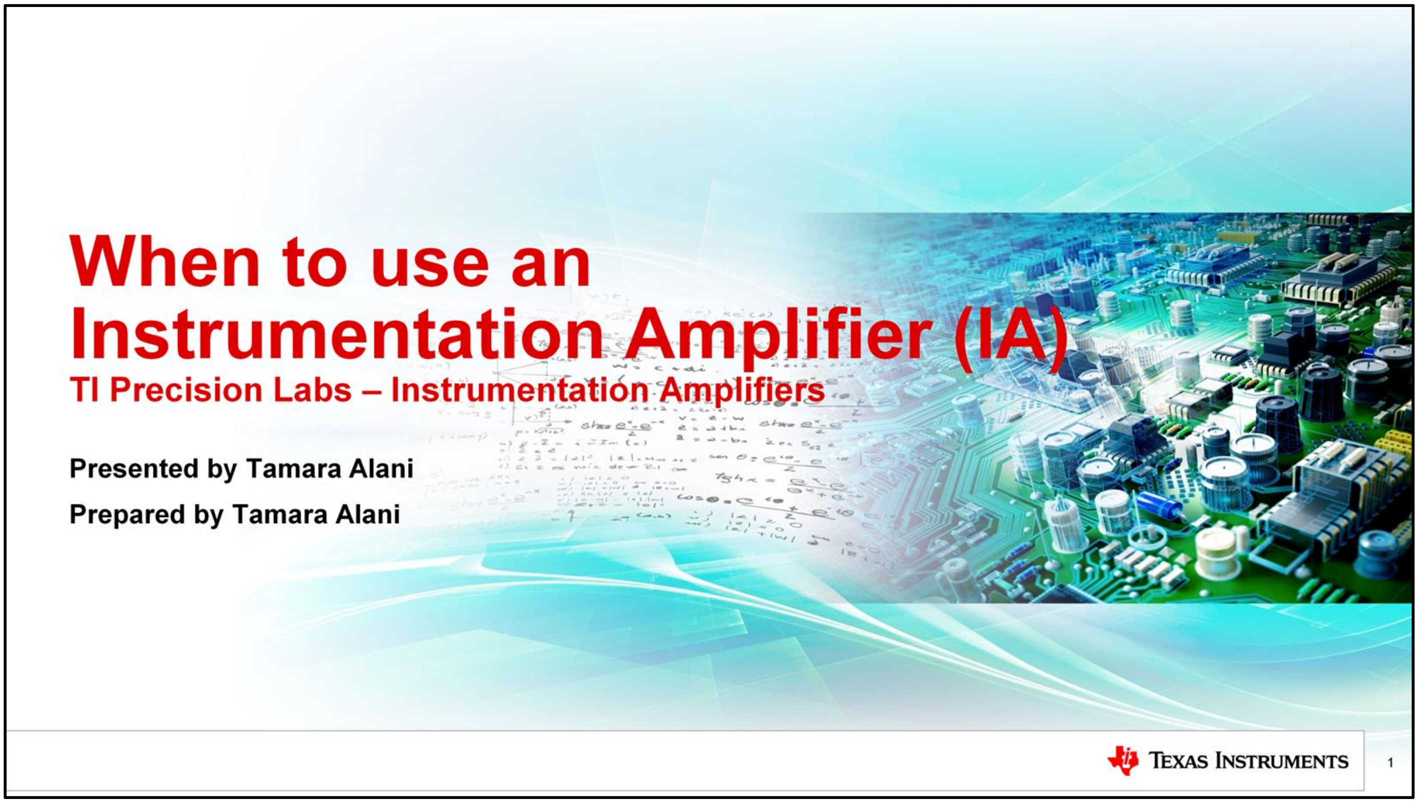
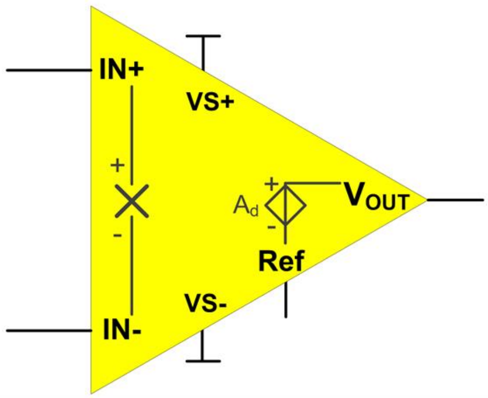


Hello, and welcome to the lecture for the TI Precision Lab discussing Instrumentation Amplifiers, specifically when do you use an instrumentation amplifier?

Instrumentation amplifier – Idealized model

Two main characteristics of an instrumentation amplifier:

1. Amplifies the signals that differ between the two inputs
2. Rejects the signals that are the same (common) to both inputs

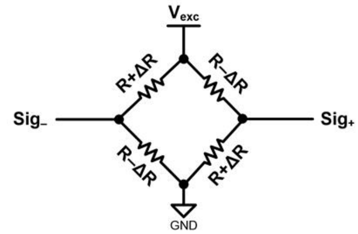


To recap from the previous lecture, an instrumentation amplifier (or IA) can be idealized as an electrical circuit that amplifies the signals that differ between its inputs and rejects the signals that are the same on both inputs.

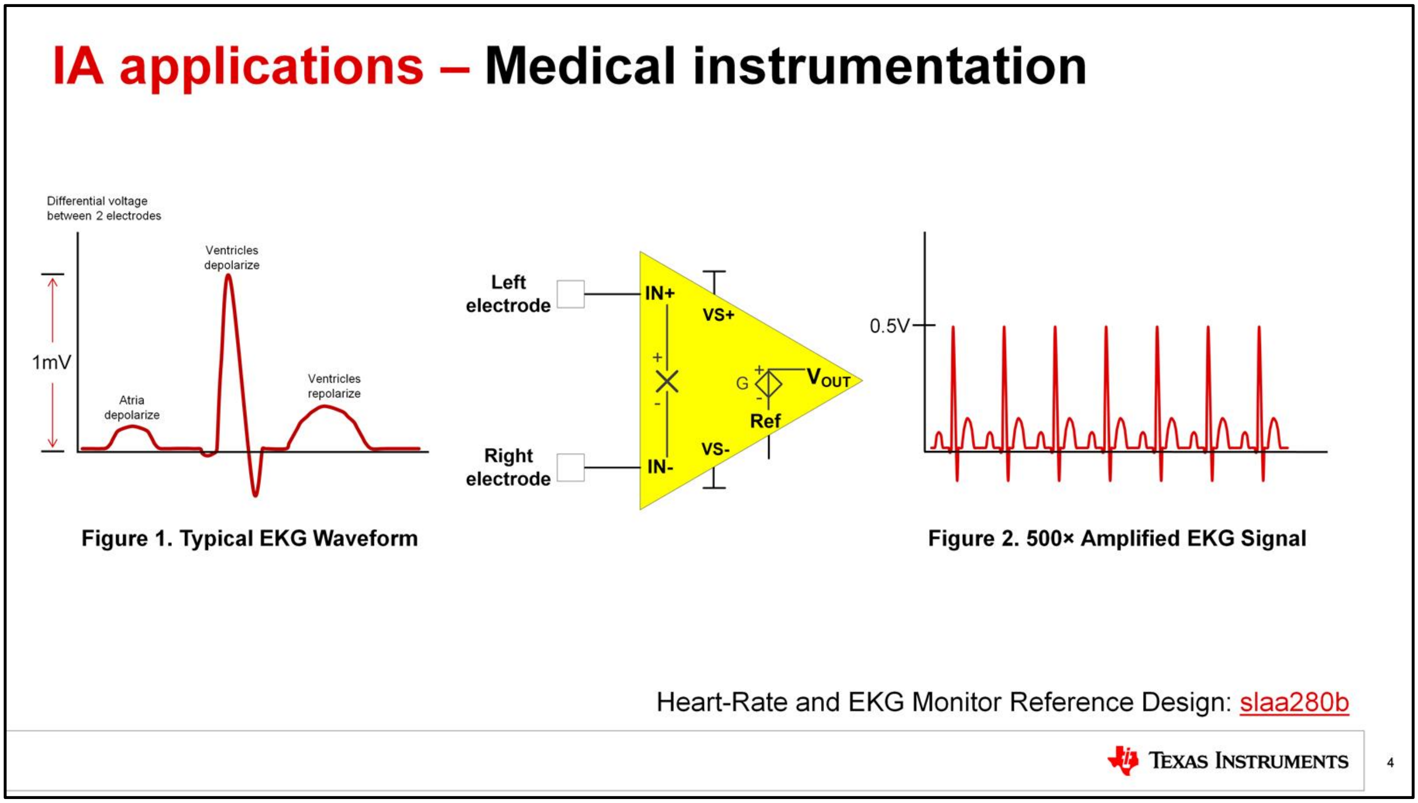
Instrumentation amplifier – Applications

Example of applications for IAs:

- Data acquisition
  - Strain gauges
  - Thermocouples
  - Wheatstone bridge sensor
- Medical instrumentation
  - ECG/EKG
  - Heart rate monitors
- Audio
- Current sense



IAs are excellent at extracting weak or small signals from noisy environments and delivering an amplified result to be precisely processed. They play a vital role in many applications; everything from precision data acquisition to signal amplification in critical medical instrumentation.



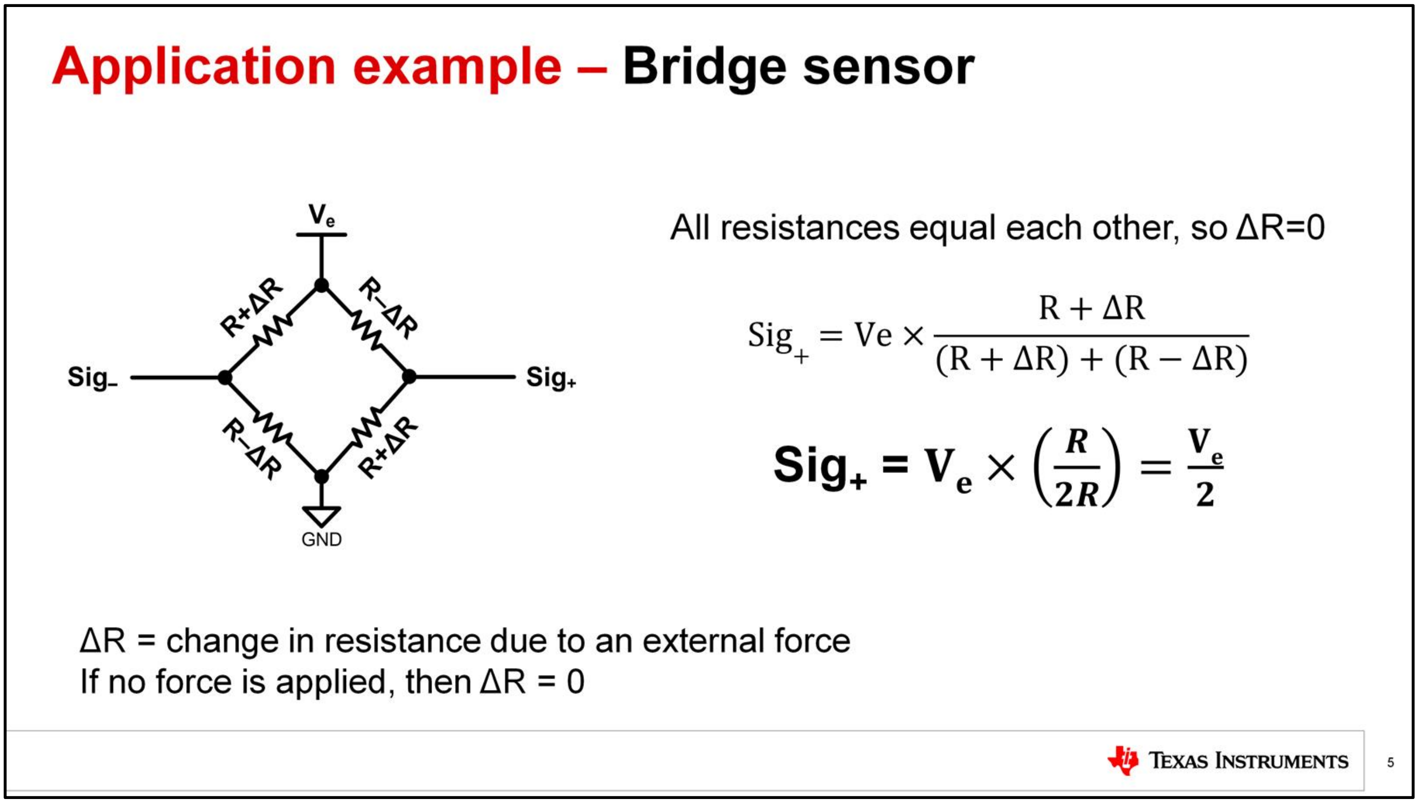
Let's take, for instance, hospital measurement systems comprised of multiple sensors. These sensors include blood pressure sensors, temperature sensors, heart rate monitors and more.

Hospitals can be one of the most electrically noisy environments with hundreds of medical devices generating electrical noise, in addition to the powerline 60Hz noise. The noise signal coming from these sources can be much larger in magnitude than the useful signal which needs to be measured.

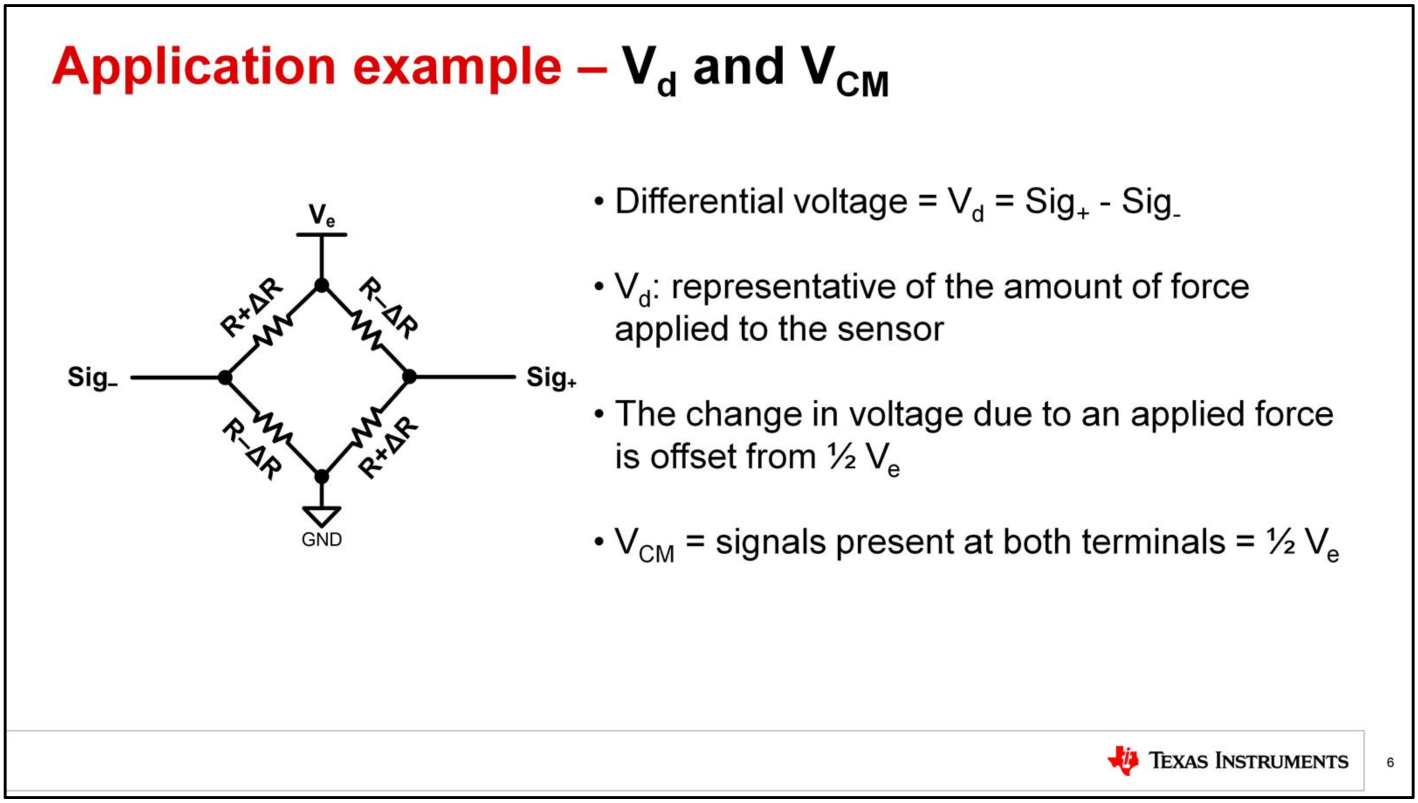
Frequently, IAs are used for amplifying signals coming from hospital system sensors, because IAs can reject external noise common to both inputs, and provide precise signal amplification.

Here is an example of an IA enabling accurate heart rate

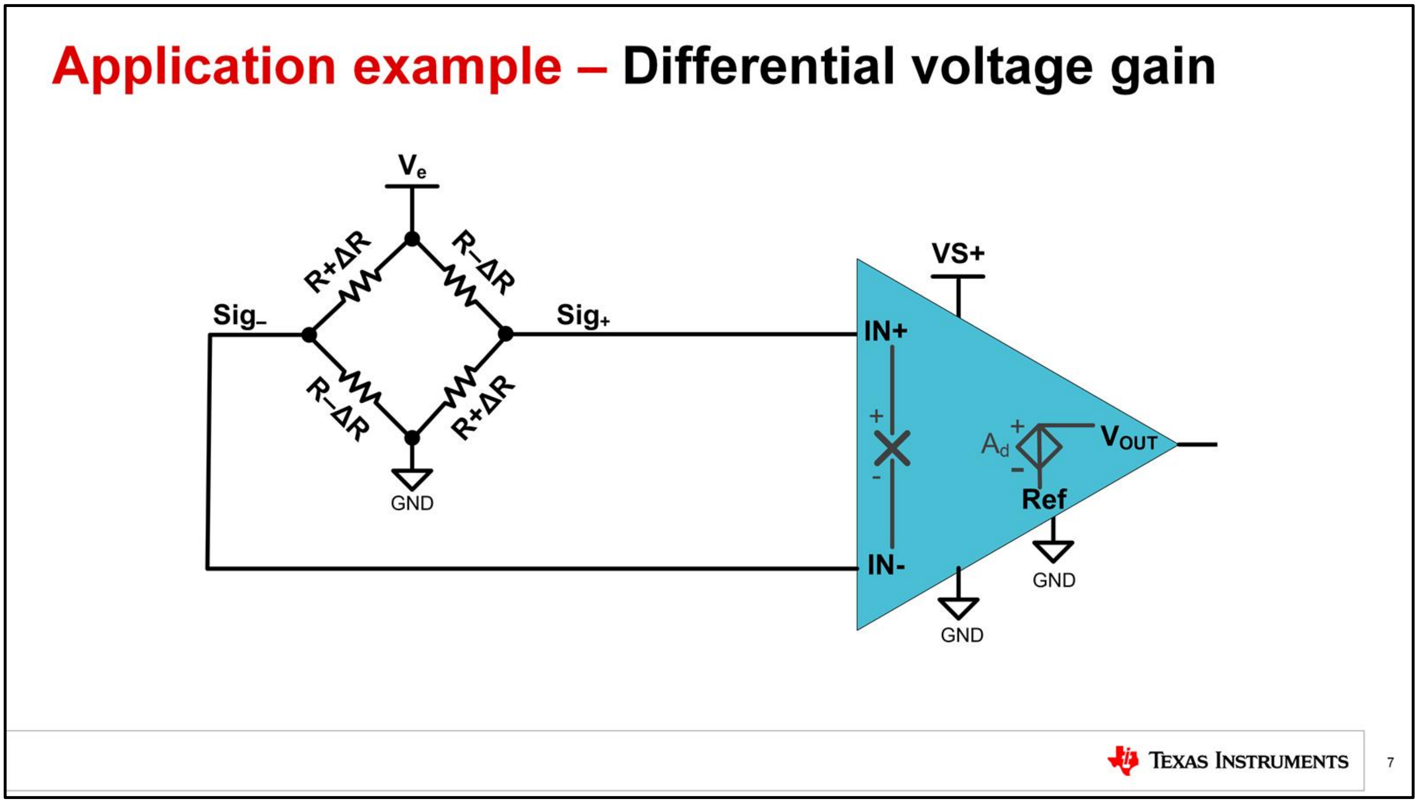
tracking in a typical electrocardiogram application.
The heart generates a series of electrochemical impulses which causes the cells to contract and expand, thus pumping blood through the body. This electrochemical action can be measured at the surface of the body, giving an electrocardiogram or an EKG plot.
Here is a typical EKG waveform. A voltage potential of approximately 1mV develops between electrodes attached to various points on the body. This signal can be processed by using an IA. The IA provides the amplification of the EKG signal while rejecting the common-mode noise signals, including the 60Hz power line noise and its harmonics.



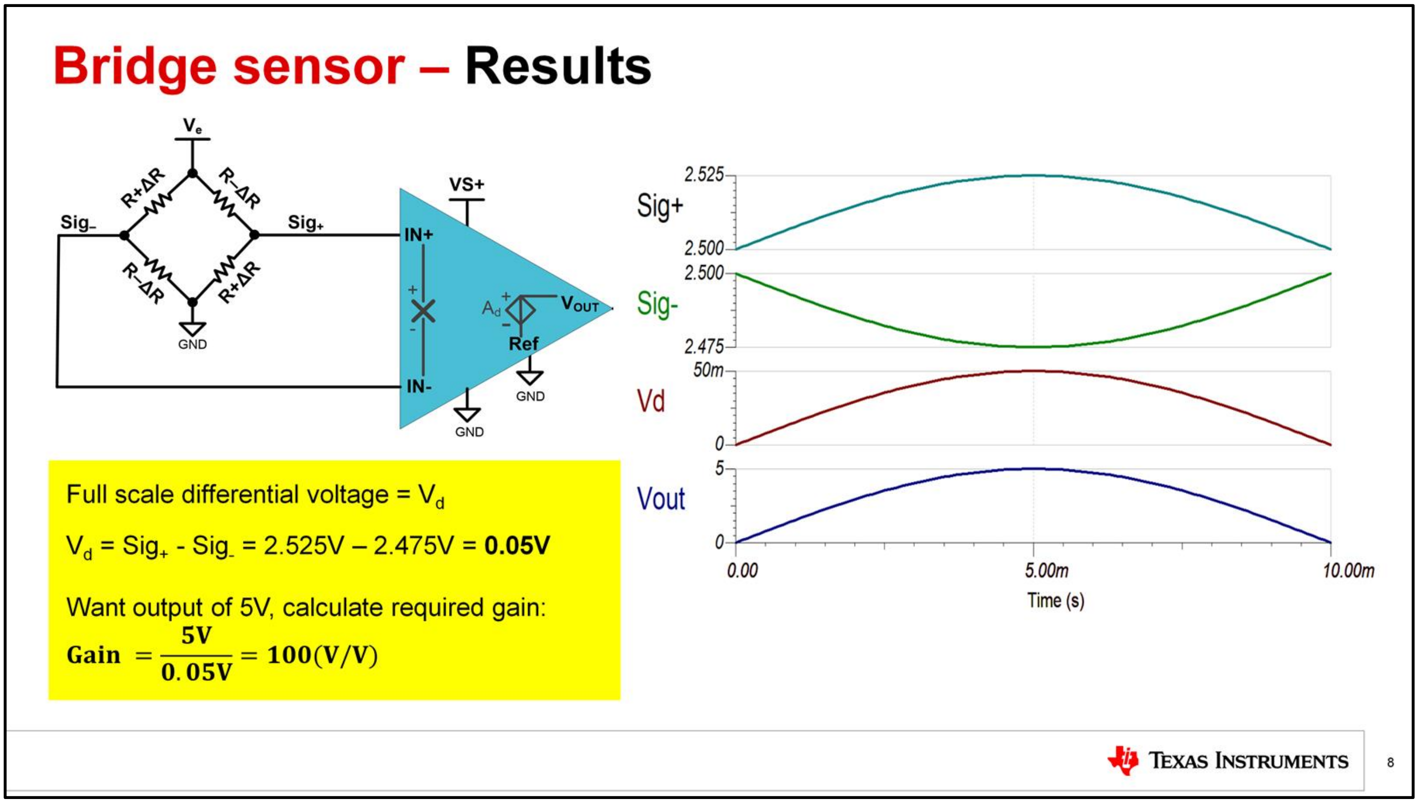
Let's now consider a sensor which converts a physical phenomenon, like temperature or pressure, into resistance. We can convert this change in resistance to a measureable voltage using a bridge sensor. This bridge sensor is commonly referred to as a Wheatstone or resistive bridge, because all the legs are resistive elements which are used to conduct force and pressure measurements. The resistance of the legs change in response to a mechanical strain. When an excitation voltage (V_e) is applied to the bridge, and all resistances are equal between V_e and GND, by basic resistive division, the voltage at Sig- and Sig+ equals half the excitation voltage.



In a system, the differential voltage (or V_d) is the difference between Sig+ and Sig-. This represents the amount of force or pressure acting upon the sensor. When this sensor is acted upon, opposite resistors in the bridge change in proportion. If the resistance of one leg increases by ΔR, the resistance of the opposite leg will decrease by ΔR. Consequently, the voltage at Sig+ and Sig- points will be offset from the nominal V_e divided by 2 value.
This offset is the differential voltage which we want to measure. The common mode voltage (or V_{CM}) is the voltage present at both terminals that we want to reject, which in this case is V_e divided by 2.



The full scale differential voltage is typically in the 1mV to 100mV range. Given that this voltage is usually fed to an ADC converter downstream, it may need to be amplified in order to utilize the ADCs full dynamic range. IAs are commonly used for this purpose because they have the ability to amplify the differential input voltage, and reject the common mode input voltage.

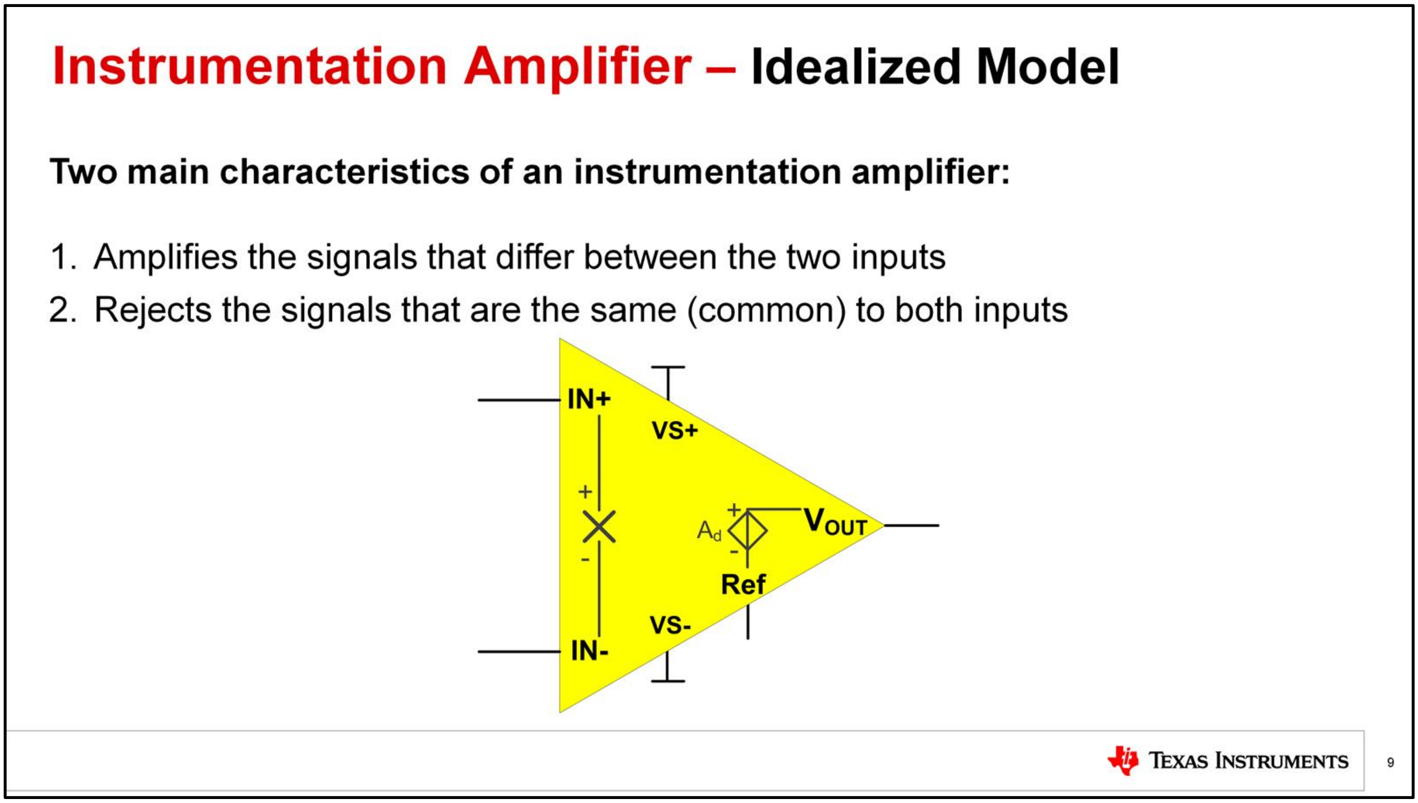


Let's take an example where all resistive legs are 1k-ohm elements and a sensitivity of 10mV/V is being used with a 5V excitation.

The differential full scale voltage in this case is 50mV. We may want to amplify this voltage in order to utilize the full scale range of the ADC. Therefore, if we want a full scale output of 5V, we need a gain of 100V/V.

Looking at the waveform to the right, we see that Sig+ and Sig- deviate from half the excitation voltage in proportion to the applied force.

The instrumentation amplifier extracted and amplified only the differential voltage (rejecting the common 2.5V) to yield a full scale output of 5V from a 50mV differential input.



This is an important and frequent slide to this series as it recaps the fundamental functions of an instrumentation amplifier and explains when a designer should consider an IA.

If you have an application where you are trying to measure only the differential voltage riding on a common mode voltage, you should consider instrumentation amplifiers.

That conclude our second video, discussing when to use an IA.

To find more Instrumentation Amplifier technical resources and search products, visit ti.com/inas