Patient monitoring 101: Part-6

Electrode configurations and interface circuitry for ECG in wearable devices

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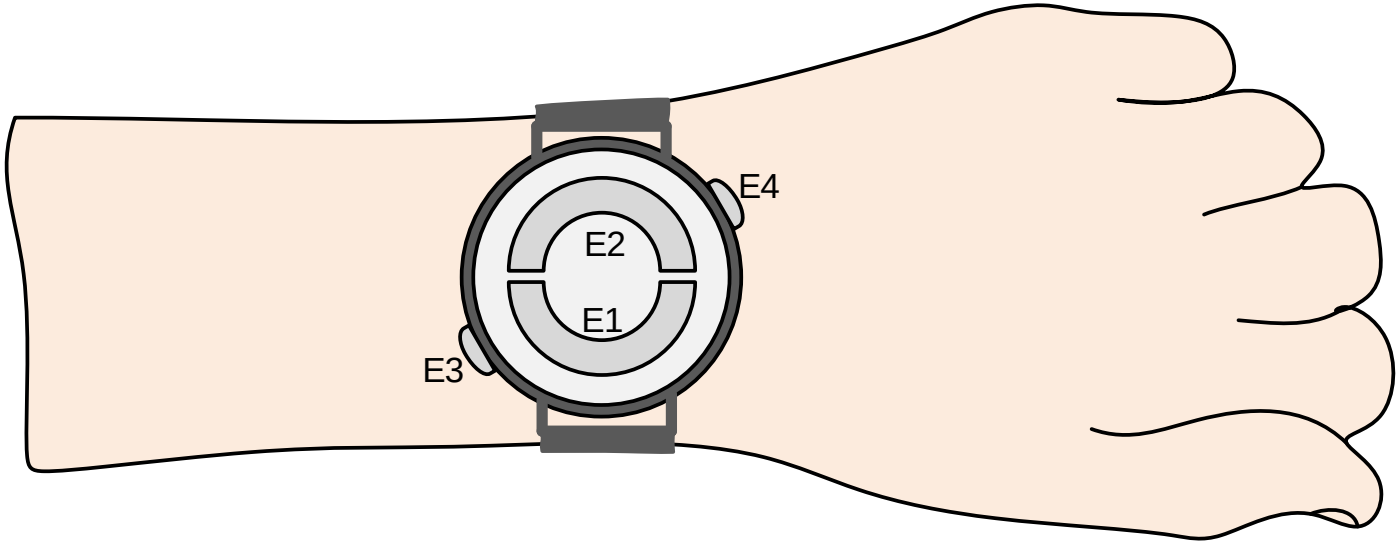
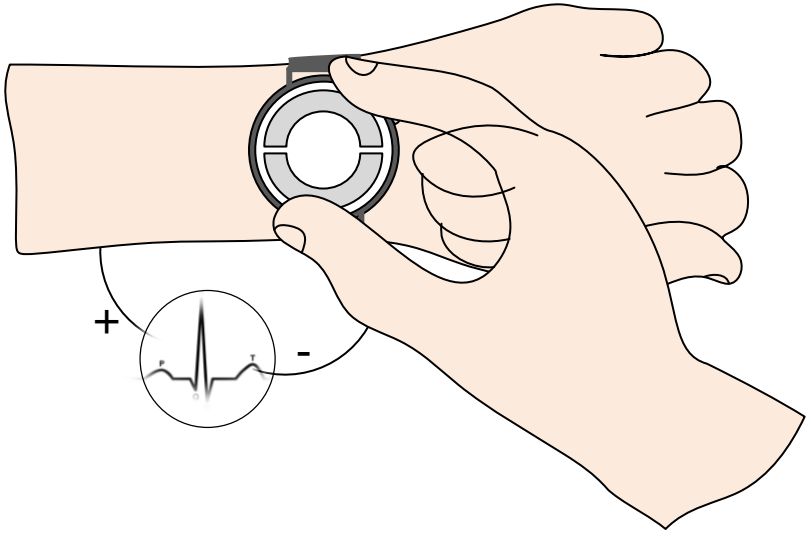
Agenda

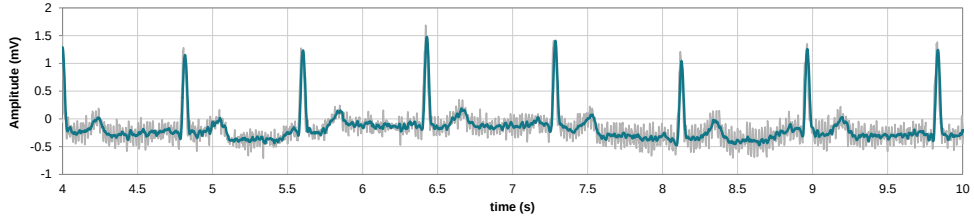
- **Overview of ECG acquisition on wearable devices**
  - Overview
  - Challenges posed by high contact impedance
- **Electrode configurations for ECG acquisition on wearable devices**
  - Role of Right Leg drive
  - 2-electrode and 3-electrode configurations
- **Electrode interface circuitry**
  - DC and AC coupled configurations
  - Filtering and buffering

ECG electrode placement on a watch



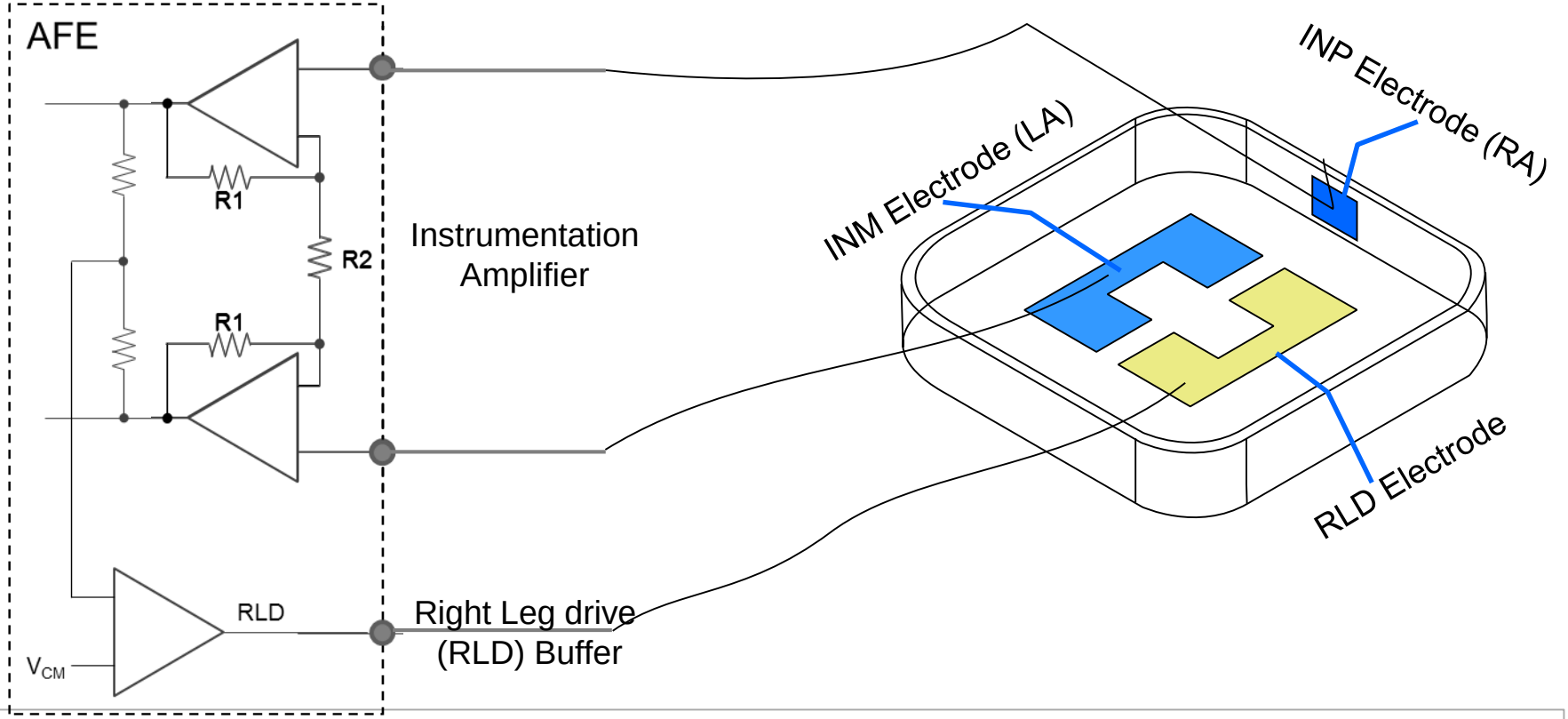
Overview of ECG acquisition on wearable devices



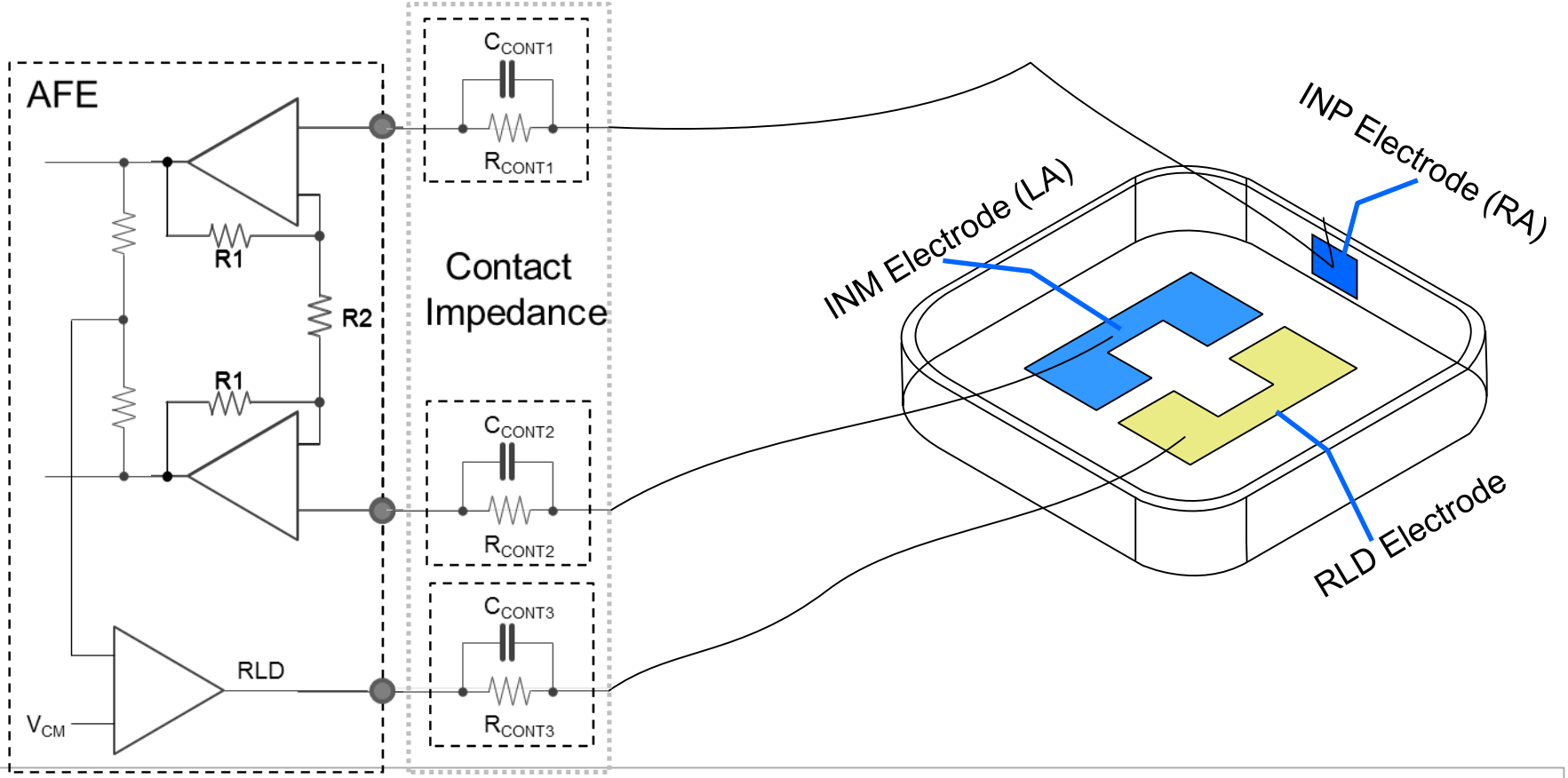


ECG signal – Raw and filtered

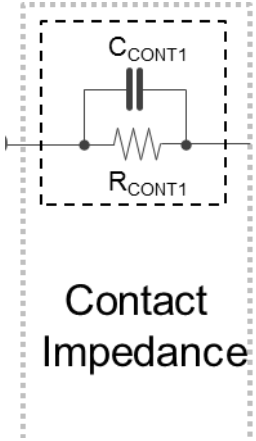
Interface of the electrodes to the analog front end



Interface of the electrodes to the analog front end



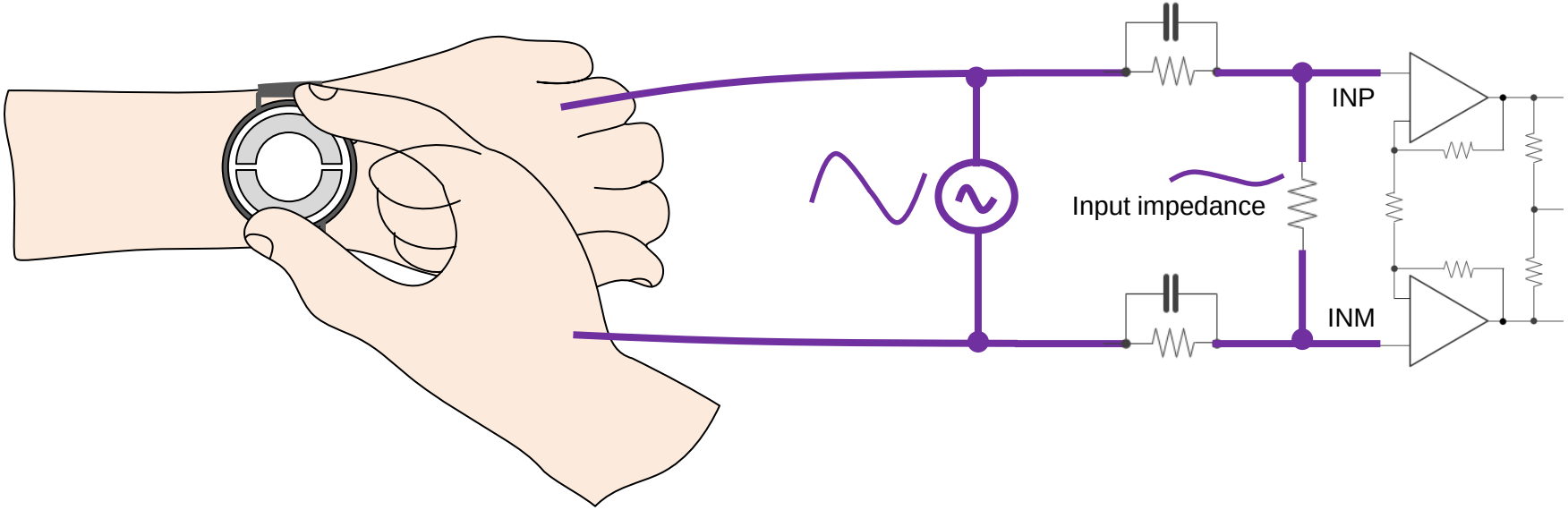
ECG on a wearable device - challenges



- Dry electrodes with small size can have high contact impedance
- High contact impedance can cause ECG signal attenuation
- Contact impedance adds thermal noise – needs to be low pass filtered before the ADC
- Mismatch in contact impedance can degrade CMRR

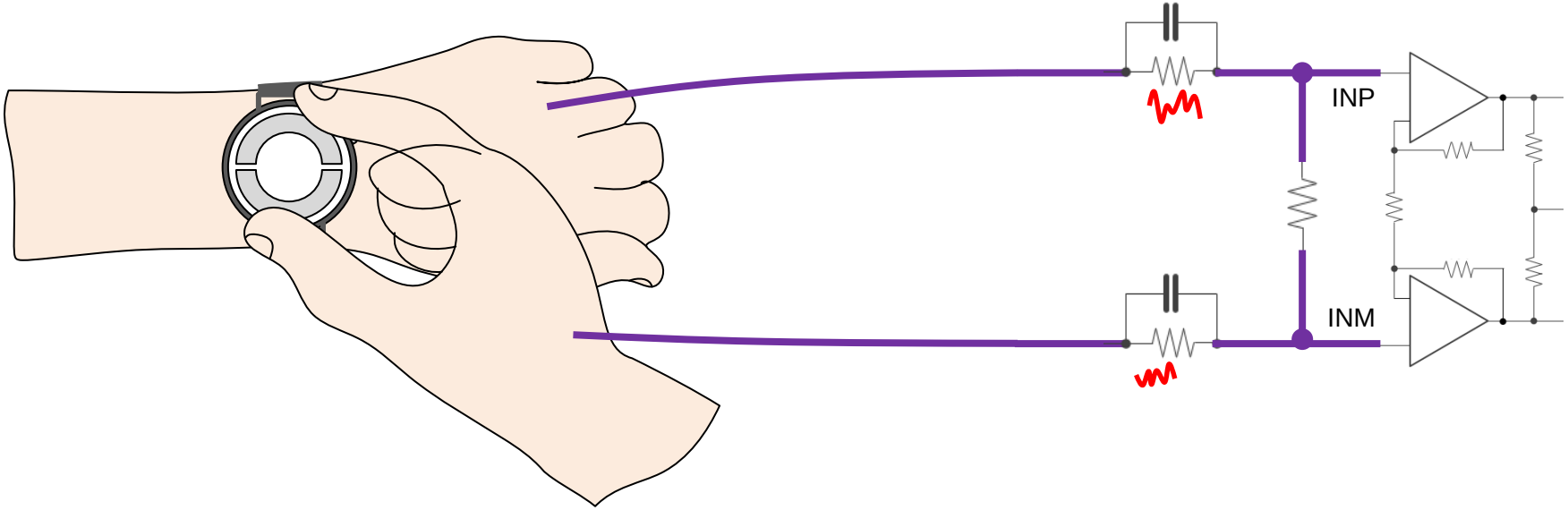
Effect of contact impedance

High contact impedance (relative to input impedance of the INA) can cause signal attenuation



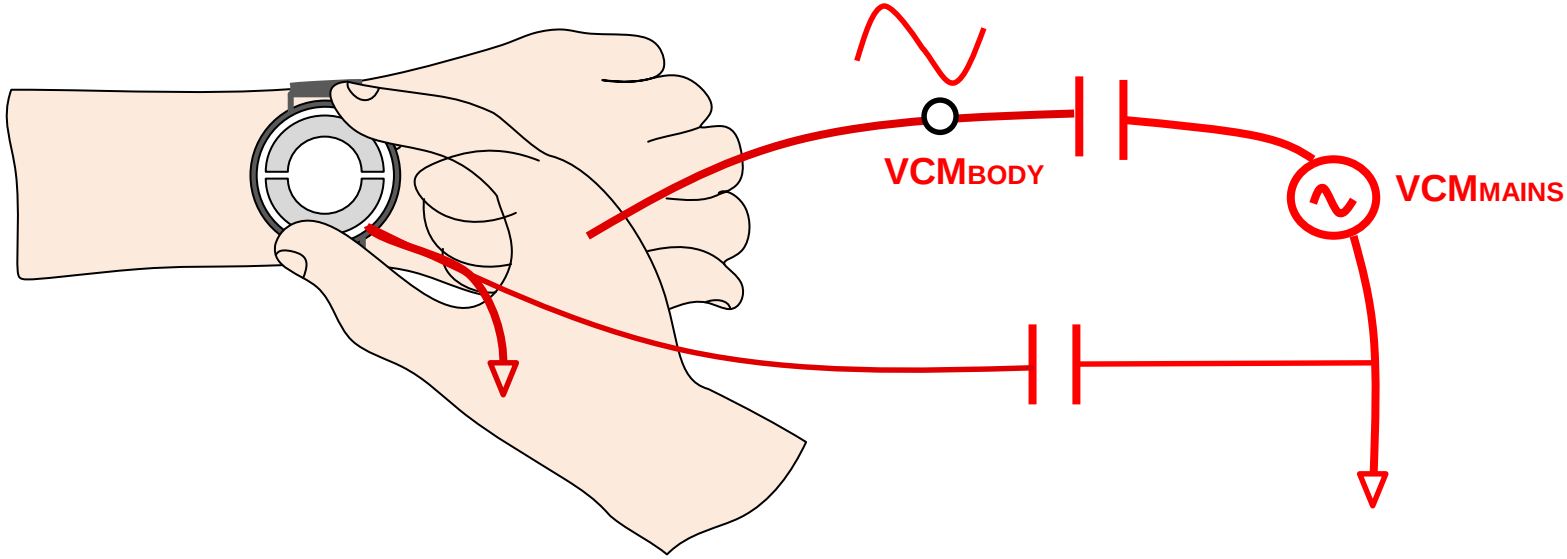
Effect of contact impedance

High contact impedance can also introduce an extra thermal noise component



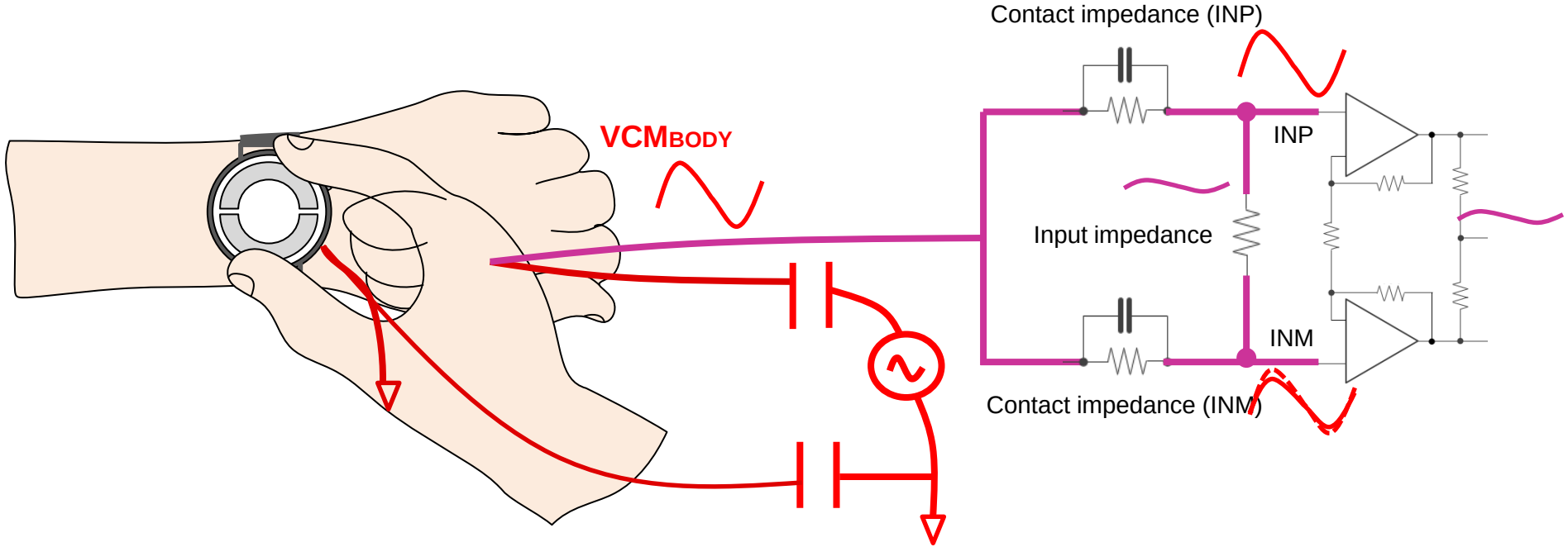
Common mode interference

Common mode interference from mains is picked up by the body

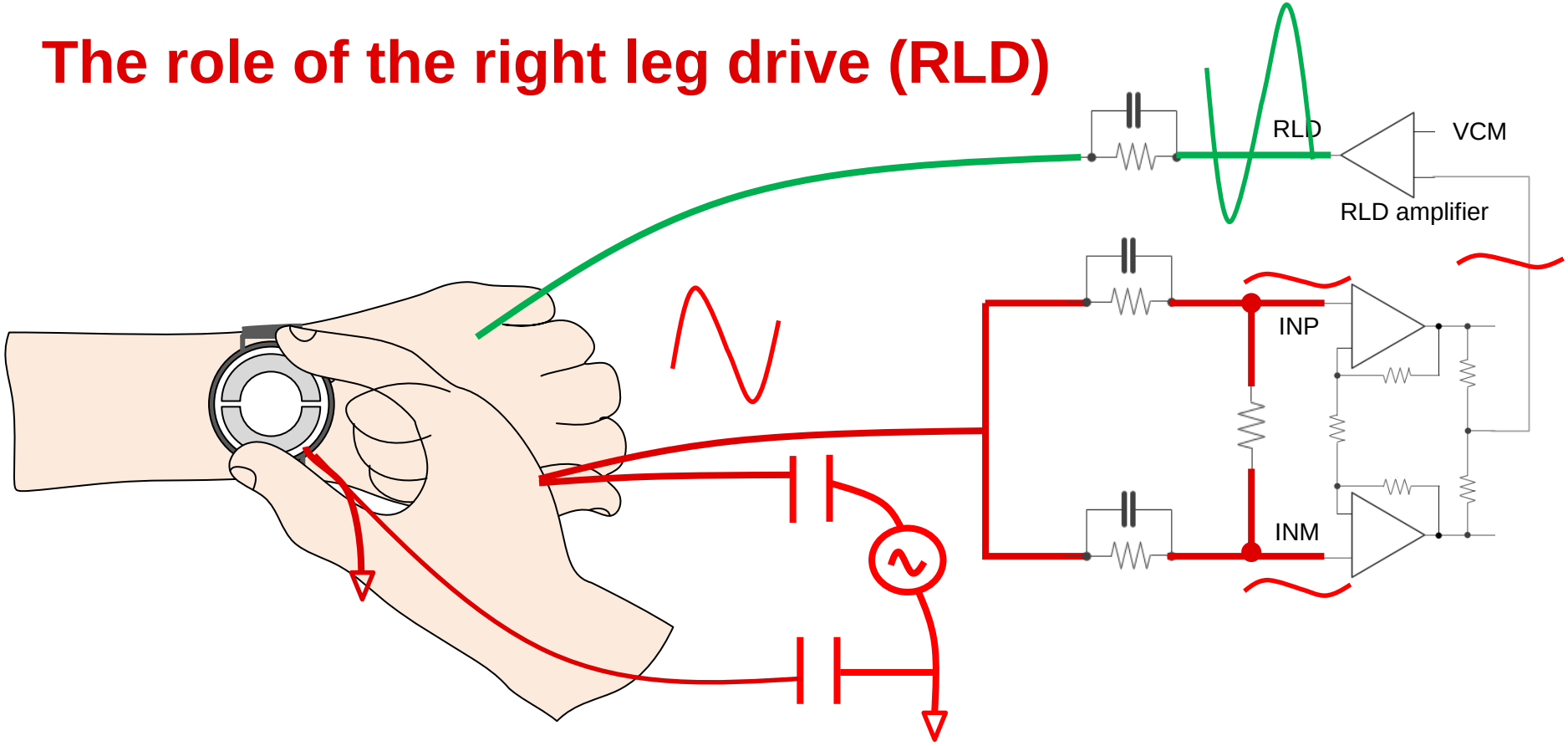


Common mode to differential conversion

Common mode interference picked up by the electrodes can get converted into differential signal if the INP & INM contact to the electrodes are mismatched



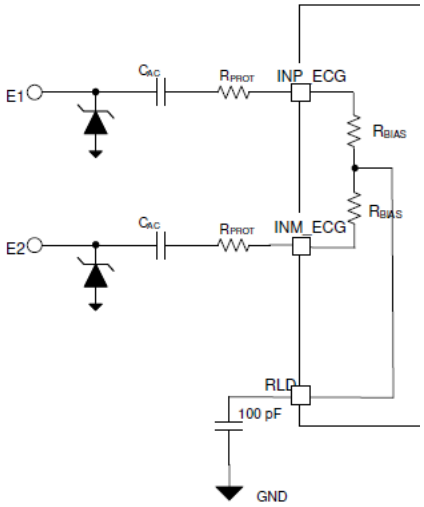
The role of the right leg drive (RLD)



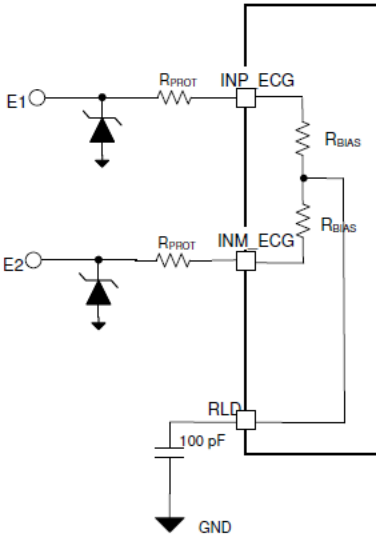
Driving RLD electrode through feedback suppresses mains pickup

Electrode configurations

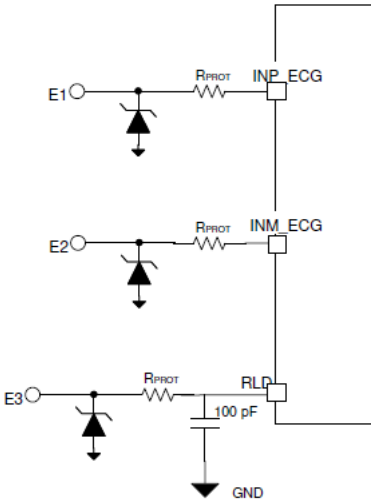
2-electrode AC coupled



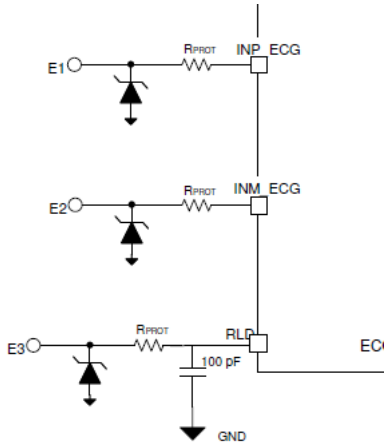
2-electrode AC coupled



3-electrode DC coupled



DC vs. AC coupling

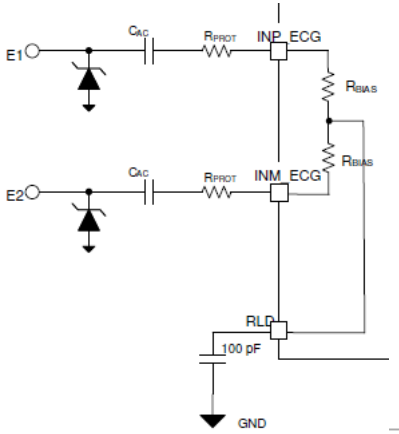


DC coupling

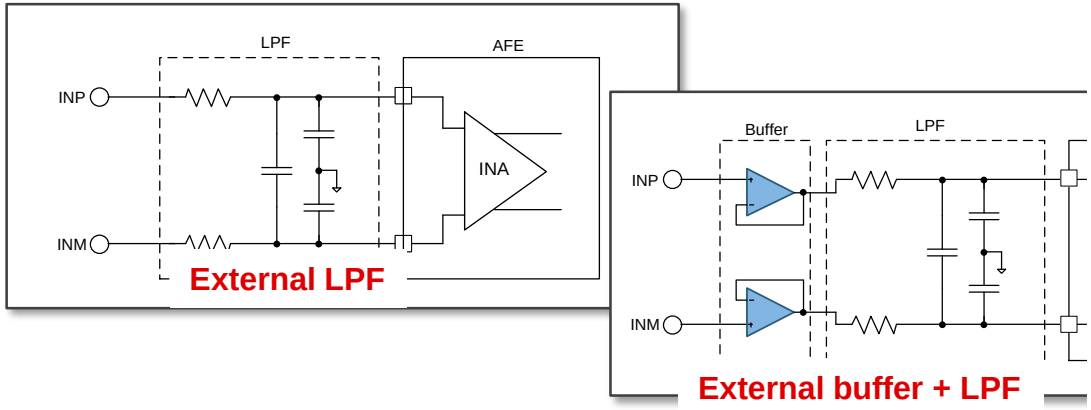
- DC coupling allows direct connection to the electrode without shunt components → Highest input impedance
- Input DC bias set by driving 3rd electrode strongly with RLD → Best CMRR
- Allows both AC and DC lead detection
- In DC coupled configuration, electrode offsets need to be handled by INA, so INA gain has to be small

AC coupling

- AC coupling helps to remove the DC offset and allows higher INA gain
- Input pins biased through R_{BIAS}
- Low R_{BIAS} → Reduces input impedance
- High R_{BIAS}: Reduces CMRR
- C_{AC}/ R_{BIAS} forms a HPF - Recovery time of HPF is high

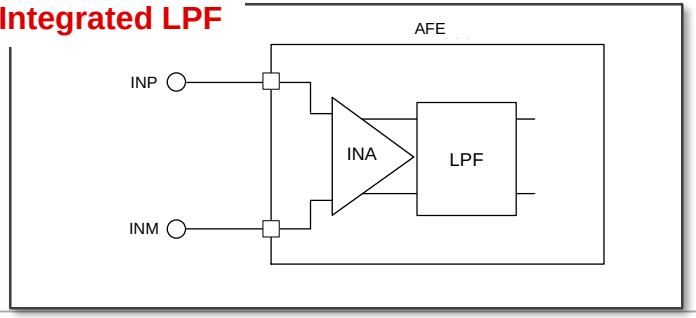


Buffering and filtering



- Contact impedance adds noise that needs to be filtered before ADC
- Other interferers also need to be filtered
- If external LPF is used to filter the noise → LPF cap reduces input impedance
- External LPF can be inserted using an external buffer to prevent input impedance degradation
- Buffer adds to power consumption

Integrated LPF



- Internal LPF solves these issues
- LPF acts as an anti-aliasing filter, helping to filter noise
- Allows direct connection to electrode without buffer