Amplifier Circuits

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Biopotential Amplifiers: Circuits

- Circuit examples from Spec Sheet
  Analog Devices AD620 Instrumentation Amplifier
  www.datasheetcatalog.org/datasheet/analogdevices/105505445AD620_e.pdf

  Single supply pressure transducer

  Driven Right leg circuit

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  Grounding: Analog vs. Digital

  Single supply operation

  Driven Ground

  Wheatstone bridge

Issues in biomedical Amplifiers

  Filtering for powerline noise

Bioimpedance Measurement

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Pressure Sensor circuit

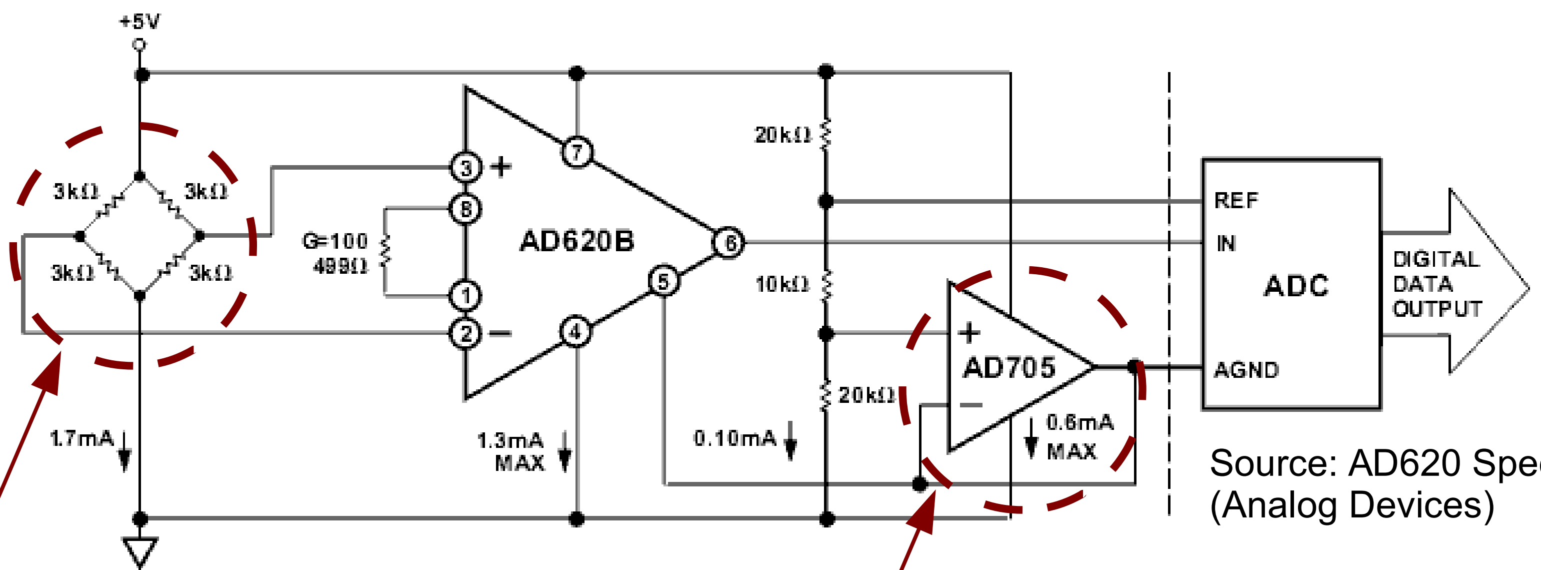

Figure 35. A Pressure Monitor Circuit which Operates on a +5 V Single Supply

Source: AD620 Spec sheet (Analog Devices)

Wheatstone Bridge Circuit

Single Supply configuration

Analog Ground

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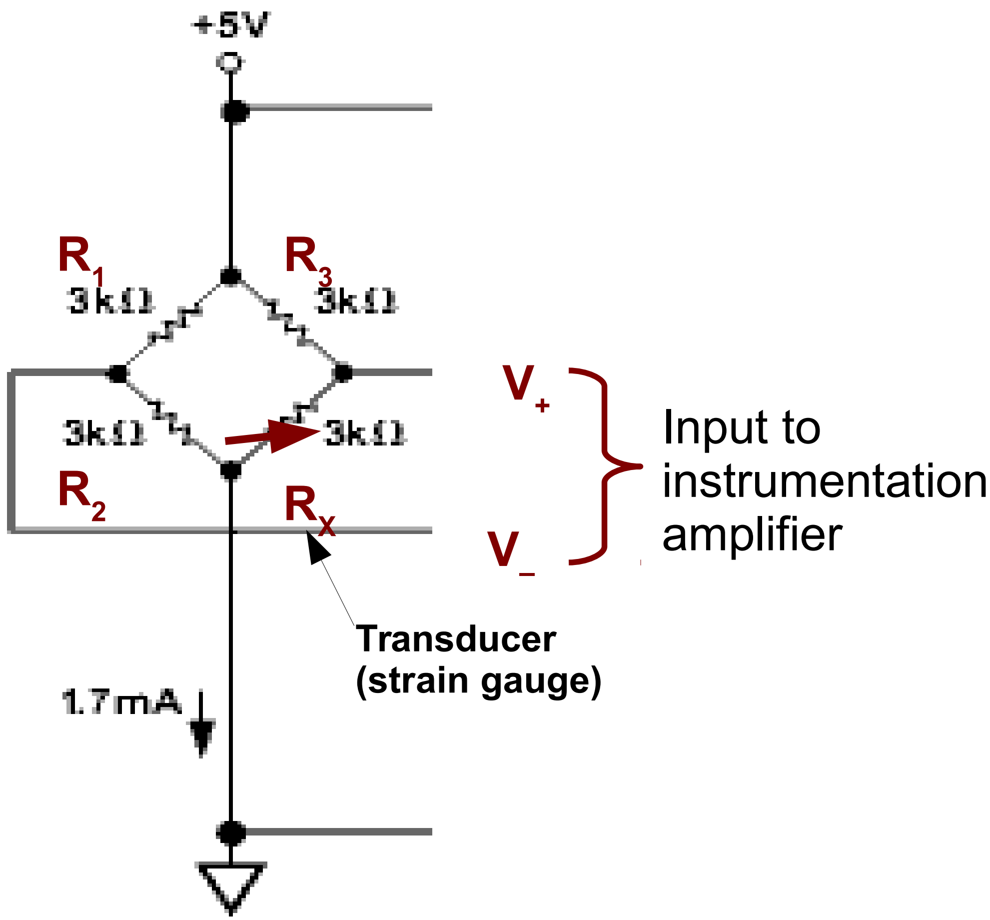
Wheatstone bridge



The Wheatstone bridge is a popular measurement instrument.

$$V_+ = \frac{R_2}{R_1+R_2}$$

$$V_- = \frac{R_X}{R_3+R_X}$$

$$V_+ - V_- = \frac{R_X}{R_3+R_X} - \frac{R_2}{R_1+R_2}$$

$$\text{Choose: } R_1 = R_3 \qquad R_X = R_2 + \Delta$$

$$V_+ - V_- = \frac{R_2+\Delta}{R_1+R_2+\Delta} - \frac{R_2}{R_1+R_2}$$

$$V_+ - V_- \approx \frac{\Delta}{R_1+R_2}$$

The advantage is that it autocalibrates for time/temperature variations

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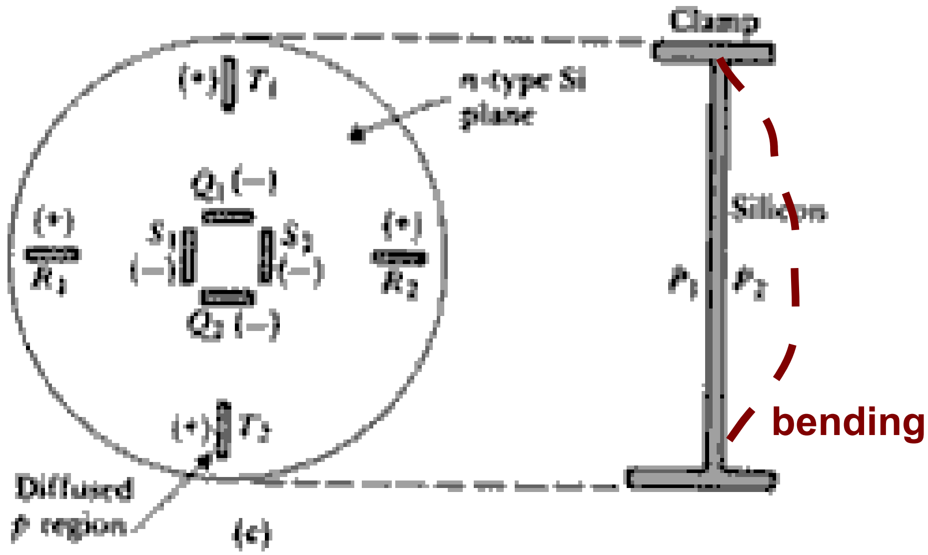
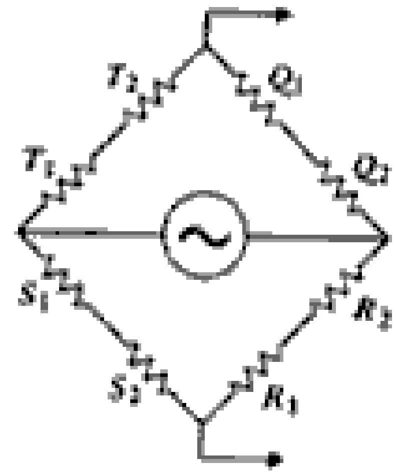
Wheatstone bridge: Question





Consider a strain gauge instrumented pressure transducer

- Before bending T_1=T_2=R_1=R_2= Q_1= Q_2=S_1=S_2= 1kΩ. What is output voltage?
- Hot fluid increases all resistances by 10%. What is output voltage?
- During bending T_1=T_2=R_1=R_2 increase by 1% and Q_1= Q_2=S_1=S_2 by 0.1%. What is output voltage?
- Hot fluid now increases resistances by 10%. What is output voltage?

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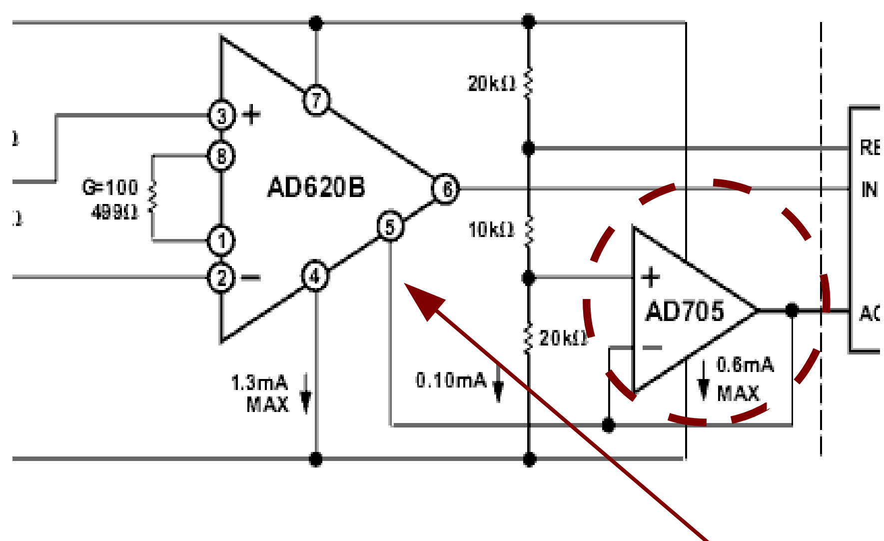
Analog Grounds

Adequate grounding is extremely important for good amplifier performance.

Any noise on the ground will become part of the output signals.

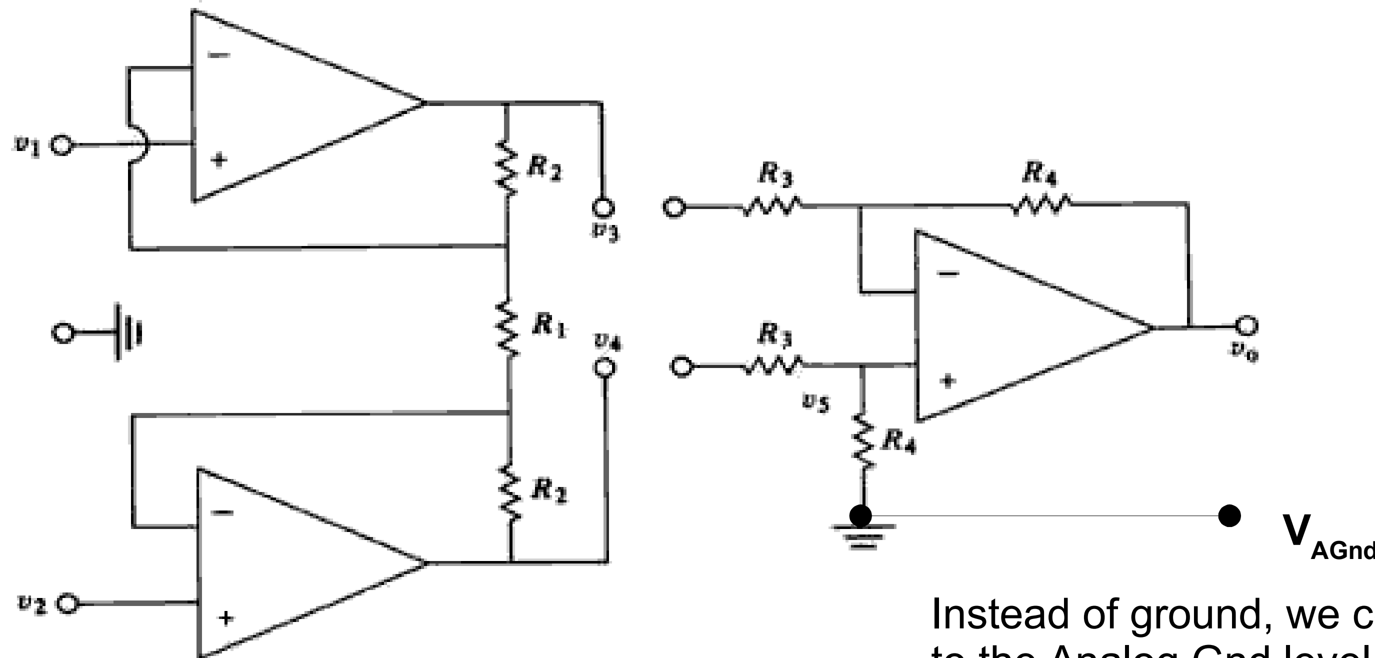
A short list of things to be careful of:

- Keep analog and digital grounds separate. Digital grounds have large switching transients which put noise onto supply and ground.
- Join analog and digital grounds at only one point. This avoids “ground loops” which can be magnetic pick-ups for line noise.
- Use lots of bypass capacitors on chip power supplies. Use both ceramic (nF range) and electrolytic (μF range).



Analog Ground.
V+ = 5V (20k)/(20k+10k+20k)
= 2V
The circuit is a unity gain follower.
The value of the follower: the output impedance is much lower, so it can source current without a drop in voltage.
I would put capacitors (a few 100nF of ceramics) on the input and output.

Single Supply Design



Instead of ground, we connect to the Analog Gnd level (=Signal Ground)

Due to linearity, we can shift the voltage level

$V_O = A(V_4 – V_3)$, where $A = R_4/R_3$

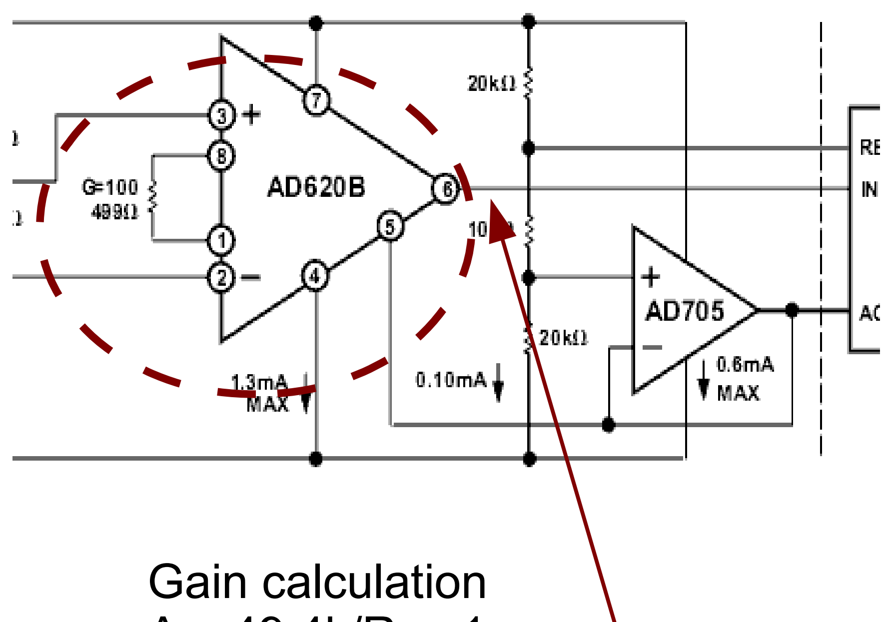
Replace $V = V'-V_{AGnd}$ (since reference level is arbitrary)

$V_O' - V_{AGnd} = A((V_4'–V_{AGnd}) – (V_3'–V_{AGnd}))$

$V_O' = A(V_4' – V_3') + V_{AGnd}$

Single Supply Design

- Single supply design allows circuits to run off a single voltage supply, typically 0 and 5V. Signal levels need to be kept in the centre of the supply range (at around 2 – 2.5V) and away from amplifier limits.
- SS design is common in hand held devices. It uses a single battery
  - Cheaper to manufacture and use
  - Lower power consumption.



Gain calculation

$A = 49.4k/R_G + 1$

$= 49.4k/0.499 + 1 = 100$

So

$V_o = 100(V_+ - V_-) + 2V$

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ECG Monitoring circuit

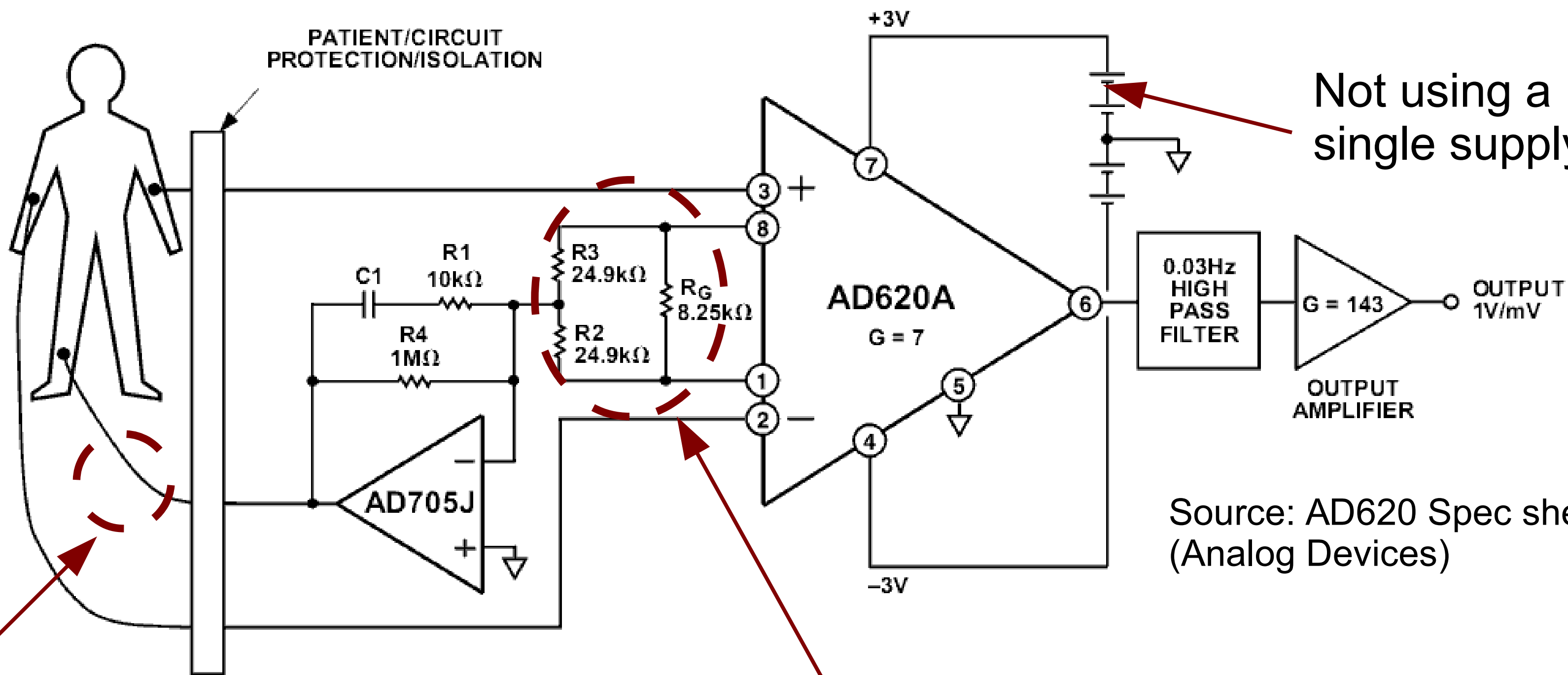

Figure 36. A Medical ECG Monitor Circuit

Not using a single supply

Source: AD620 Spec sheet (Analog Devices)

I would put a resistor in this Line, for patient protection (may be in protection/isolation circuit)

Driven Ground Circuit

Gain is

R_G = (24.9k+24.9k)||8.25k

R_G = 7.08k

A = 49.4k/7.08k + 1 = 8

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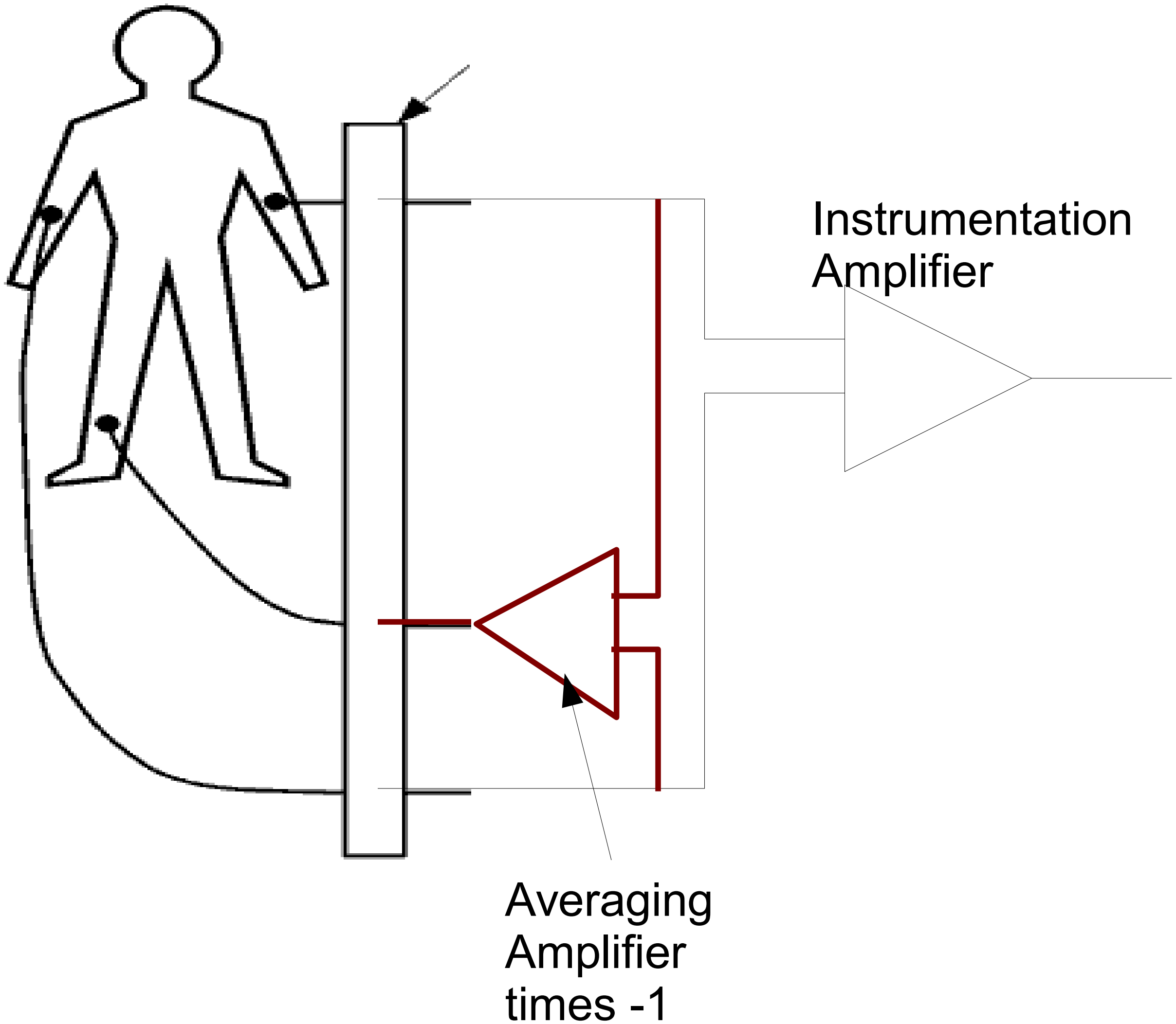
Driven Right Leg circuit



Idea: if CMRR is such a problem, why don't we just force it to ground.

So we measure the Vcm, by averaging V_+ and V_-.

Next we build a negative feedback loop to drive V_{cm} to zero.

The driven right leg circuit also provides some safety (driving high voltages to zero ... but limited by transistor breakdown)

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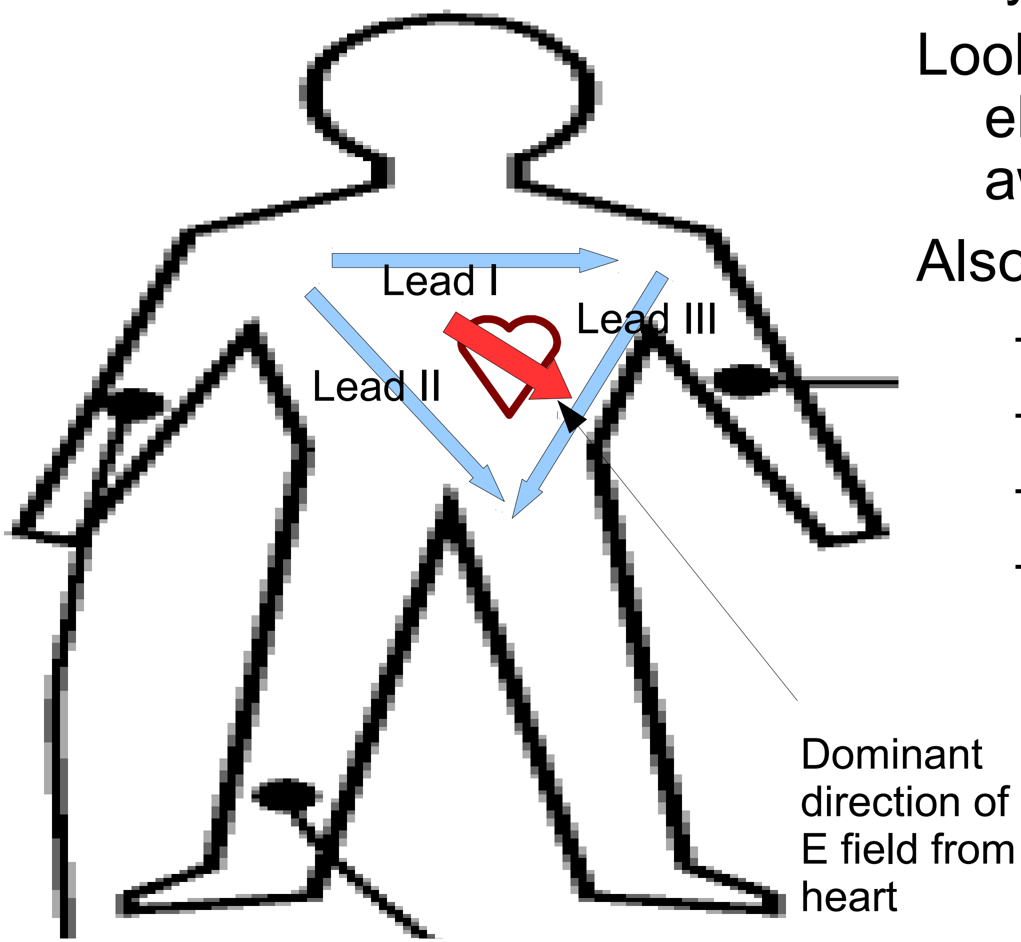
Driven Right Leg circuit



Why right leg?

Looking at the heart, the dominant electrical fields are generated away from the right leg.

Also, for Einthoven's leads

- Lead I: RA → LA
- Lead II: RA → LL
- Lead III: LA→LL
- Thus, only the RL is left unused for the diagnostic information

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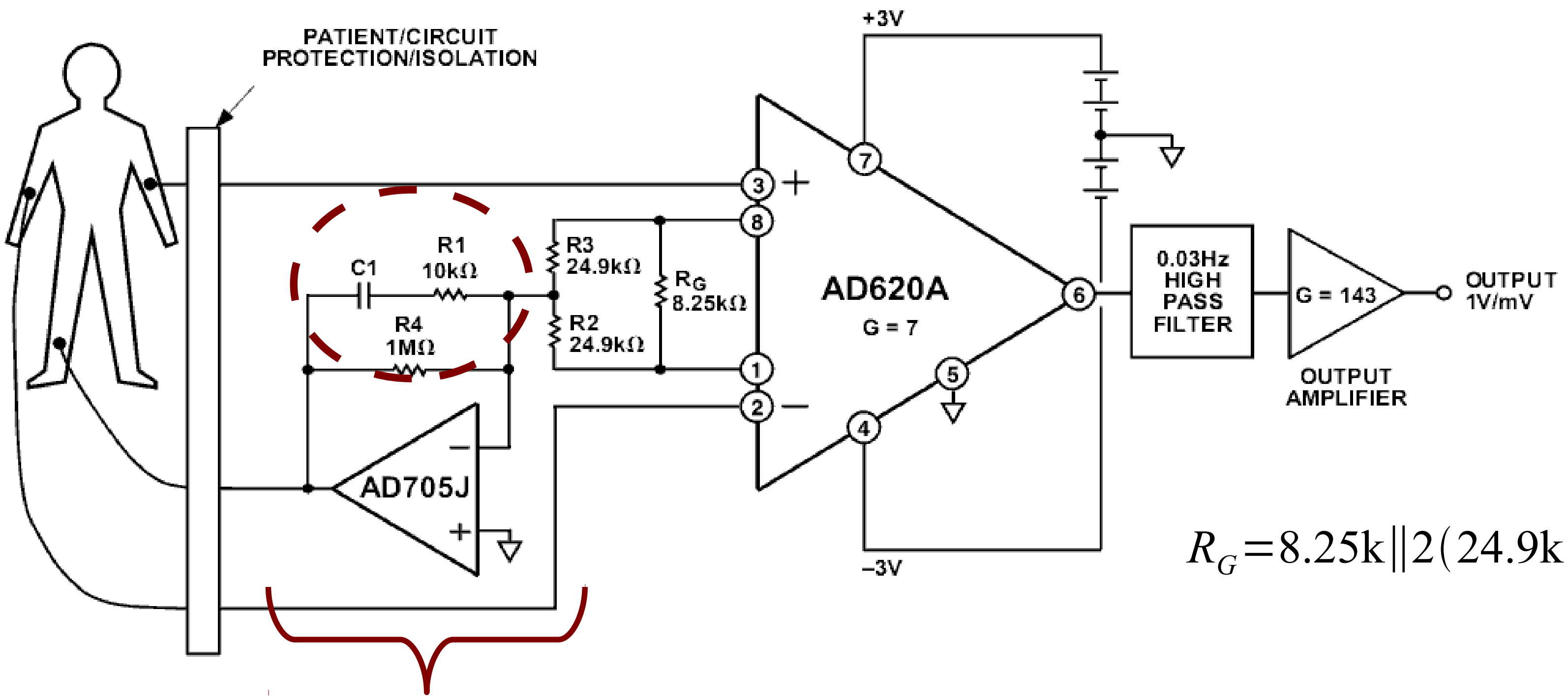
Analysis of Driven Leg gain



$$R_G = 8.25\text{k} \| 2(24.9\text{k}) = 7.07\text{k}$$

$$DC\ Gain = \frac{-R_4}{R_3} = -\left(\frac{1\text{M}}{24.9\text{k}\|24.9\text{k}}\right) = -80$$

$$AC\ Gain = \frac{-R_4}{R_3} = -\left(\frac{1\text{M}\|10\text{k}}{24.9\text{k}\|24.9\text{k}}\right) = -0.8$$

AC |gain|<1 to prevent oscillations

$$f_b\ point\ when: \left|\frac{1}{j\omega C} + 10\text{k}\right| = 1\text{M}$$

$$\sqrt{\frac{1}{(\omega C)^2} + 10\text{k}^2} = 1\text{M}$$

$$\omega = \left(C\sqrt{1\text{M}^2 - 10\text{k}^2}\right)^{-1} = (C \times 995\text{k})^{-1}$$

Components of a medical ECG amplifier

Functional Blocks

- Protection Circuits
- Isolation Circuits
- Lead selector
- Calibration signal
- Preamplifier (with high CMRR)
- Main amplifier (with settable gain)
- Driven RL circuit
- Analog to Digital Converter
- Memory
- Local display
- Upload / link to hospital IT system

And if the unit is wireless, then there are still more components required:

- Battery, wireless LAN connection, security, local storage & upload for when LAN not available ...

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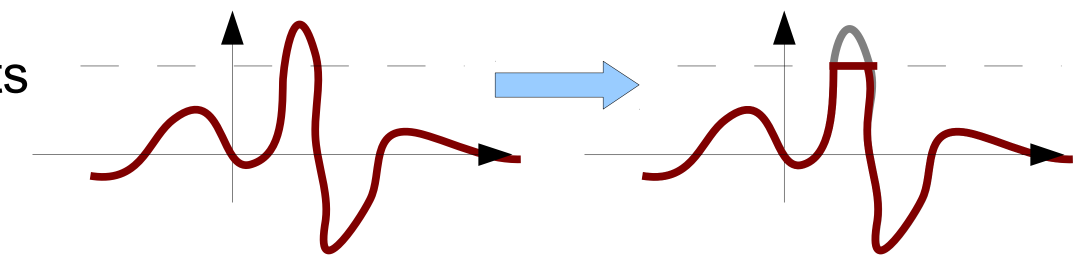
Issues in medical amplifiers

Saturation (clipping) of signal

- gain larger than ADC limits



Ground loops

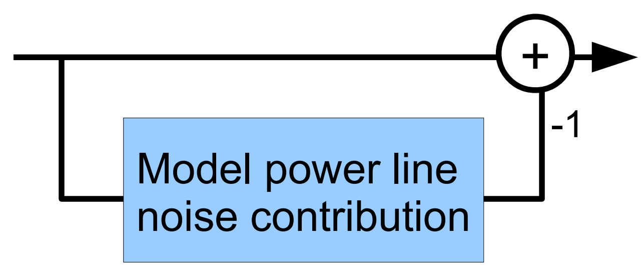
Open lead wires

Large signal transients

- Transient protection required on all inputs, usually using zener diodes (or for smaller signals, back to back Si diodes)

Power line interference

- Can remove with analog filters (60Hz notch filter) in the device, or in post processing
- Post-processing: use a strategy of modelling and subtraction



Interference from other devices

Questions

- Draw a Wheatstone bridge circuit. What types of circuit changes does it provide resistance against?
- In what situations is single supply design a good idea? Sketch a block diagram of a single supply amplifier.
- What is CMRR? Why is it a problem in medical instrumentation? What kinds of interference causes a large CM signal?
- Sketch a block diagram of a driver right leg circuit?
- How does a driver right leg circuit help improve CM response?
- What causes signal saturation (clipping)? How can you detect it?
- Describe how an infusion pump near a biomedical amplifier can cause power line interference. Describe some strategies to remove power line interference.
- What is a problem with open lead lines into an amplifier?