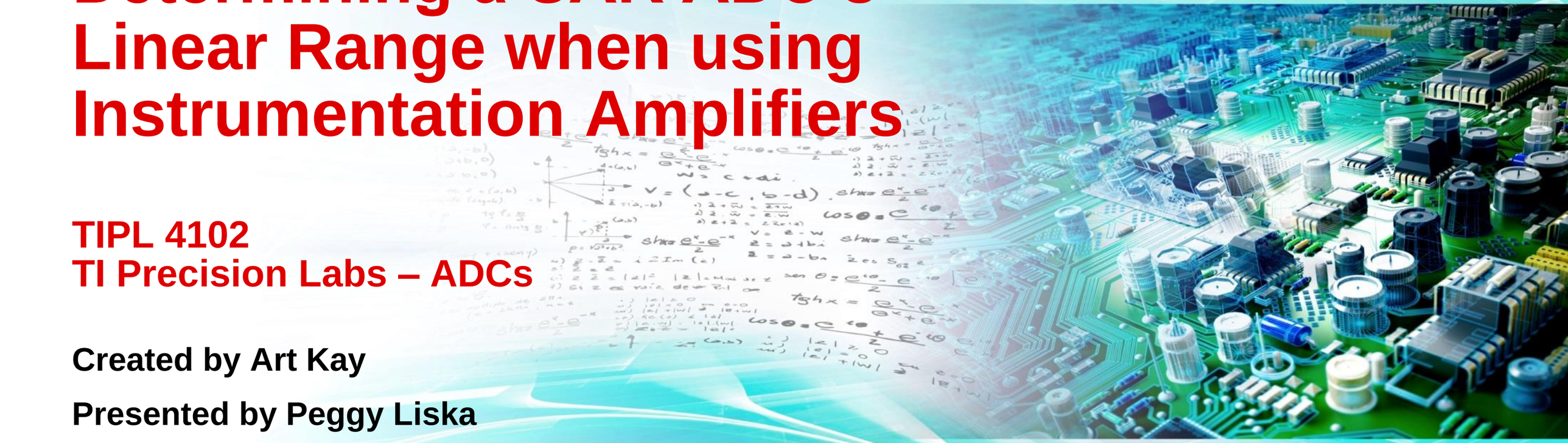
Determining a SAR ADC's Linear Range when using Instrumentation Amplifiers



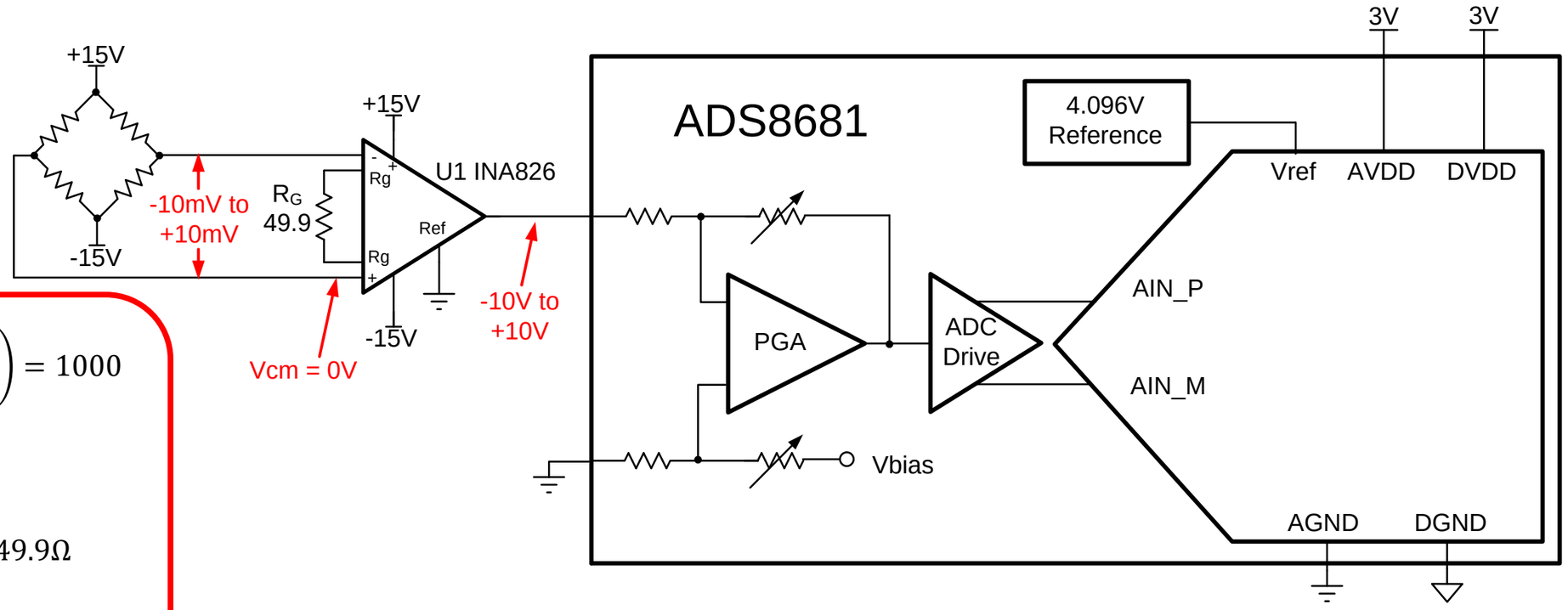
TIPL 4102
TI Precision Labs – ADCs

Created by Art Kay

Presented by Peggy Liska

Instrumentation Amplifier (INA): Choose Gain

PARAMETER ADS8681		TEST CONDITION	MIN	TYP	MAX	UNIT
ANALOG INPUT						
V_{IN}	Full-scale input voltage span	Input range = ±3 x V_{REF}	-12.288		12.288	V
		Input range = ±2.5 x V_{REF}	-10.24		10.24	
		Input range = ±1.5 x V_{REF}	-6.144		6.144	



$$G_{826} = \left(\frac{\Delta V_{OUT}}{\Delta V_{IN}}\right) = \left(\frac{10V - (-10V)}{10mV - (-10mV)}\right) = 1000$$

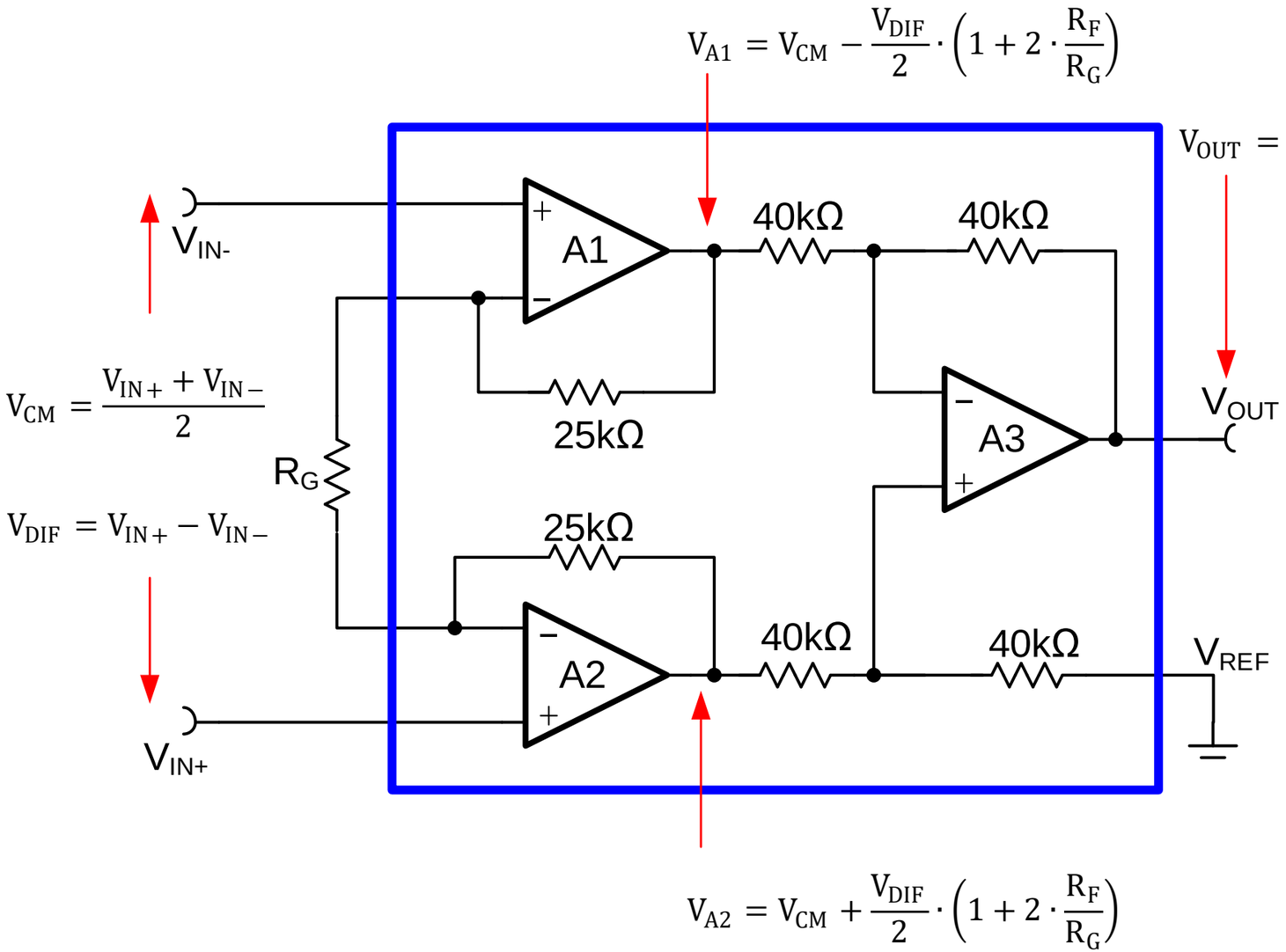
$$G_{826} = 1 + \left(\frac{49.4k\Omega}{R_G}\right)$$

$$R_G = \frac{49.4k\Omega}{G_{826} - 1} = \frac{49.4k\Omega}{1000 - 1} = 49.5\Omega \; or \; 49.9\Omega$$

$$V_{OUT} = G_{826} \cdot V_{IN} + V_{REF}$$

$$V_{OUT} = 1000 \cdot (10mV) + 0V = 10V$$

Common mode and output swing for INAs



INA Common mode

- Output swing and common mode of internal amplifiers is a complex relationship.
- Different INAs have different topologies
- Vref, V+, V-, and gain determine common mode vs output swing relationship.
- A software tool simplifies this calculation

Verify INA Common Mode Range (INA826)

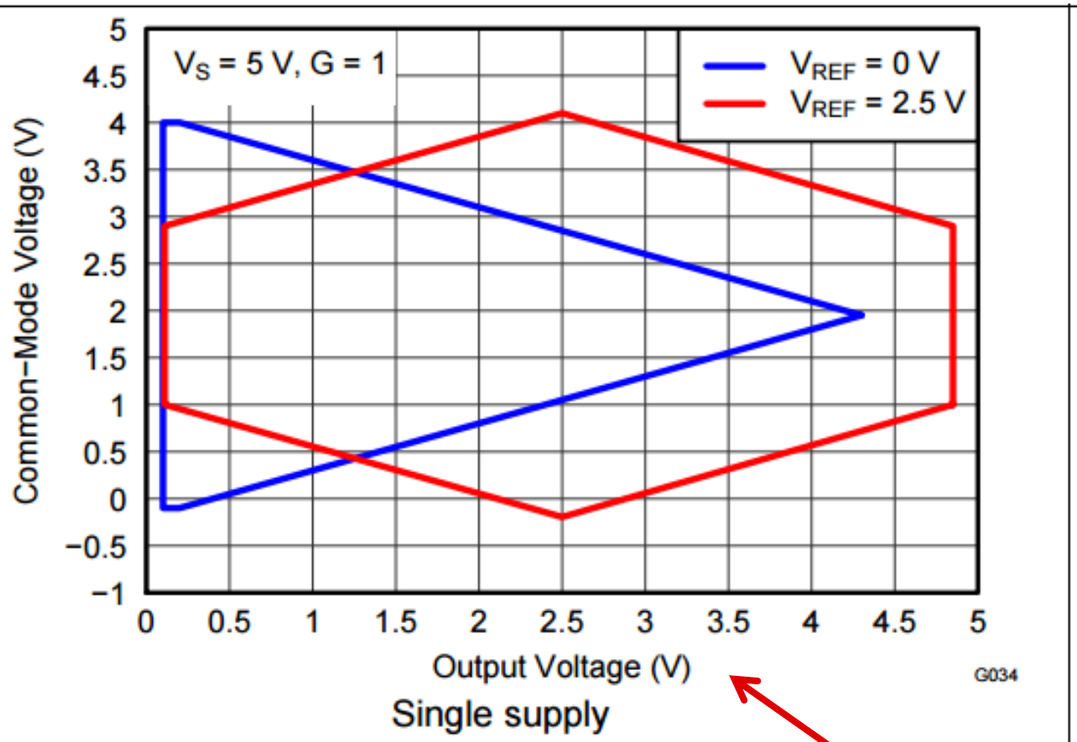


Figure 11. Input Common-Mode Voltage vs Output Voltage

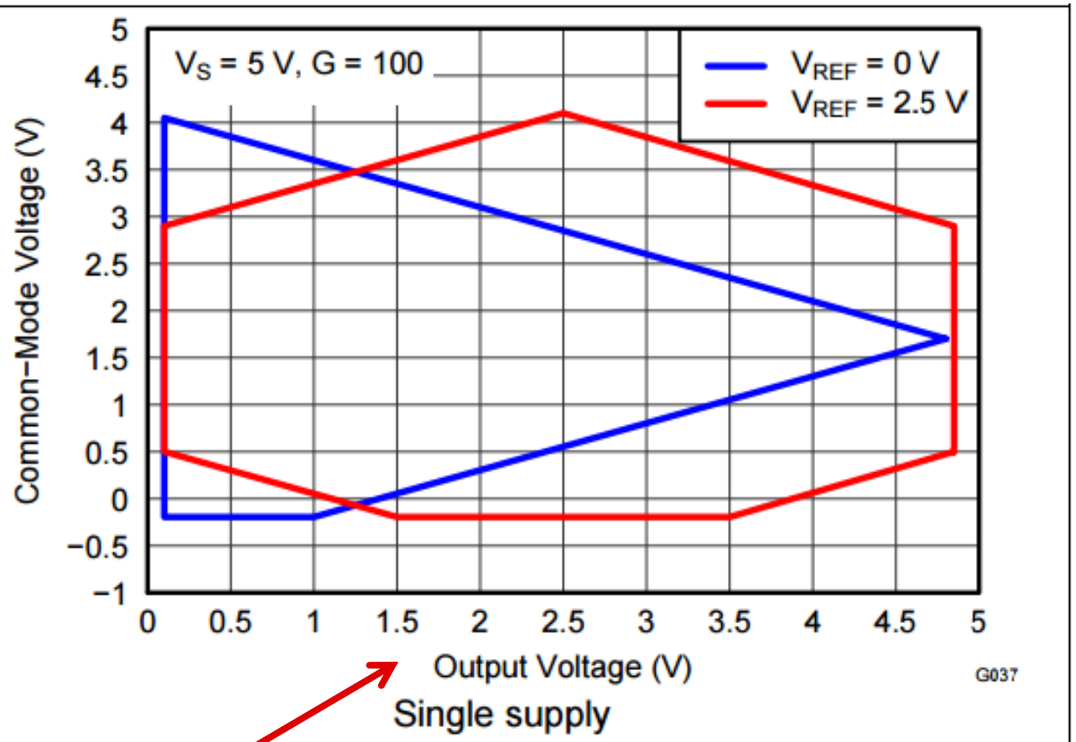
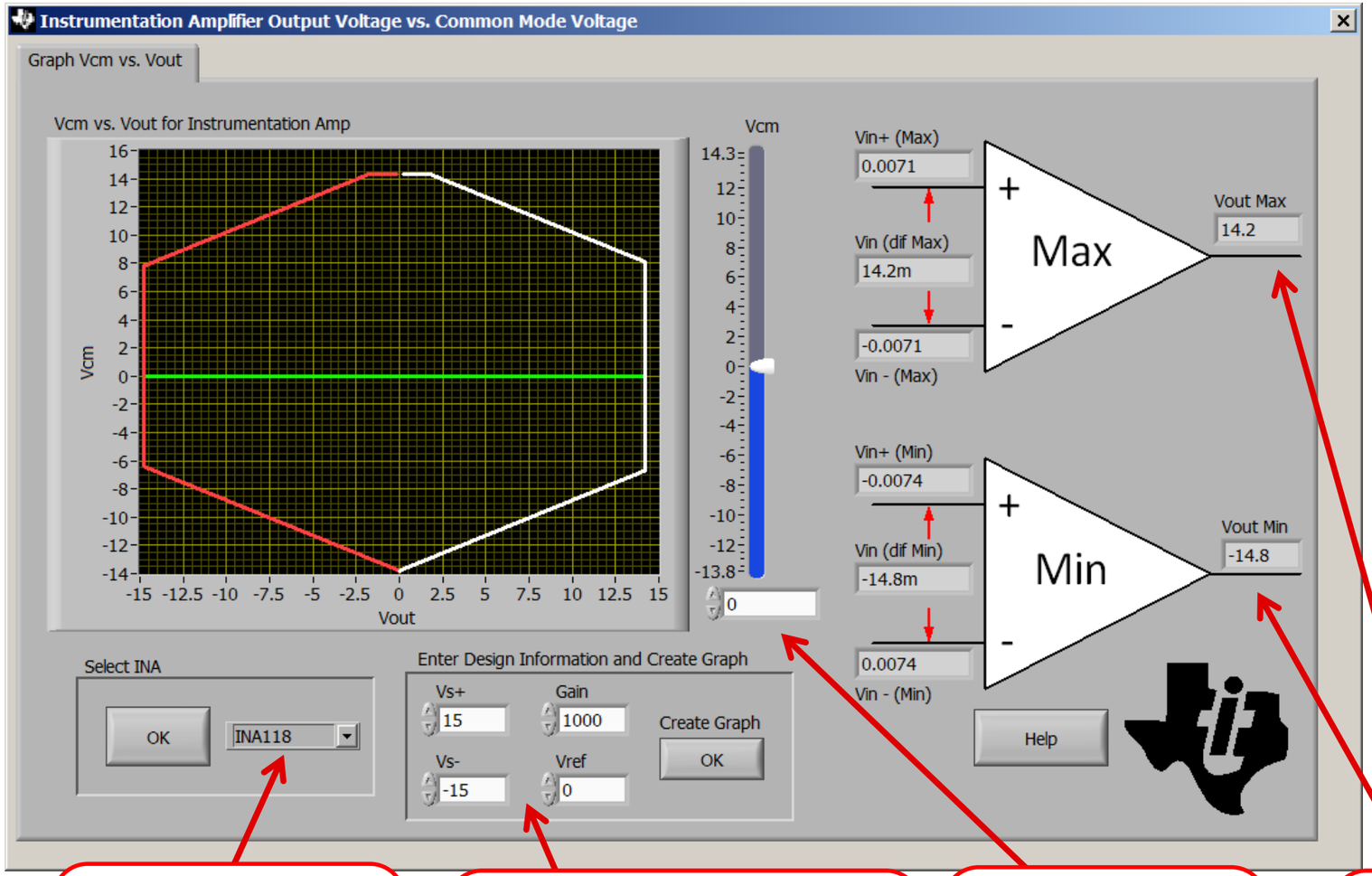
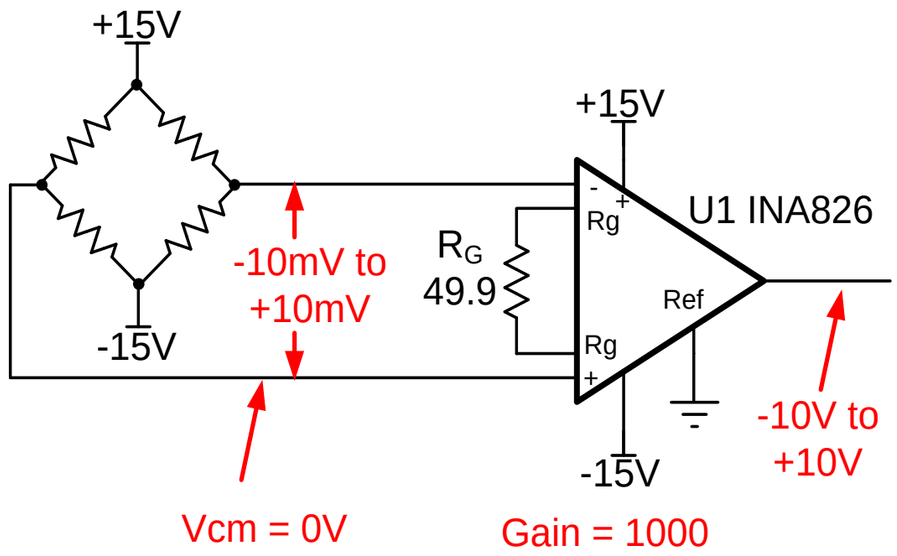


Figure 12. Input Common-Mode Voltage vs Output Voltage

Output Voltage = V_{DIF} * Gain

Verify INA Common Mode Range





- Vout range limited to -14.8V to +14.2V
- -10V to 10V output inside the range
- http://www.ti.com/tool/ina-cmv-calc

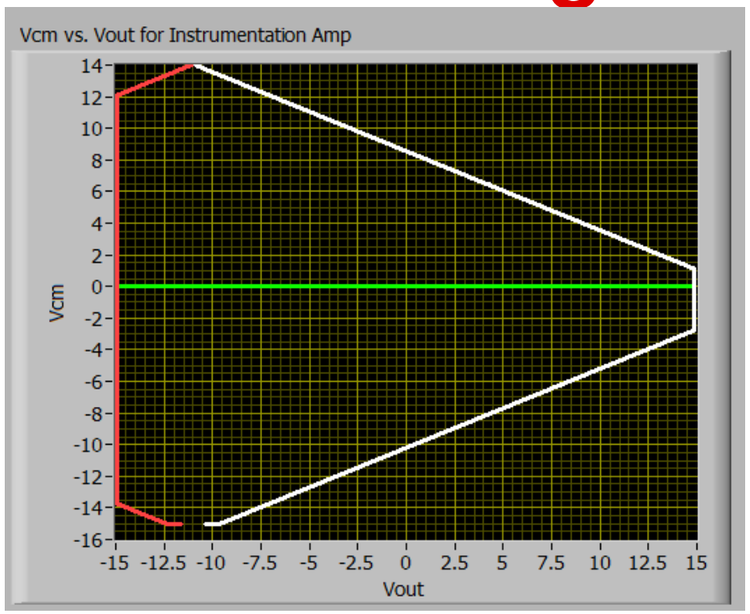
1. Select your instrumentation amplifier

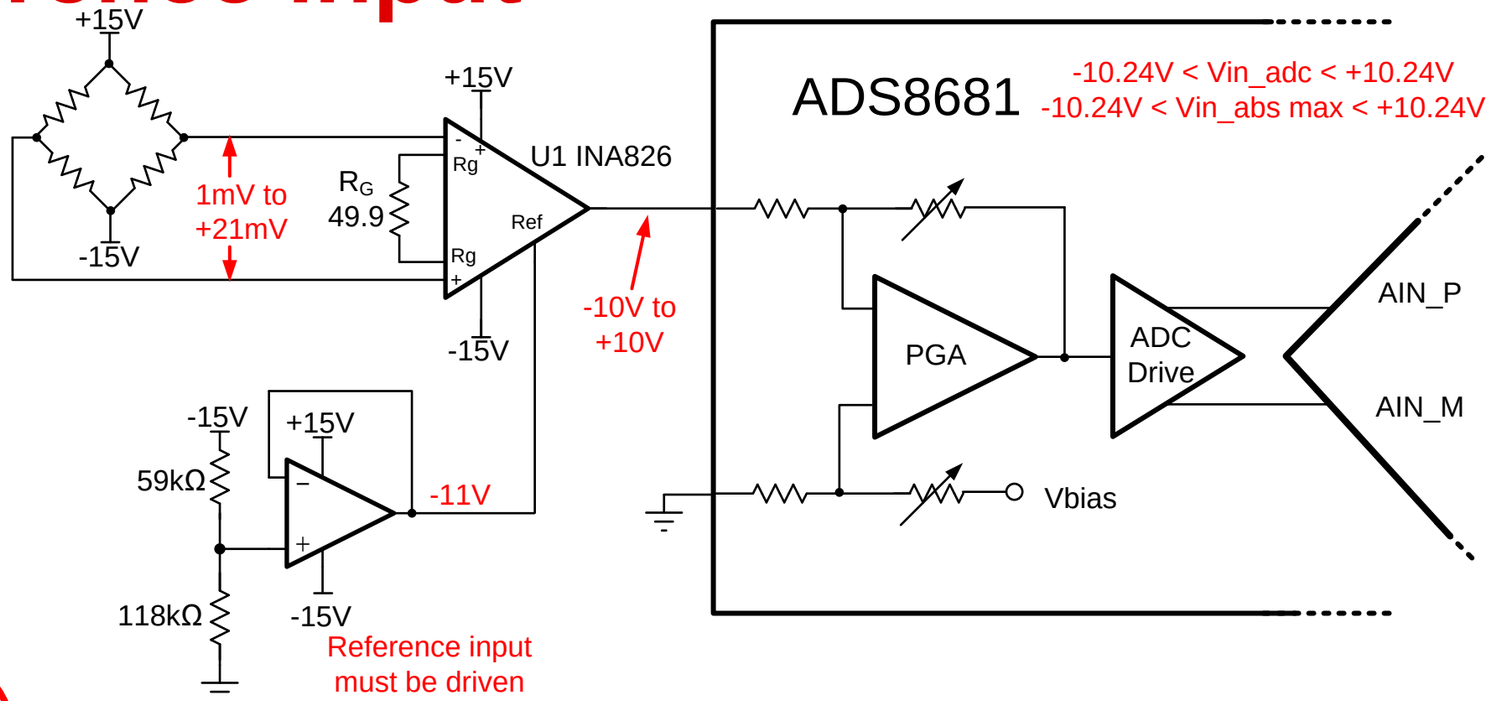
2. Enter the supplies, gain, reference and press “Create Graph”.

3. Enter the common mode voltage.

4. Does the output range work for your system?

INA: Setting the reference input





$$G_{826} = \left(\frac{\Delta V_{OUT}}{\Delta V_{IN}}\right) = \left(\frac{10V - (-10V)}{1mV - (-21mV)}\right) = 1000$$

$$G_{826} = 1 + \left(\frac{49.4k\Omega}{R_G}\right)$$

$$R_G = \frac{49.4k\Omega}{G_{826} - 1} = \frac{49.4k\Omega}{1000 - 1} = 49.5\Omega \text{ or } 49.9\Omega$$

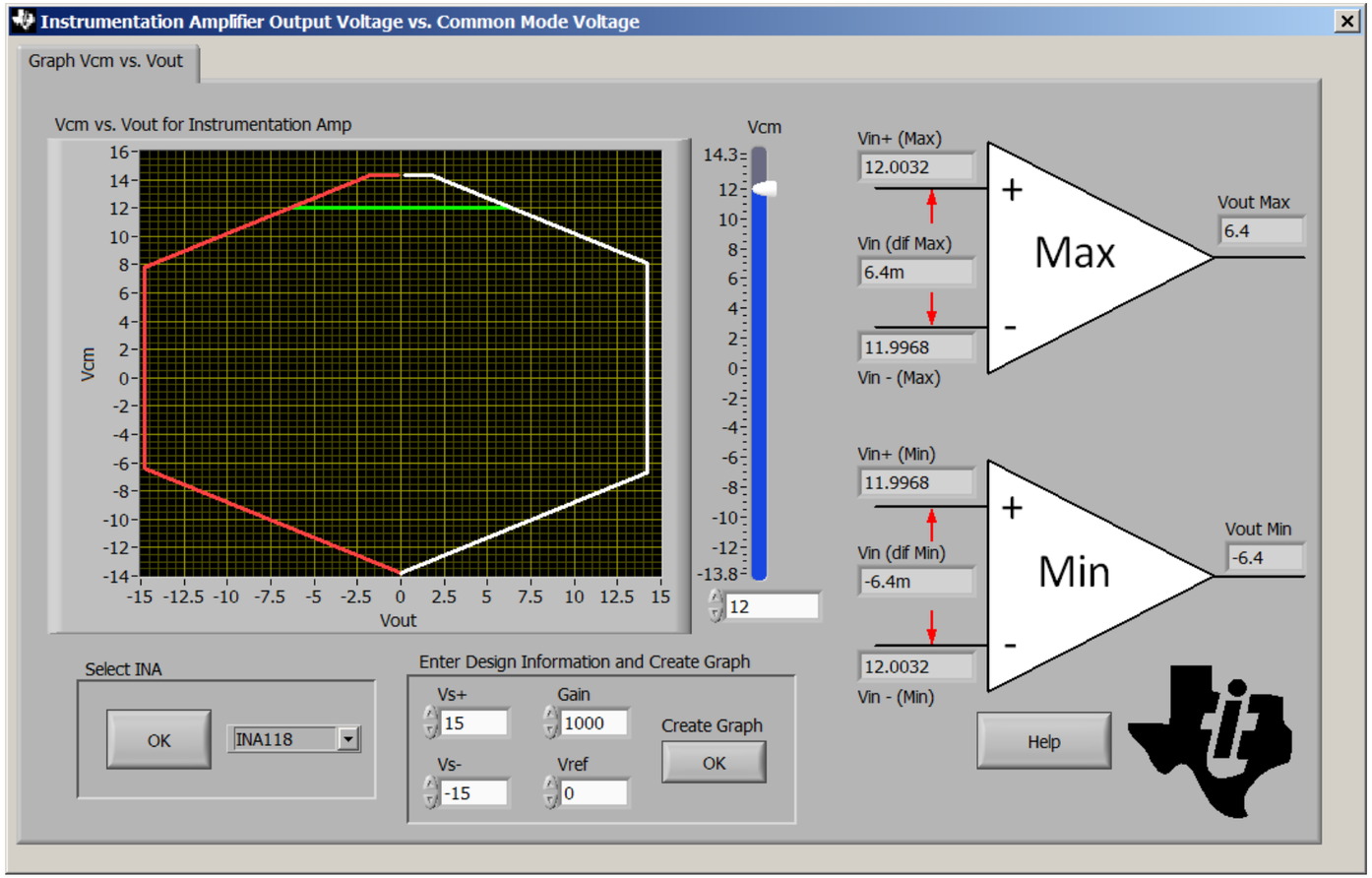
$$V_{OUT} = G_{826} \cdot V_{IN} + V_{REF}$$

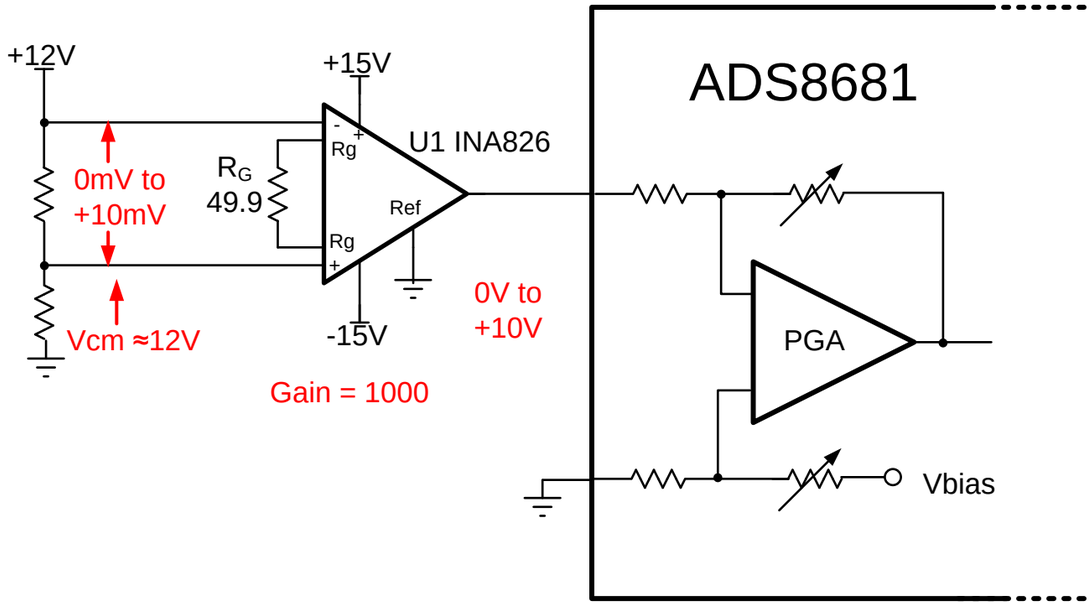
$$V_{REF} = V_{OUT\_Min} - G_{826} \cdot V_{IN\_Min}$$

$$V_{REF} = -10V - (1000)(1mV) = -11V$$

- Gain is calculated same as before
- Negative Vref input to shift the signal
- Reference input must be driven

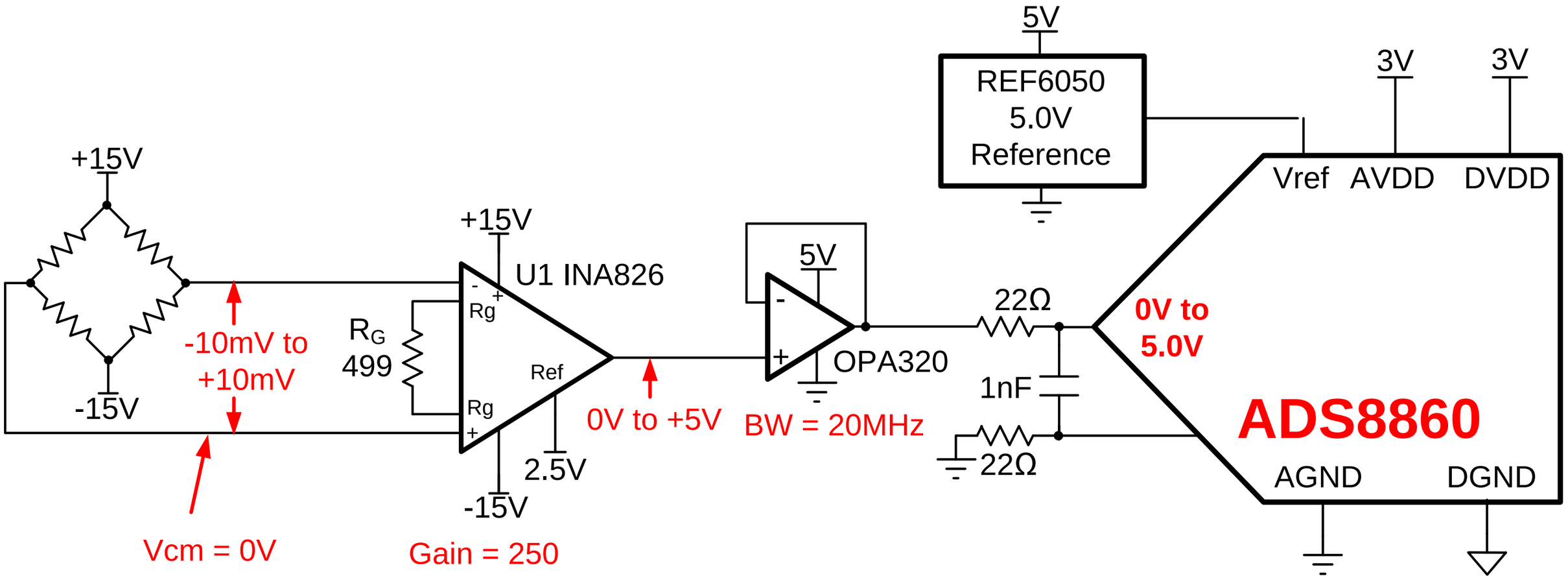
Output range limited by input common mode





- Vout range limited to ±6.4V
- Cannot achieve 0 to 10V output

Two Stage Approach



Precision DC Input **Wide Bandwidth Driver**

Thanks for your time!
Please try the quiz.

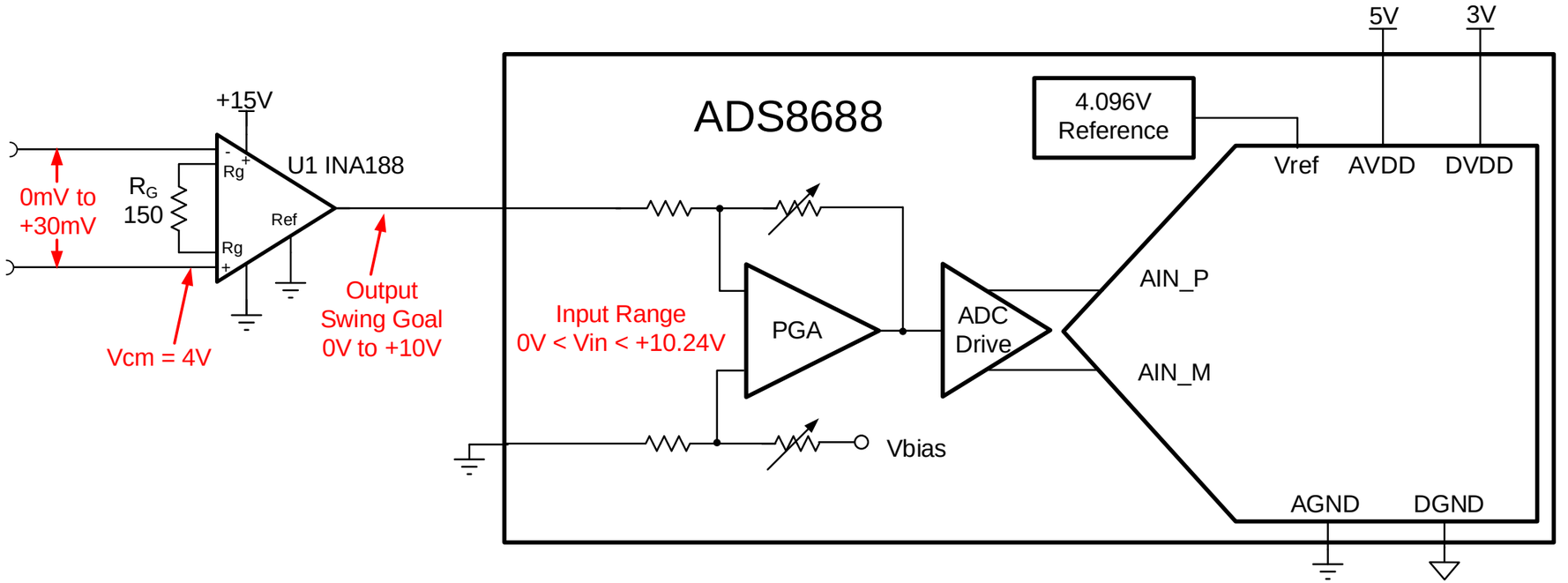
Quiz: Determining a SAR ADC's Linear Range when using Instrumentation Amplifiers

TIPL 4102
TI Precision Labs – ADC

Created by Art Kay

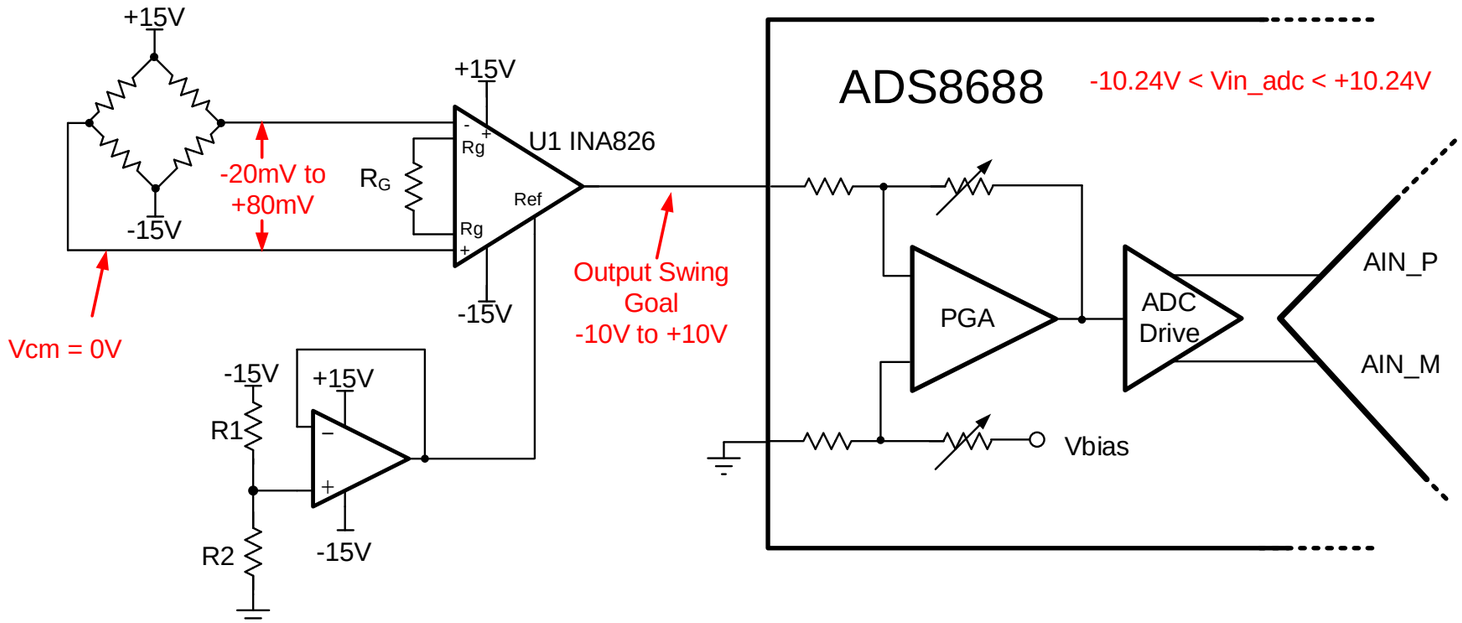
Quiz: Linear Range ADC + INA

1. The data converter below is configured so that the input range is 0V to 10.24V. The goal of the INA188 is to translate the 0mV to 30mV input signal to 0V to 10V. Use the INA188 data sheet to answer these questions.
   a. Is the INA188 gain set correctly to achieve the goal?
   b. Does the INA188 have the linear output range to achieve the goal?



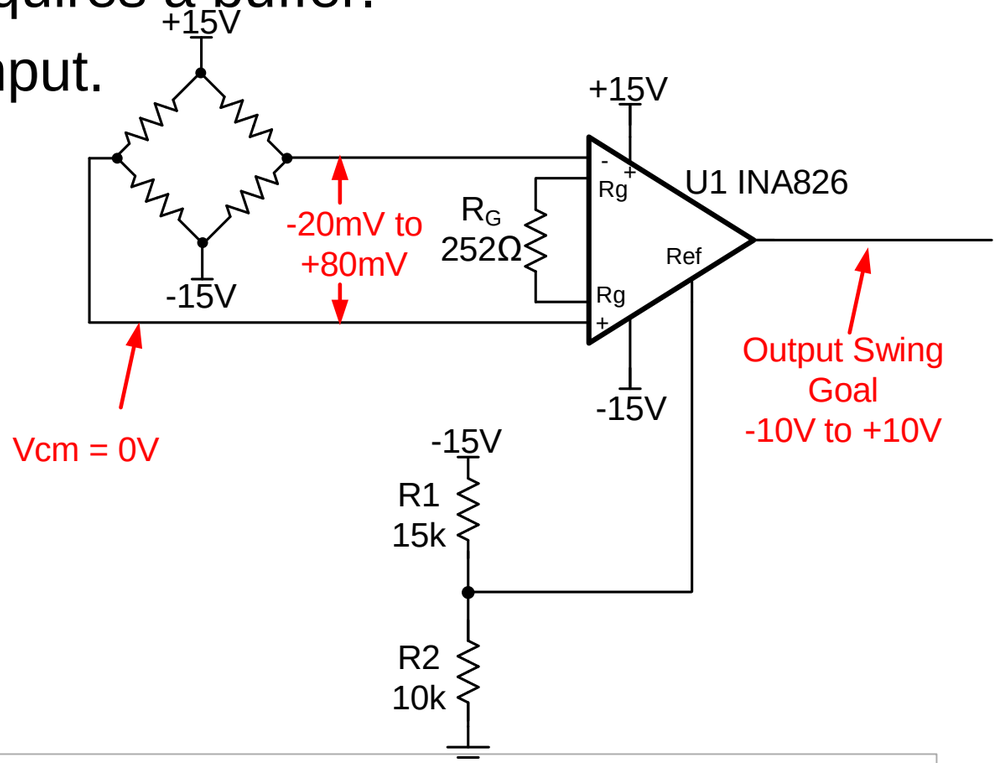
Quiz: Linear Range ADC + INA

2. The data converter below is configured so that the input range is -10.24V to 10.24V. The goal of the INA188 is to translate the -20mV to 30mV input signal to -10V to 10V. Use the INA188 data sheet to answer these questions.
   a. What gain, and 0.1% standard value of RG is required to achieve the goal?
   b. What INA188 reference, and voltage divider 0.1% standard resistor values will achieve this goal.
   c. Confirm linear output swing.



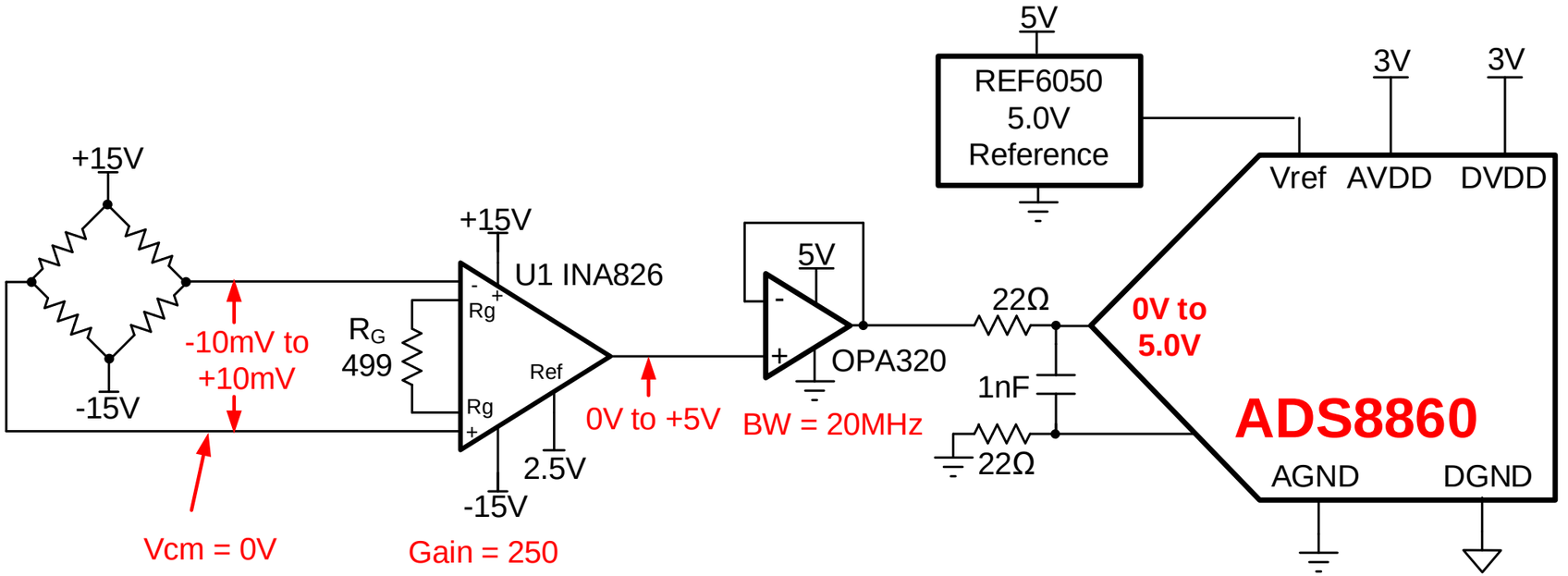
Quiz: Linear Range ADC + INA

3. The objective of the circuit below is to translate the -20mV to 80mV input signal to a -10V to +10V output signal. What is wrong with the circuit below?
   a. No issue. The circuit should properly scale the output to ±10V
   b. The gain is not set correctly.
   c. The voltage divider on the INA188 reference pin requires a buffer.
   d. The output swing is limited by the common mode input.



Quiz: Linear Range ADC + INA

4. Referring to the circuit below, what is the purpose of the OPA320?
   a. It is required to achieve good settling on the switched capacitor input SAR.
   b. The amplifier is not necessary.
   c. The amplifier translates the ±15V signal from the INA826 to 0V to 5V range.
   d. It matches the output impedance of the INA826 to the ADS8860 input impedance.

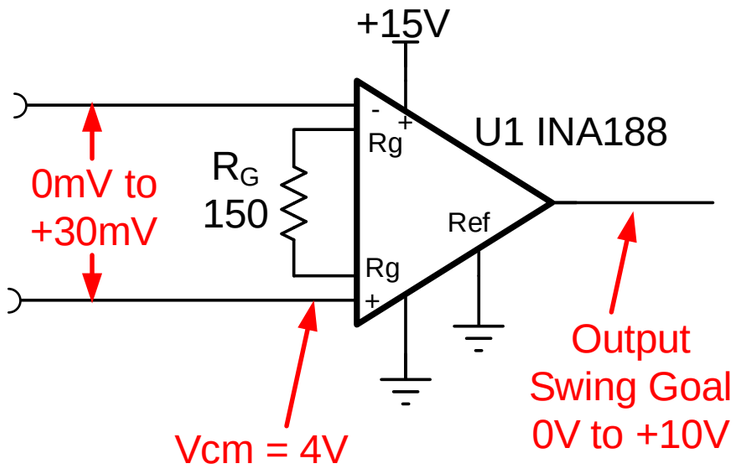


Solutions

Quiz: Linear Range ADC + INA

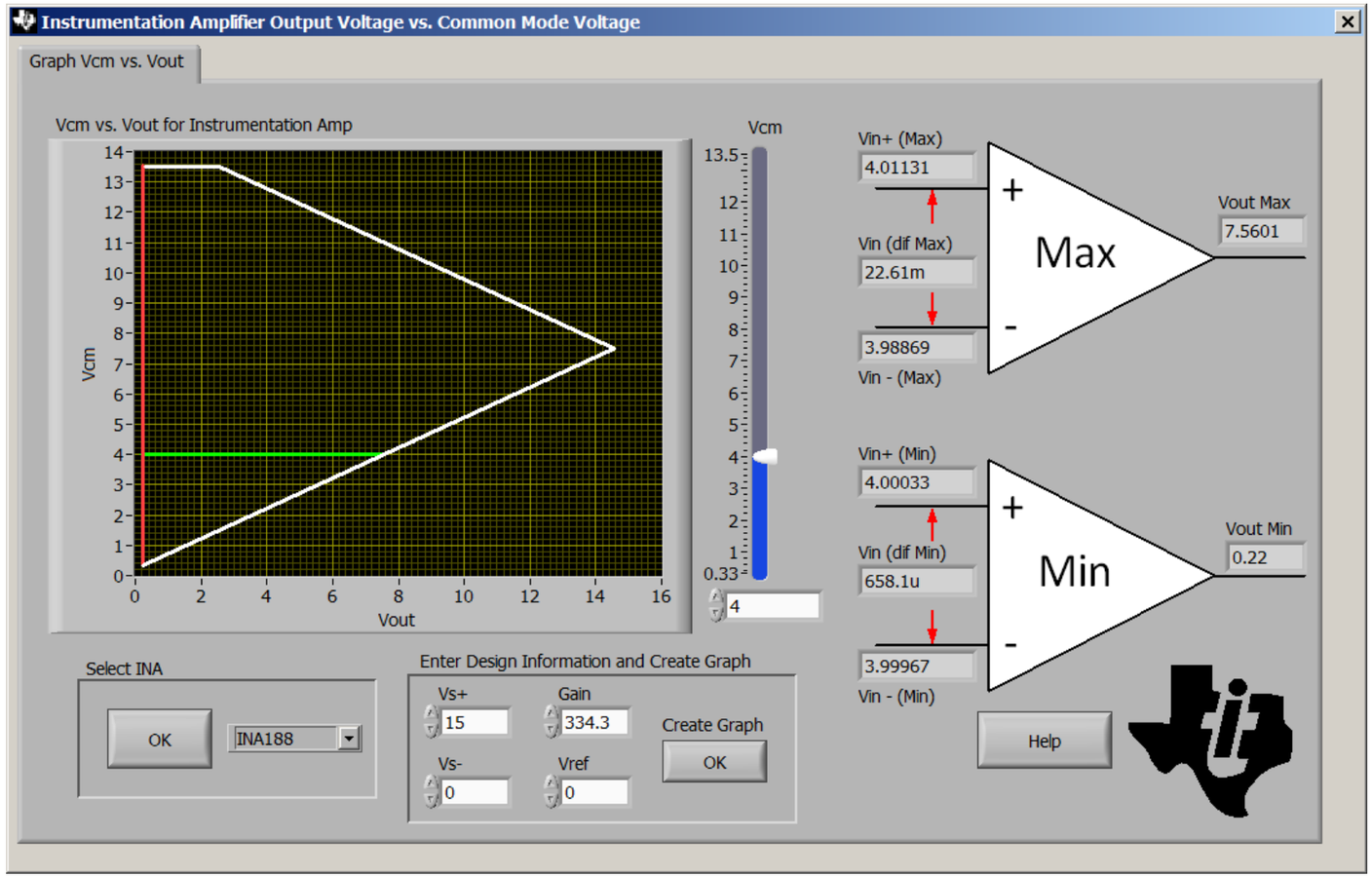
1. The data converter below is configured so that the input range is 0V to 10.24V. The goal of the INA188 is to translate the 0mV to 30mV input signal to 0V to 10V. Use the INA188 data sheet to answer these questions.
   a. Is the INA188 gain set correctly to achieve the goal? Yes. See calculation below.

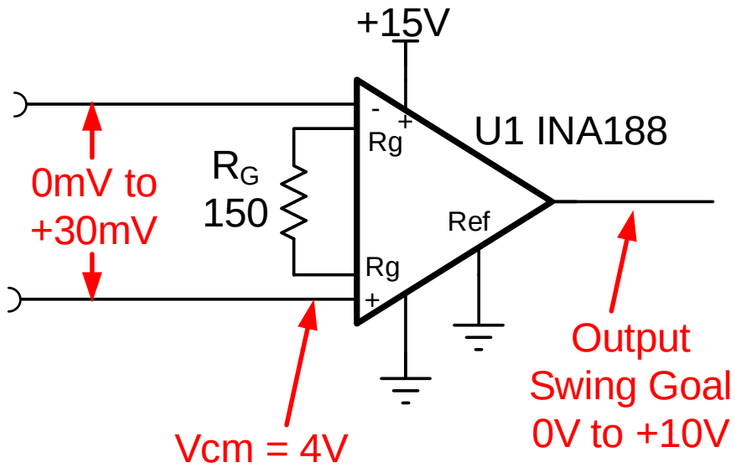
$G = 1 + \frac{50k\Omega}{R_G} = 1 + \frac{50k\Omega}{150\Omega} = 334.3$
$V_{out} = G \cdot V_{in} + V_{ref} = (334.3) \cdot (30mV) + (0V) = 10.03V$



Quiz: Linear Range ADC + INA

1b. Does the INA188 have the linear output range to achieve the goal? No, the output swing is limited to 0.22V to 7.56V

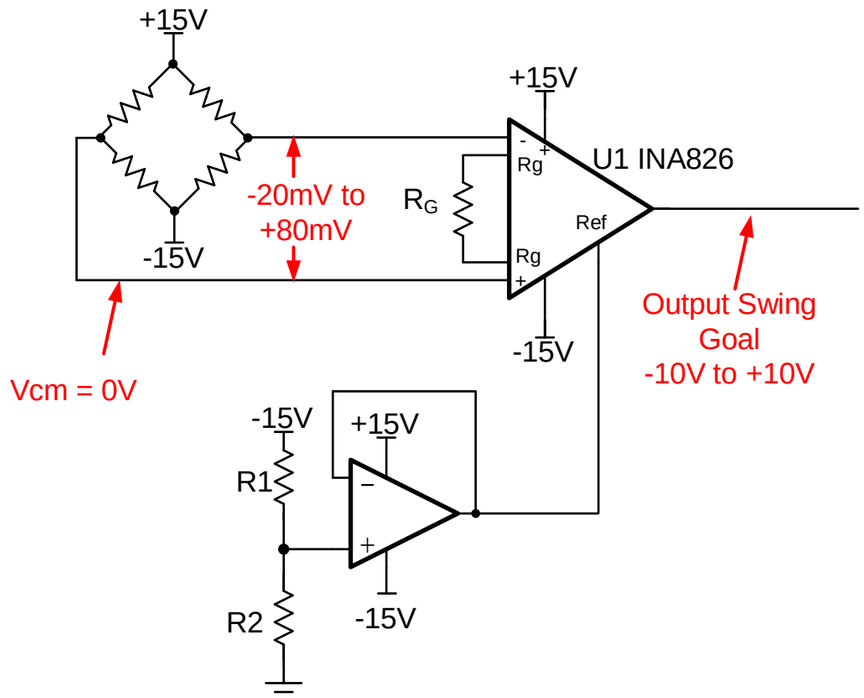




Quiz: Linear Range ADC + INA

2. The data converter below is configured so that the input range is -10.24V to 10.24V. The goal of the INA188 is to translate the -20mV to 30mV input signal to -10V to 10V. Use the INA188 data sheet to answer these questions.
   a. What gain, and 0.1% standard value of RG is required to achieve the goal?

$G = \frac{\Delta V_{out}}{\Delta V_{in}} = \frac{10V - (-10V)}{80mV - (-20mV)} = 200$
$G = 1 + \frac{50k\Omega}{R_G}$
$R_G = \frac{50k\Omega}{G - 1} = \frac{50k\Omega}{200 - 1} = 251.3\Omega \text{ or } 252\Omega$



Quiz: Linear Range ADC + INA

2b. What INA188 reference, and voltage divider 0.1% standard resistor values will achieve this goal.

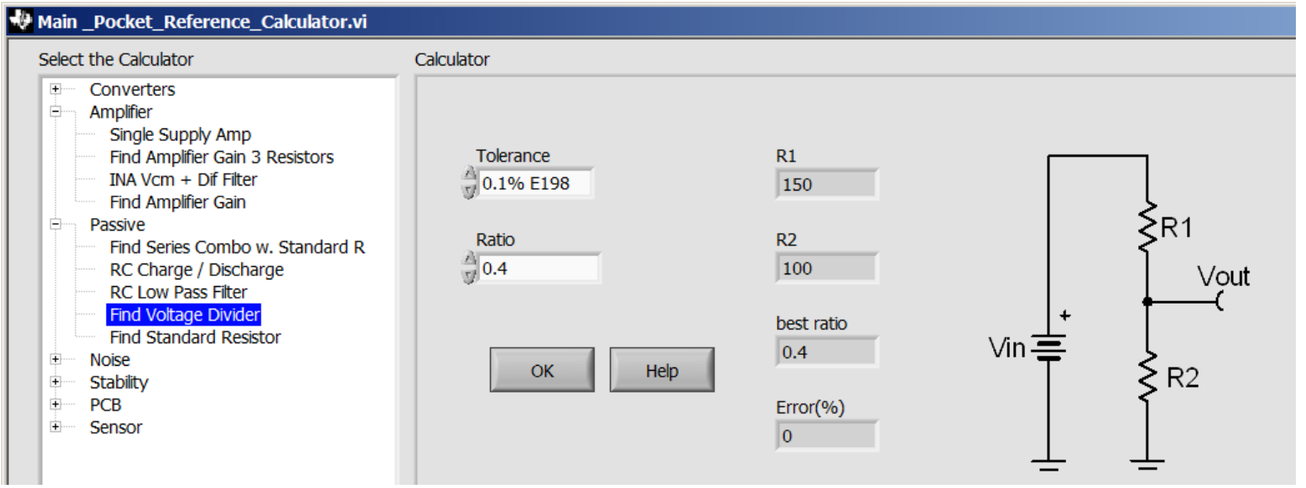
$$V_{out} = G \cdot V_{in} + V_{ref}$$

$$V_{ref} = V_{out} - G \cdot V_{in} = 10V - 200 \cdot 80mV = -6V$$

$$V_{ref} = -15V \cdot \left(\frac{R_2}{R_1 + R_2} \right)$$

$$\left(\frac{R_2}{R_1 + R_2} \right) = \frac{V_{ref}}{-15V} = \frac{-6V}{-15V} = 0.4$$

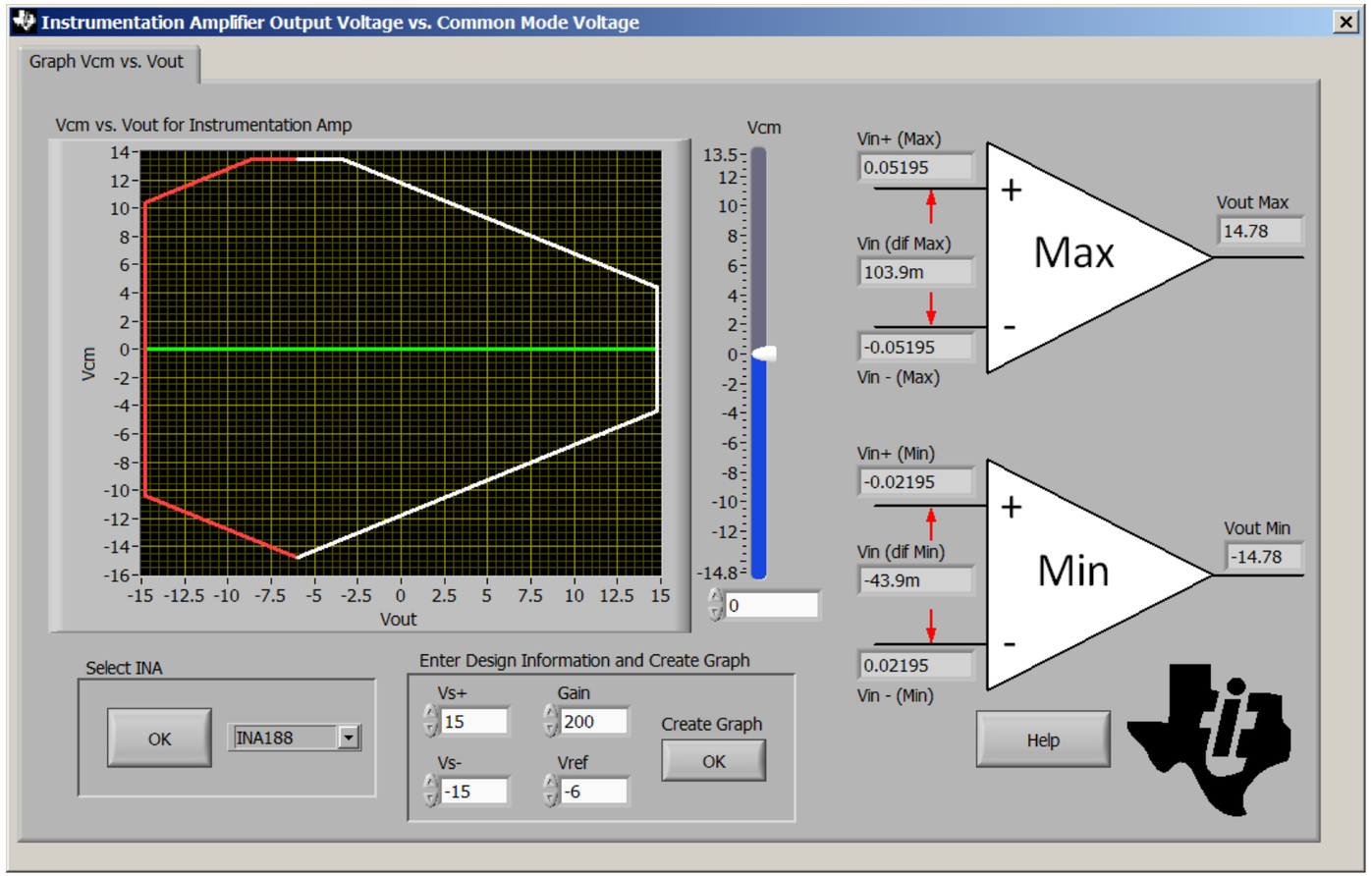
$$R_1 = 15k\Omega,\ R_2 = 10k\Omega$$

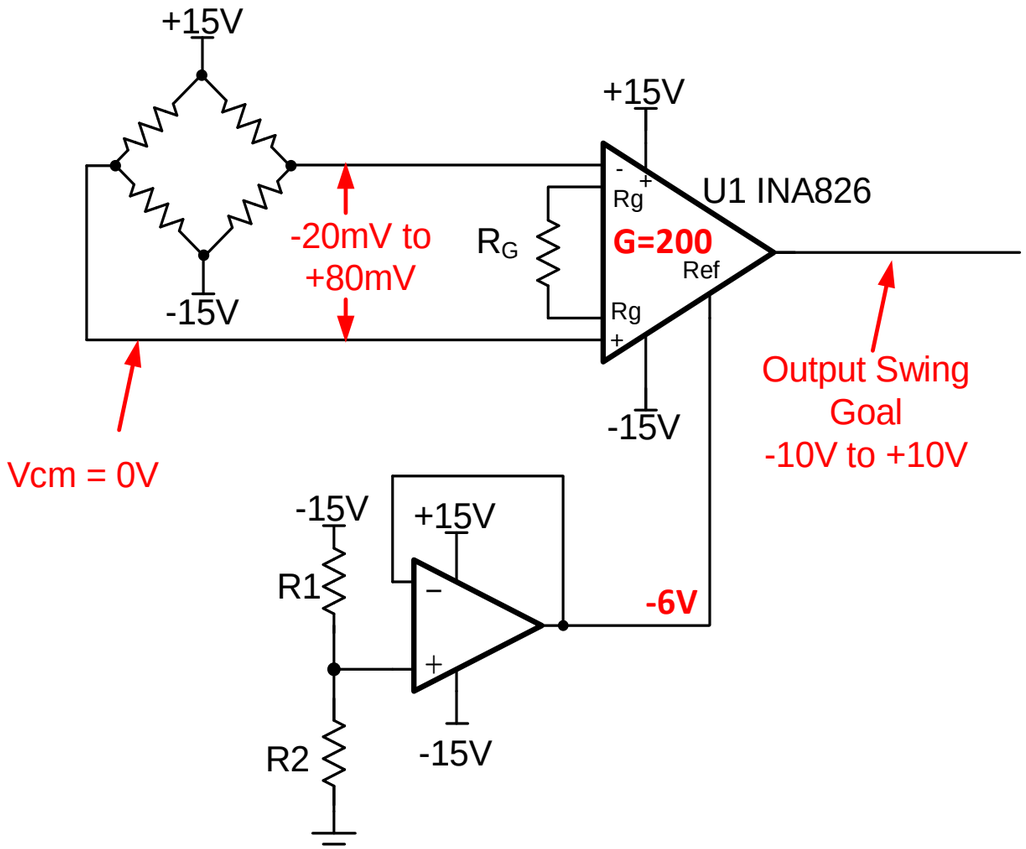


Use the calculator as simple way to find the voltage divider resistors.

Quiz: Linear Range ADC + INA

2c. Confirm linear output swing. The INA188 can swing from -14.78V to +14.87V, so no problem with -10V to +10V.





Quiz: Linear Range ADC + INA

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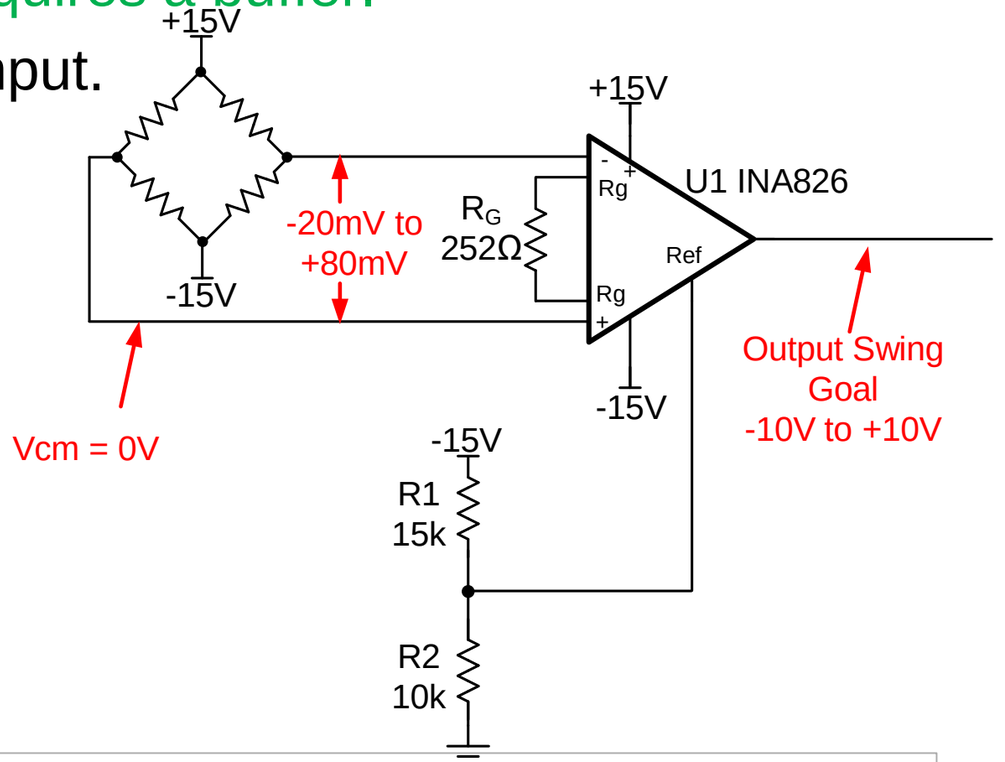

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