Microcomputer interface – Bandwidth, noise and gain in db, continuous-time and discrete-time signal

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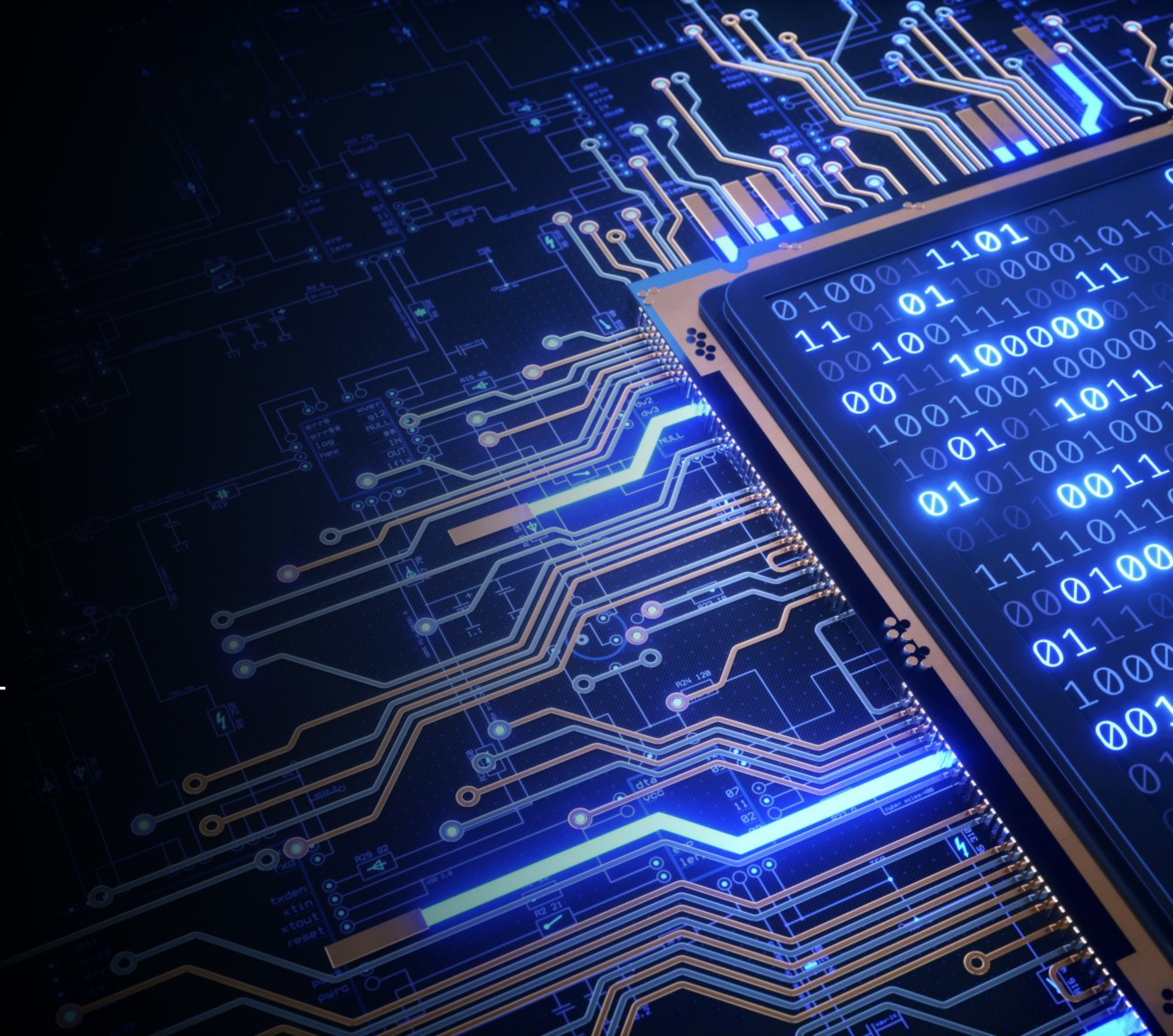
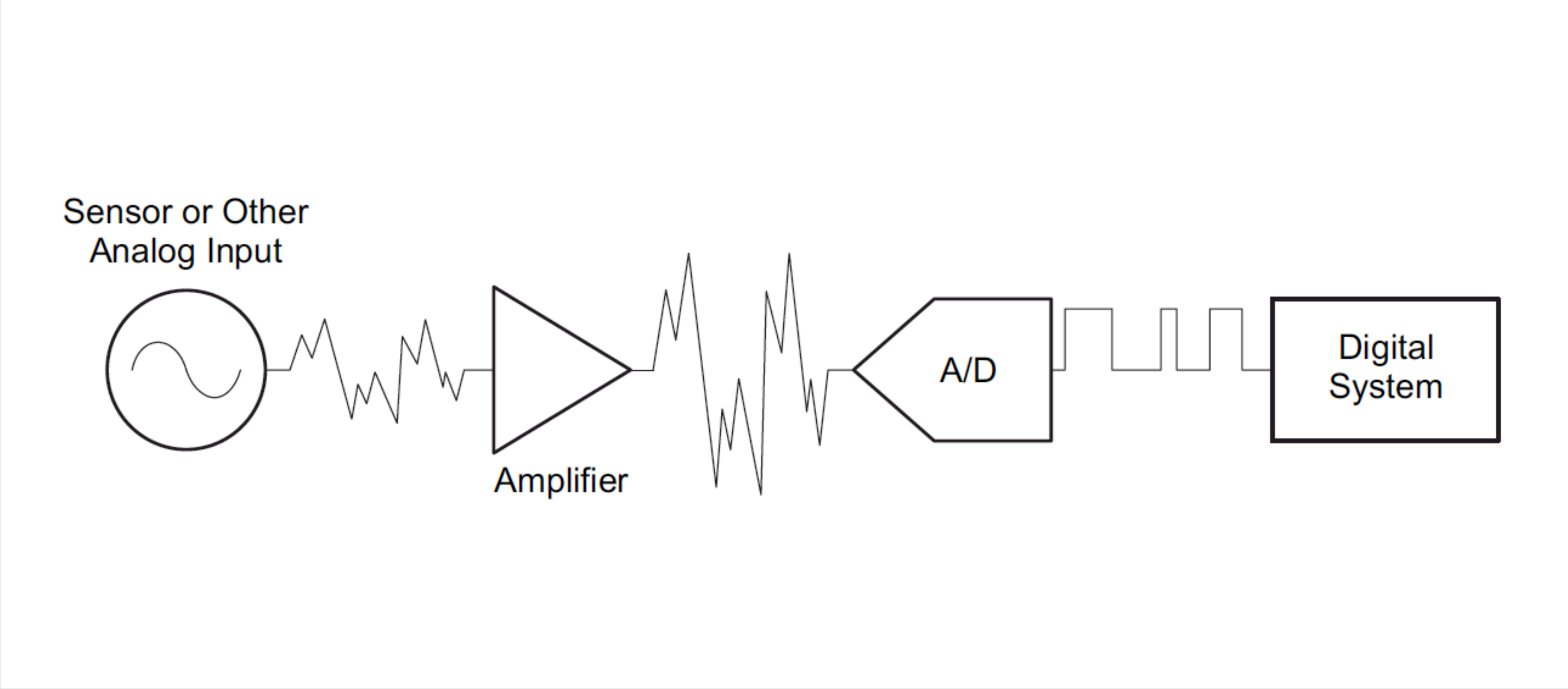


Contents

Basic architecture

It shows how a sensor output or analog signal is converted into a form suitable for the digital system. It consists of two main parts:

a. Amplifier or signal conditioning circuit
b. Analog-to-digital (A/D) converter or ADC



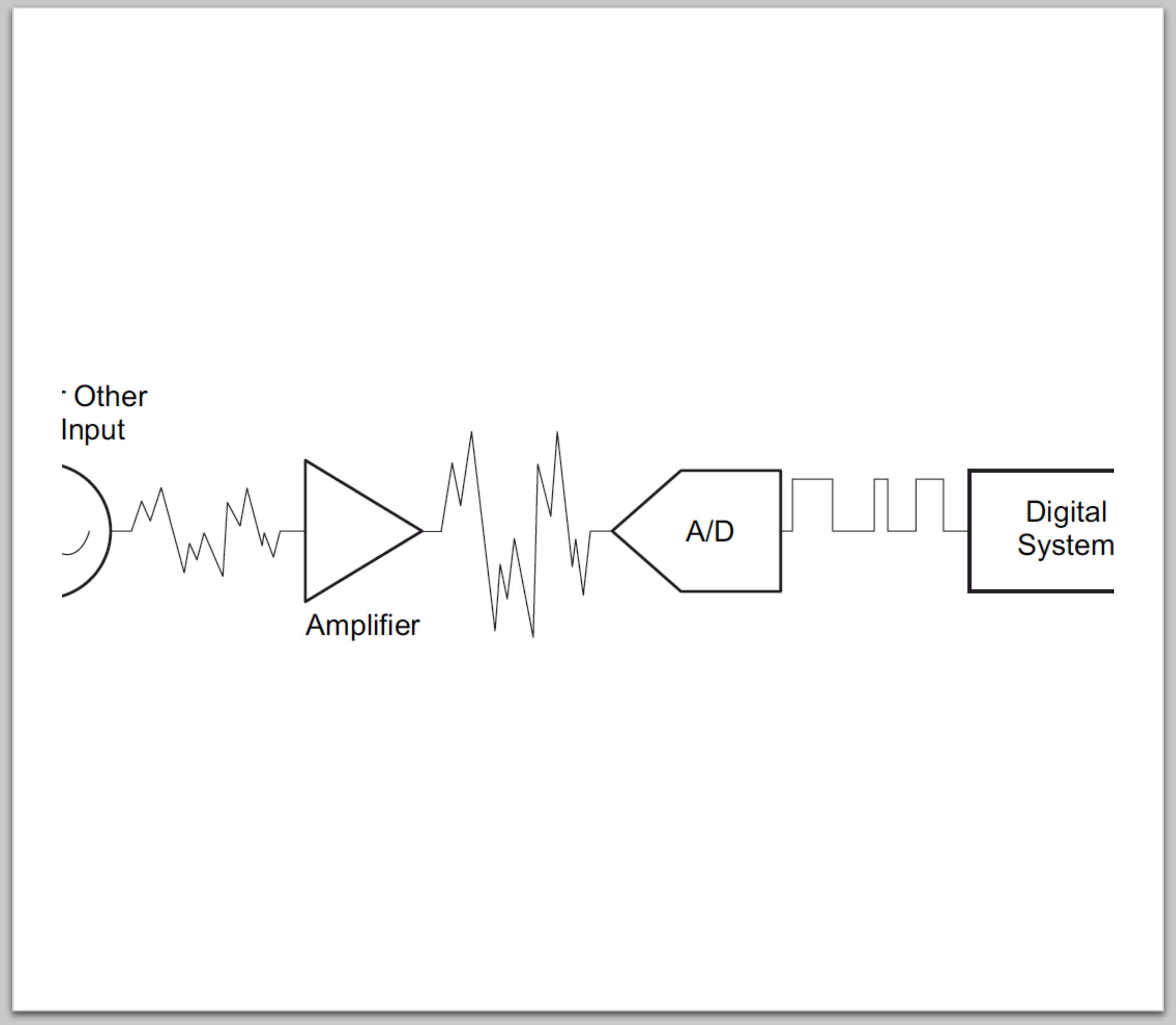
Basic requirements for the amplifier

Its input specification meet the output requirements of the sensor / signal source

Its output specification meet the input requirement of the ADC

What are the major considerations in the specification?

- Voltage or current type
- DC level
- AC level
- Frequency range



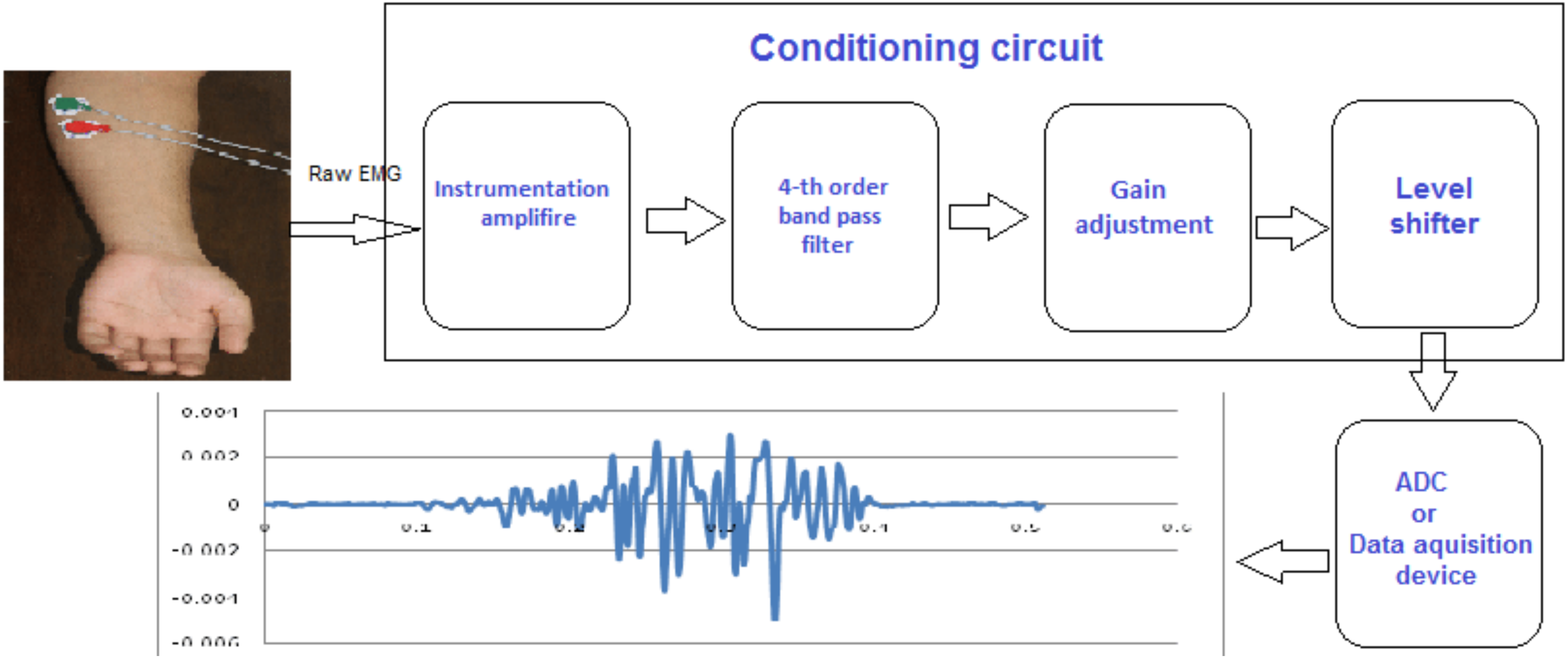
Amplifier or Signal Conditioning Circuit

The process of interfacing an input to an analog to digital converter may involve some or all of the following processes:

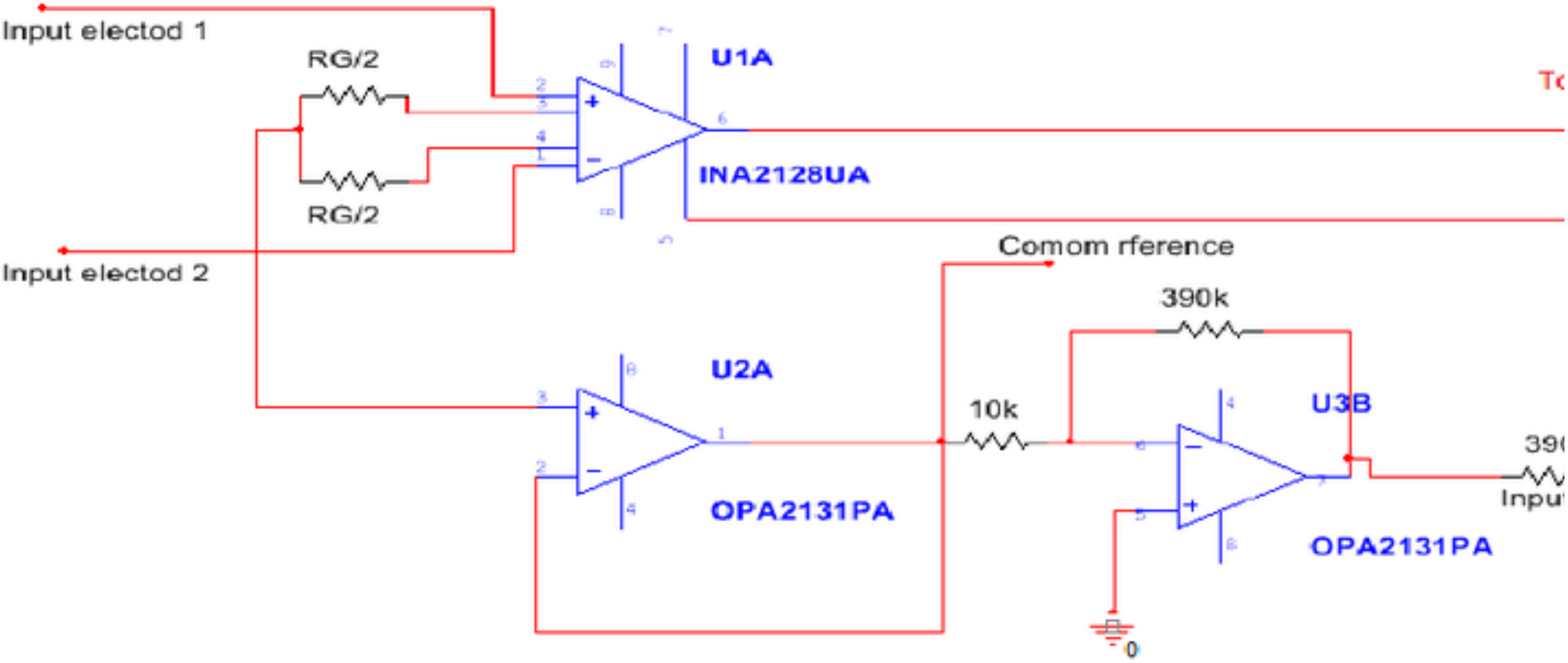
- Amplification / attenuation – scaling the input signal level to the level required by the input circuitry of the ADC.
- DC offsetting / level shifting – moving the dc level of the input signal up or down by a fixed offset to match the operating range of the ADC.
- Filtering – removing unwanted signal components from the input signal, and providing only the bandwidth of interest to the ADC.

Typically, *operational amplifier circuits* are used to perform the above functions.

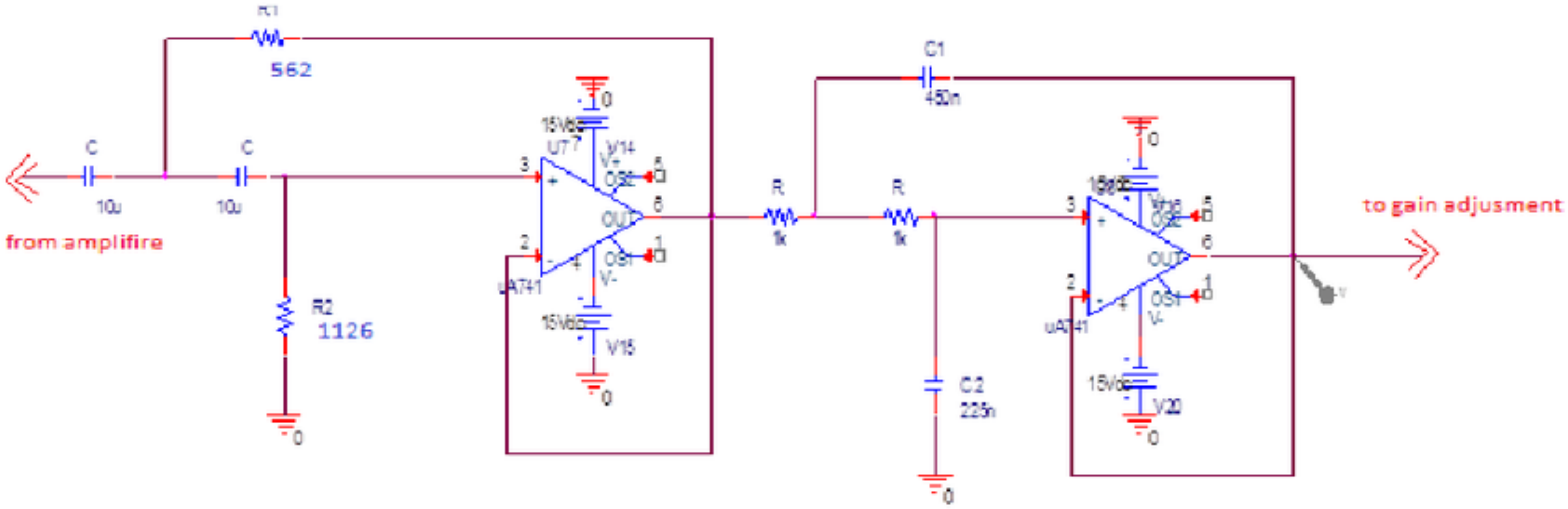
Example –Signal Conditioning Circuit for Electromyography



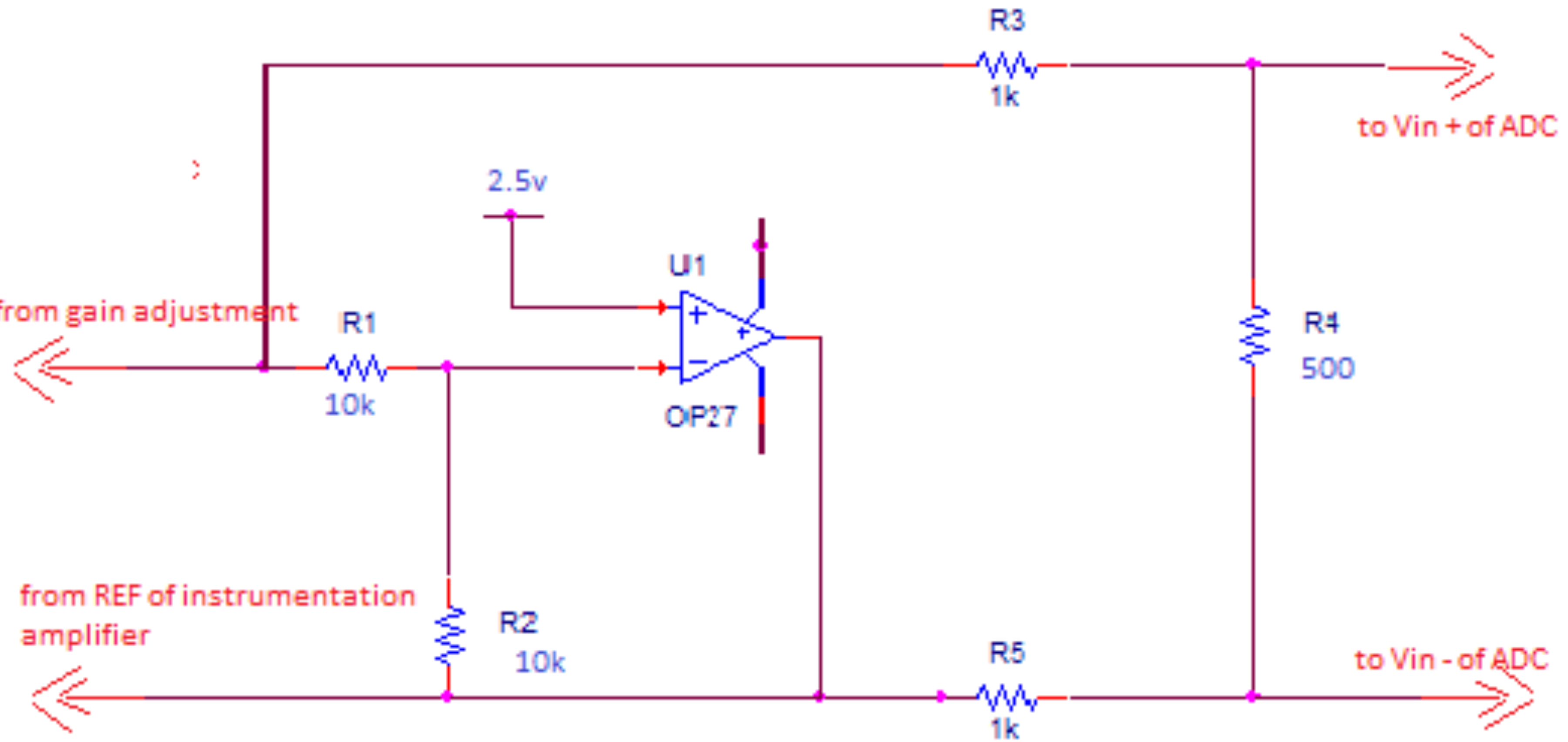
Instrumentation amplifier [For Ref only]



4th-order Bandpass filter [For Ref only]



Gain adjustment circuit [For Ref only]



Considerations

- **Impedance matching:** Signal sources are not necessarily low impedance. The input of an ADC may well load the source, affecting it. A unity-gain operational amplifier buffer has very high input impedance, and therefore will not load the source. In addition, its low output impedance is well-suited to driving the input of an ADC.
- **Reducing the effects of capacitive loading:** Most types of ADCs present a capacitive as well as resistive load on their input. This requires an external compensation circuit, usually a resistor and capacitor. Texas Instruments often specifies this network. It is important to follow the recommendation, but doing so presents a capacitive load to the source. The resistor isolates the source from the capacitor, but is usually a low value. The low output impedance of an operational amplifier interface can usually drive this network with no problem.
- **Conversion from single-ended to differential signals:** Even if an operational amplifier is not required for the reasons above, many new analog to digital converters have differential inputs. Most input sources are single ended. Therefore, an operational amplifier interface is required to perform the conversion.

Gain

The Voltage Amplification (A_v) or Gain of a voltage amplifier is given by:

$$A_v = \frac{V_{out}}{V_{in}}$$

where V_{out} and V_{in} are the output and input voltage of the amplifier, respectively.

With both voltages measured in the same way (i.e. both RMS, both Peak, or both Peak to Peak), A_v is a ratio of how much bigger is the output than the input, and so has no units. It is a basic measure of the Gain or effectiveness of the amplifier.

Logarithmic Scales

Response curves normally use a logarithmic scale of frequency, plotted along the horizontal x-axis. This allows for a wider range of frequency to be accommodated than if a linear scale were used.

The gain is expressed in decibels.

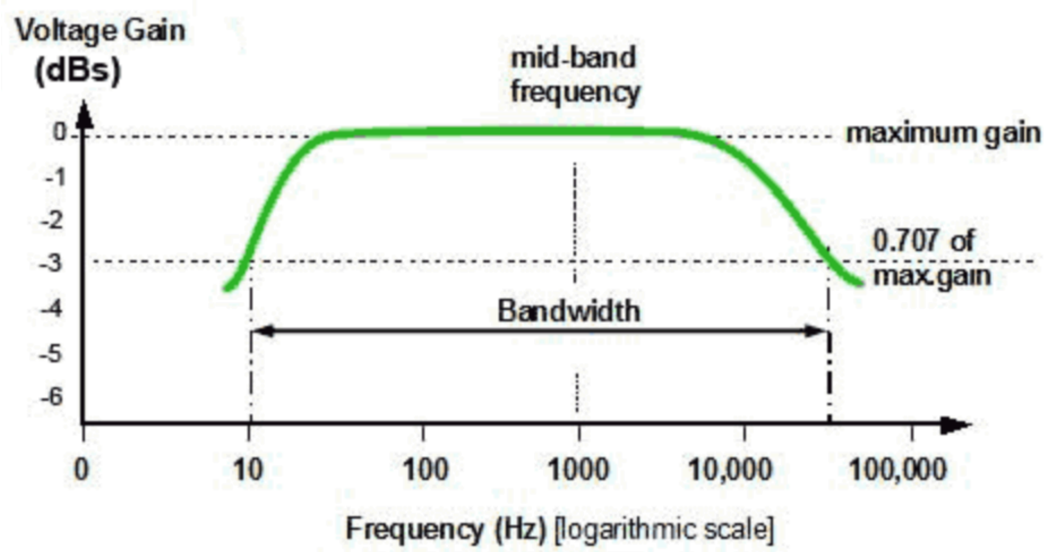
Think about the expression?

dB	Power ratio	Amplitude ratio
100	10 000 000 000	100 000
90	1 000 000 000	31 623
80	100 000 000	10 000

$$\text{dB} = 10\, Log_{10} \frac{P_{out}}{P_{in}} = 10\, Log_{10} \left(\frac{Vout}{vin}\right)^2$$

Frequency response curve

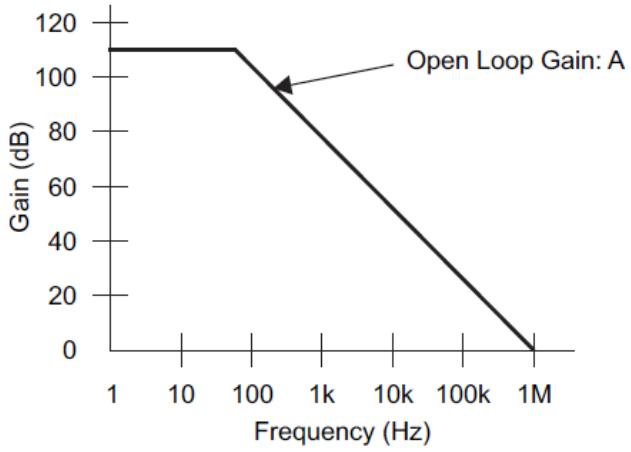
When voltage gain(A_v) is plotted against frequency the −3dB points (half power) are where the gain falls to 0.707 of the maximum (mid band) gain.



Why is -3dB point equivalent to the half-power point?

Bandwidth of operational amplifiers

- The open loop gain (A) at DC and low frequencies, which is characterized by a horizontal line (gain is constant with frequency).
- The breakpoint due to the internal compensation. At this point, the operational amplifier response changes from being constant with frequency to a region with a roll off of 20 dB per decade of frequency.
- The point at which the roll off of the frequency reaches the unity gain (0 dB) line on the Bode plot. This is considered the bandwidth of the amplifier.



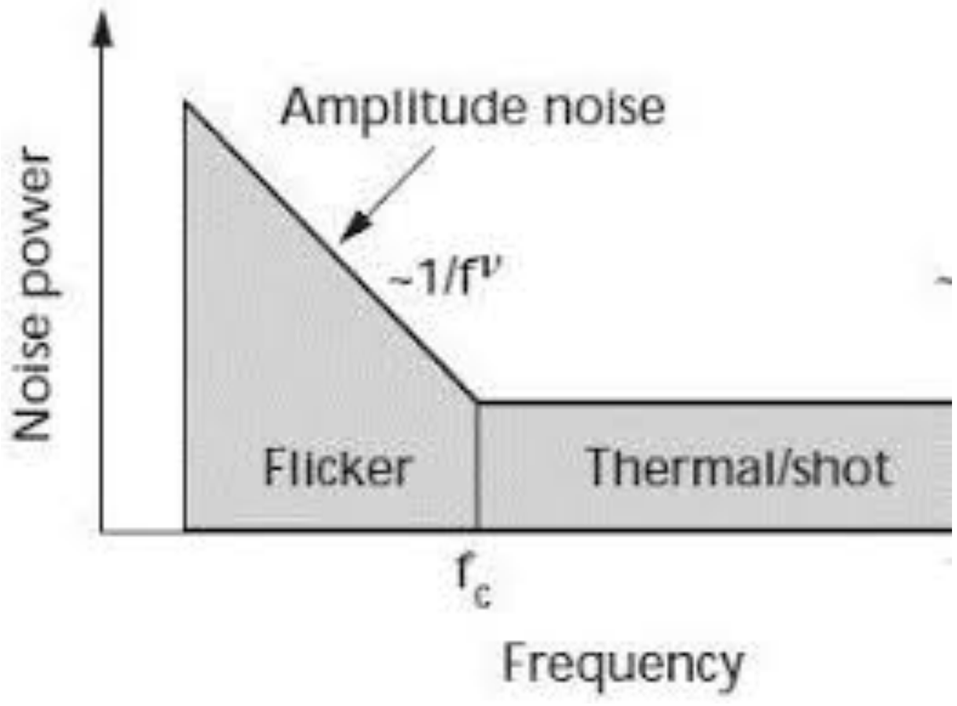
Types of noise

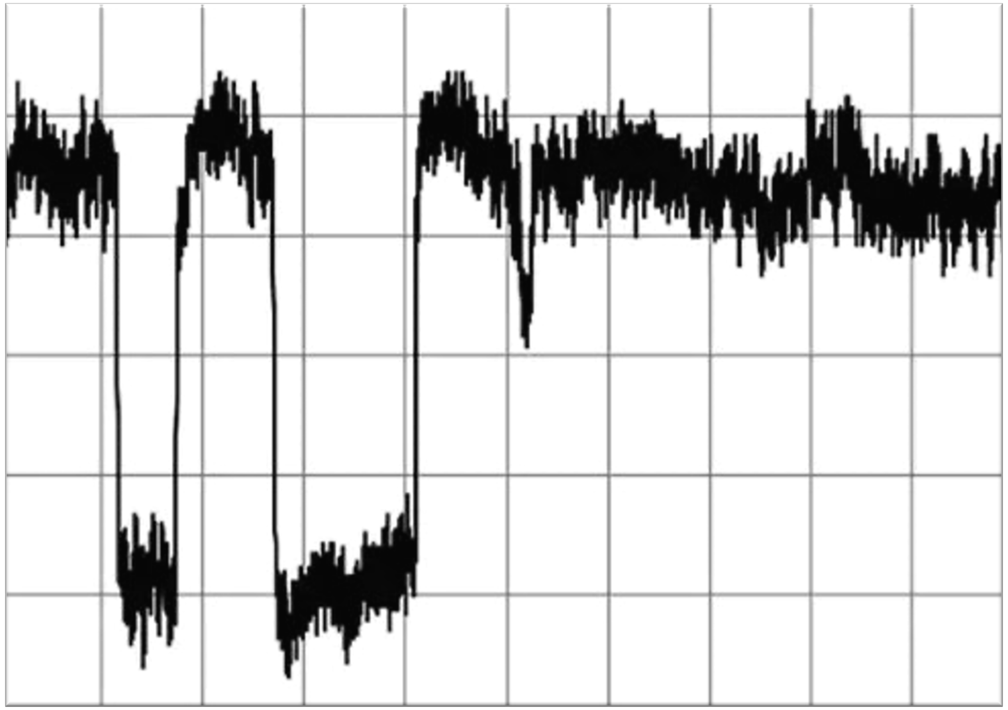
Noise is an unwanted disturbance in an electrical signal.

Types of noise:

- **Thermal or White noise** – power spectral density is the same over frequency spectrum
- **Shot noise** - arises because of the discrete nature of the charges carried by charge carriers, electrons or holes.
- **Flicker noise** - signal or process with a frequency spectrum that falls off steadily into the higher frequencies, with a pink spectrum.
- **Burst noise** - transitions between two or more discrete voltage or current levels at random and unpredictable times.

Spectra of different noise

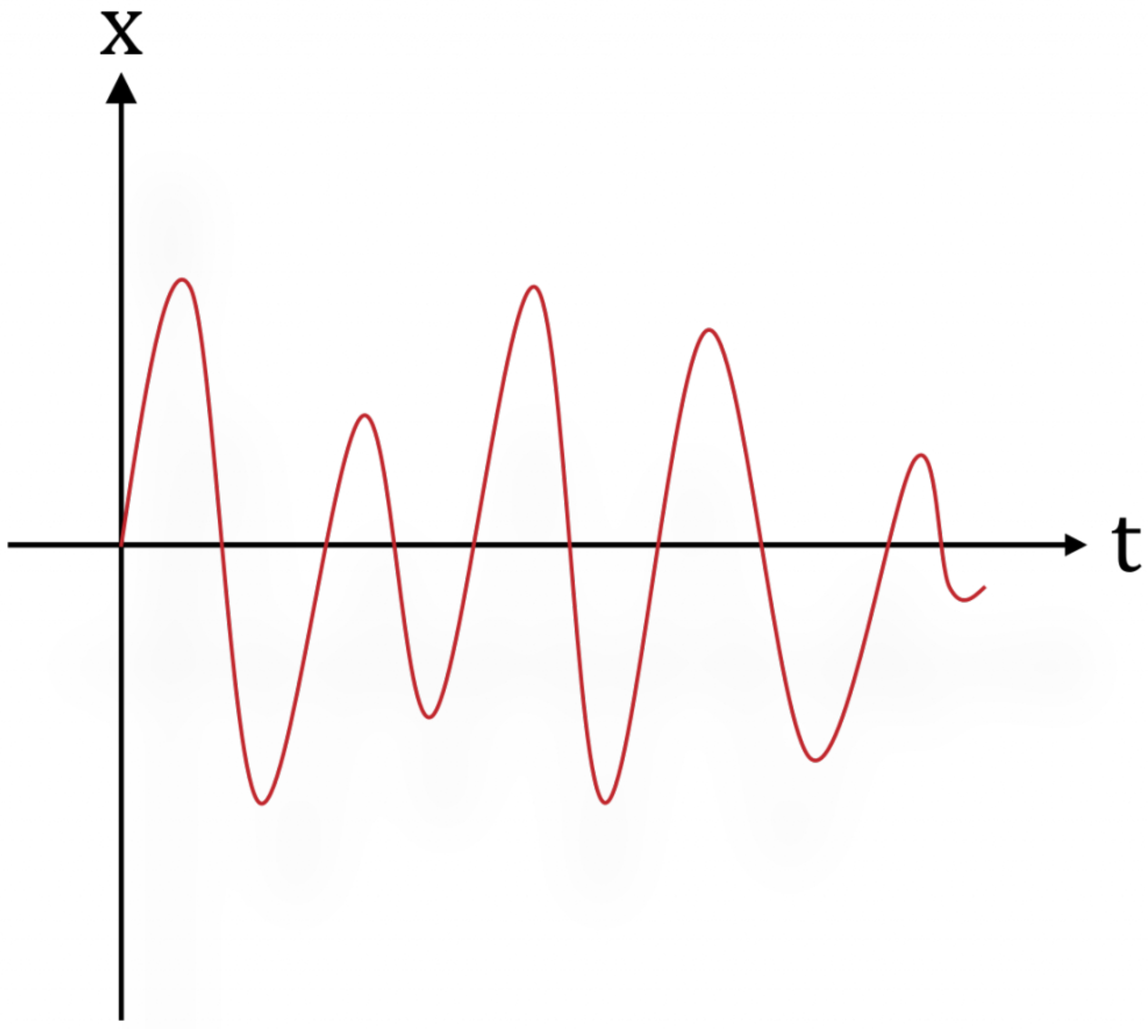




Burst noise

Analog Signals

- Voltage of a pin with reference to signal ground (GND)
- What is an analog value?
  - Vary within a range, not in discrete values; Theoretically infinite number of possible values within that range.
- Typically, sensors delivers analog signal. However, some will give discrete levels, such as 0V and 3.3V, or a numerical value.



Digital Signals

- Digital signals carry the data although it is a bit different. These signals are discrete or not continuous.
- A digital signal carries the data in the form of binary because it signifies in the bits. [Later, we will discuss in analog to digital conversion.]

Discuss the advantages of digital and analog systems.

How to convert an Analog into a Digital Signal?