Hello, and welcome to the lecture for the TI Precision Lab discussing Instrumentation Amplifiers, specifically what is an Instrumentation Amplifier and what does it do?

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

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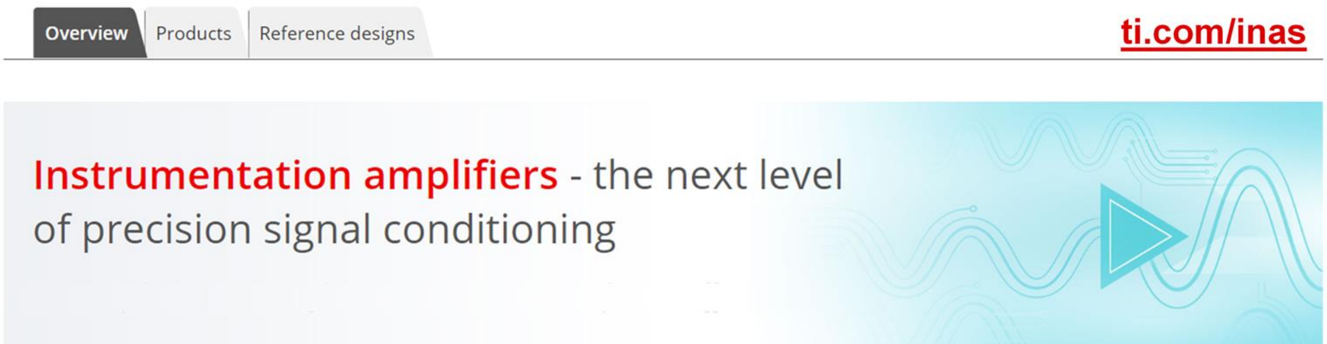

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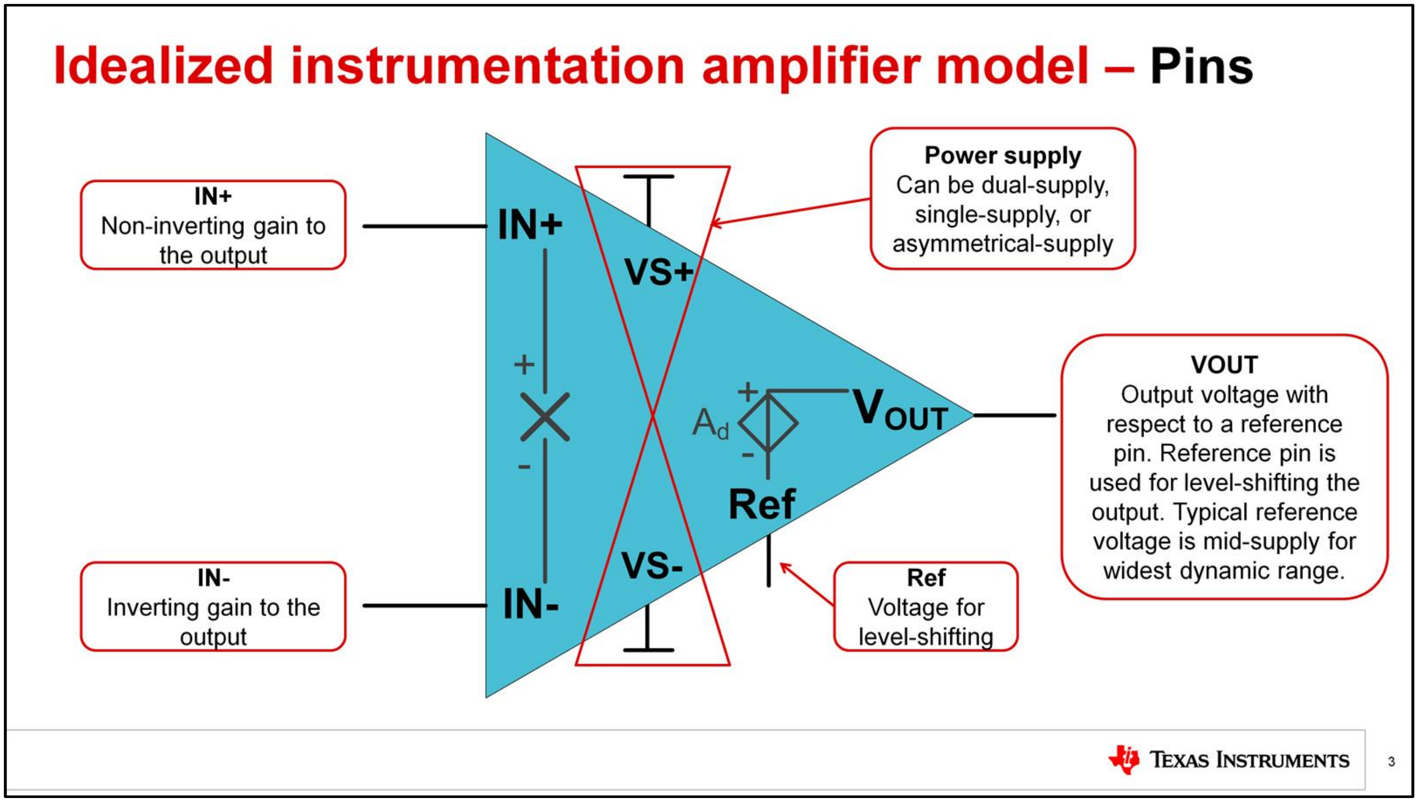
An instrumentation amplifier (or IA) can be idealized as an electrical circuit that amplifies the signals that differ between the inputs and rejects the signals that are the same on both inputs.

We will first discuss the first characteristic: the ability of an IA to amplify the signals that differ between the two inputs.

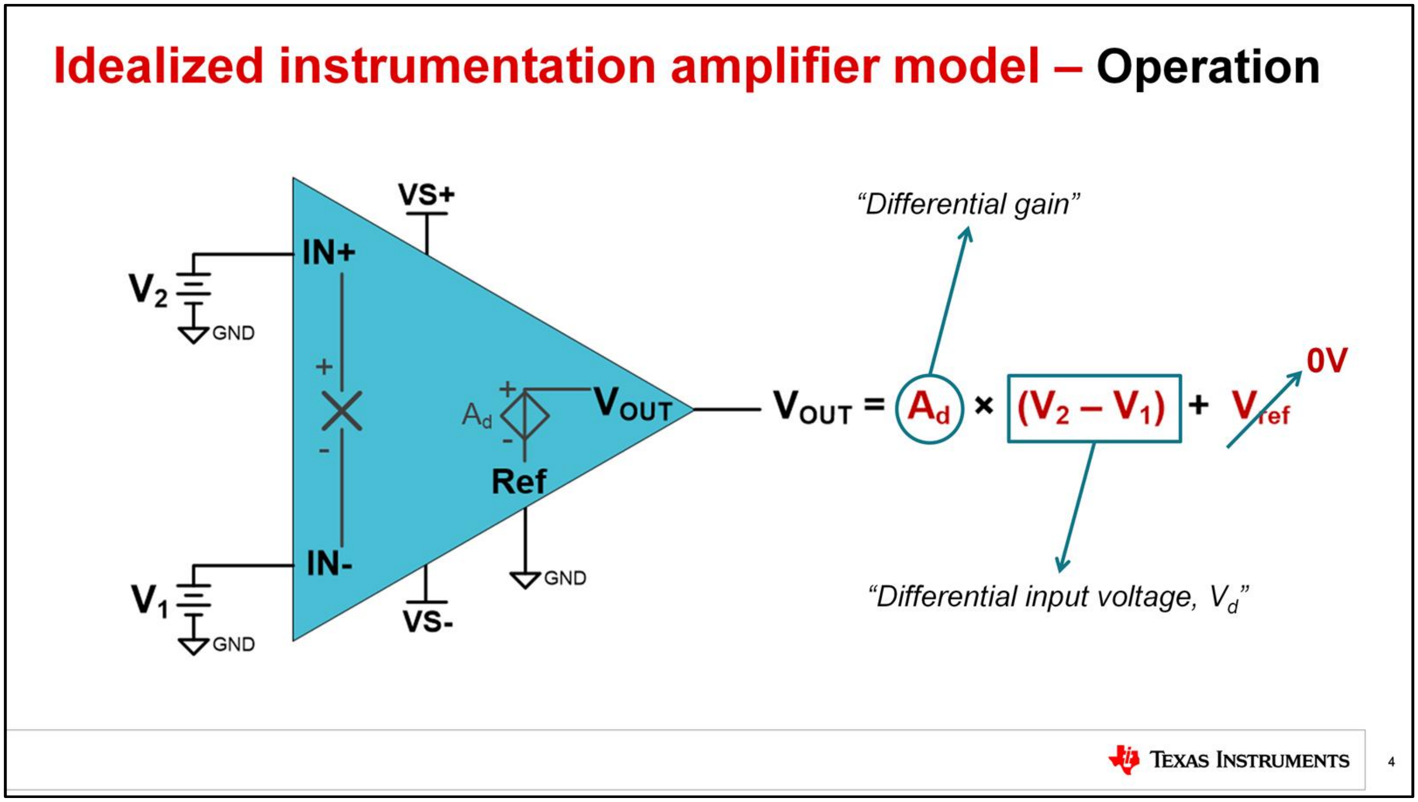


Before delving into this function, though, let us first define the various pins on an IA.

The inputs are IN- and IN+. IN- means it has inverting gain to the output. IN+ has non-inverting gain to the output. Either pin can be positive or negative voltages and be greater or less than each other.

VS+ and VS- are the power supply pins that can be dual-supply like +/-5V, or single-supply like ground to 5V, or asymmetrical supplies like -5V to +10V.

The Vout pin is the output of the amplifier. It's important to note that this output pin is with respect to reference pin, labeled ref. The ref pin is used to level-shift the output of the amplifier. A typical reference voltage for level-shifting is mid-supply, as this provides the widest dynamic range. For the rest of this presentation, Ref will be set to ground so the output will not be level-shifted.

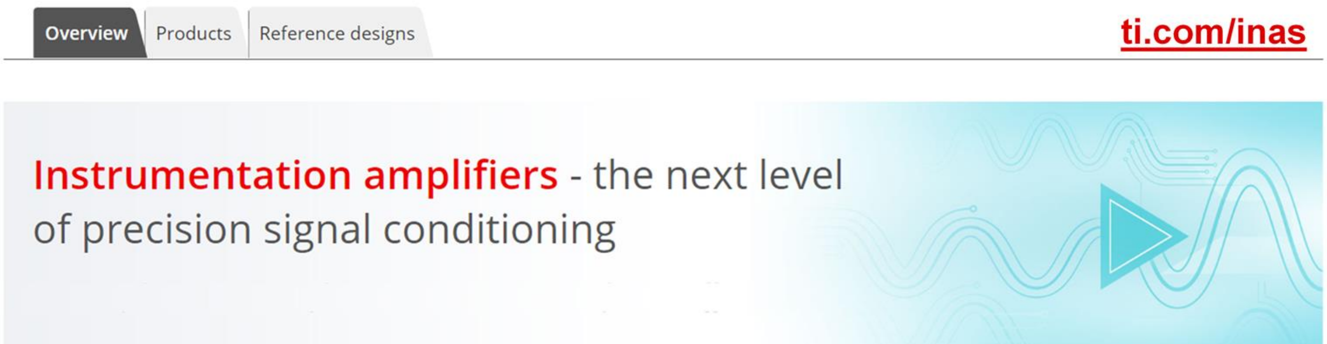


Now let's discuss this operation of amplifying the signals that differ between both inputs. In basic terms, an instrumentation amplifier amplifies the voltage difference between its two inputs. Its output is a single-ended signal proportional to the voltage difference between its two inputs, given with respect to a set reference voltage. In this example, we have a generic IA. The inputs are set to generic voltages, V_1 and V_2. The difference between these two inputs is simply V_2 minus V_1, and we refer to this as the differential input voltage, V_d. The gain of the circuit, or differential gain Ad, may be set externally, or is sometimes internally fixed to the IA. The instrumentation amplifier output will be equal to the product of the differential gain and the differential input voltage plus the reference voltage (remember that we are going to set this reference voltage to 0V for the remainder of the video).

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



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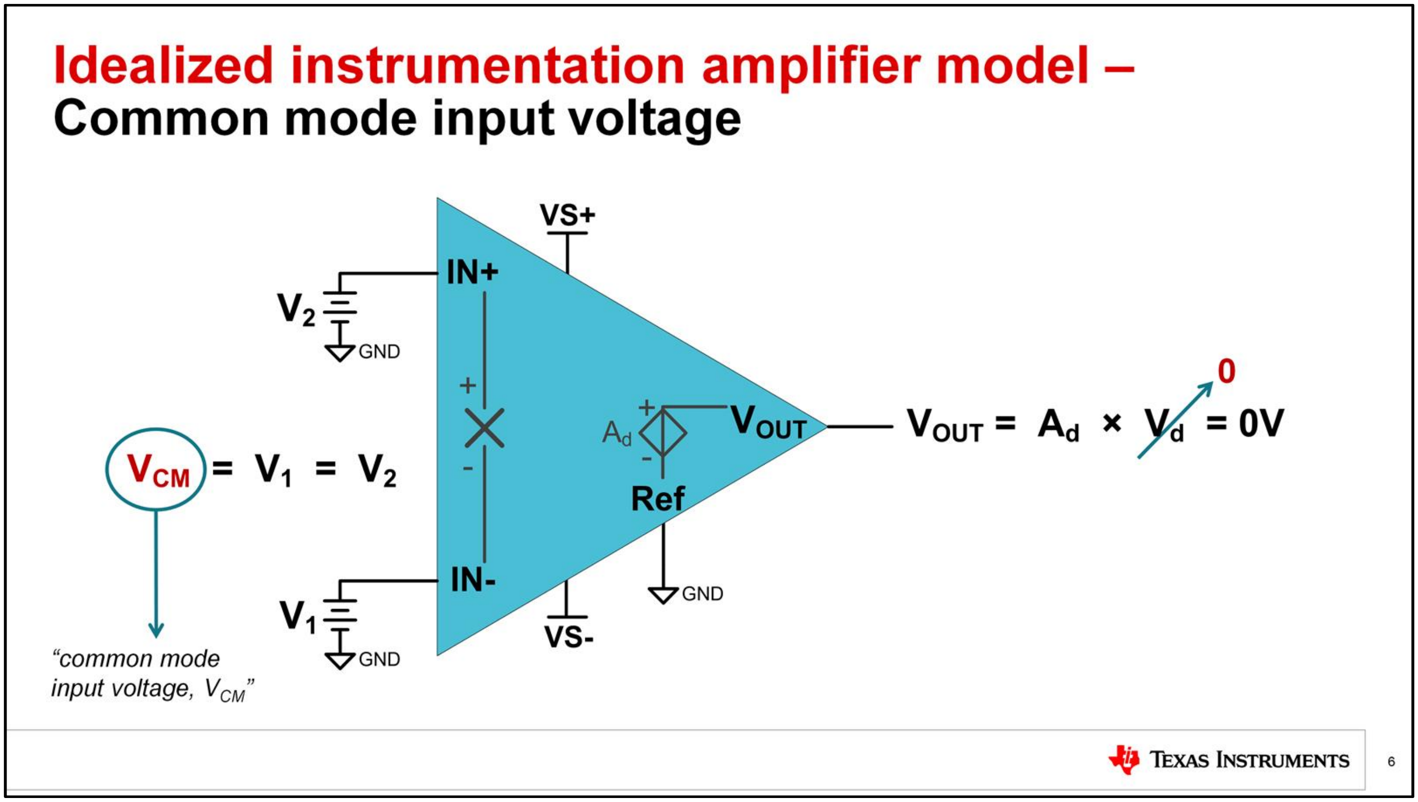
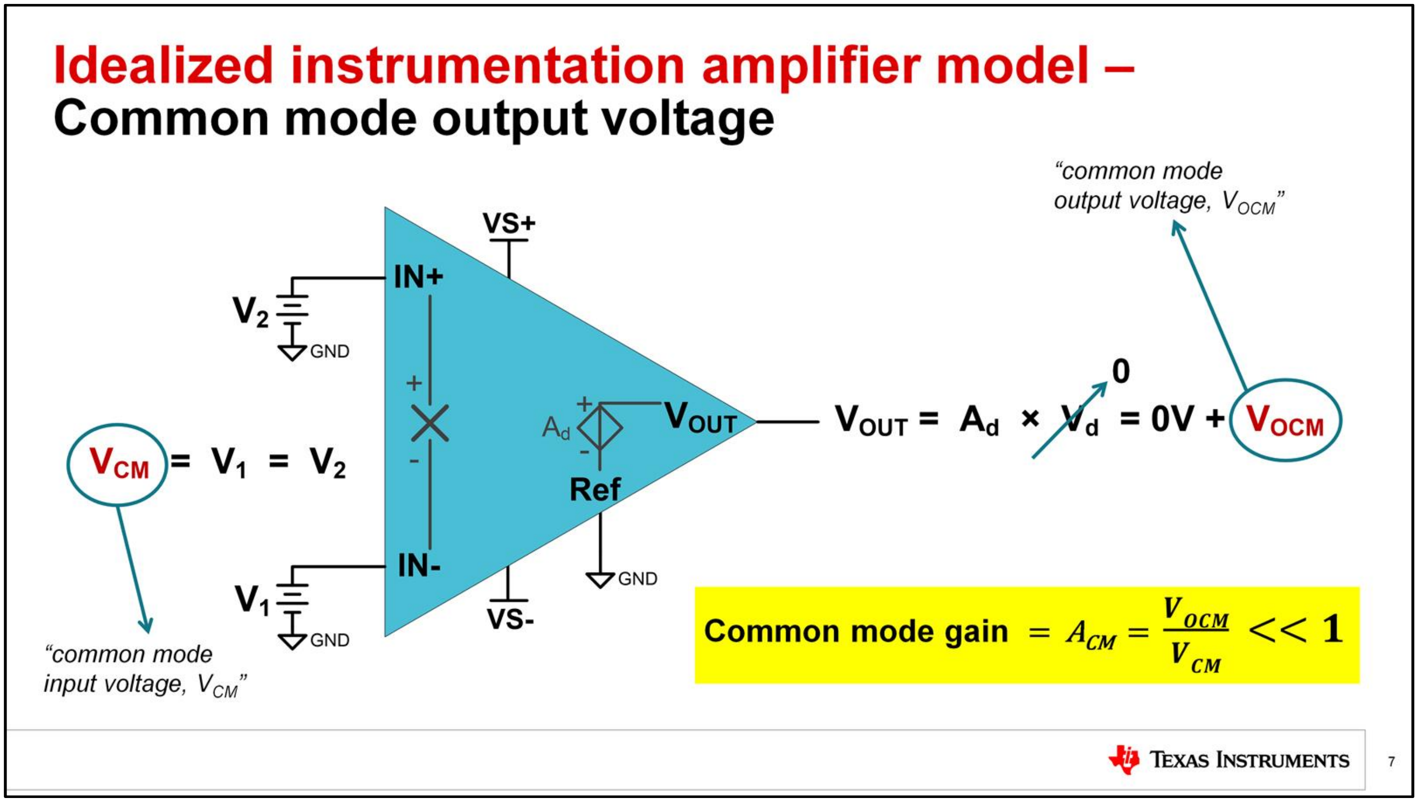
In addition to amplifying the differential signal, IAs also reject the signals which are common to both inputs. We will now discuss what this means.



Let us examine now a case where the inputs are equal to each other, and both are tied to a common mode input voltage or V_{CM}.

By the virtue of differential input voltage amplification, we expect to see 0V at the output.

In other words, if the two input terminals are tied together to a common mode input voltage, then there is no input voltage difference, so V_d is 0V and the expected output is 0V.



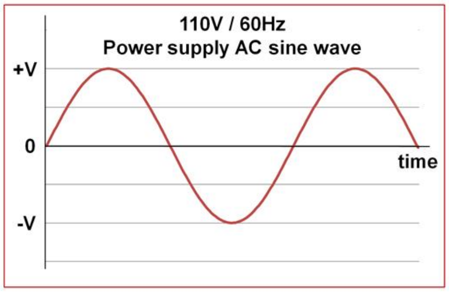
But in actuality, there will be some small voltage at the output. This is called the common mode output voltage, or V_{OCM}.

V_{OCM} is usually much less than the applied input voltage, so the ratio of the common mode output voltage to the common mode input voltage is much less than 1.

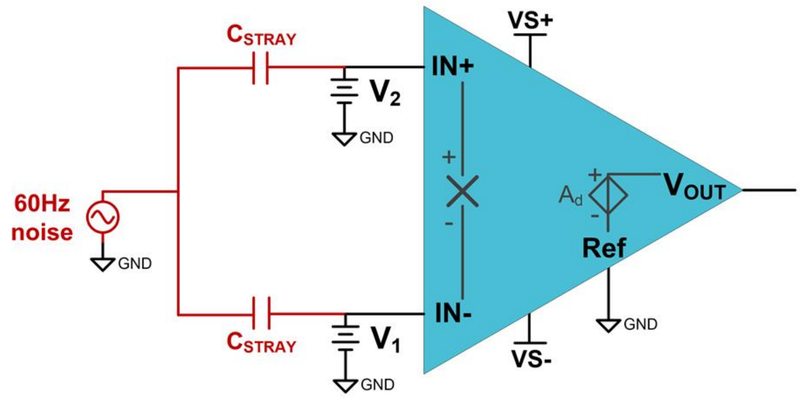
This ratio is called the common mode gain (or attenuation) of the instrumentation amplifier, or A_{CM}.

For an ideal instrumentation amplifier, A_{CM} is equal to zero. In a later practical example, we will see how you can use a product data sheet to find the practical value for this gain.

Common mode noise – Sources



Examples of common mode noise:
- Power line noise
- Signals capacitively coupled



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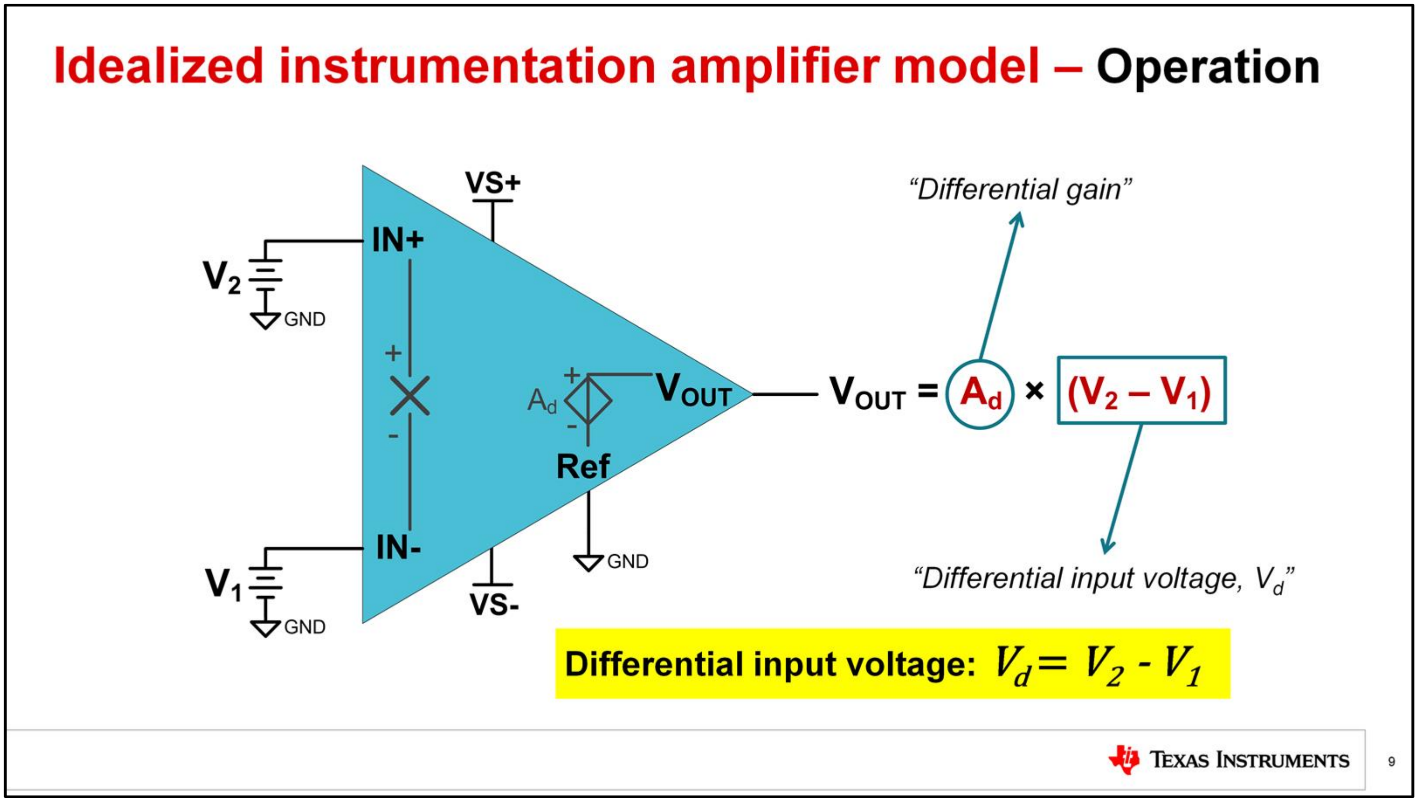
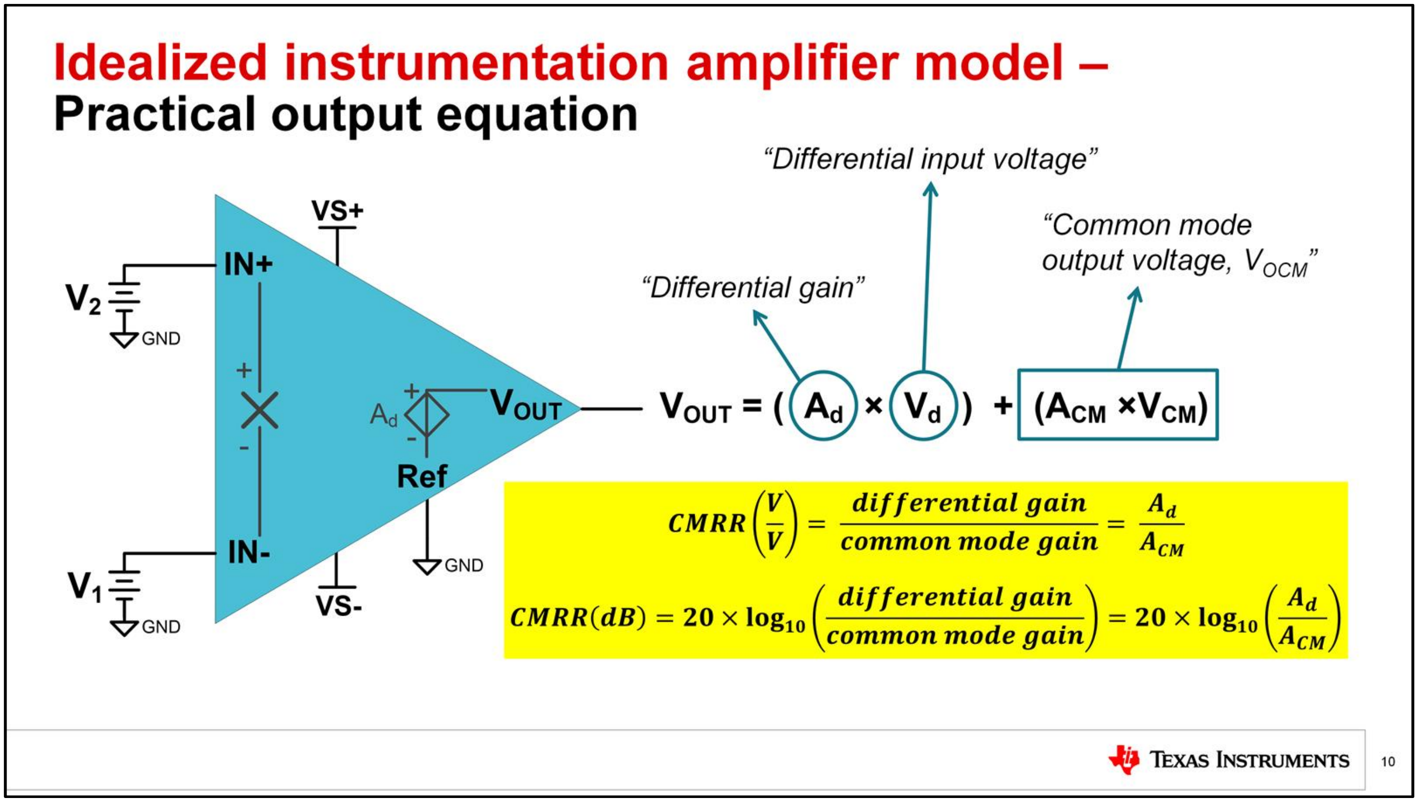
When the IA inputs are tied together to a common mode voltage, the experienced output voltage (V_{OCM}) could be due to common mode noise sources.
Examples of sources of noise signals common to both input terminals can be: 50-60Hz power line noise or other signals capacitively coupled in from adjacent conductors.
These are common mode input signals and error that we don't want to see at the output of the amplifier.



To re-cap our original circuit, we have a differential input voltage equal to (V_2 - V_1) and the differential gain (A_d). Again, for an ideal IA, we expect the output be equal to the differential gain (A_d) multiplied by the differential input voltage (V_d).



However, because of the common mode input signal dependence discussed previously, a non-ideal IA will exhibit some degree of output voltage error. This error, the "common mode output voltage", is equal to the common mode gain multiplied by the common mode input signal.

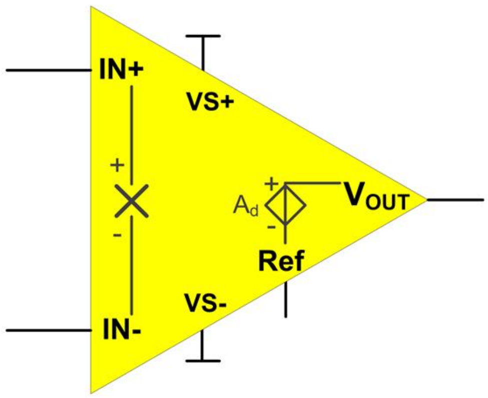
The goal with any instrumentation amplifier is to make this common mode output voltage error term as small as possible. Therefore, a large common mode rejection ratio (or CMRR) is desired.

This CMRR parameter measures how well the amplifier is able to suppress the common mode input signal, and is defined as the ratio of the differential gain to the common mode gain.

Equivalent value of CMRR in dB can be calculated as 20 times log base 10 of the differential gain to the common mode gain ratio.

In a future video, we will cover CMRR in more depth with a practice example.

Instrumentation amplifier



Characteristics of an IA:

1. Amplify the signals that differ (V_d) between the two inputs
2. Rejects the signals that are the same (common, V_{CM}) to both inputs.

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In real world applications, there is often a large unwanted signal, common to the two inputs of the amplifier. In some instances. The unwanted amplitude may exceed the amplitude of the signal itself.

Historically, a number of methods have been developed to increase CMRR and thus reduce the associated common mode error. The wires to the two input terminals can be twisted and shielded to suppress the common mode error, for example.

Ultimately, engineers devised the instrumentation amplifier to achieve high rejection of noise that is common to both inputs, while also achieving excellent amplification of the differential input signal.

Thanks for your time!
Please try the quiz.

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That concludes our first video, discussing what an IA is and what an IA does.
Please try the quiz to check your understanding of this video's content.

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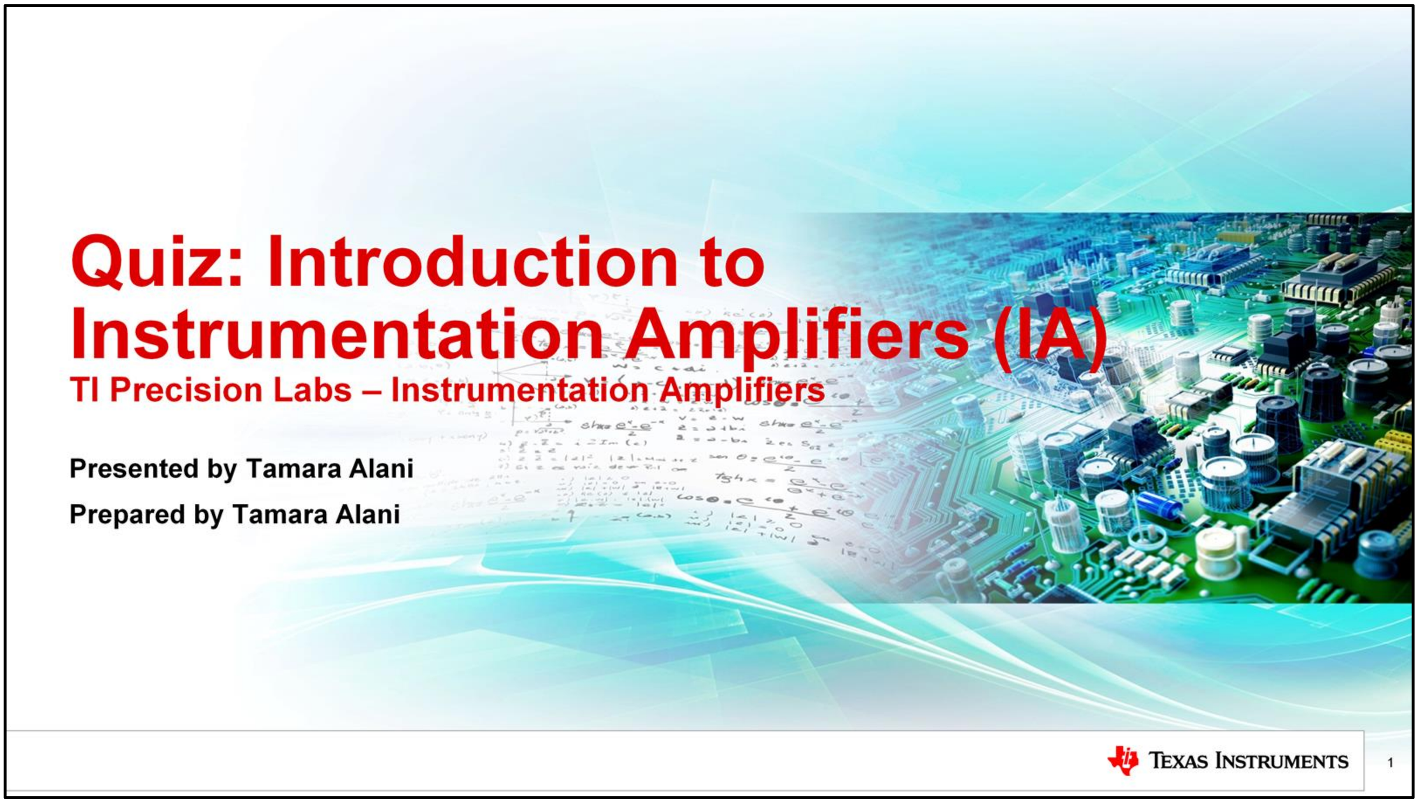
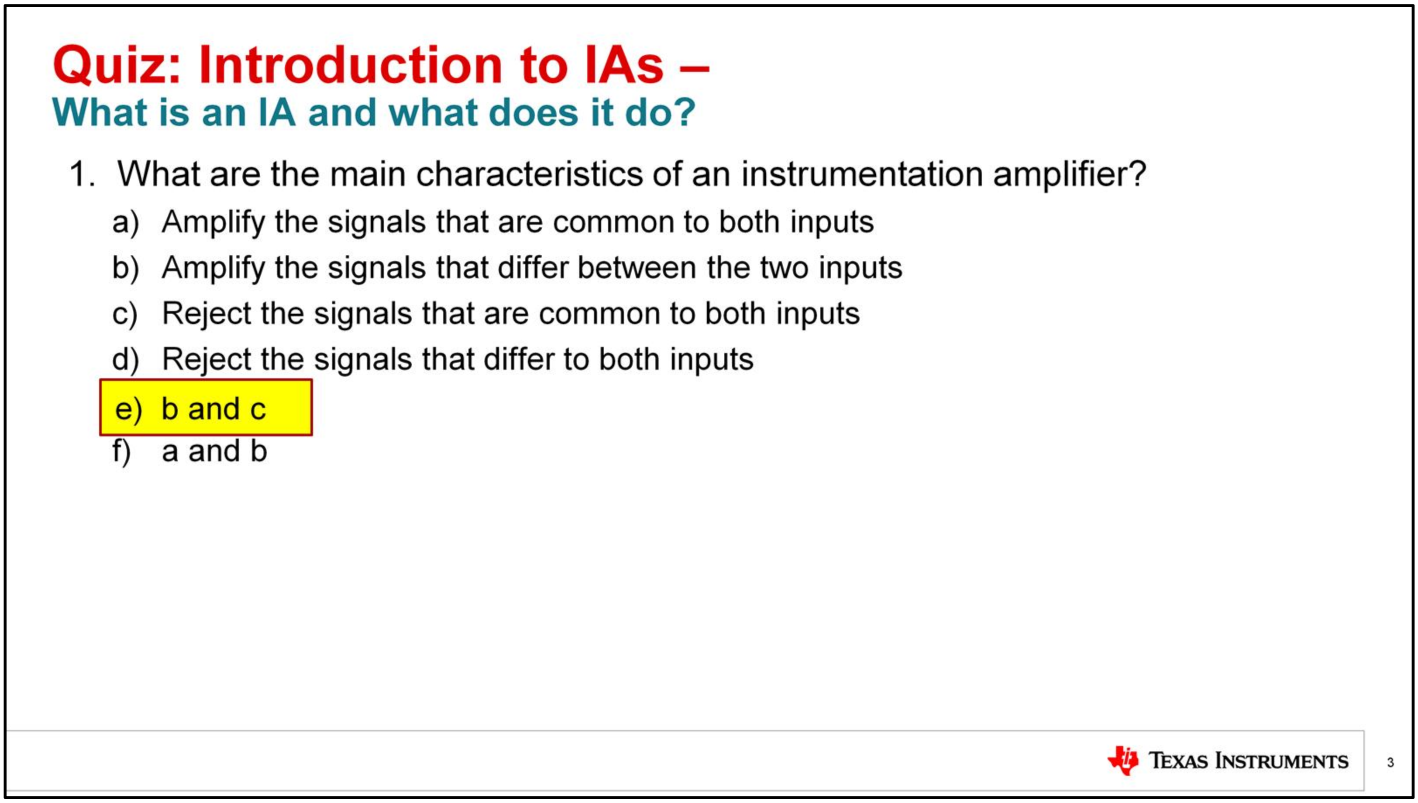


Hello, and welcome to the quiz for the TI Precision Lab discussing Instrumentation Amplifiers, specifically what is an Instrumentation Amplifier and what does it do?

Quiz: Introduction to IAs –
What is an IA and what does it do?

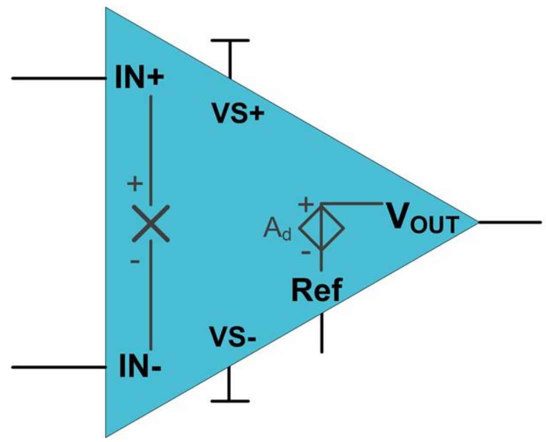
1. What are the main characteristics of an instrumentation amplifier?
   a) Amplify the signals that are common to both inputs
   b) Amplify the signals that differ between the two inputs
   c) Reject the signals that are common to both inputs
   d) Reject the signals that differ to both inputs
   e) b and c
   f) a and b

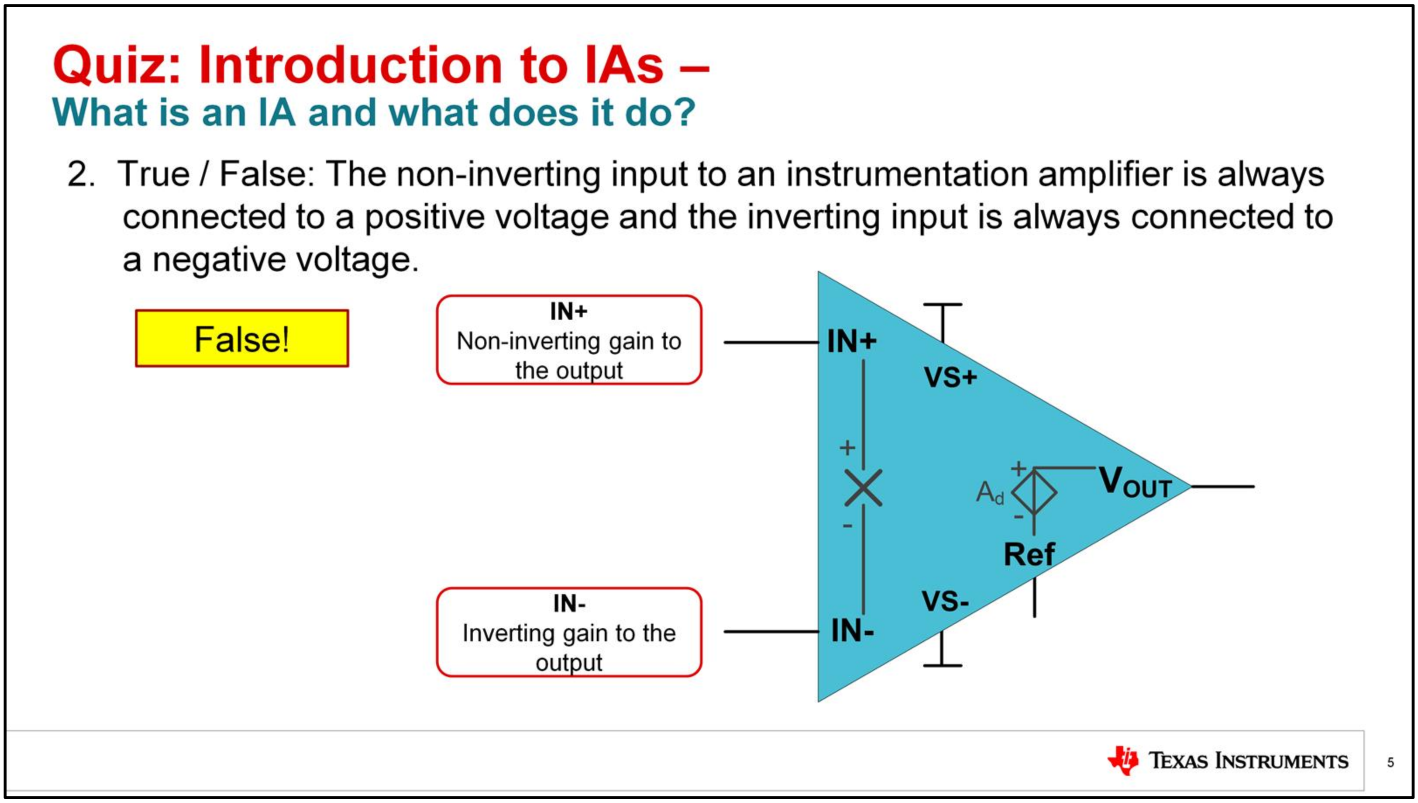


The answer is e: Instrumentation amplifiers amplify the signals that differ between the two inputs and reject the signals that are common.

Quiz: Introduction to IAs –
What is an IA and what does it do?

2. True / False: The non-inverting input to an instrumentation amplifier is always connected to a positive voltage and the inverting input is always connected to a negative voltage.





This is false. IN- means it has inverting gain to the output. IN+ has non-inverting gain to the output. Either pin can be positive or negative voltages and be greater or less than each other.

Quiz: Introduction to IAs –
What is an IA and what does it do?

3. In the ideal instrumentation amplifier model, if the inputs are tied to a common mode input voltage, what is the expected output equation?
   a) $V_{out} = (2V_{in} \times Gain) + V_{CM}$
   b) $V_{out} = A_d \times V_d = 0V$
   c) $V_{out} = Gain / V_{in}$
   d) $V_{out} = infinity$

Quiz: Introduction to IAs –
What is an IA and what does it do?

3. In the ideal instrumentation amplifier model, if the inputs are tied to a common mode input voltage, what is the expected output equation?
   a) $V_{out} = (2V_{in} \times Gain) + V_{CM}$
   b) $V_{out} = A_d \times V_d = 0V$
   c) $V_{out} = Gain / V_{in}$
   d) $V_{out} = infinity$

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The answer is b. The inputs are tied to the same voltage potential, so there is no differential input voltage and the resulting product is 0V ideally.

Quiz: Introduction to IAs –

What is an IA and what does it do?

4. Which of the following is true of the common mode output voltage, V_{OCM}?
   a) V_{OCM} is usually less than the applied input voltage, so the ratio of the common mode output voltage to the common mode input voltage is much less than 1.
   b) V_{OCM} is usually more than the applied input voltage, so the ratio of the common mode output voltage to the common mode input voltage is greater than 1.
   c) V_{OCM} is equal to the input voltage, so the ratio of the common mode output voltage to the common mode input voltage is equal to 1.
   d) V_{OCM} is always equal to 0V

Quiz: Introduction to IAs –
What is an IA and what does it do?

4. Which of the following is true of the common mode output voltage, V_{OCM}?

a) V_{OCM} is usually less than the applied input voltage, so the ratio of the common mode output voltage to the common mode input voltage is much less than 1.

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c) V_{OCM} is equal to the input voltage, so the ratio of the common mode output voltage to the common mode input voltage is equal to 1.

d) V_{OCM} is always equal to 0V

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The answer is a, the common mode output voltage is usually smaller than the applied input voltage, so the ratio of V_{OCM} to V_{CM} is less than 1

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