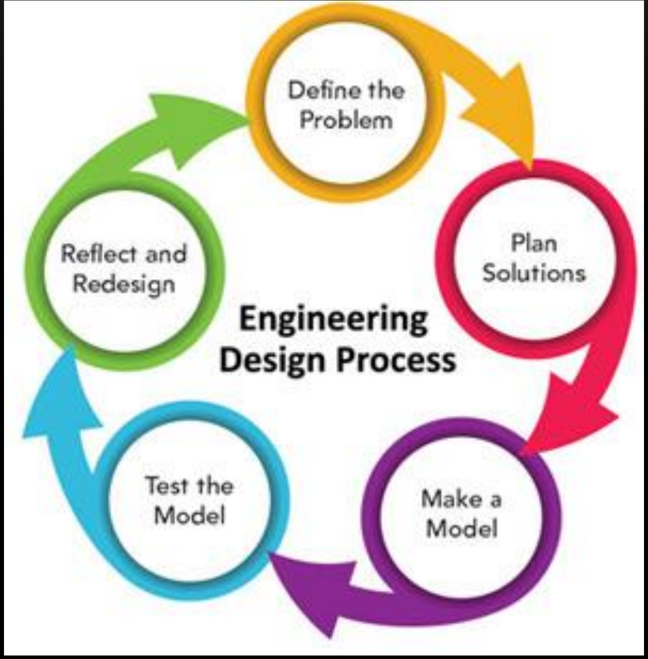
BE87 FRESHMAN SEMINAR

WEEK 2: SYSTEM DESIGN

- Engineering design: electronic hardware
- ECG amplifier: electronic breadboarding, amplifiers
- Noise and patient safety

INSTRUMENTATION DESIGN PROCESS



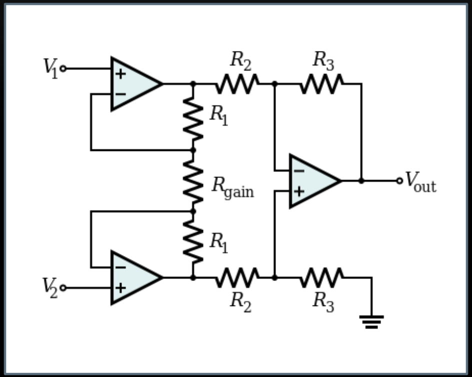
- Full engineering design includes a needs assessment, defining the goals of the design, listing specifications, prototyping, testing and re-design.

DESIGN FOR BE87

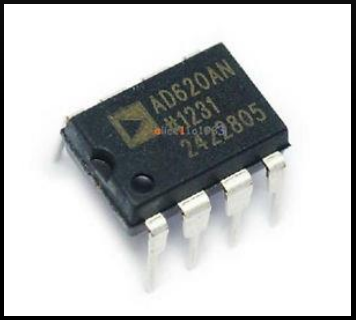
- Think about design process, but will take shortcuts this quarter!

- First steps:
  - Use information from last week, and other resources to propose electronic amplifier circuit for biosignals
  - Find an existing schematic (next week!), and “breadboard” the circuit with discrete components
  - Design may change based on parts availability and time constraints
  - Consider user electrical safety and sources of noise

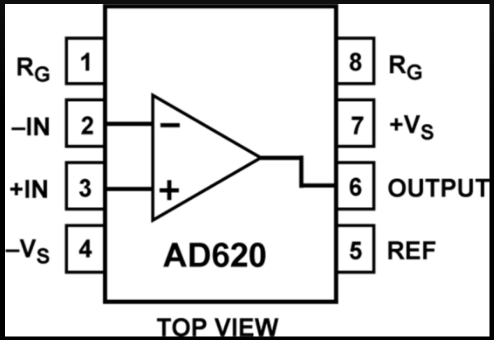
ELECTRONIC AMPLIFIERS



Schematic of Amplifier circuit



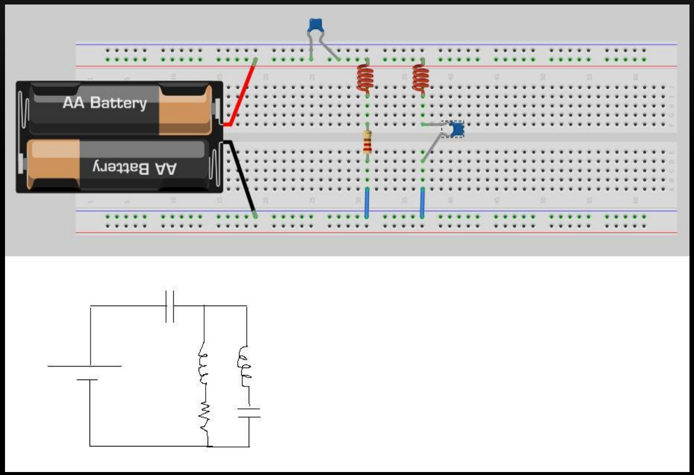
8-pin integrated circuit



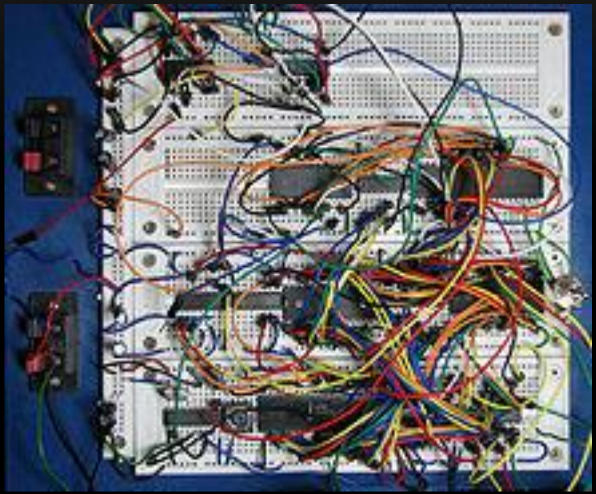
Pin-out diagram for a single amplifier

- Instrumentation amplifier: most functions needed in a single integrated circuit.

BREAD BOARDING



Convert your schematic into a working circuit



Try to avoid this!

- Build prototype electronic circuits with components inserted into a proto-board

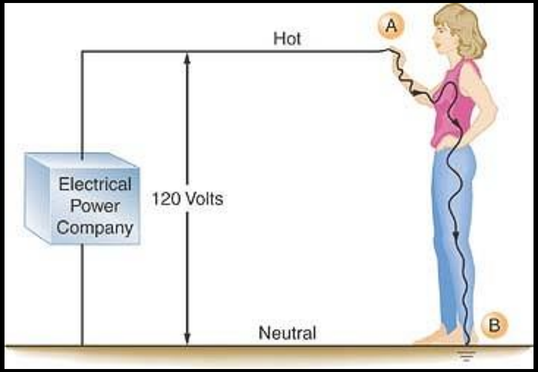
USER/PATIENT SAFETY WITH INSTRUMENTATION

- Electrical currents through the body can be dangerous!
- For bread boarding, lab work, at home in your garage:
  - Dangers are from 120V AC circuits
  - AC = alternating current (60Hz), can cause ventricular fibrillation
  - Common sense: do not touch exposed AC wiring!

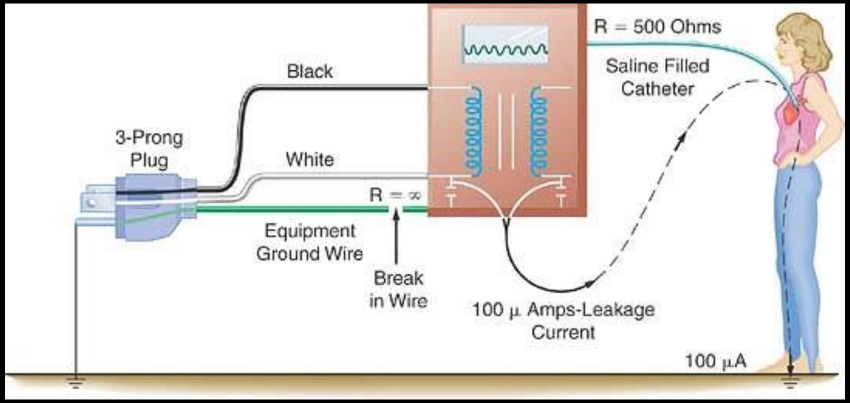
CLINICAL INSTRUMENTATION

- Electrical safety is a serious consideration for patient-connected devices

- Resistance through skin is protective in many cases. With skin electrodes or devices inserted directly into the body, much lower resistance, thus lower voltages or small currents can be hazardous.



Shock hazard via skin

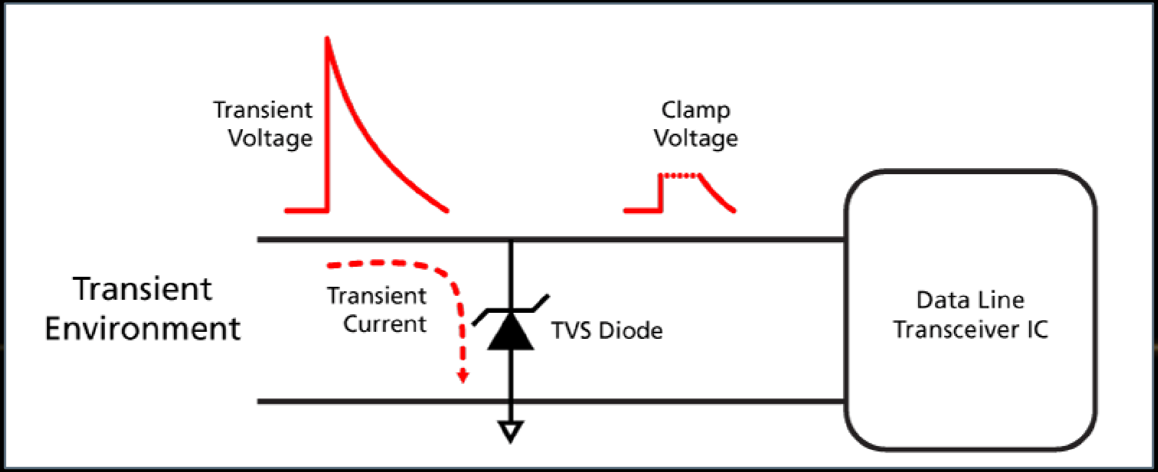


Micro-amps can kill if directly through the heart

ELECTRICAL SAFETY CONSIDERATIONS

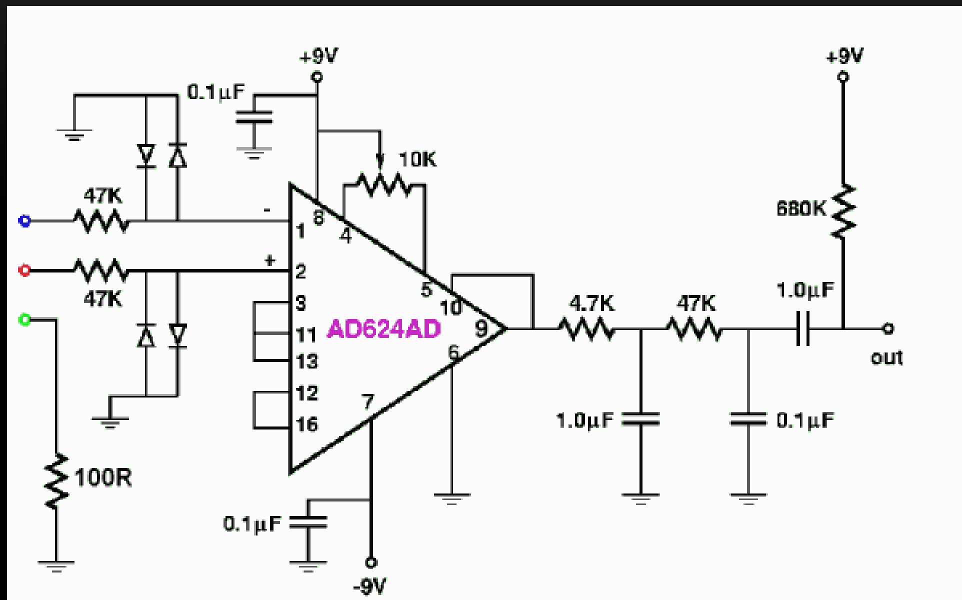
- For bread boarding and ECG amplifier, risk is small, but consider:
- Use battery power for amplifier instead of 120V AC with a power supply. Both low voltage and DC (direct current) have much lower risk of shock hazard.
- Do not touch other instrumentation while connected to an ECG amp.
- Path still exists from computer (plugged in the wall) to patient. Only real hazard is during an electrical storm, with lightning strike back though system.

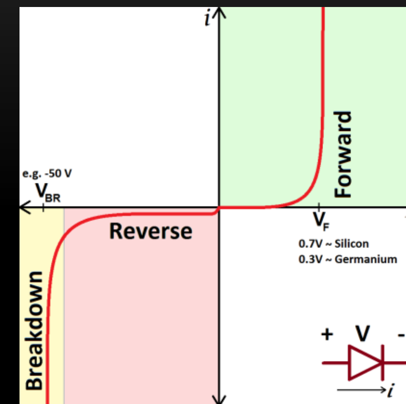
Add input diodes to ECG circuit to shunt/clamp possible large currents:



DIODES FOR USER SAFETY

User connections



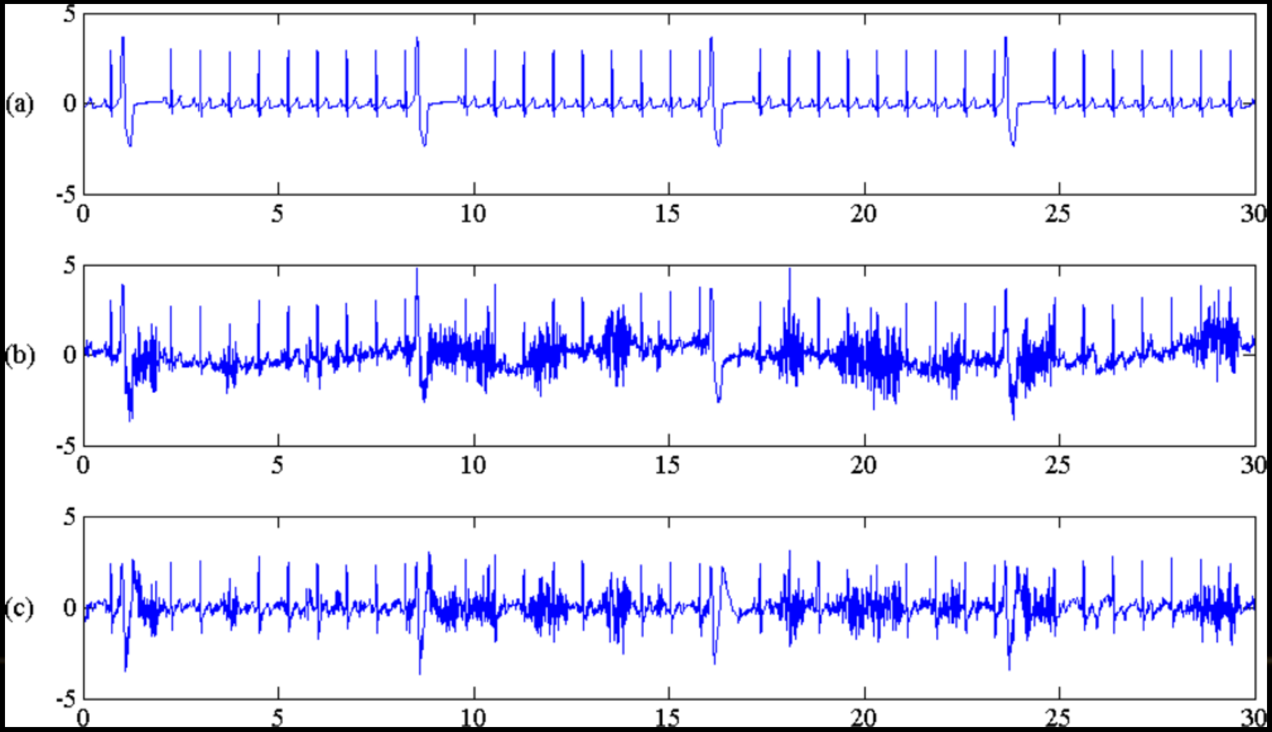


Diodes ”rectify” current: allow flow in one direction once a small threshold voltage is reached

- During normal operation, voltage on the skin from ECG is in the mA range
- Diodes will conduct + or – current at each input if voltage is greater than about 1V, thus shunting large currents away from the inputs (user electrodes).

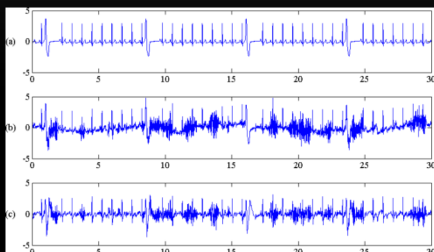
ELECTRICAL NOISE

- All electrical signals have unwanted noise (think of that bad WiFi signal on your phone!)
- "Electrical noise" may not be hazardous, but will add to the biosignal and make analysis difficult
- Can reduce noise at the source, and also use various filters after acquisition

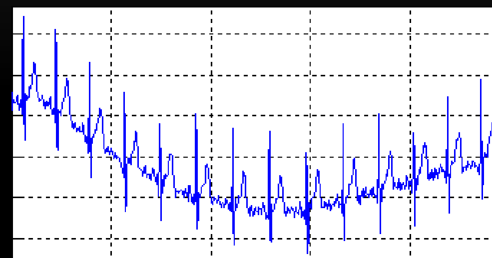


ELECTRICAL NOISE

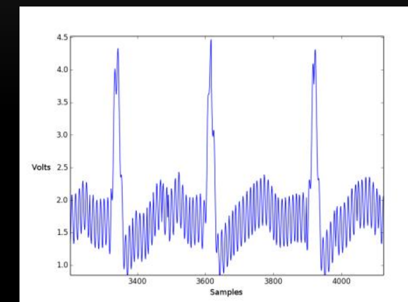
- Sources/improvements for ECG acquisition



Random white noise from electronic and unknown sources:
Low-pass filter to remove high frequencies



Baseline drift from respiration:
High-pass filter to remove very low frequencies



60 Hz noise from AC:
Battery power, 60 Hz filters

- Some simple design changes can help reduce noise in real time
- Other procedures can be done off-line, after the signal is acquired (not in real time)

FINAL REPORT SAMPLE PAGE:

The Electrocardiogram: Design and testing of hardware and software instrumentation

BE87, Spring 2017

Lab partners: Jeff Omens and Joe Partner

Overview and summary of an ECG recording system

The Electrocardiogram: definition and measurement

The electrocardiogram (ECG or EKG) is a recording of the electrical potentials generated by the heart. The signals are recorded on an electrocardiograph machine for clinical assessment. In this course we designed, constructed and tested a hardware/software solution for recording and displaying human electrocardiograms. Simple analysis of noise and clinical ECG parameters were measured. The following document is a compilation of the 9 sections of the course.

Physiologic Basis of the ECG

The electrocardiogram is a representation of the electrical activity of the heart that is typically recorded with a clinical system, and displayed in a standard format for clinical interpretation.

Need for ECG measurements

The ECG is widely used as a clinical tool for diagnosis of many diseases with abnormal electrophysiology in the heart. The electrical recordings of and ECGs can also be used in portable devices such as simple heart rate monitors and portable defibrillators.

The overall ECG measurement system

Figure 1 shows a block diagram with the main components of most ECG measurement systems. The systems connects to a patient via skin electrodes, uses electronic amplifiers to increase the amplitude of the electrical signal, then typically converts the signal to a digital form that can be displayed on computer or other display systems.

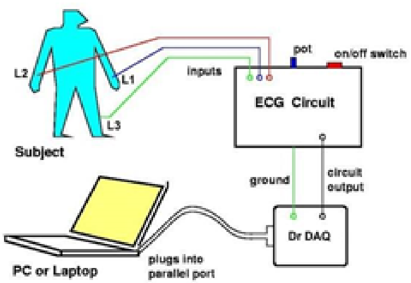


Figure 1. Block diagram of a typical ECG recording system, including human subject, electronic instrumentation and display system.

Goals for BE87 instrumentation design

- Describe the need for this type of device
- Who would use the device, and for what purposes?
- Use existing technology to design your electronic instrument and data acquisition system
- Design incudes: block diagram, schematic, parts list, circuit, computer acquisition, test results
- Document the design so another knowledgeable engineer could replicate it
- Review and summarize design process, and next steps for ECG "version II".
- Work as a 2-person team for more efficient and constructive outcomes

Word file on Web site, can use Figure/legend as template

WEEK 2 TOPICS FOR FINAL REPORT

- Summary of a typical engineering design process.
- Electrical safety considerations in the clinic and for the BE87 design.
- Sources of noise on an ECG signal and possible solutions.