IA Parameters - Input Bias Current

TI Precision Labs – Instrumentation Amplifiers

Presented by Tamara Alani

Prepared by Tamara Alani

IA parameters – input bias current

Common application problems:

1. Sensor high output impedance processing
2. Input bias current return paths

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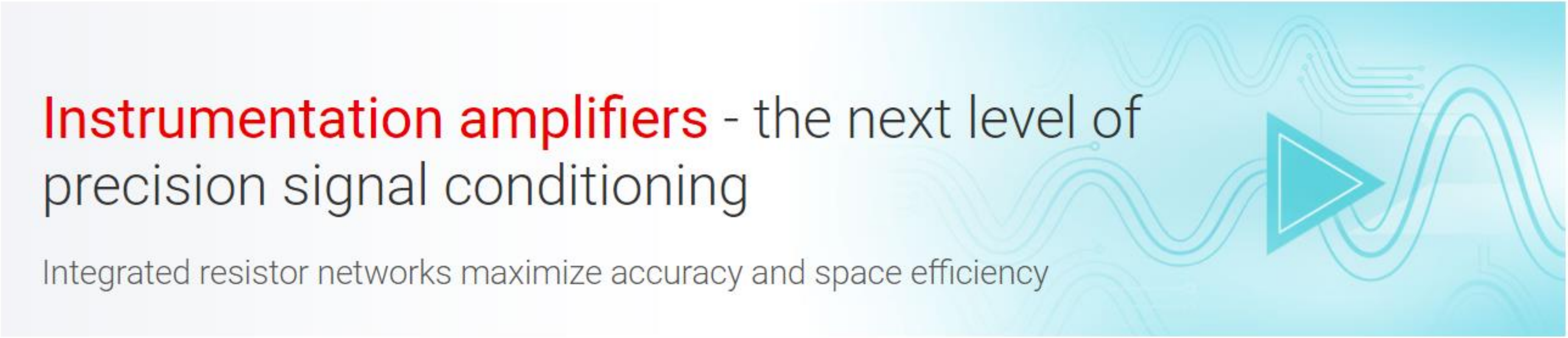
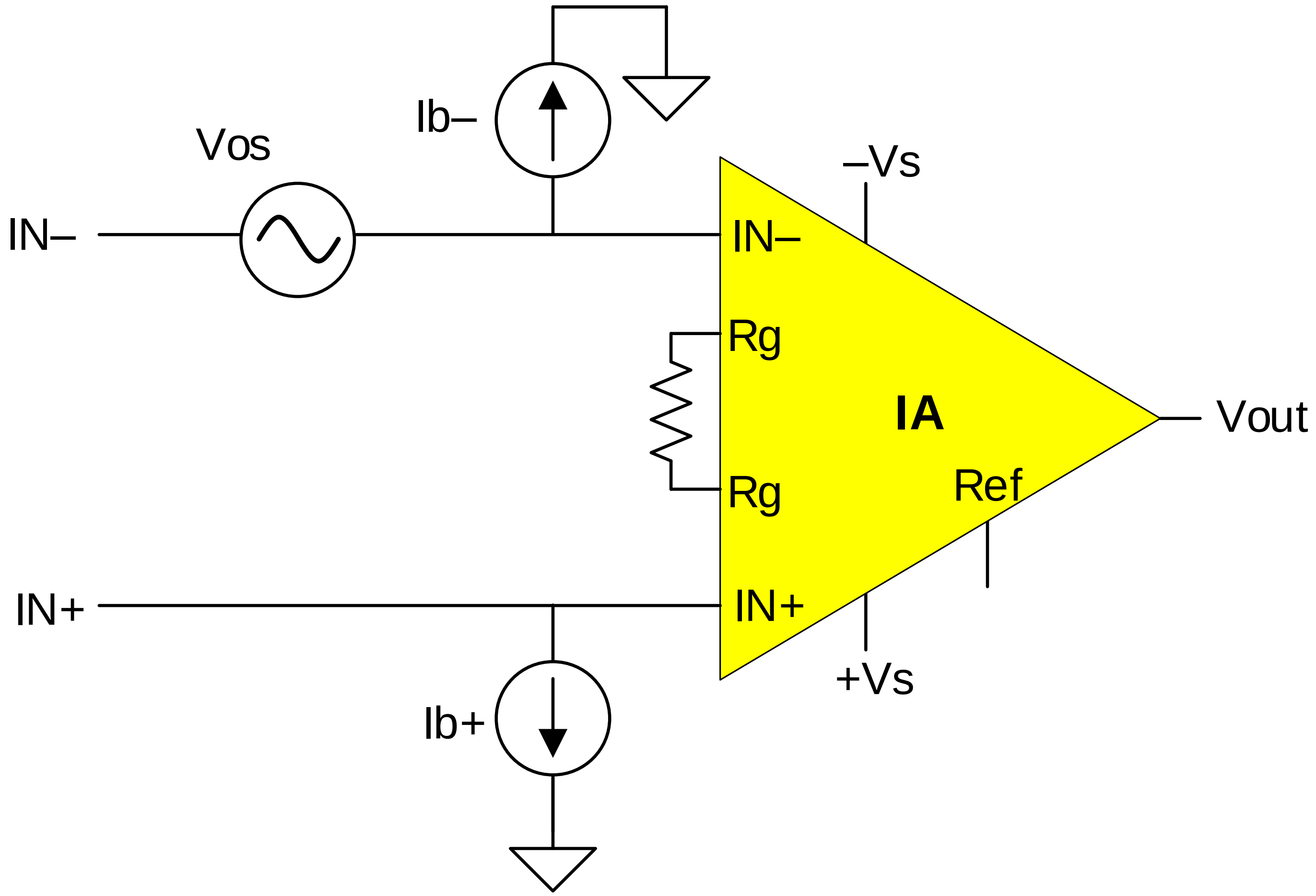


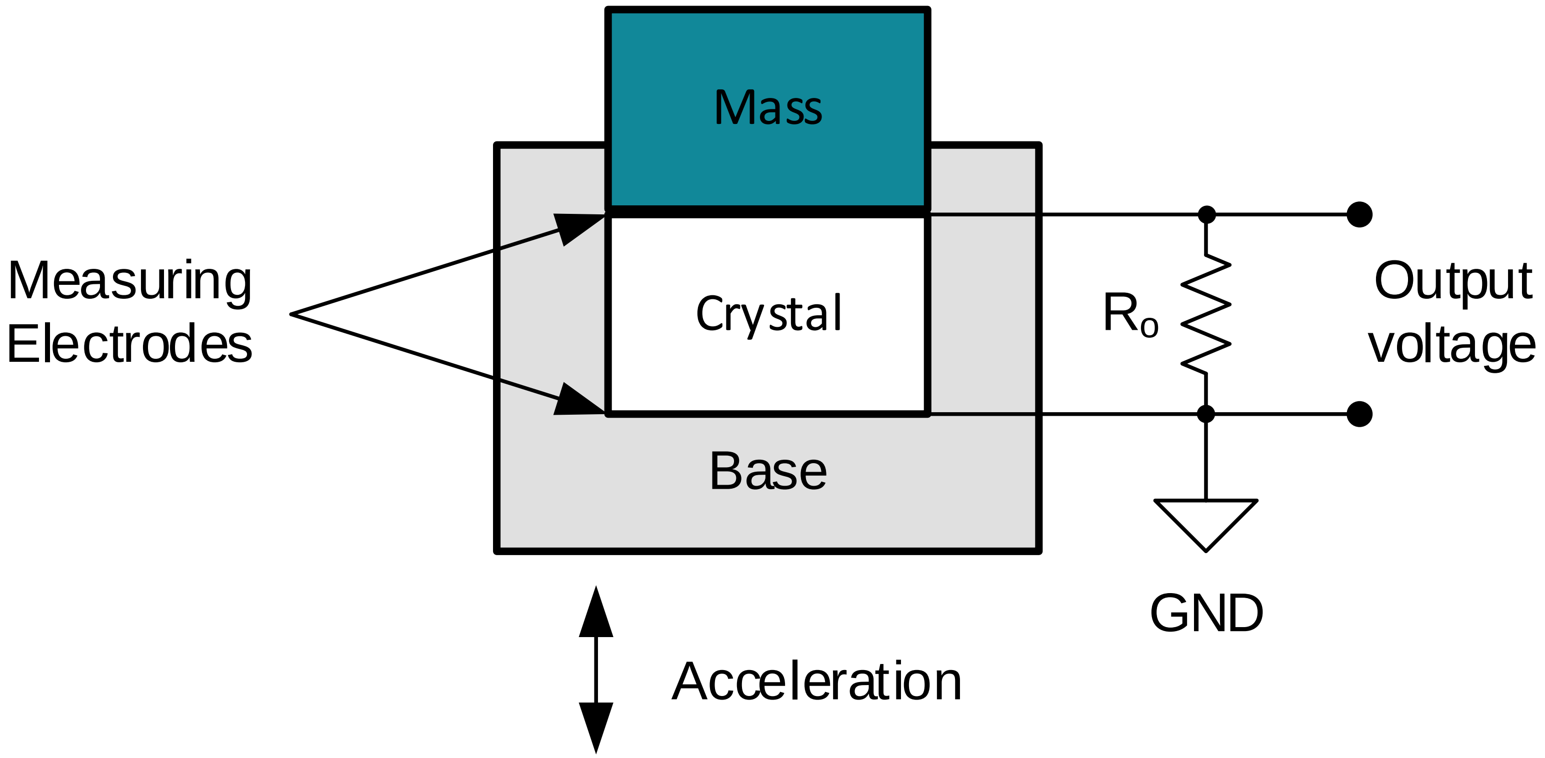
V_{os} and I_b – definition and recap

- Input bias current (I_b): current flowing into or out of the inputs of an IA. Can be modeled as a current source connected to each input.
- Input offset current (I_{os}): mismatch between Ib flowing into the two inputs of the IA
- Typical values of I_b (at room temperature):
  - Bipolar input: 1 nA to 50 nA
  - FET input: 1 pA to 50 pA
- Input offset voltage (V_{os}): differential input voltage that would have to be applied to force the IA's output to 0 V. Can be modeled as a voltage source in series with the inverting input terminal of the IA.
- Typical values of V_{os} (at room temperature): 2 mV down to 10s of µV



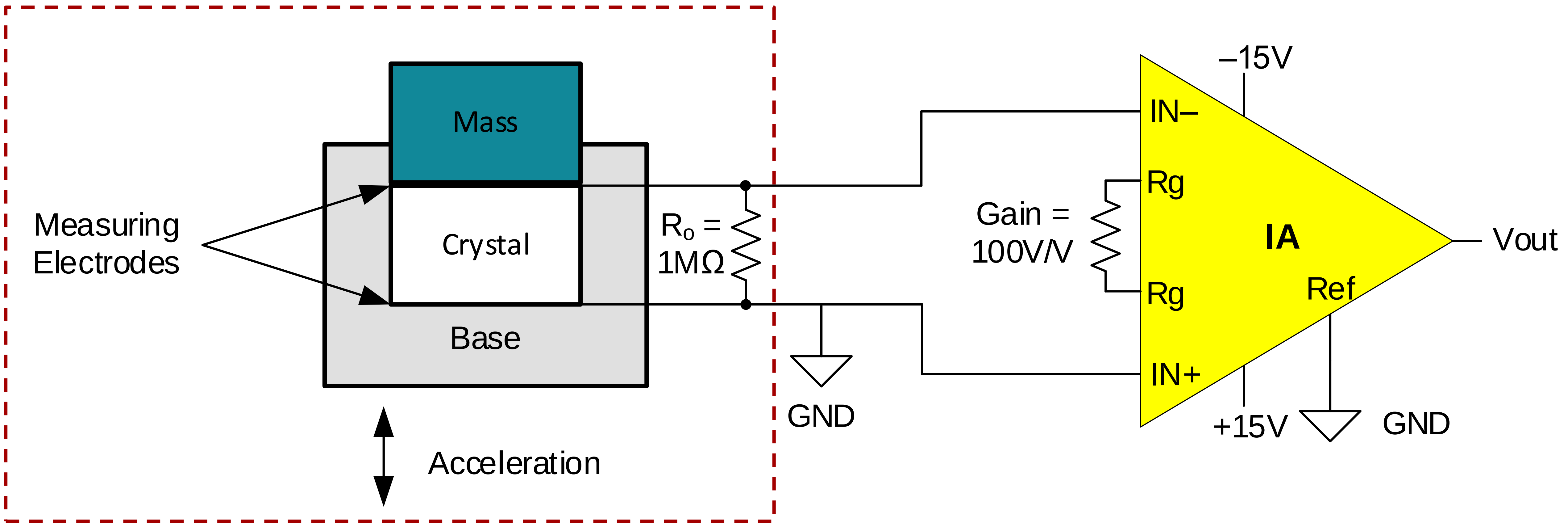
Input bias current effects – application example

- Piezoelectric accelerometer: consists of a mass attached to a piezoelectric crystal which is mounted on a base. This device measures acceleration when subjected to vibration and produces a voltage output.
- Applications which employ piezoelectric accelerometers:
  - dynamic response testing,
  - shock and vibration isolation,
  - auto chassis structural testing,
  - structural analysis,
  - reactors,
  - control systems and
  - materials evaluation



Piezoelectric accelerometer – IA processing

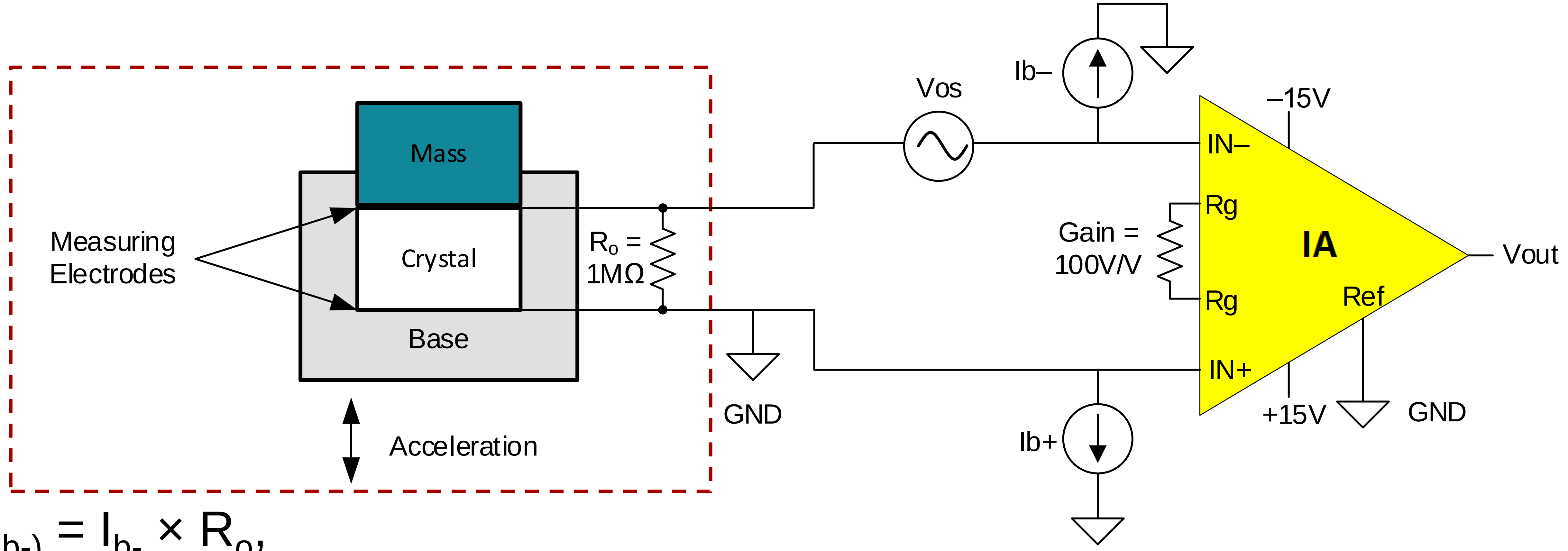
Piezoelectric accelerometer preamp circuit to convert acceleration to a potential:



Assume IA input bias current = 2.5 µA and the gain of the circuit is 100 V/V

Piezoelectric accelerometer – IA processing

Piezoelectric accelerometer preamp circuit to convert acceleration to a potential



$V_{OS(Ib-)} = I_{b-} \times R_o$,

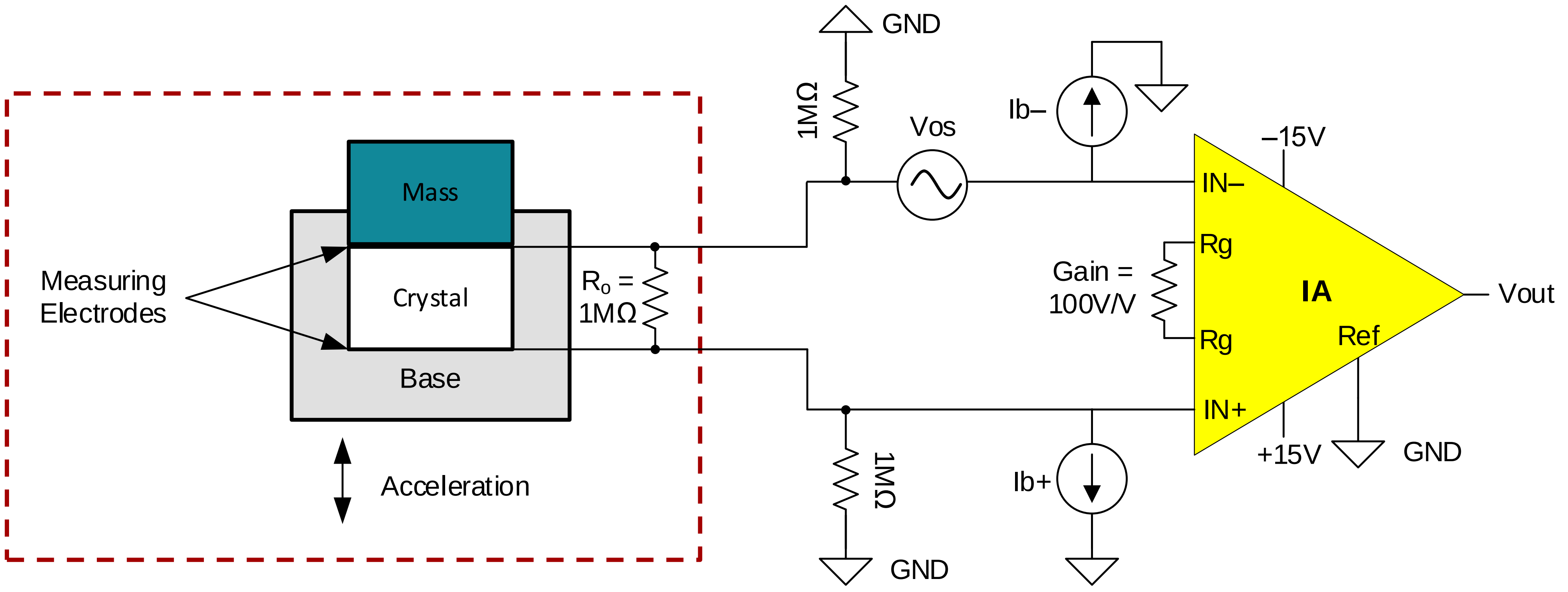
where I_{b-} is 2.5 µA and R_o is 1 MΩ

$V_{OS(Ib-)} = 2.5$ V

$V_{out} = V_{OS(Ib-)} \times$ Gain = 2.5 V × 100 V/V = 250 V (impossible due to 15 V supply voltage)

IA processing – cancel I_b error effects

- Idea: balance IA inputs so that $V_{OS(Ib-)} = V_{OS(Ib+)}$



- Input offset current: I_{os} = difference between the input bias current at the non-inverting terminal (I_{b+}) and the input bias current at the inverting terminal (I_{b-}) of the instrumentation amplifier.
- Assume input offset current of this IA to be I_{os} = 30 nA

IA processing – cancel I_b error effects

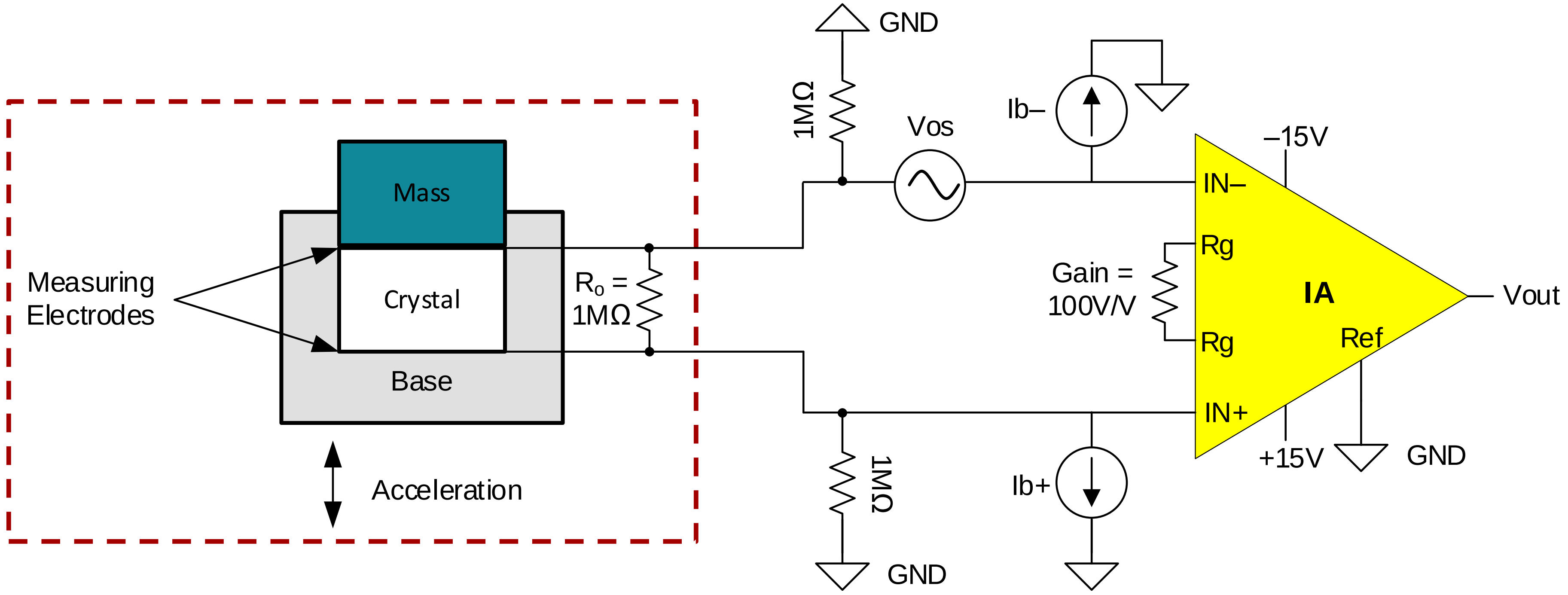
Idea: balance IA inputs so that $V_{OS(Ib-)} = V_{OS(Ib+)}$

Input offset current: $I_{os} = I_{b+} - I_{b-} = 30$ nA

$\mathbf{I_{b-} = 2.5\ \mu A}$, $I_{os} = 30$ nA, so $\mathbf{I_{b+} = 2.5\ \mu A + 30\ nA = 2.53\ \mu A}$

$V_{os(Ib-)} = 2.5$ V, $V_{os(Ib+)} = 2.53\ \mu A \times 1\ M\Omega = 2.53$ V → $\mathbf{\Delta V_{os} = 30\ mV}$

$\mathbf{V_{out} = \Delta V_{os} \times Gain = 30\ mV \times 100\ V/V = 3\ V}$



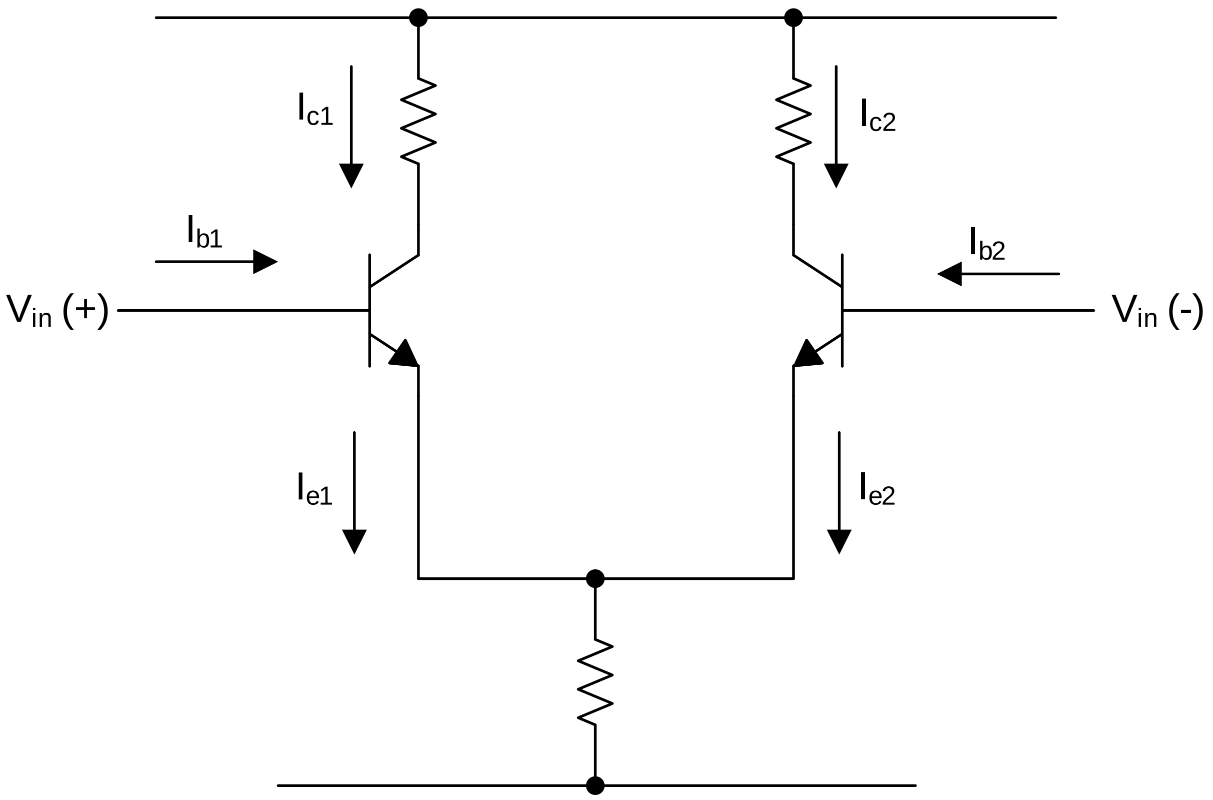
High impedance IA processing – solution

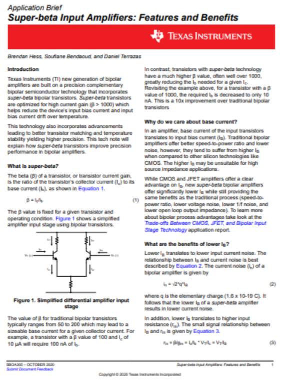
- Idea: Pick a low I_b IA
- Typical values of input bias current (at room temperature):
  – Bipolar input: 1 nA to 50 nA
  – FET input: 1 pA to 50 pA

Part number	Input technology	Input bias current (typ, max)
INA121	FET	4 pA, 50 pA
INA331	FET	0.5 pA, 10 pA
INA111	FET	2 pA, 20 pA
INA827	Bipolar	35 nA, 50 nA

Super-β input amplifiers

- $\beta = I_c/I_b$
- Traditional bipolar transistor β: 50 to 200
  - If $\beta = 100$ and $I_c = 10\ \mu A$, then I_b = 100 nA
- Transistors with super-β technology > 1000
  - If $\beta = 1000$ and $I_c = 10\ \mu A$, then I_b = 10 nA
  - Typical I_b for super-β input IAs: 0.1 nA to 5 nA




Application Brief
Super-beta Input Amplifiers: Features and Benefits

https://www.ti.com/lit/an/sboa305/sboa305.pdf

Super-β input amplifiers – benefits

- Low input bias current → suitable for high source impedance applications
- Low current noise → suitable for precision applications where current noise combines with input impedance to produce a DC offset voltage error ($i_n \times R_{in}$)
- Preserve low voltage noise and 1/f noise → suitable for high precision applications across all frequency ranges

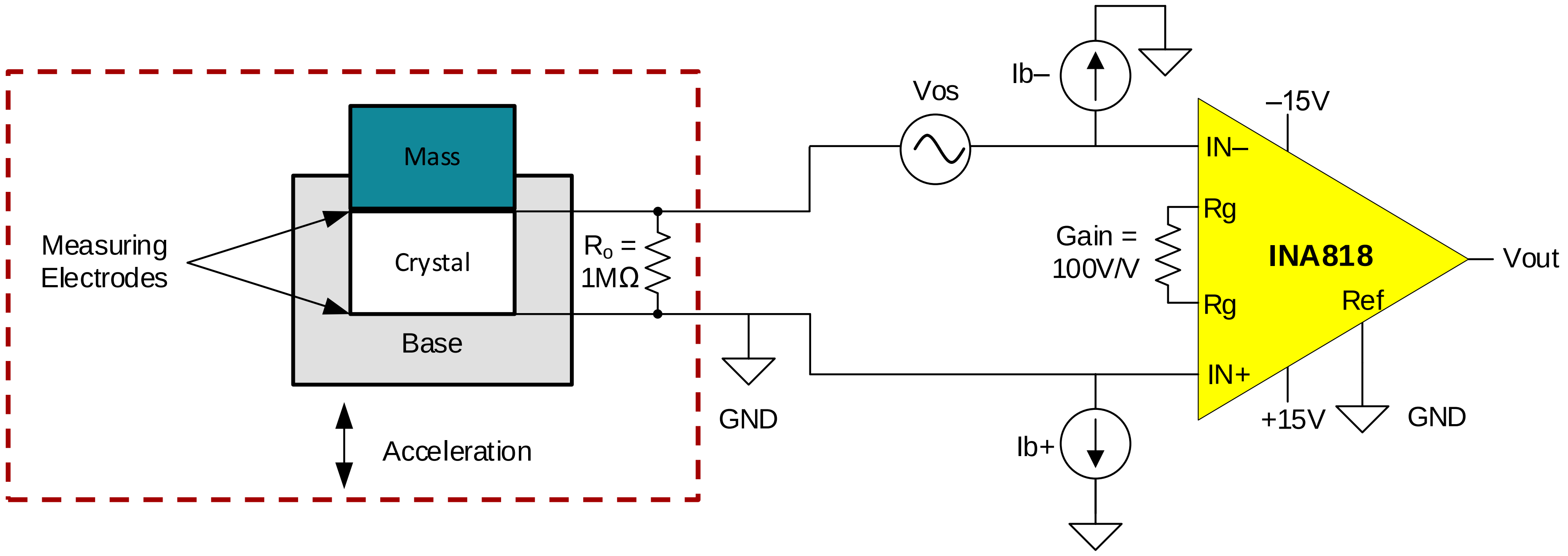
Device	Attribute	I_B (nA)	i_n (pA_{pp})
INA818 (super-beta)	Typical	0.15	4.7
	Maximum	0.50	-
INA118 (traditional)	Typical	1.00	80.0
	Maximum	5.00	-

Super-β input IA	Input bias current (max)
INA818	0.5nA
INA819	0.5nA
INA821	0.5nA
INA828	0.6nA

Browse TI's super-beta portfolio on ti.com/inas

Example revisit – piezoelectric accelerometer

- Piezoelectric accelerometer preamp circuit to convert acceleration to a potential



Summary of accelerometer example:

- Take 1: IA with 2.5 µA of I_b:
  output limited to 15 V supply
- Take 2: Balance IA inputs:
  3 V error
- Take 3: use IA with super-β inputs:
  15 mV error

$V_{OS(Ib-)} = I_{b-} \times R_o,$

where I_{b-} is 0.15 nA and R_o is 1 MΩ

$V_{OS(ib-)} = 0.00015\ V$

$V_{out} = V_{OS(ib-)} \times Gain = 0.00015\ V \times 100\ V/V = 15\ mV$

IA parameters – input bias current

Common application problems:

1. Sensor high output impedance processing
2. Input bias current return paths

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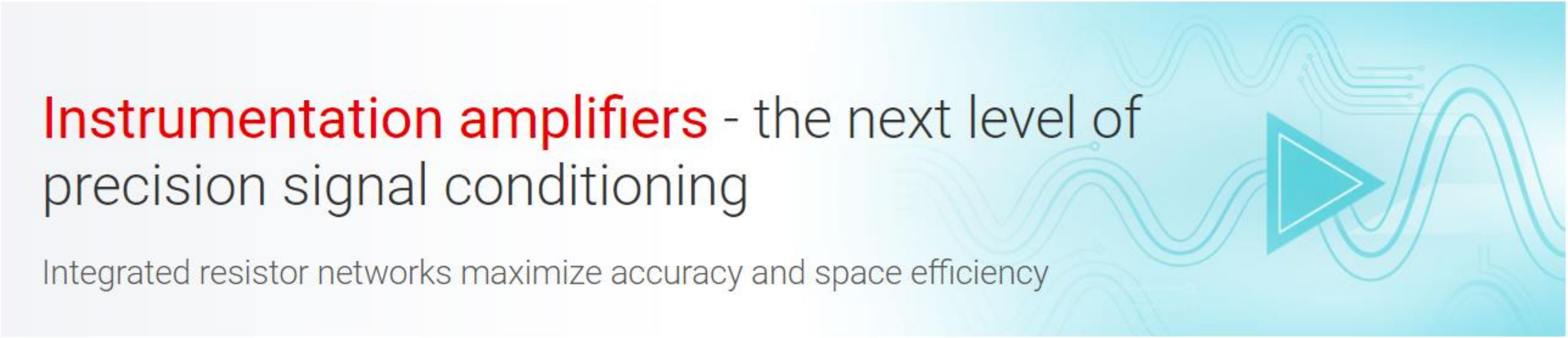
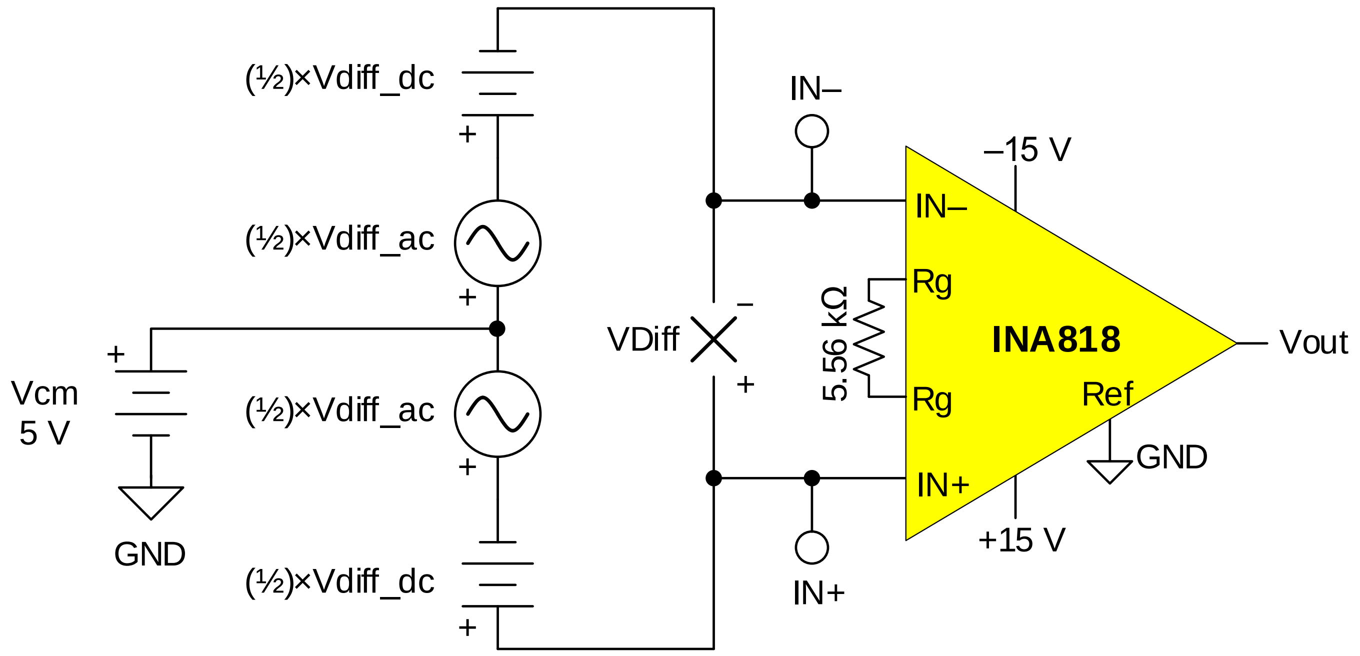


Importance of input bias current return paths



- Input: 100-Hz sine wave with an amplitude of 100 mV in the presence of a 5 V common-mode voltage and a 3 V dc voltage.
- Desired V_{out} = ±1 V signal
- Calculate gain:

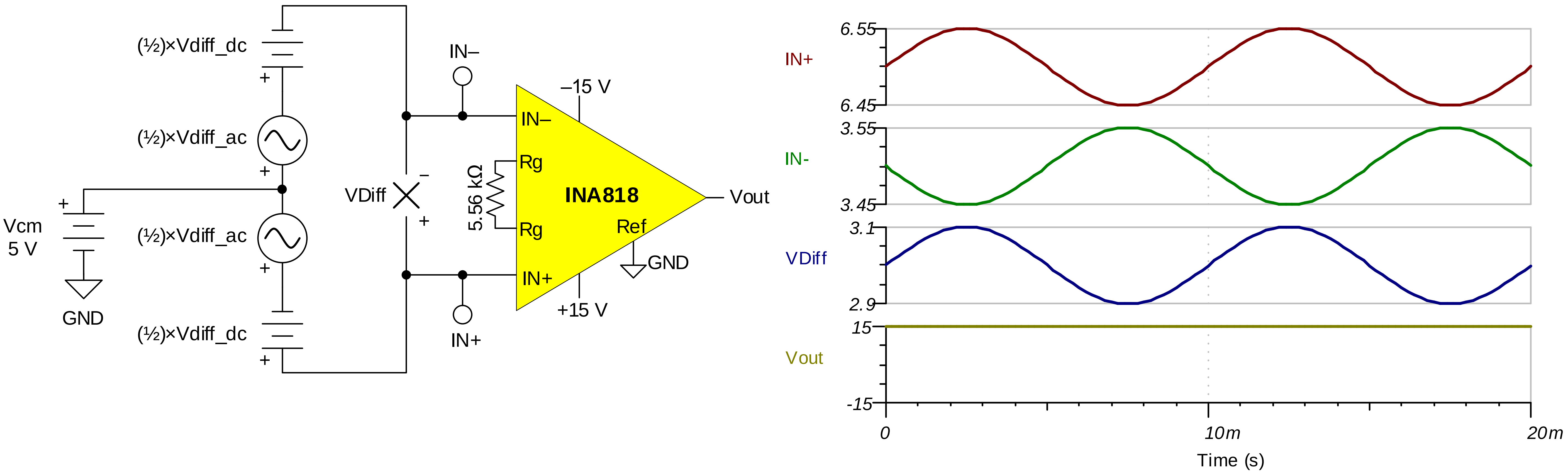
$$\text{Gain} = V_{out} / V_{in}$$

$$= 1\ \text{V} / 100\ \text{mV}$$

$$= 10\ \text{V/V}$$

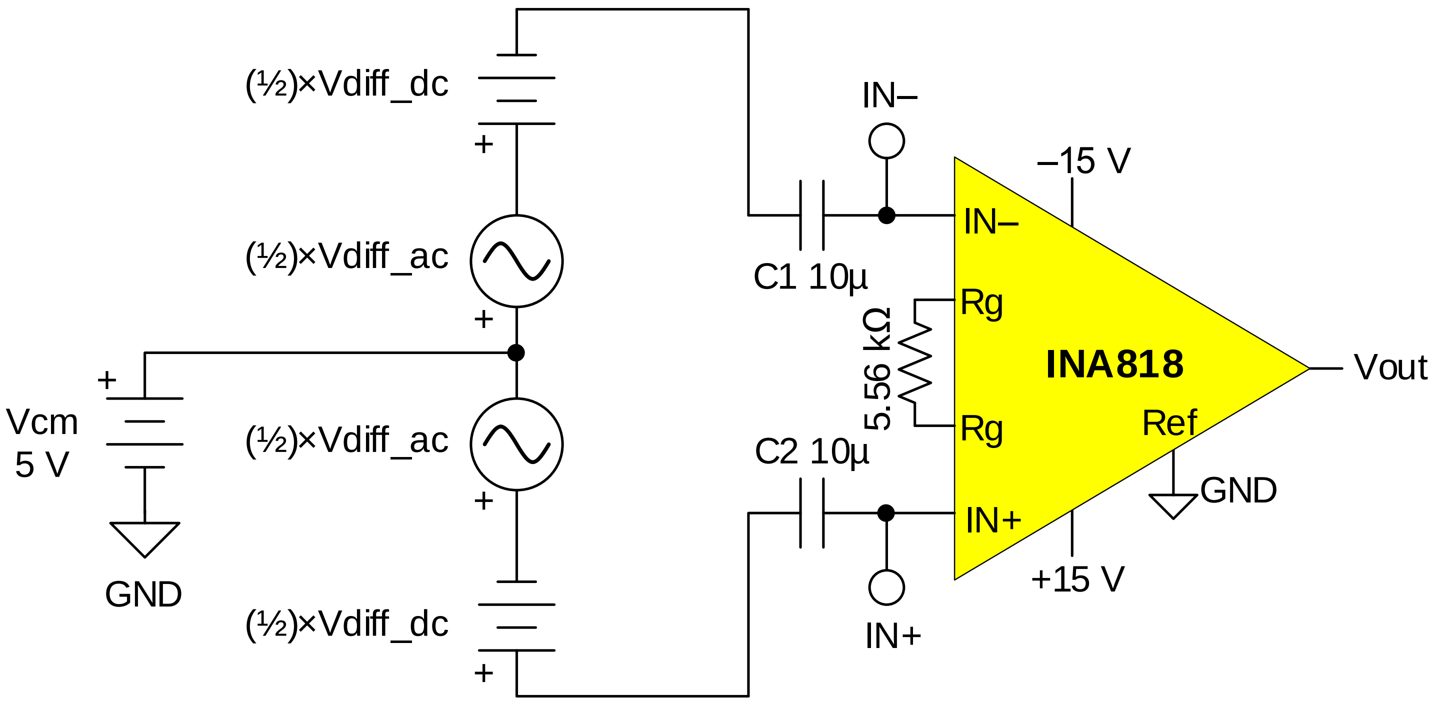
I_b return paths – transient analysis

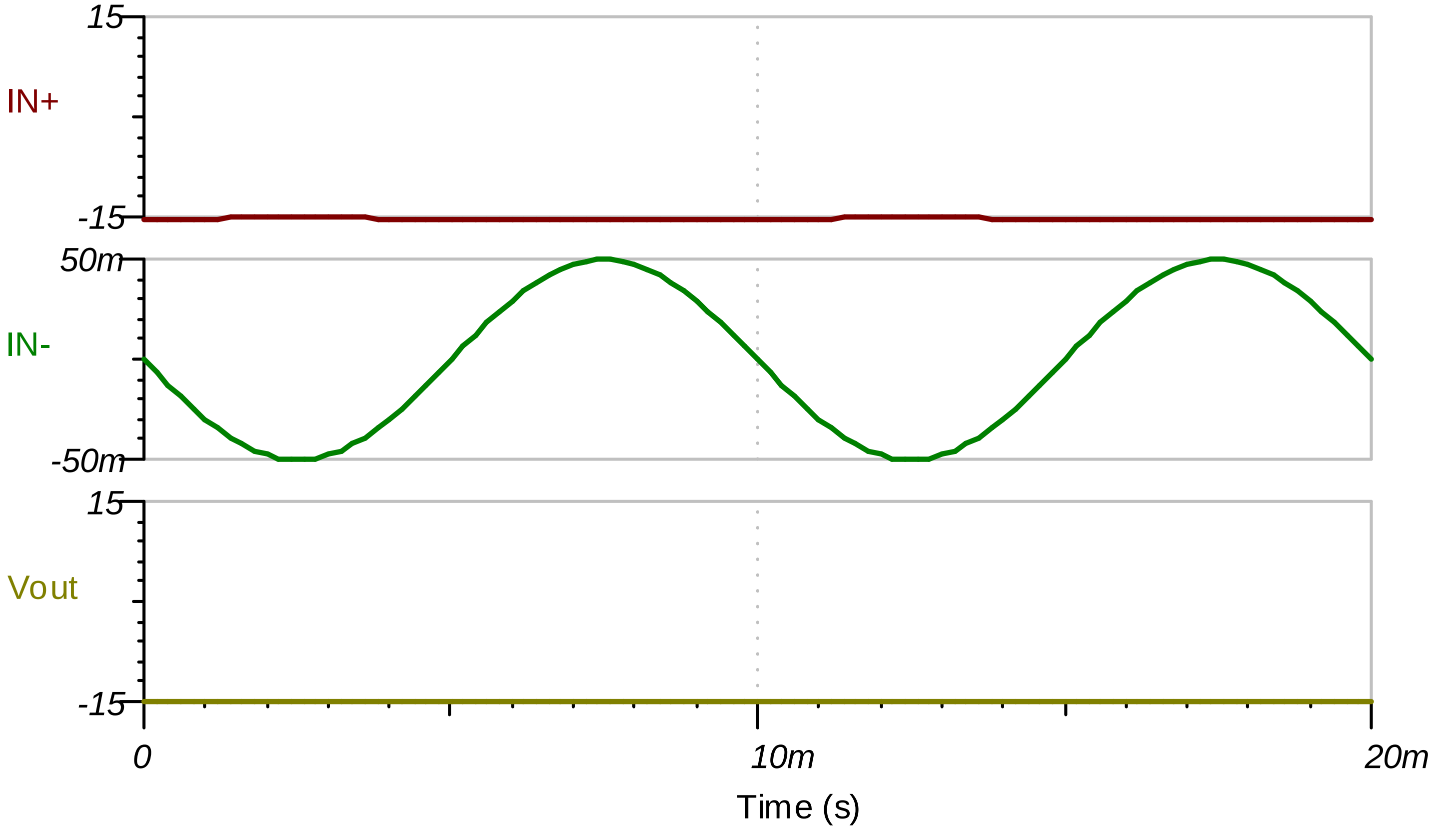
- IA rejected the 5 V common mode signal but the 3 V dc voltage summed with the differential voltage → Vdiff curve
- Vout saturated to the positive power supply rail



AC coupling – common mistake

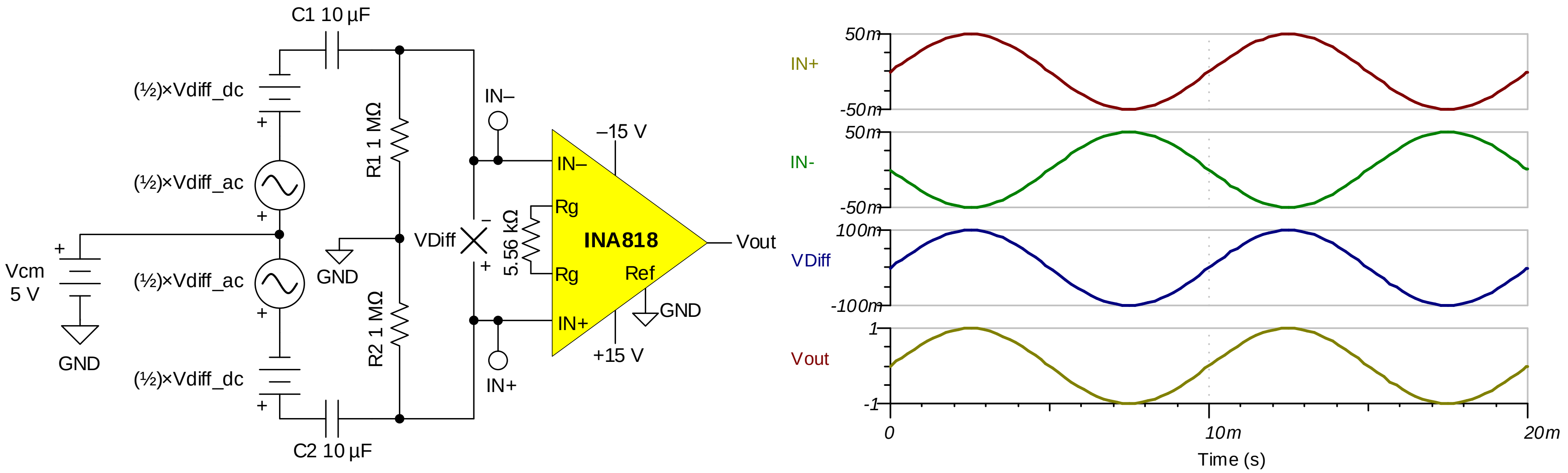
- Incorrect ac-coupled circuit by adding a capacitor in series with each IA input terminal, without providing a path for the input bias current → I_b of the IA will charge the capacitor until the output is saturated

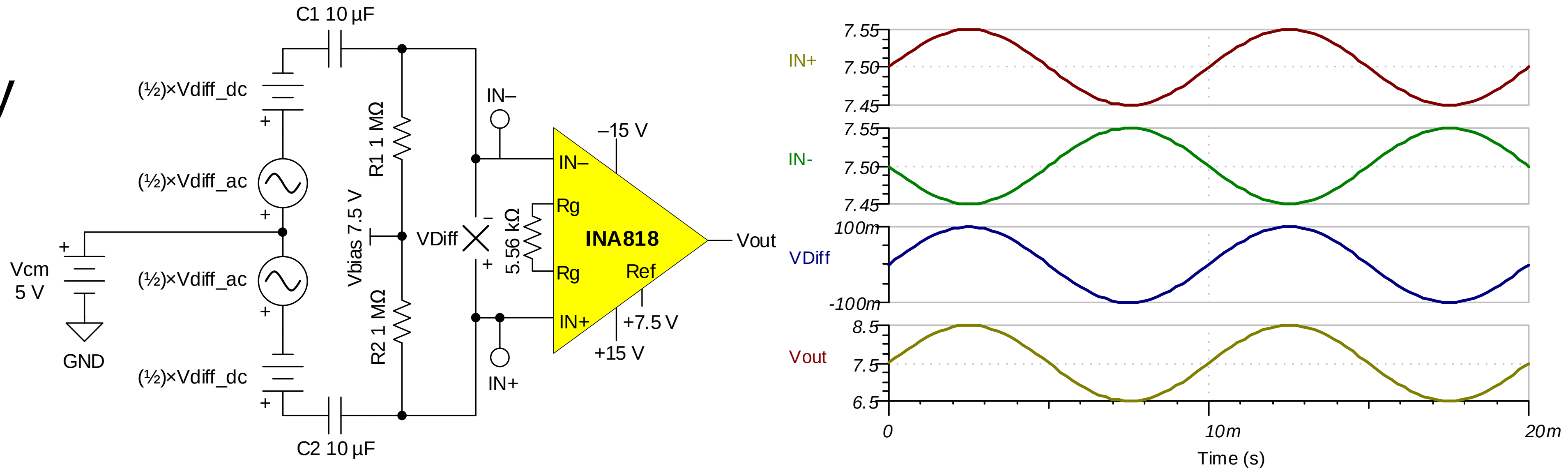




AC coupling – proposed solution

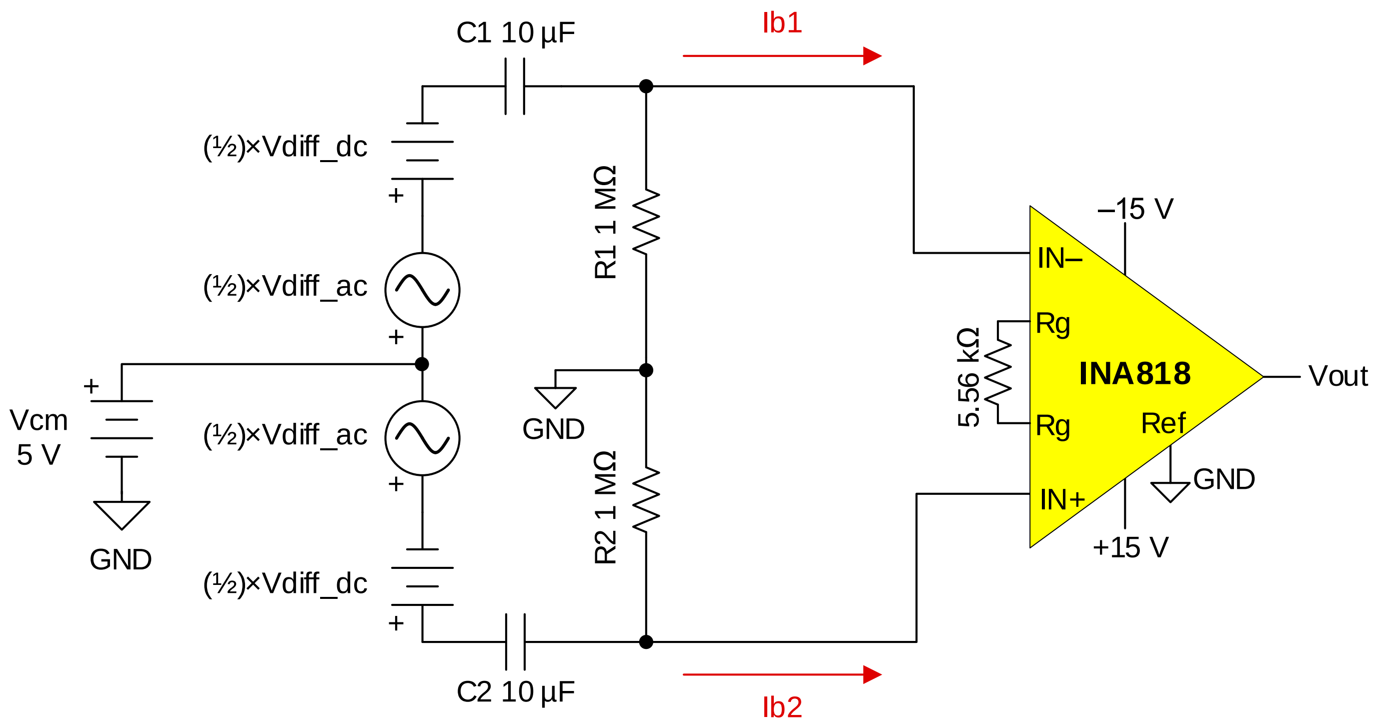
- **Proposed solution:** connect a resistor from each IA input to system ground or other bias voltage
- **Warning:** Vref and Vbias must be able to sink and source current; using an LDO may be unacceptable because an LDO can only source current. A buffer or a voltage reference is usually needed.





Component selection and trade-offs

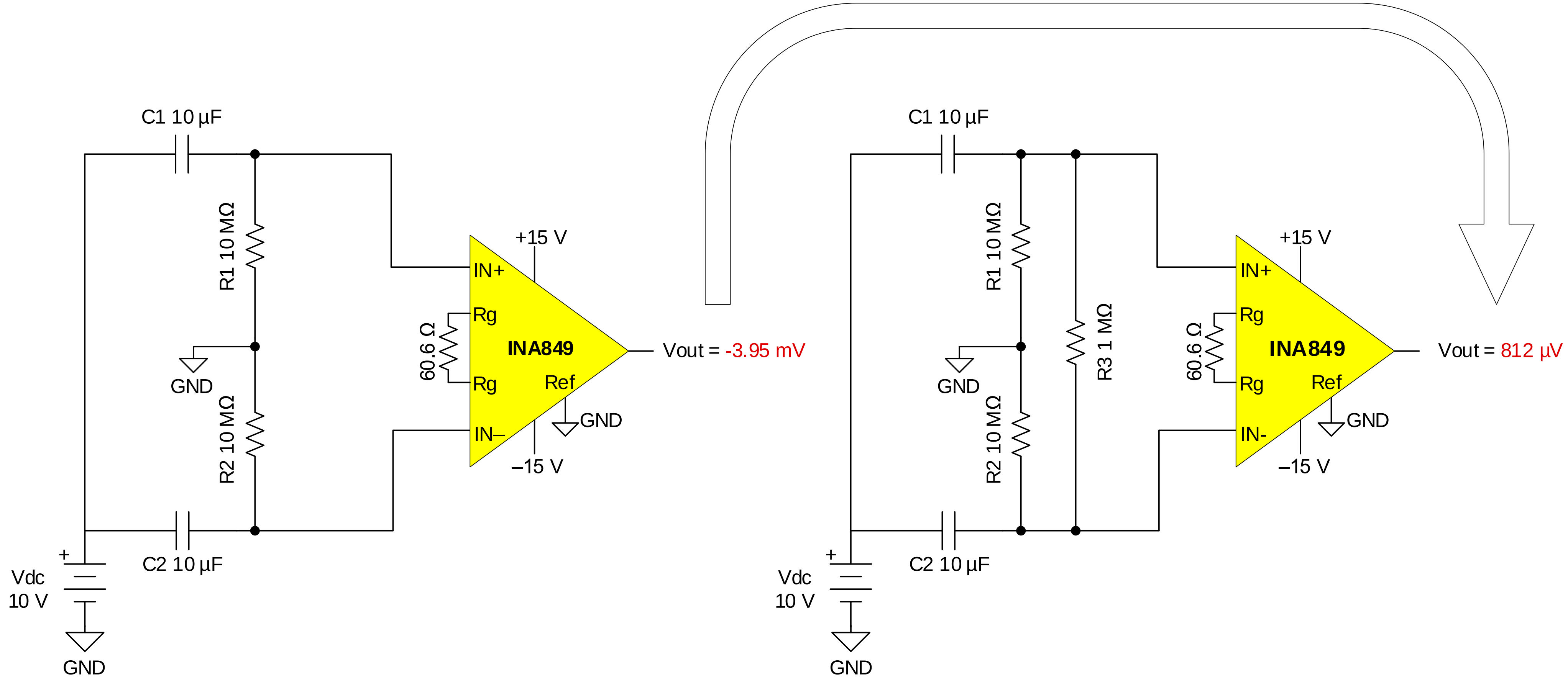
- Adding resistors and capacitors → increased noise, offset and limited board space
- Typical resistor values for R1 and R2; 100 kΩ to 1 MΩ
- I_b flows into these input impedances and produces V_{OS} adding to overall system error
- Precision: R1 must match R2 and C1 must match C2 to preserve CMRR



$$V_{OS(Ib)} = (Ib1 \times R1) - (Ib2 \times R2)$$

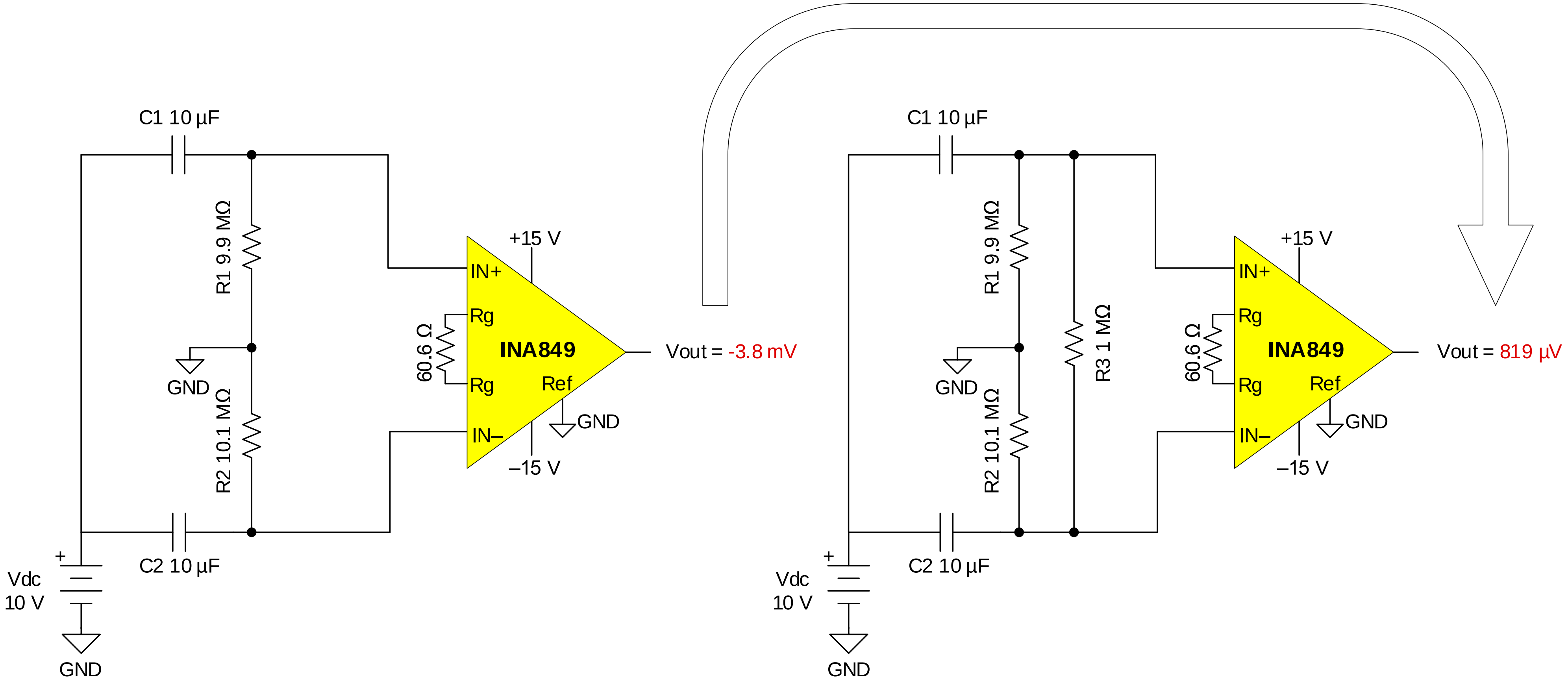
Component selection – increasing precision

- Add a third resistor between IA inputs: one-tenth the value of the other two
- Adding a third resistor between the inputs of the IA reduces the overall input impedance, which results in less system error at the output.



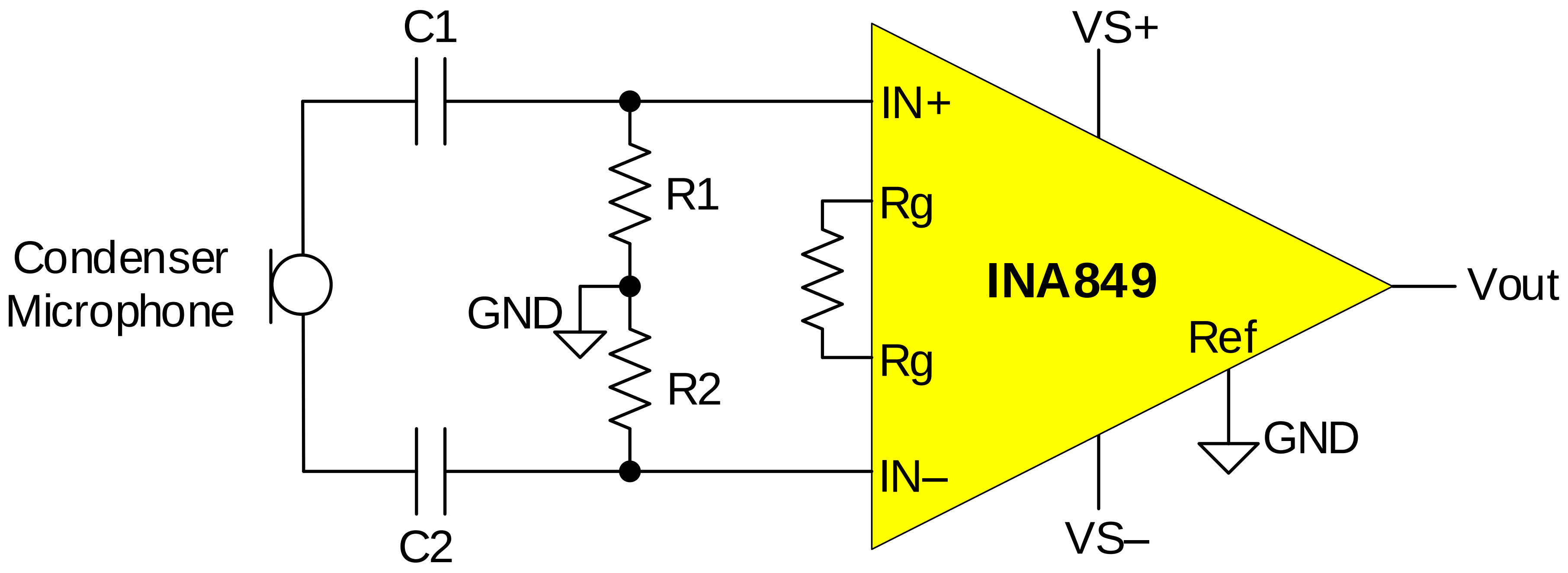
Resistor selection – tolerance

- Advantage of third resistor: Resistors cannot be perfectly matched, they are rated according to tolerance. Adding a third resistor can allow a designer to use lower tolerance resistors
- Disadvantage of third resistor: reduces the overall impedance



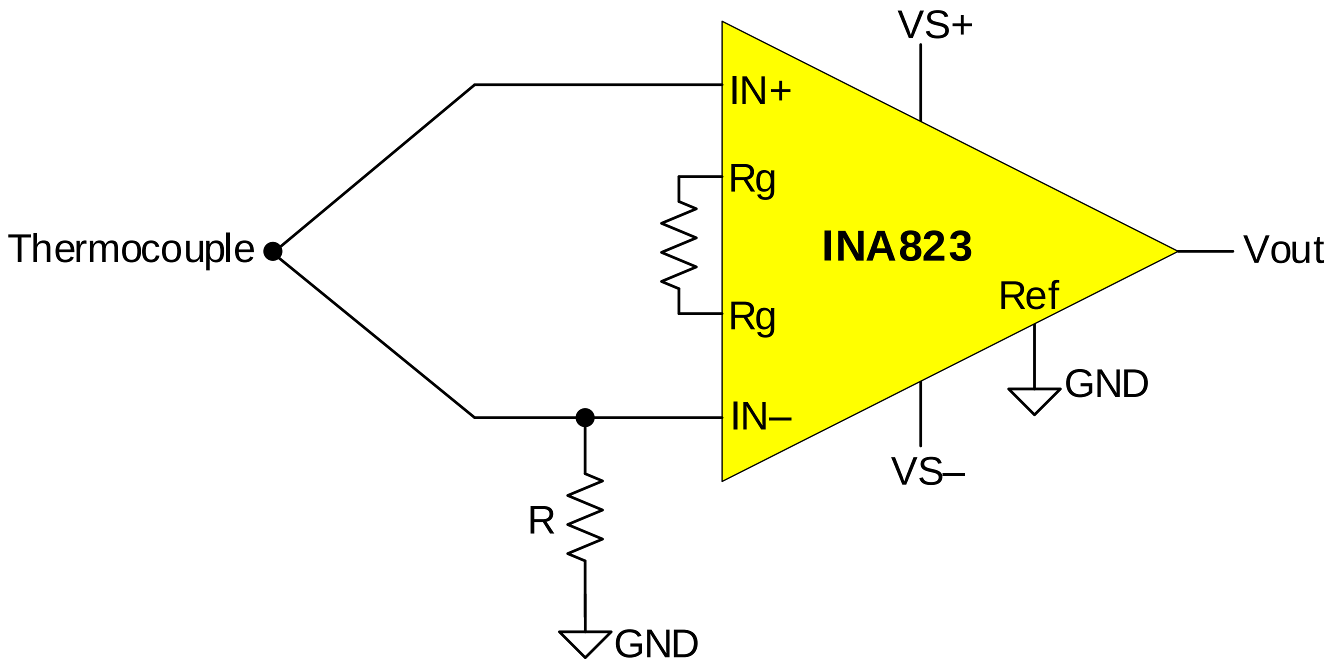
Application example – mic preamp

- 2 terminal electret microphone
- Microphone parameters determine the required biasing resistors
- Warning: do not use biasing resistors low enough to load the microphone and cause distortion, and large enough to induce excessive thermal noise.



Application example – thermocouple

- Thermocouple: temperature measurement that produces a small-signal dc signal
- The thermocouple has a low output impedance; therefore, two biasing resistors are not required. One biasing resistor can provide the necessary path to ground without creating a large offset error due to I_b.



Input bias current – summary

- Input bias current, I_b: Current flowing in to, or out of, the inputs of the IA
  - Combines with input impedance to create additional offset error:
    - Typical I_b for CMOS input: 1pA to 50pA
    - Typical I_b for traditional bipolar input: 1nA to 50nA
    - Typical I_b super-β bipolar input: 0.1nA to 5nA
  - Design with precision:
    - Provide a dc path to ground in dc or ac applications

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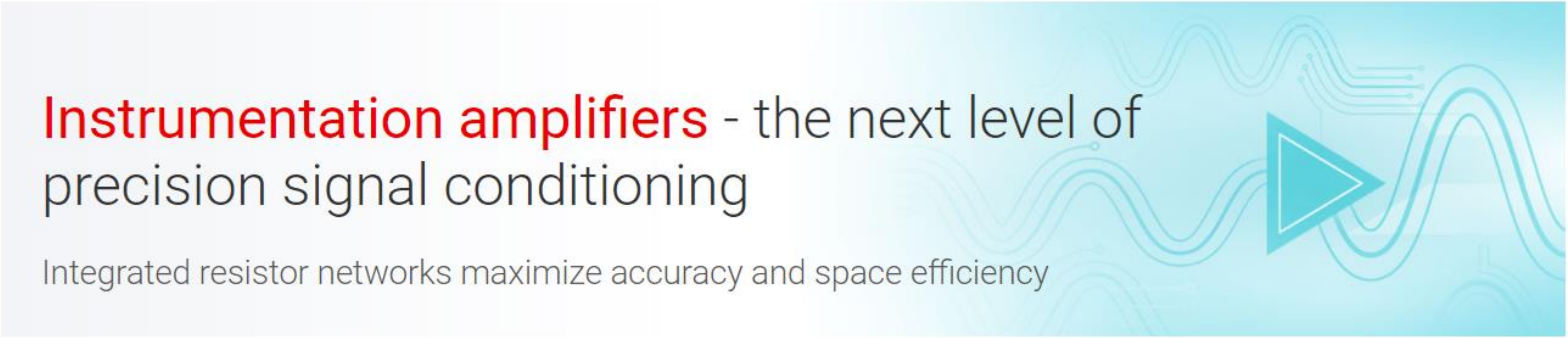

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