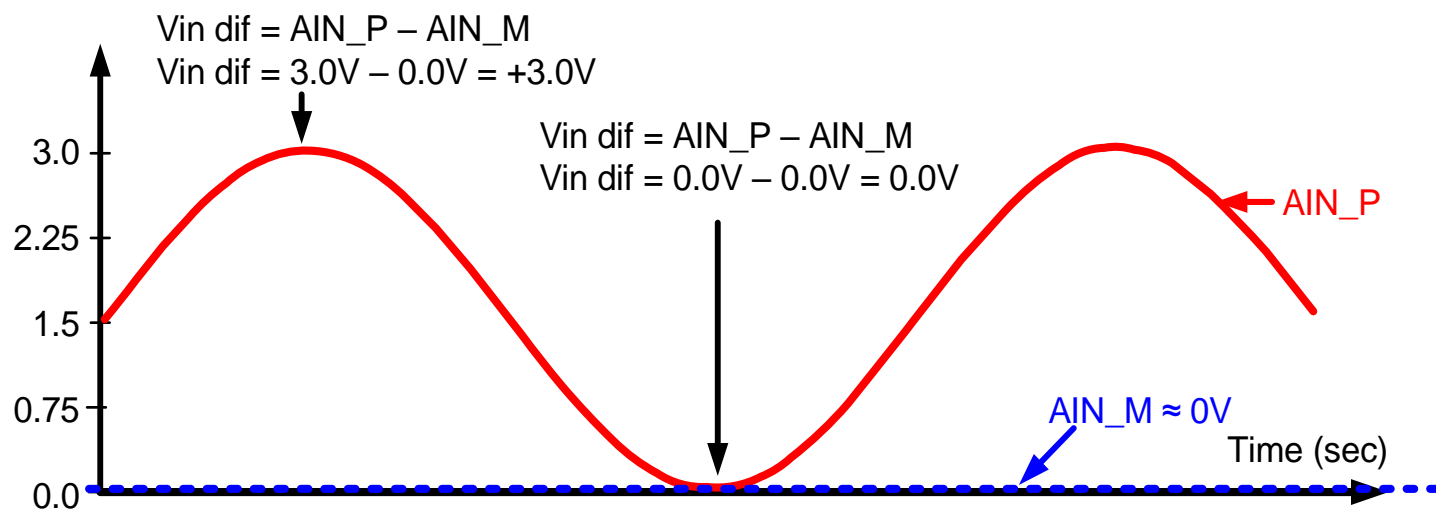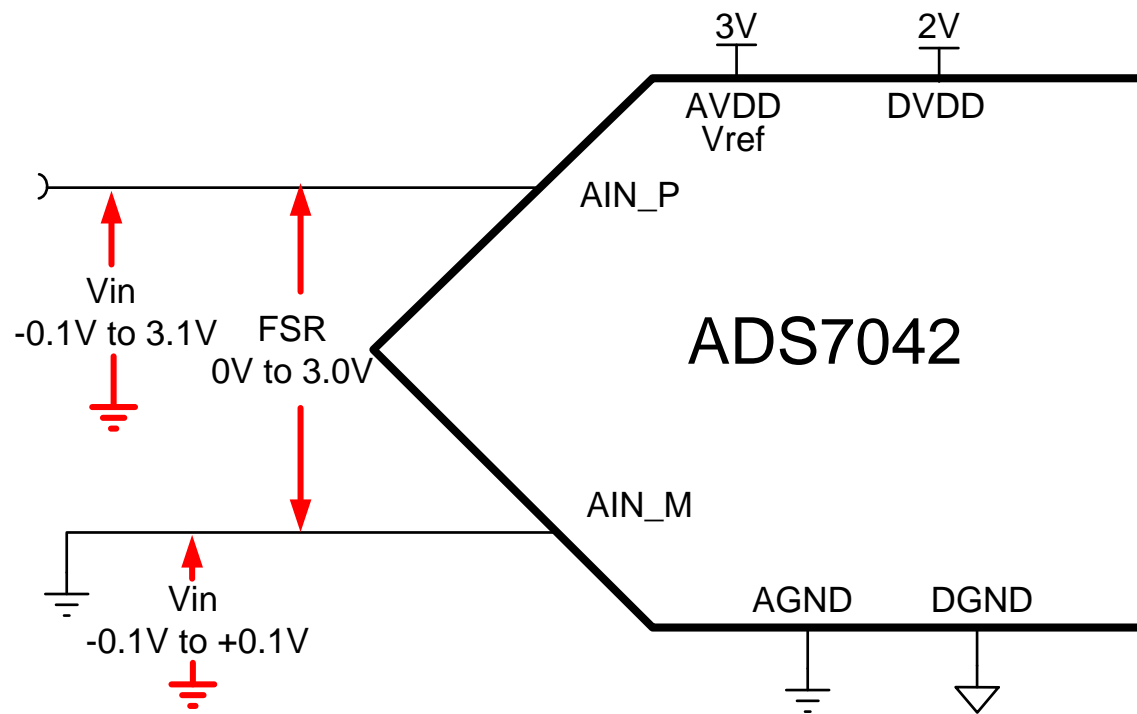# SAR ADC Input Types

TIPL 4003
TI Precision Labs – ADCs
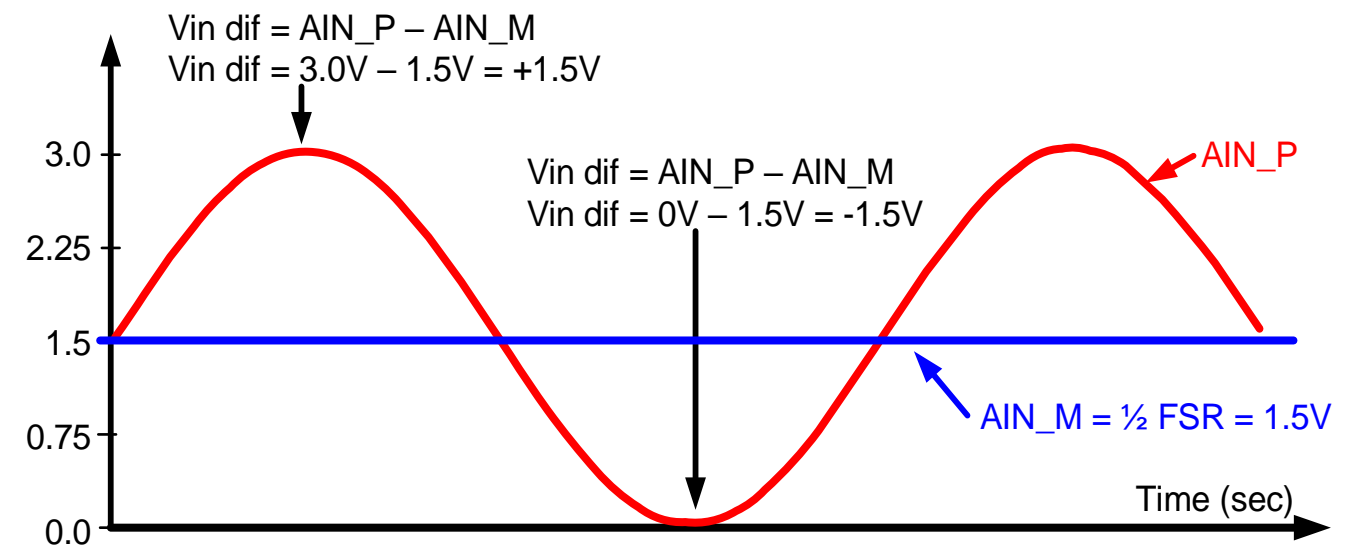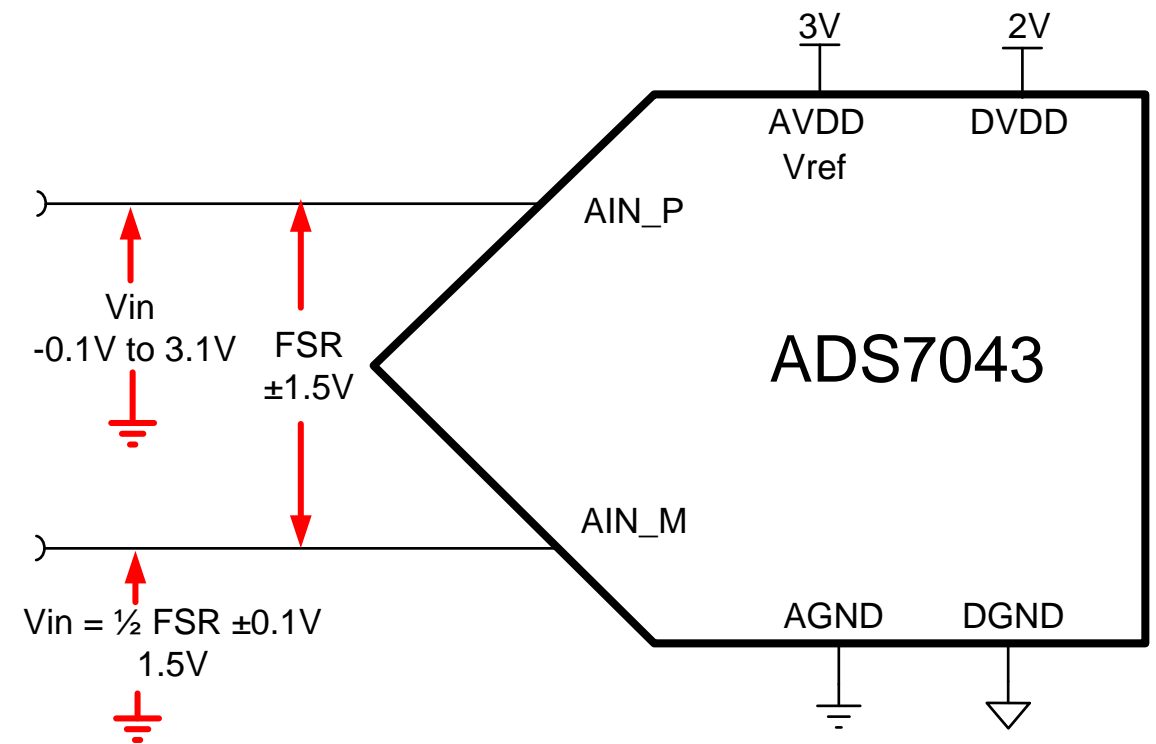
Created by Art Kay
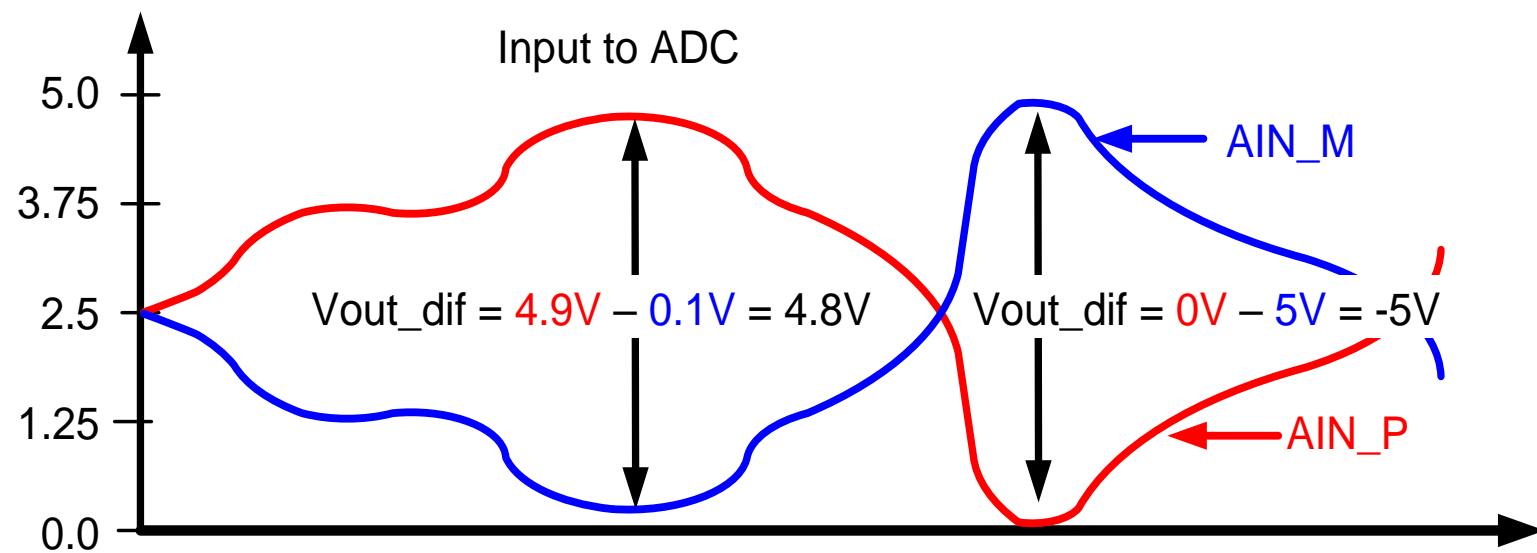
Presented by Peggy Liska

Single Ended

Pseudo-differential

ADC Input Swing and Common Mode

Input to ADC

Vout_dif = 4.9V − 0.1V = 4.8V

Vout_dif = 0V − 5V = -5V

AIN_M

AIN_P

$$V_{dif} = AIN\_P - AIN\_M$$

- Differential of ±5V (10Vpp)
- Single ended equivalent 0V to 5V (5Vpp)
- Double the range of single ended
- Negative differential output can occur when absolute output voltage of each output is positive (unipolar single supply)
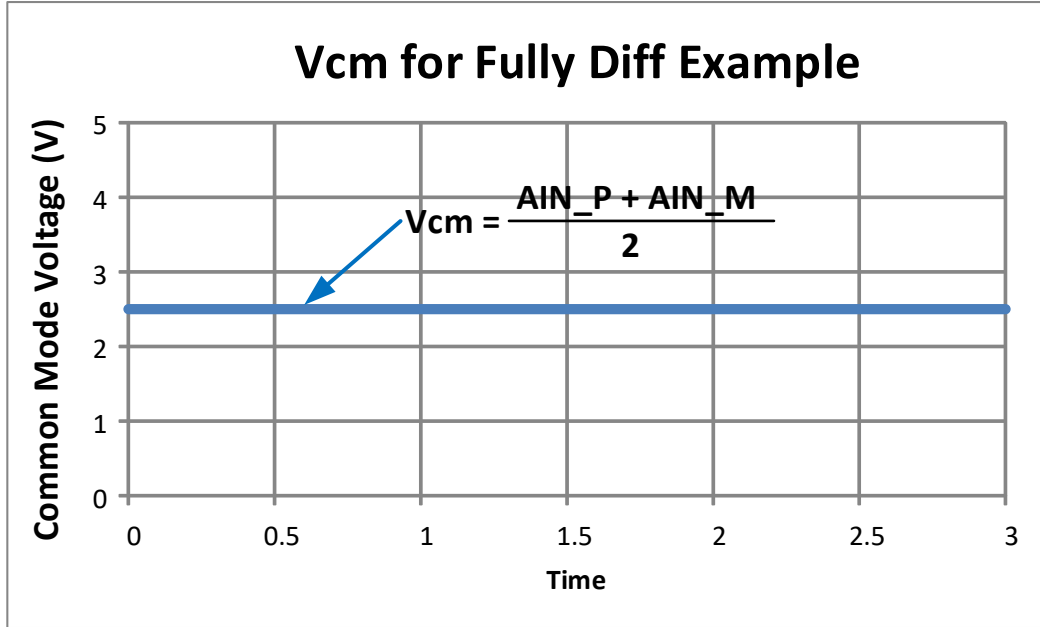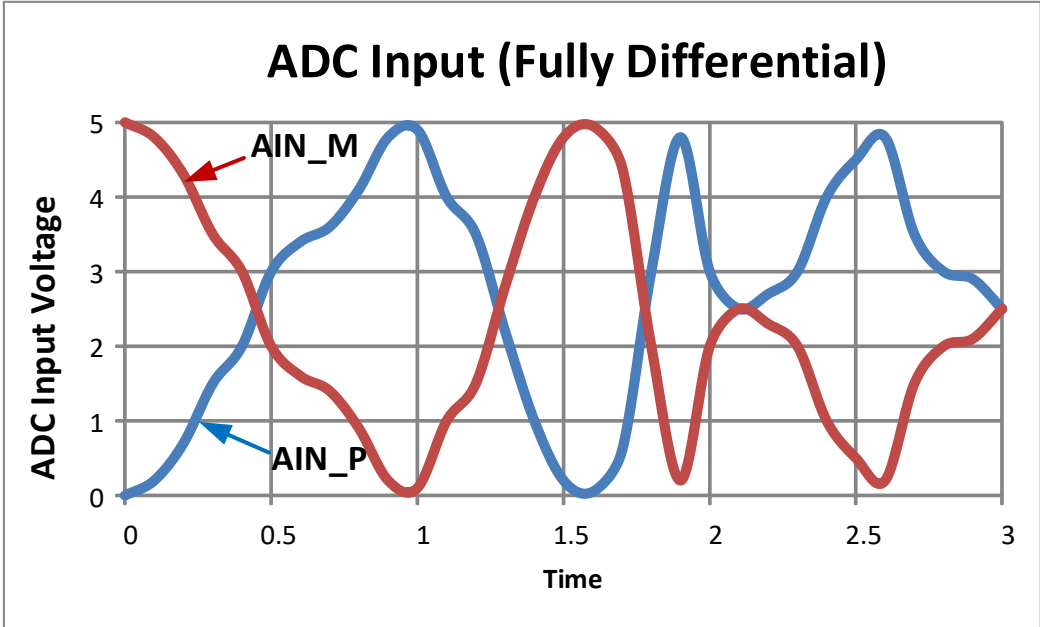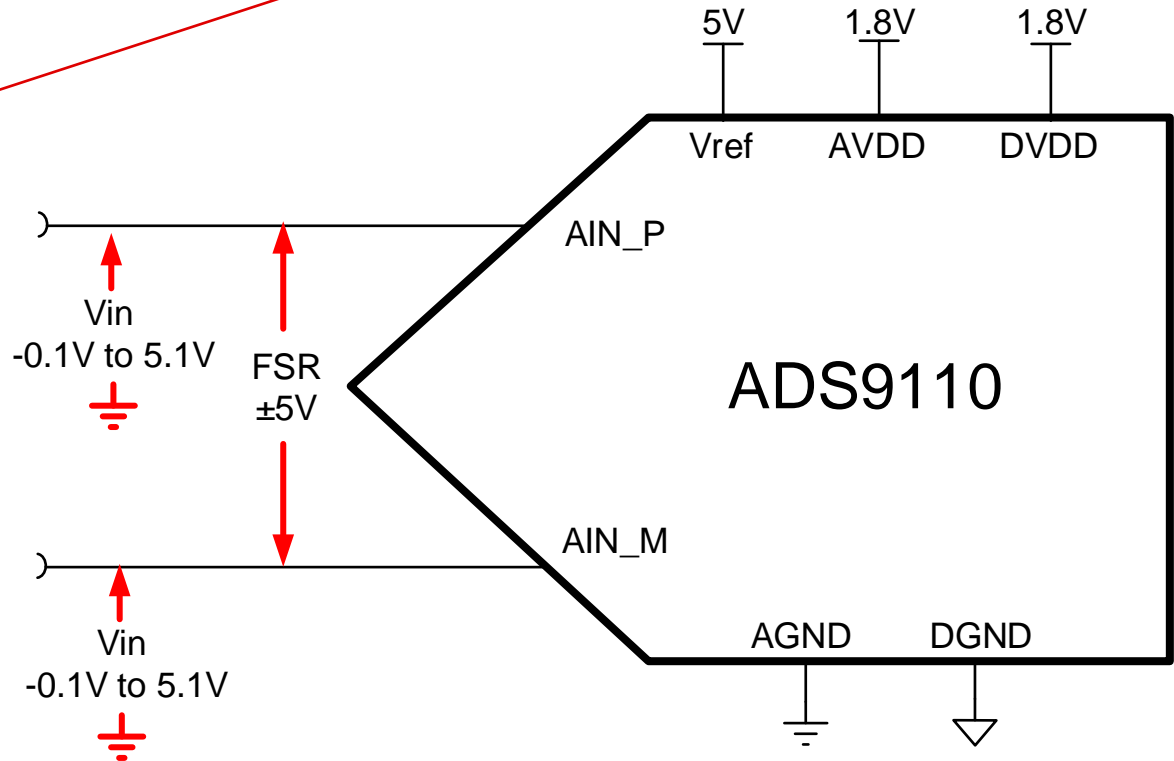
Input to ADC

$$Vcm = \frac{3.75V + 1.25V}{2} = 2.5V$$
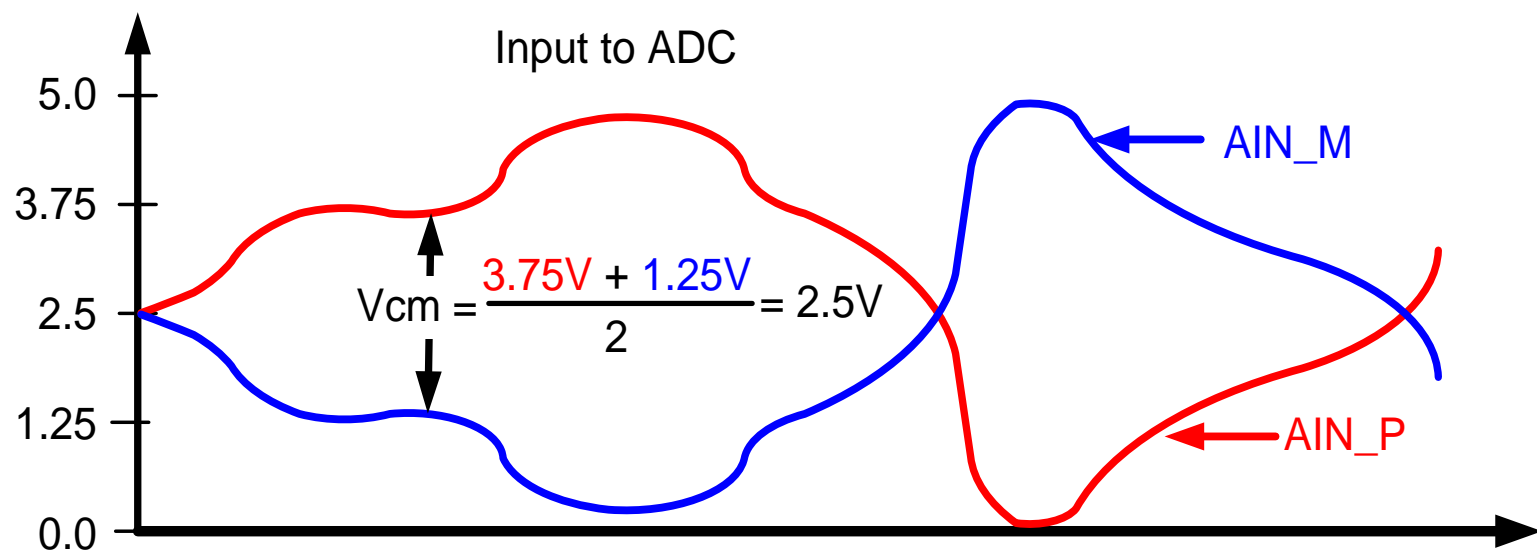
AIN_M

AIN_P

$$Vcm = \frac{AIN\_P + AIN\_M}{2}$$

- In this example common mode is always 2.5V

Fully Differential Input

PARAMETER 9110		MIN	TYP	MAX	UNIT
ANALOG INPUT					
Full-scale input voltage span		-Vref		Vref	
Absolute Input voltage range	AIN_P to GND	-0.1		Vref + 0.1	V
	AIN_M to GND	-0.1		Vref + 0.1	
Common-mode voltage range (AIN_P + AIN_M)/2		**(Vref/2)-0.1**	**Vref/2**	**(Vref/2)+0.1**	

Vcm must be constant at Vref/2

ADC Input (Fully Differential)

Vcm for Fully Diff Example

$$Vcm = \frac{AIN\_P + AIN\_M}{2}$$

ADS9110

5V 1.8V 1.8V
Vref AVDD DVDD
AIN_P
AIN_M
AGND DGND

Vin -0.1V to 5.1V
FSR ±5V
Vin -0.1V to 5.1V

True Differential Input

PARAMETER ADS8881		MIN	TYP	MAX	UNIT
ANALOG INPUT					
Full-scale input voltage span		-Vref		Vref	
Absolute Input voltage range	AIN_P to GND	-0.1		Vref + 0.1	V
	AIN_M to GND	-0.1		Vref + 0.1	
Common-mode voltage range (AIN_P + AIN_M)/2		**0.0**	**Vref/2**	**Vref**	

Vcm has a wide voltage range.
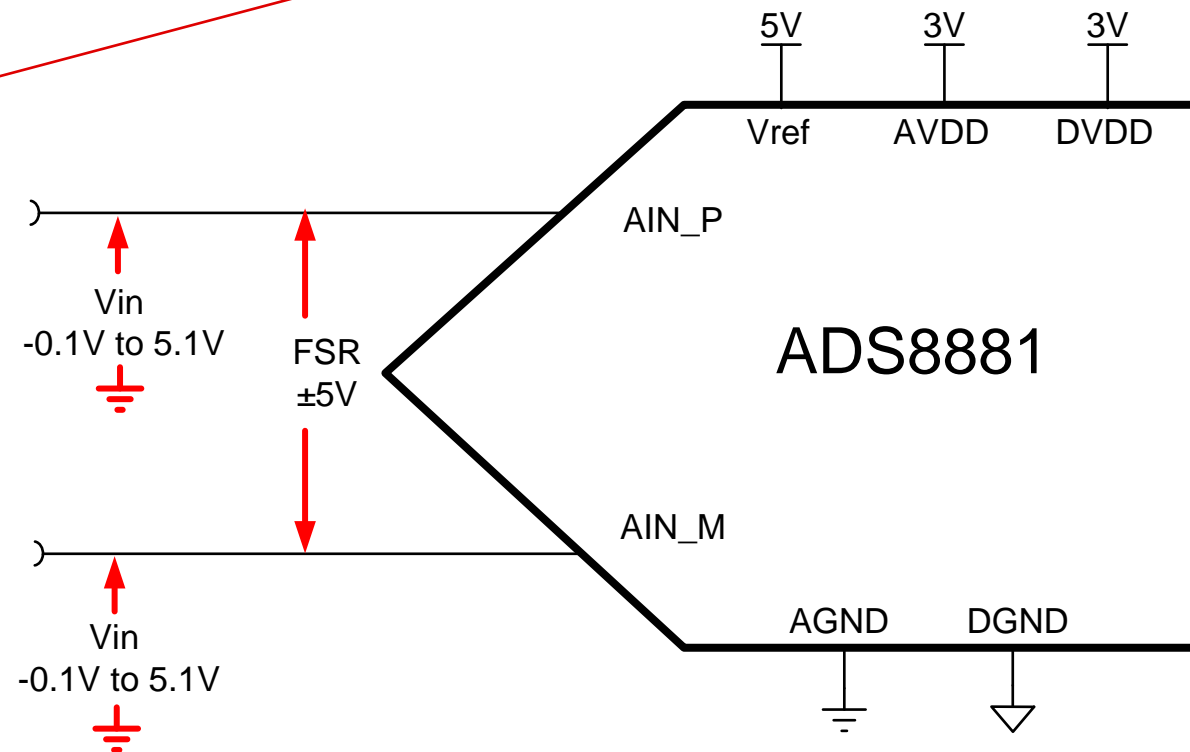
ADC Input Voltages (True Differential)
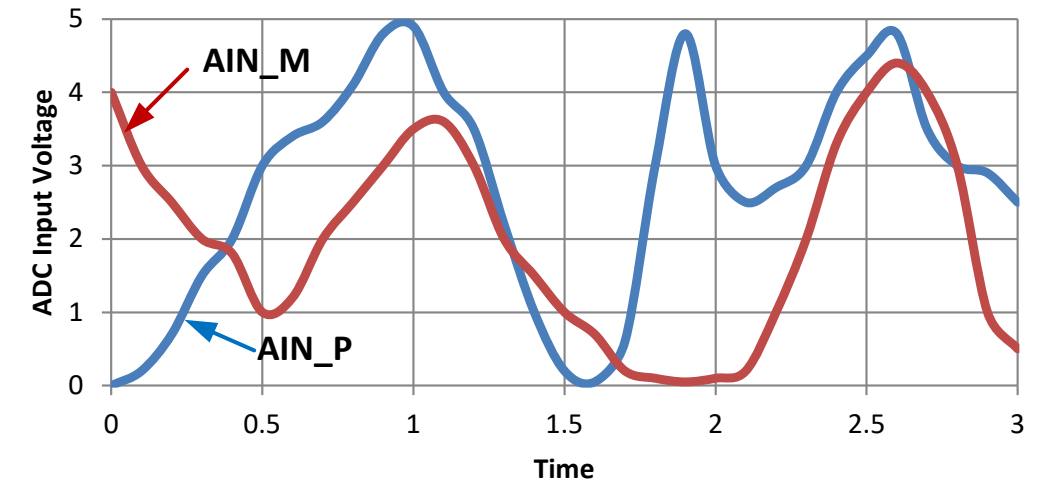
Vcm for True Diff Example

$$Vcm = \frac{AIN\_P + AIN\_M}{2}$$

Vin -0.1V to 5.1V

FSR ±5V

Vin -0.1V to 5.1V

AIN_P

AIN_M

5V — Vref
3V — AVDD
3V — DVDD

ADS8881

AGND DGND

TEXAS INSTRUMENTS
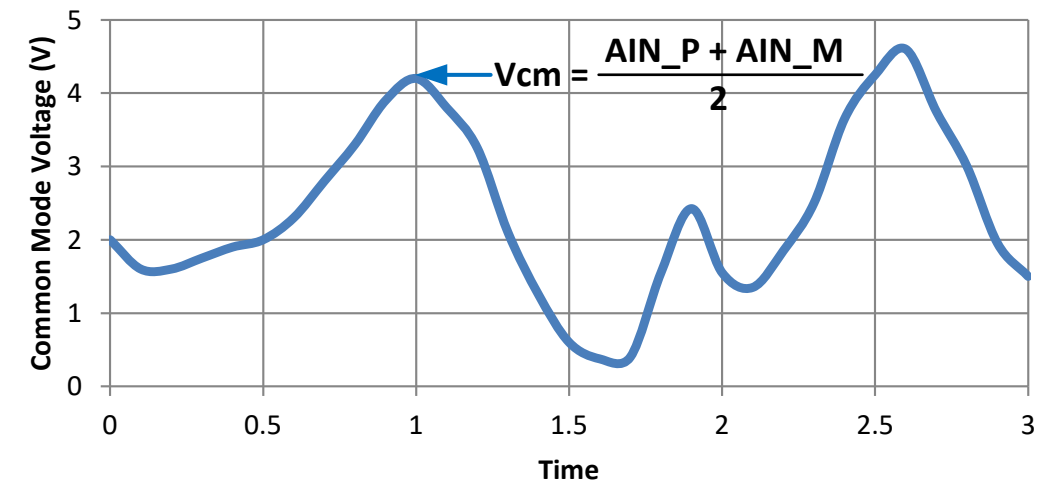
Summary of ADC input types

| Input Type	Vref	Ain_P	Ain_M	Vcm	FSR	Example 16 Bit Output
Single Ended	5V	0V to 5V	GND (+/- 100mV)	n/a	0V to 5V	0000 = 0V FFFF = FSR = 5V
Pseudo Differential	5V	0V to 5V	Set ½ * Range (2.5V)	n/a	-2.5V to +2.5V	8000 = -2.5V 7FFF = +2.5V
Fully Differential	5V	0V to 5V	0V to 5V	Set ½ * Range (2.5V)	-5V to +5V	8000 = -5V 7FFF = +5V
True Differential	5V	0V to 5V	0V to 5V	Can vary from –FS to +FS	-5V to +5V	8000 = -5V 7FFF = +5V

TEXAS INSTRUMENTS

Unipolar vs Bipolar
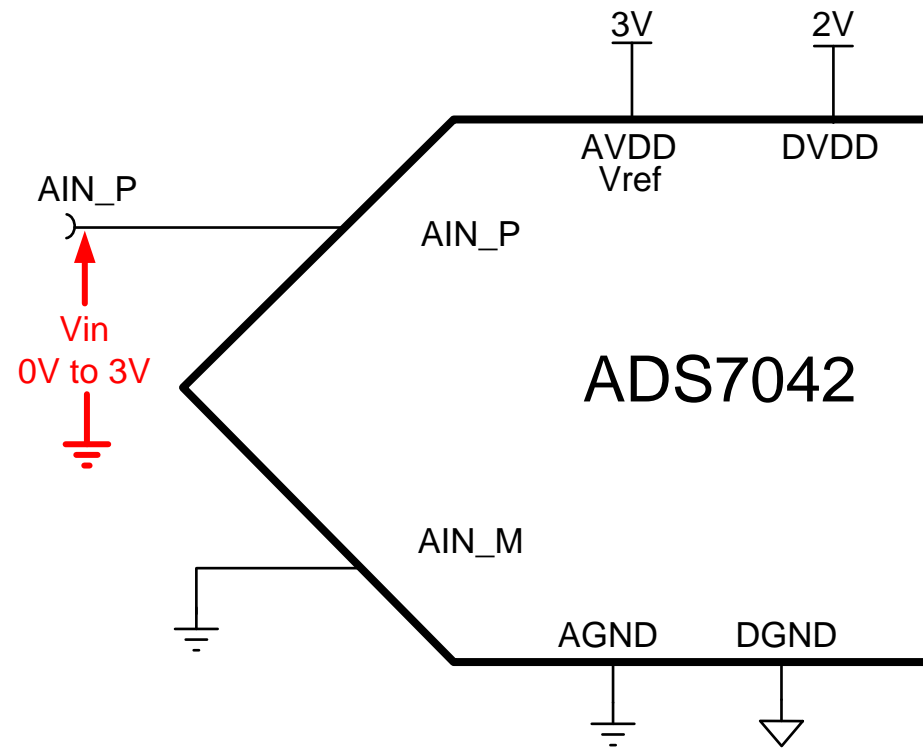
Unipolar Input
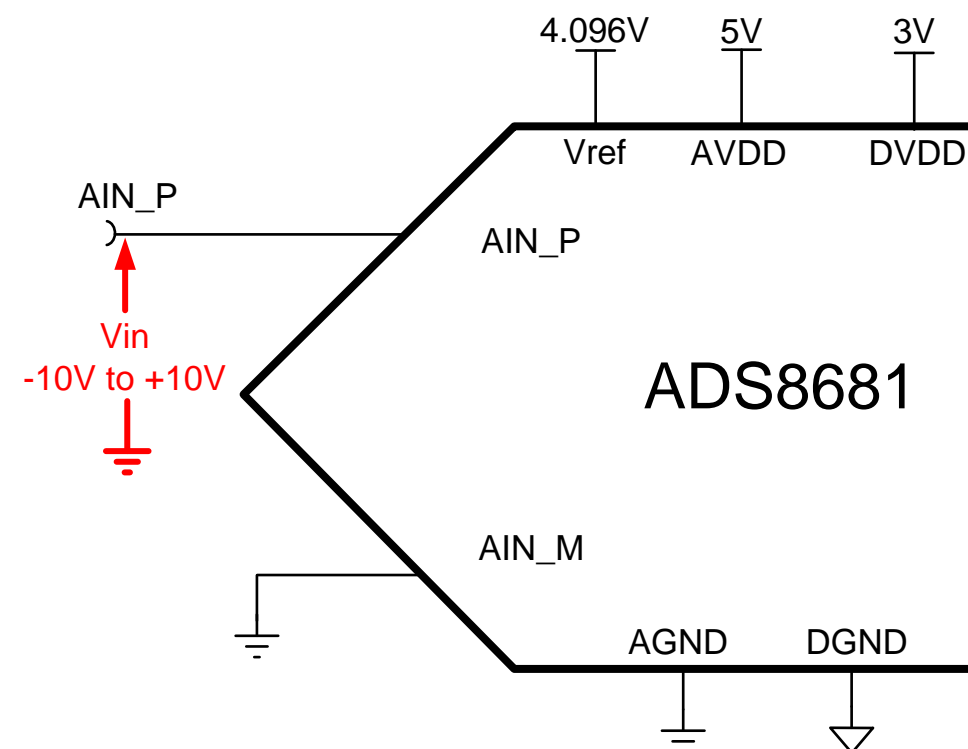
Bipolar Input

Unipolar with Differential Input

Negative Full Scale Input

Positive Full Scale Input

Transfer Function:
Unipolar with Differential Inputs
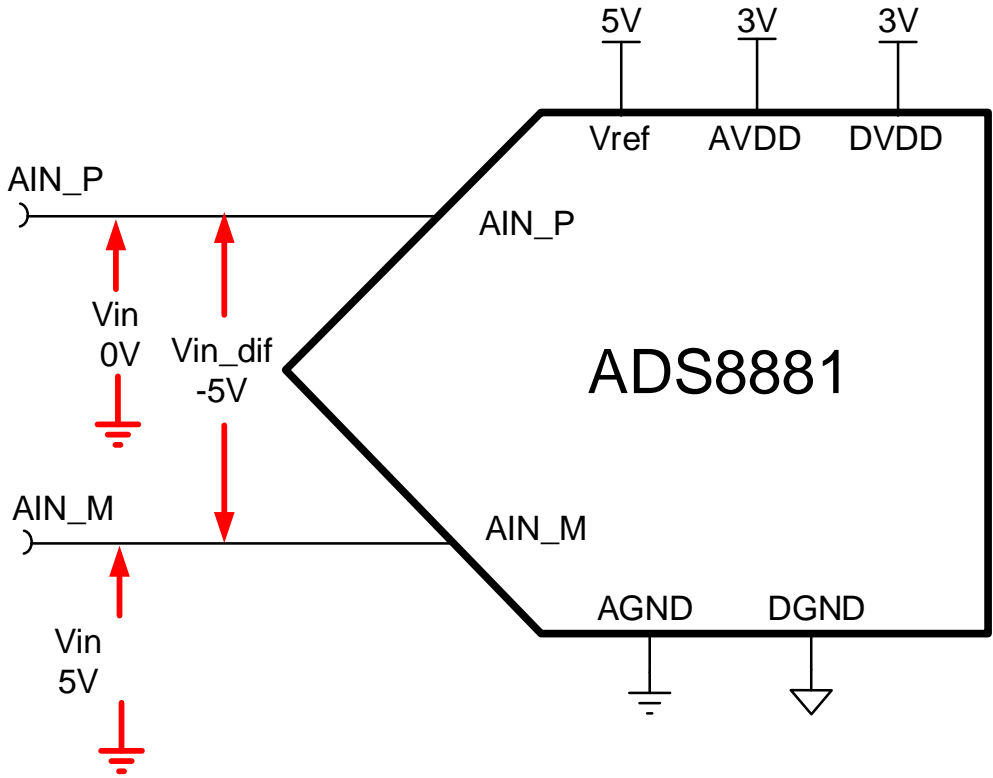
Vin_dif = AIN_P – AIN_M
Vin_dif = 0V - 5V = -5V
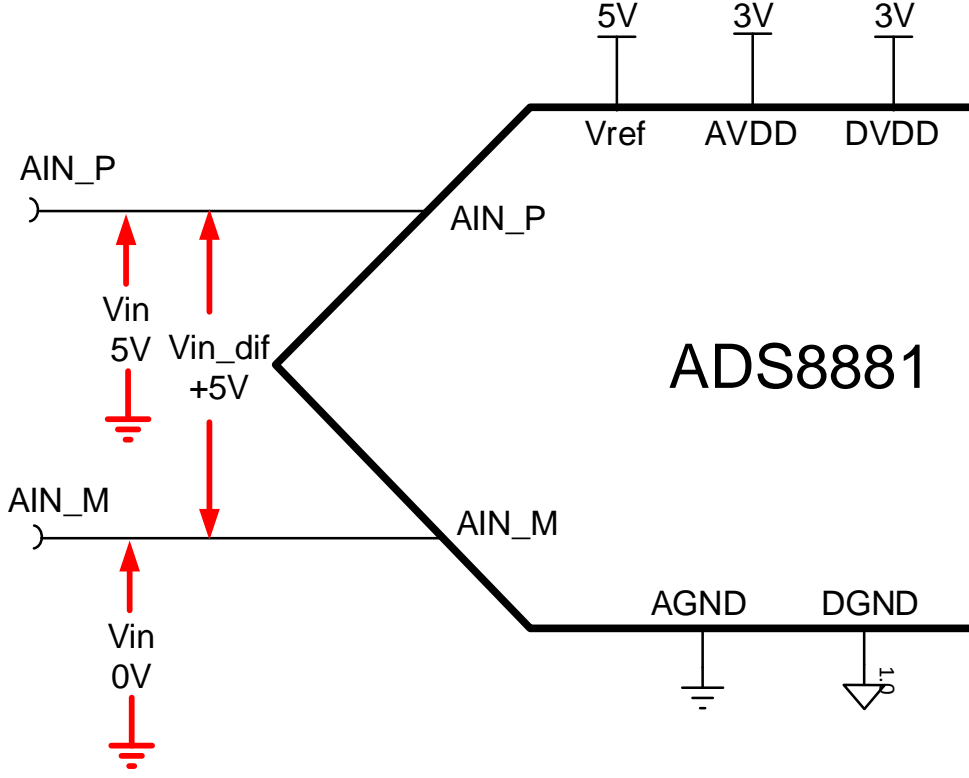
Vin_dif = AIN_P – AIN_M
Vin_dif = 5V - 0V = +5V
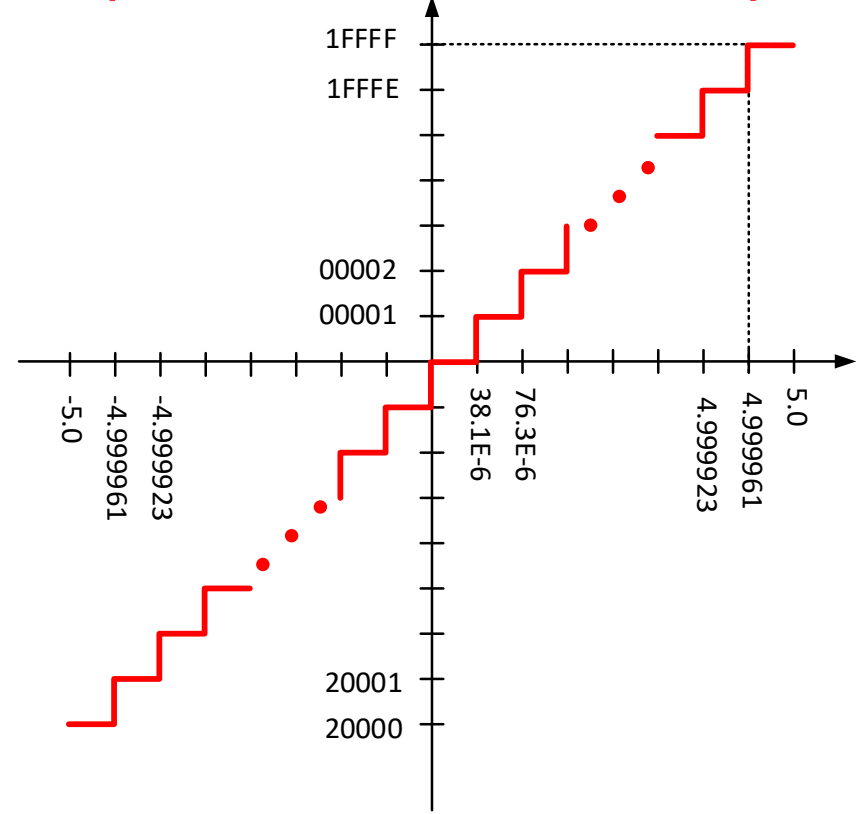
Input Impedance: Resistive vs. Switched Capacitor

Switched Capacitor Input

Input Range = 0 to Vref
Abs Max Input = Vref + 0.3V
Dynamic input impedance

REF6050 5.0V Reference

OPA320 BW = 20MHz

ADS8860
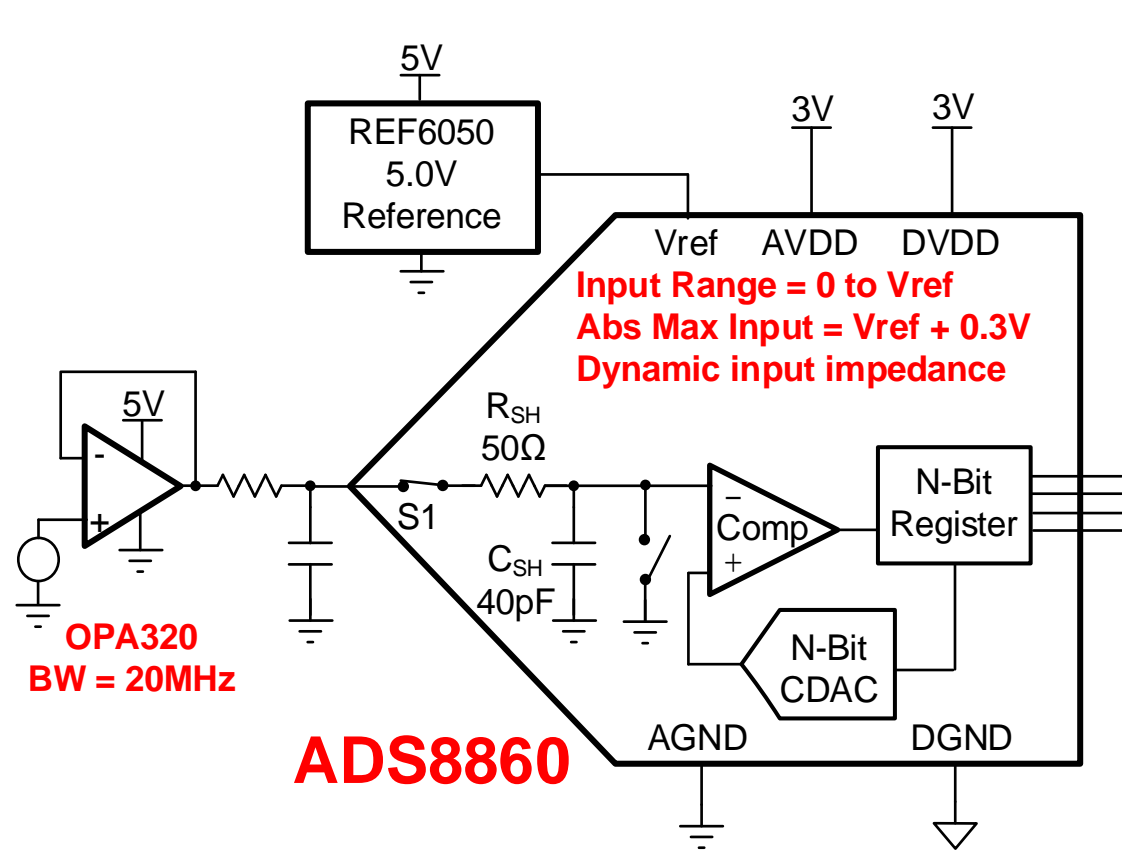
- Wide bandwidth external amp required
- Dynamic input impedance
- Input voltage range set by reference

Resistive, High Voltage, PGA input

Input Range = ±12.288V
Abs Max Input = ±20V
1MΩ Resistive input impedance

OPA188 BW = 2MHz

4.096V Reference

ADS8681
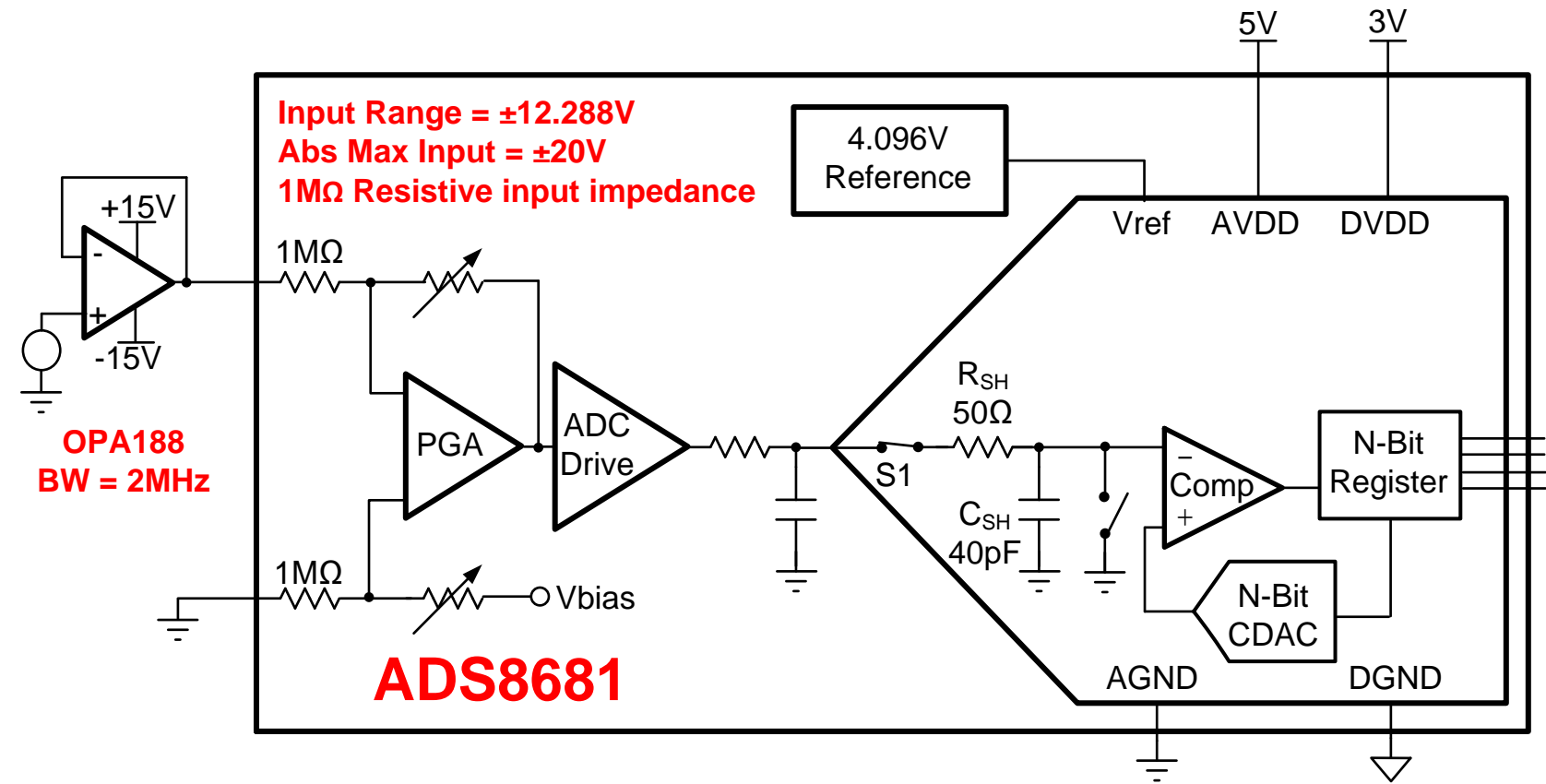
- External amplifier bandwidth not critical
- Internal PGA, ADC driver, and reference
- High voltage input (±12.288V) with 5V supply

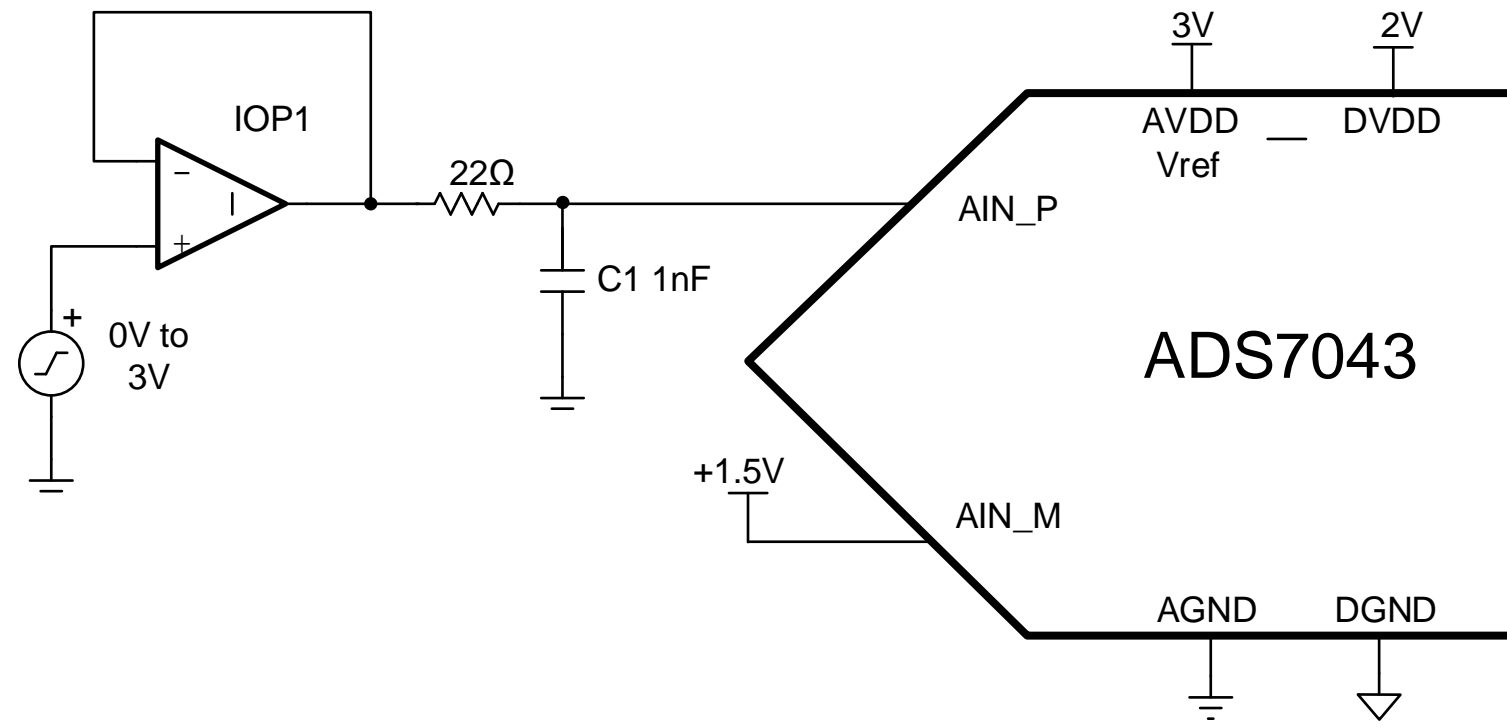# Thanks for your time! Please try the quiz.

Quiz: SAR ADC Input Types

TIPL 4003
TI Precision Labs – SAR

Created by Art Kay

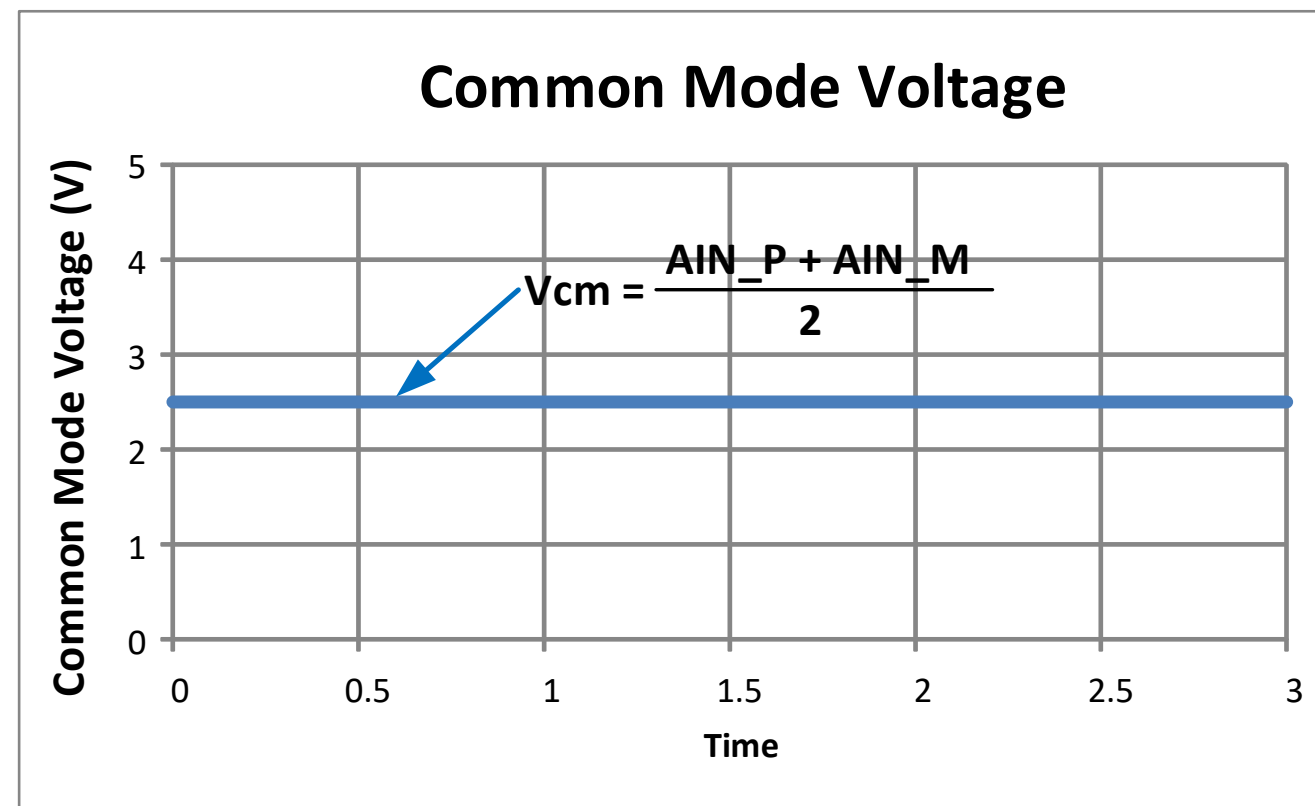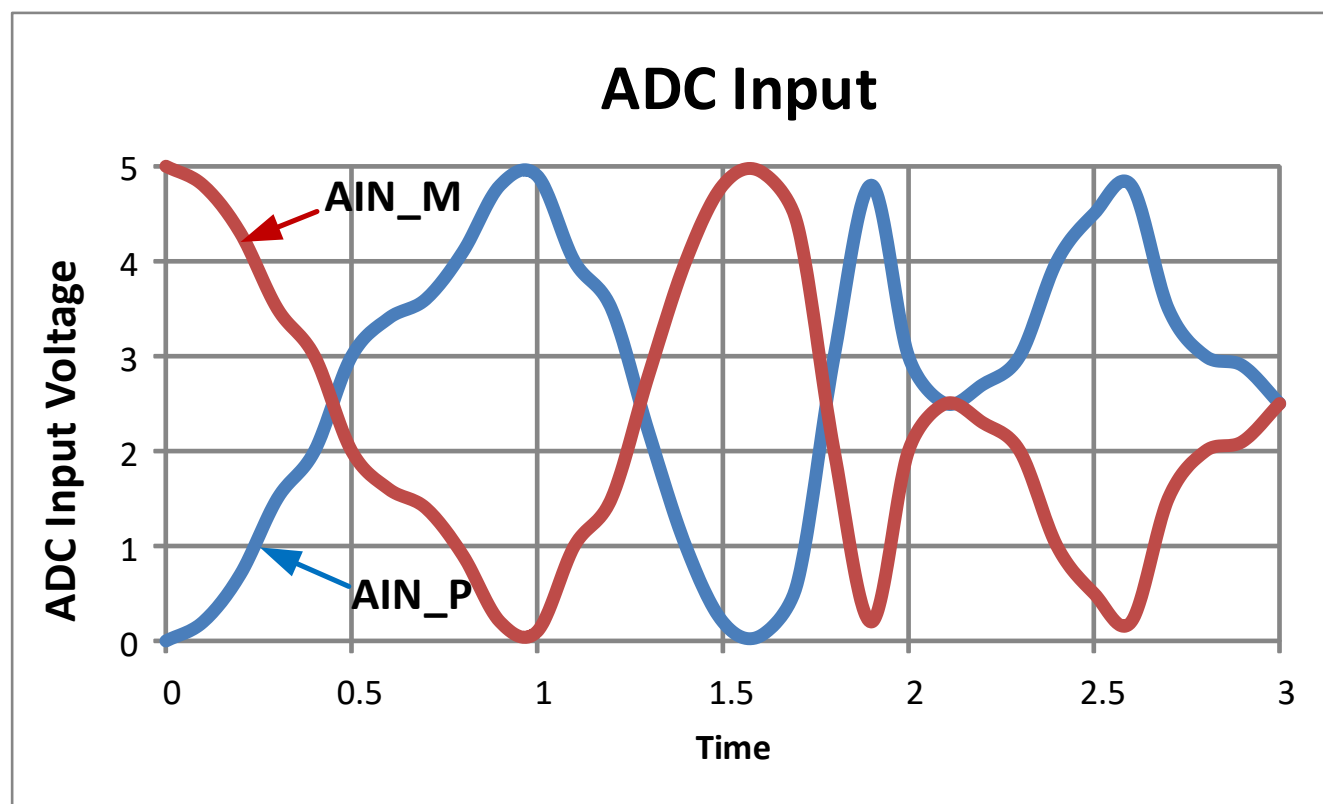# Quiz: SAR ADC Input Types

1. The circuit in the figure below is a ____.
   a. Single ended ADC.
   b. Pseudo-differential ADC.
   c. Fully Differential ADC.
   d. True Differential ADC.

Quiz: SAR ADC Input Types

2. (T/F) The signal below can be directly applied to an ADC with a fully differential input.

   a. True.

   b. False.

ADC Input

AIN_M

AIN_P

ADC Input Voltage

Time

Common Mode Voltage

Common Mode Voltage (V)
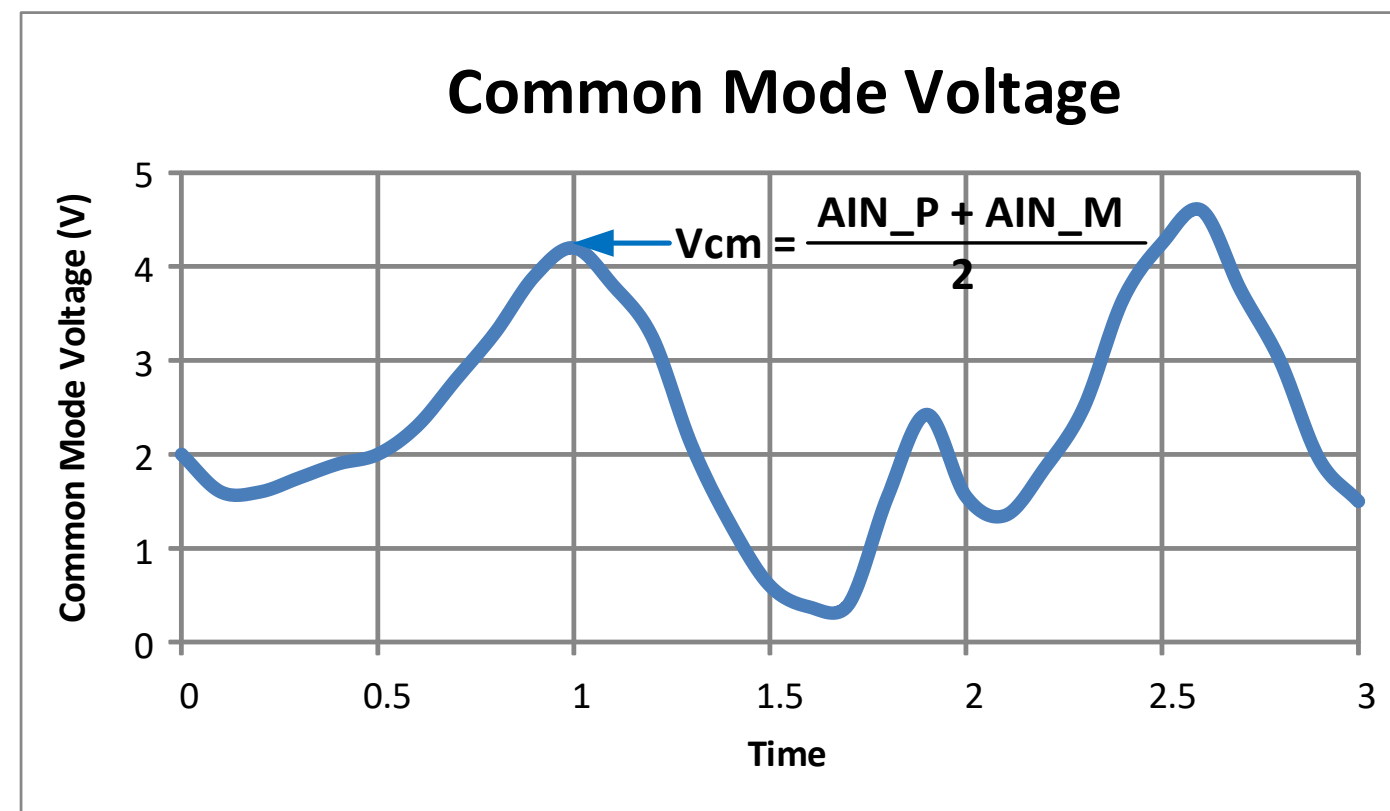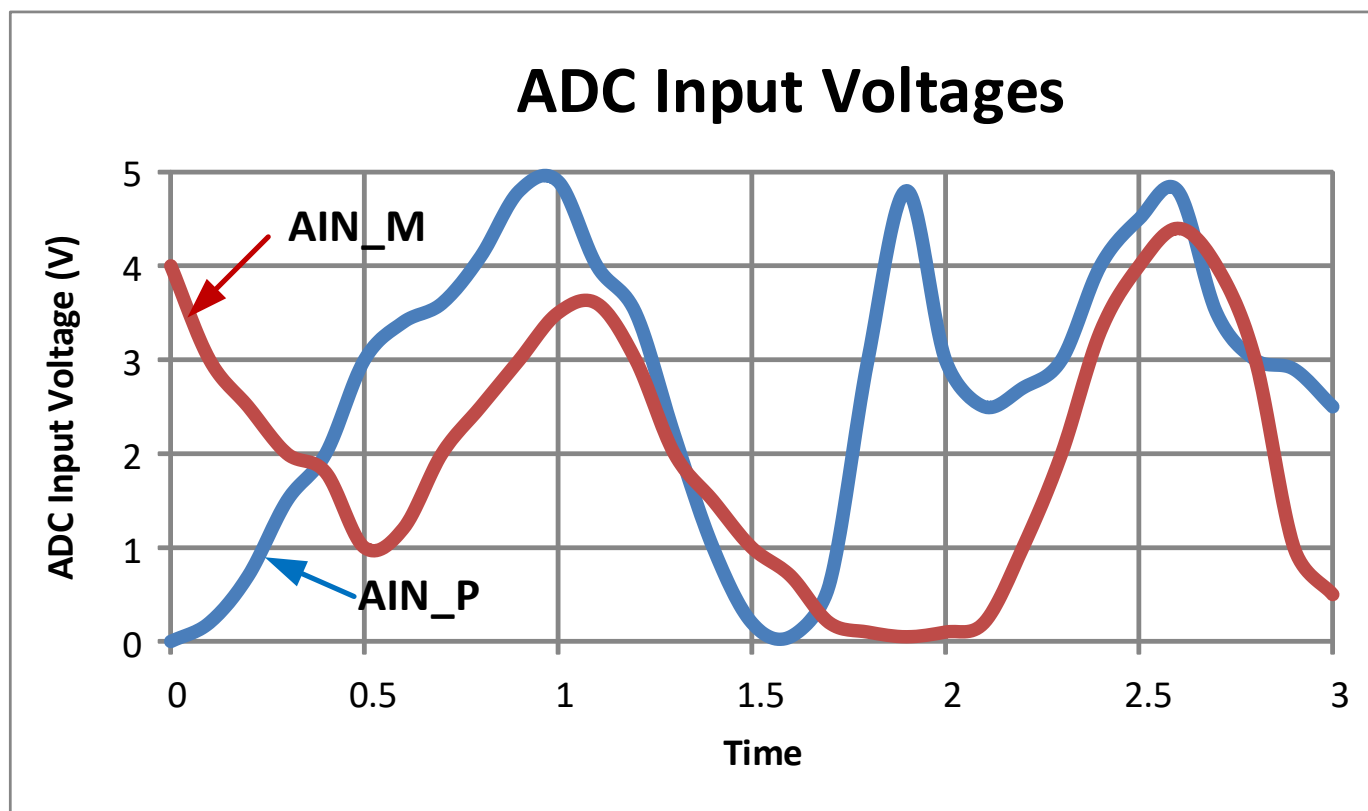
$$Vcm = \frac{AIN\_P + AIN\_M}{2}$$

Time

Quiz: SAR ADC Input Types

3. (T/F) The signal below can be directly applied to an ADC with a fully differential input.

   a. True.

   b. False.

Quiz: SAR ADC Input Types

4. Which type of ADC would require a wide bandwidth amplifier and a RC charge bucket filter?

   a. A high voltage SAR with an internal PGA.
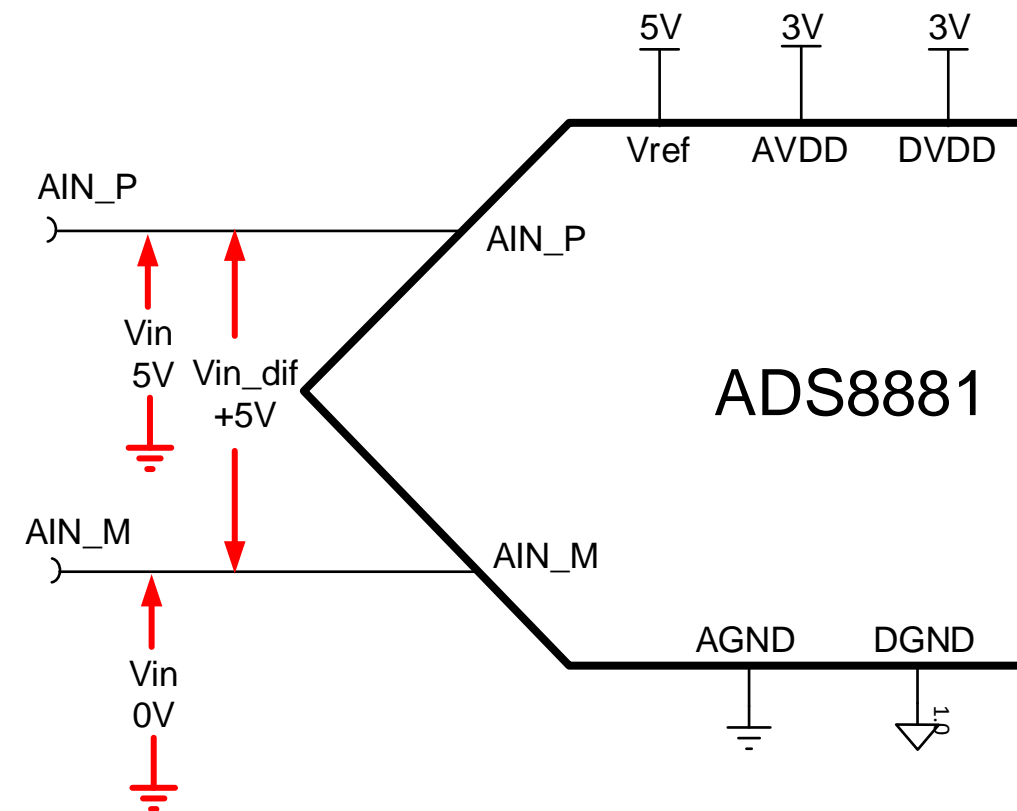
   b. A switched capacitor input SAR ADC.

5. (T/F) In general, a fully differential input has double the range of a single ended input assuming the same reference voltage.

   a. True.

   b. False.

Quiz: SAR ADC Input Types

6. The circuit in the figure below has a ____.

    a. Unipolar, differential input.

    b. Bipolar, differential input.
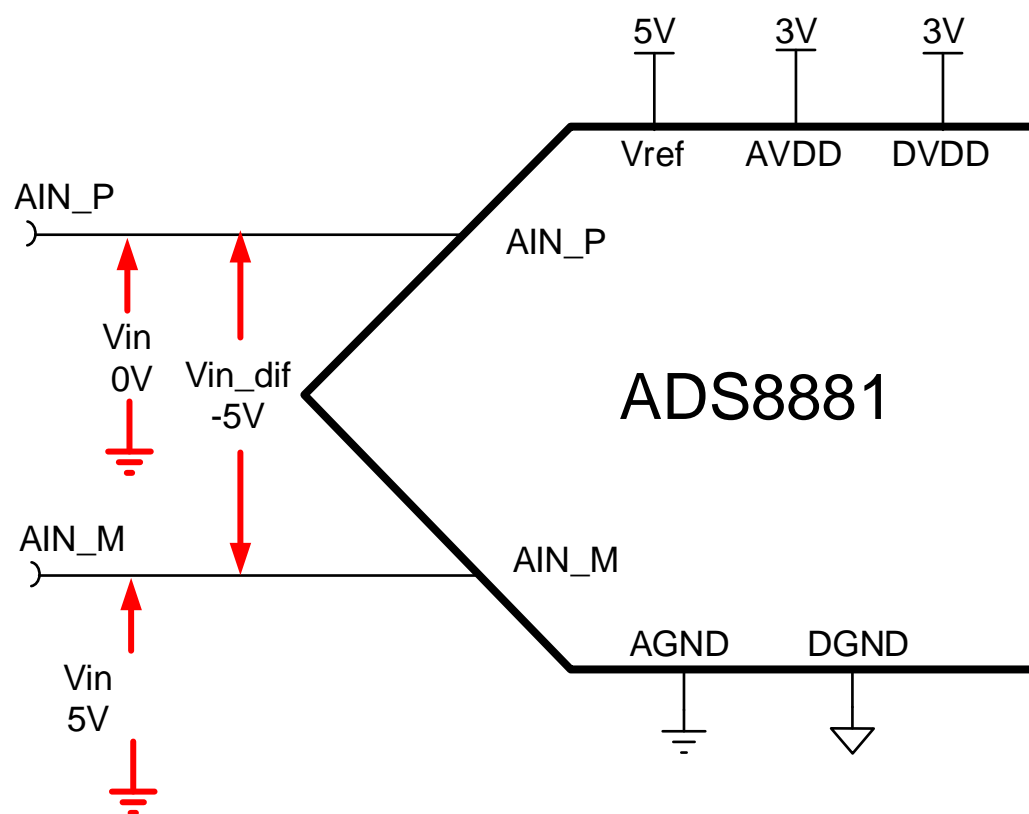
Negative Full Scale Input
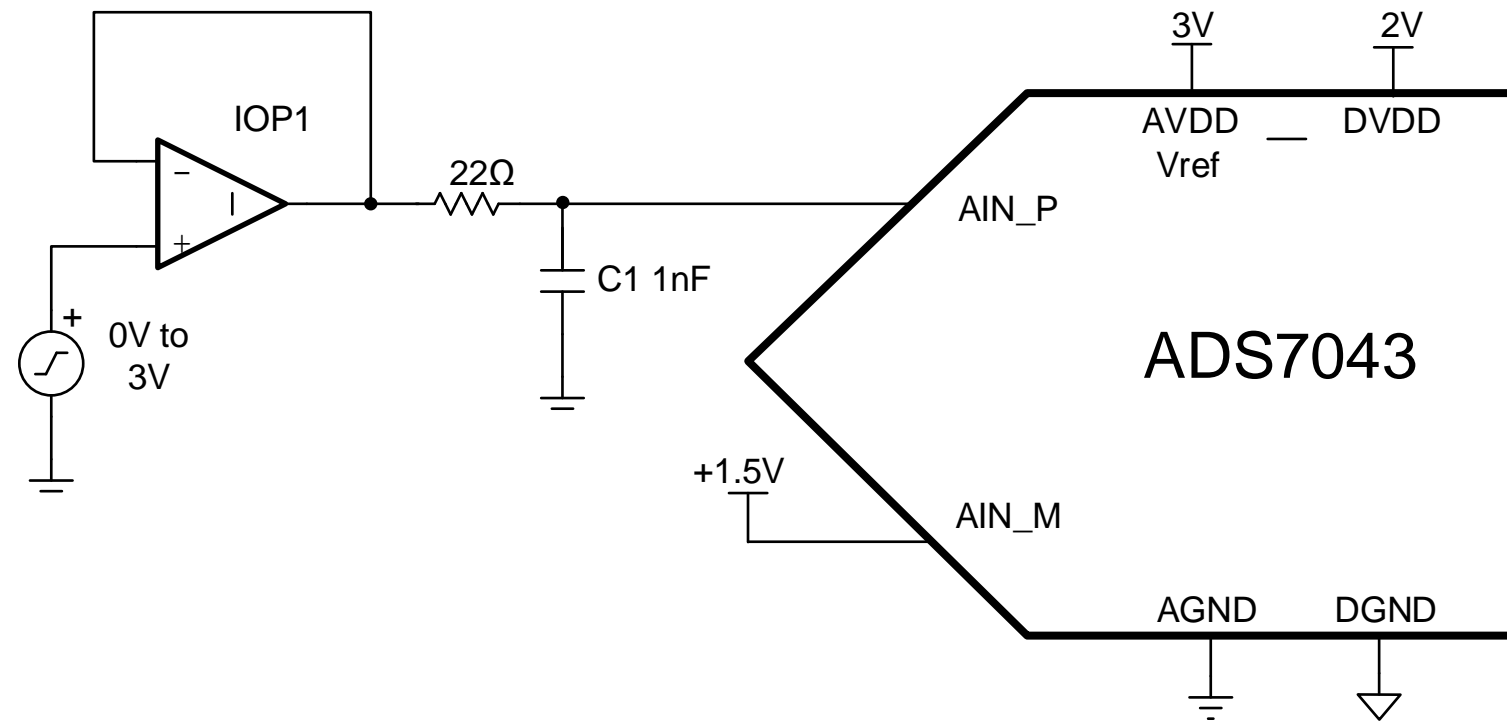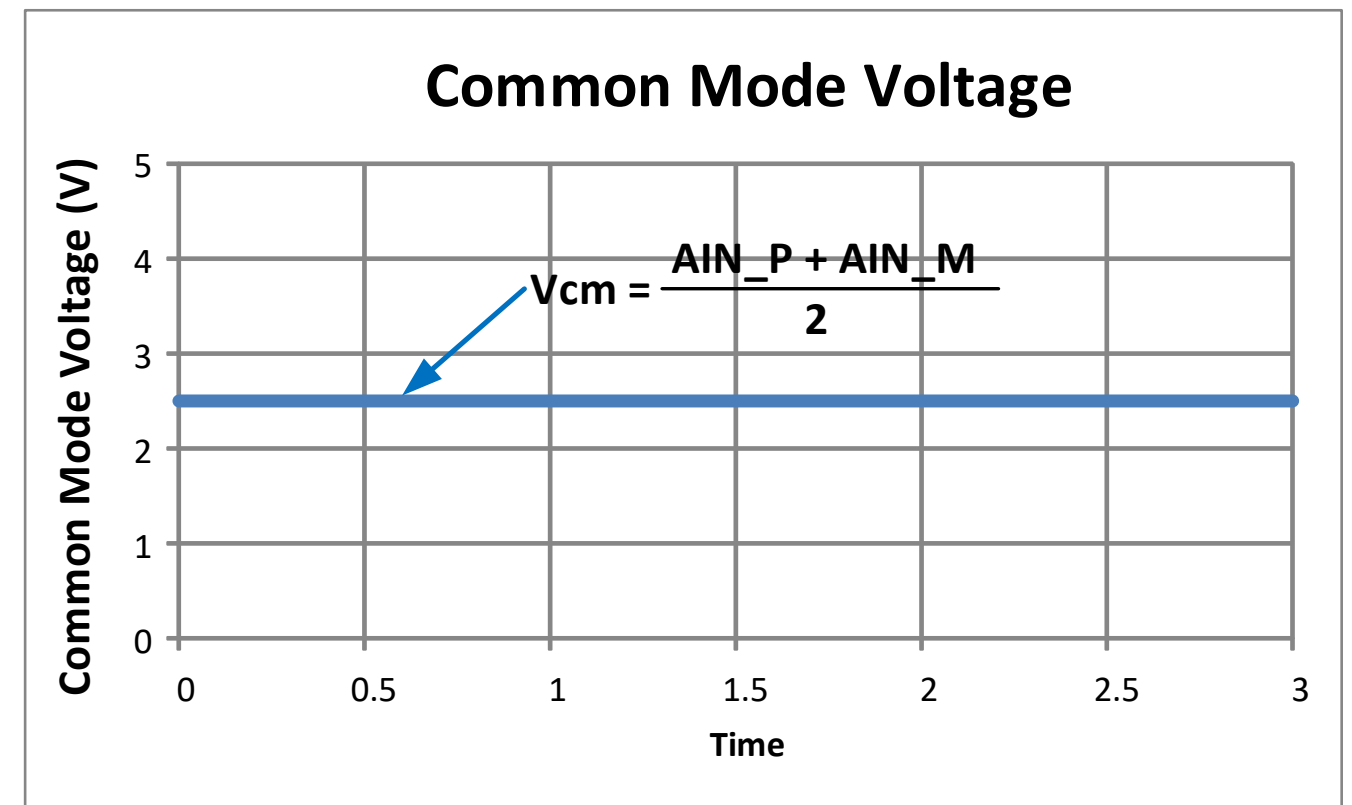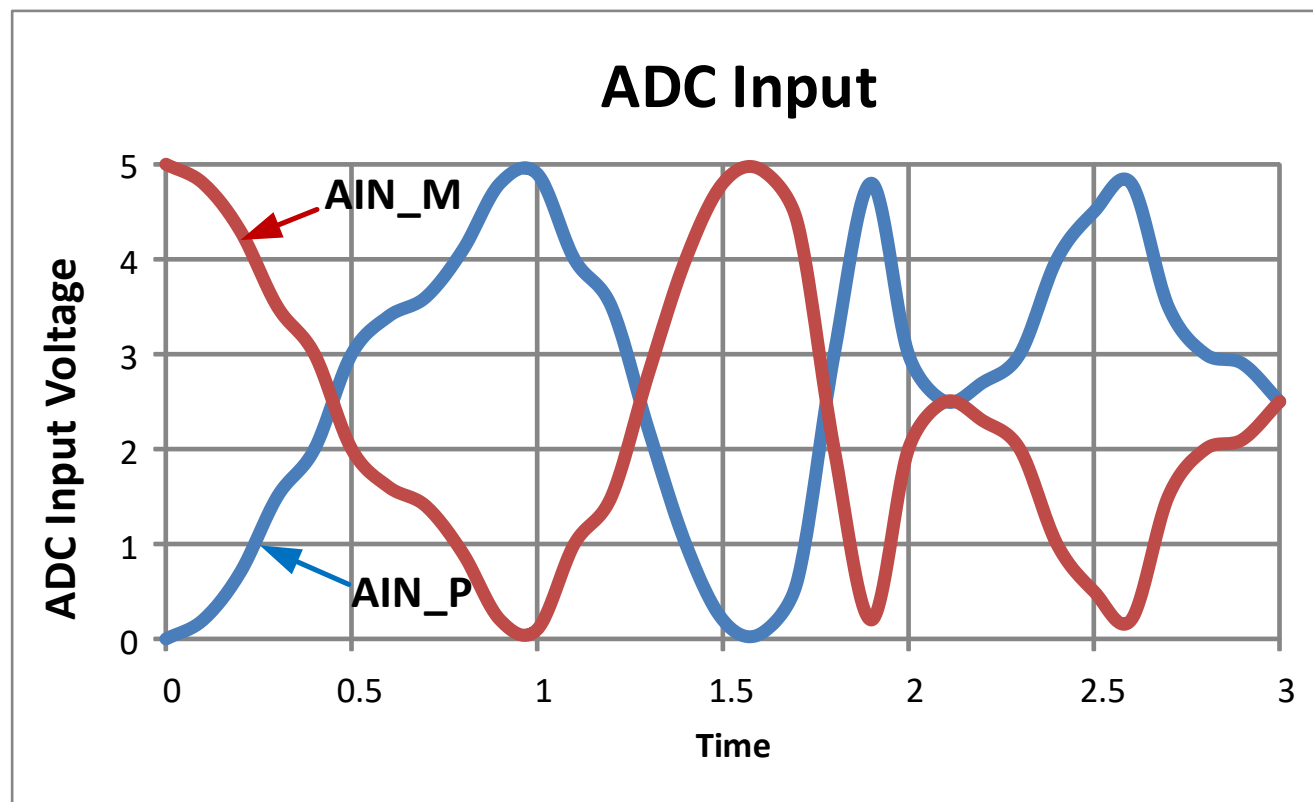
Positive Full Scale Input

Solutions

TEXAS INSTRUMENTS

Solutions Quiz: SAR ADC Input Types

1. The circuit in the figure below is a _____.

   a. Single ended ADC.

   b. **Pseudo-differential ADC.**

   c. Fully Differential ADC.

   d. True Differential ADC.

Solutions Quiz: SAR ADC Input Types

2. (T/F) The signal below can be directly applied to an ADC with a fully differential input.

    a. **True**.

    b. False.

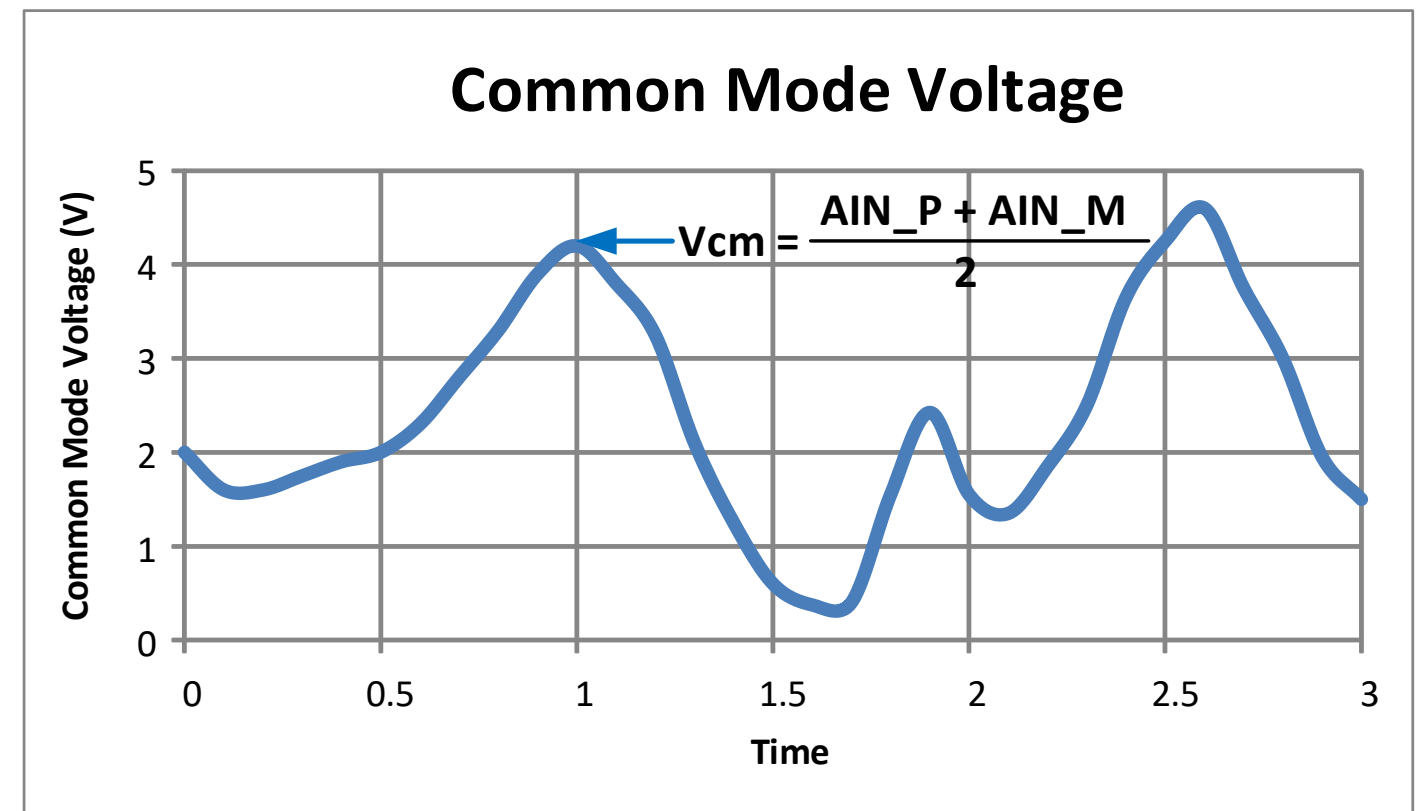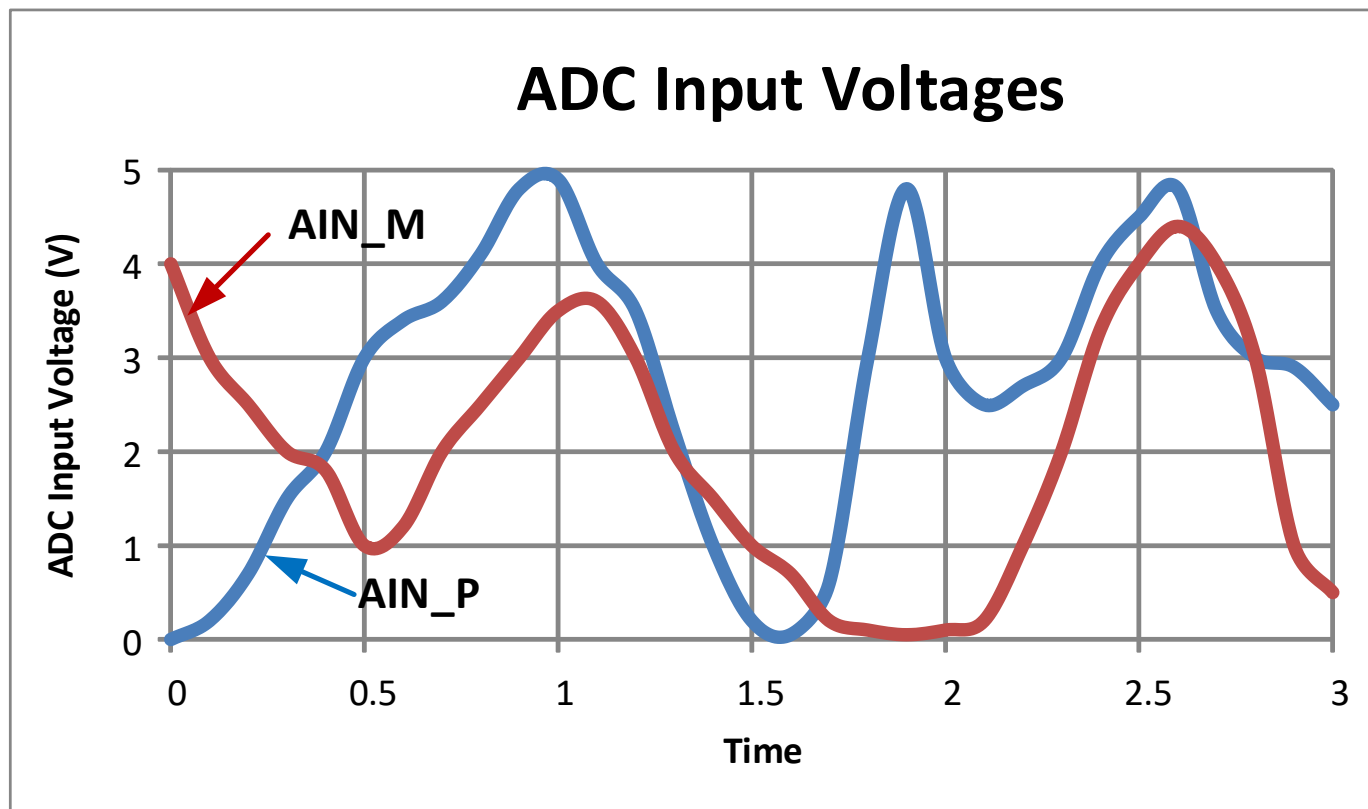# Solutions Quiz: SAR ADC Input Types

3. (T/F) The signal below can be directly applied to an ADC with a fully differential input.

   a. True.

   b. **False.**

ADC Input Voltages

AIN_M

AIN_P

Common Mode Voltage

$$Vcm = \frac{AIN\_P + AIN\_M}{2}$$

Solutions Quiz: SAR ADC Input Types

4. Which type of ADC would require a wide bandwidth amplifier and a RC charge bucket filter?

    a. A high voltage SAR with an internal PGA.

    b. A switched capacitor input SAR ADC.

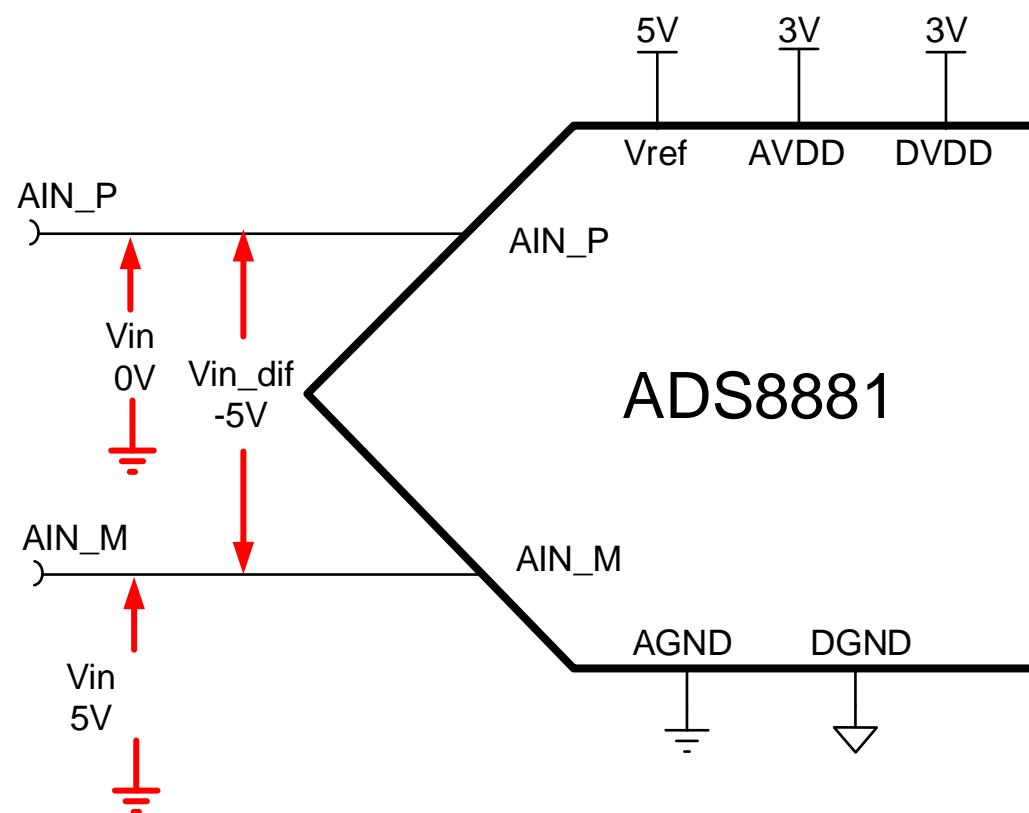5. (T/F) In general, a fully differential input has double the range of a single ended input assuming the same reference voltage.

    a. True.

    b. False.

Solutions Quiz: SAR ADC Input Types
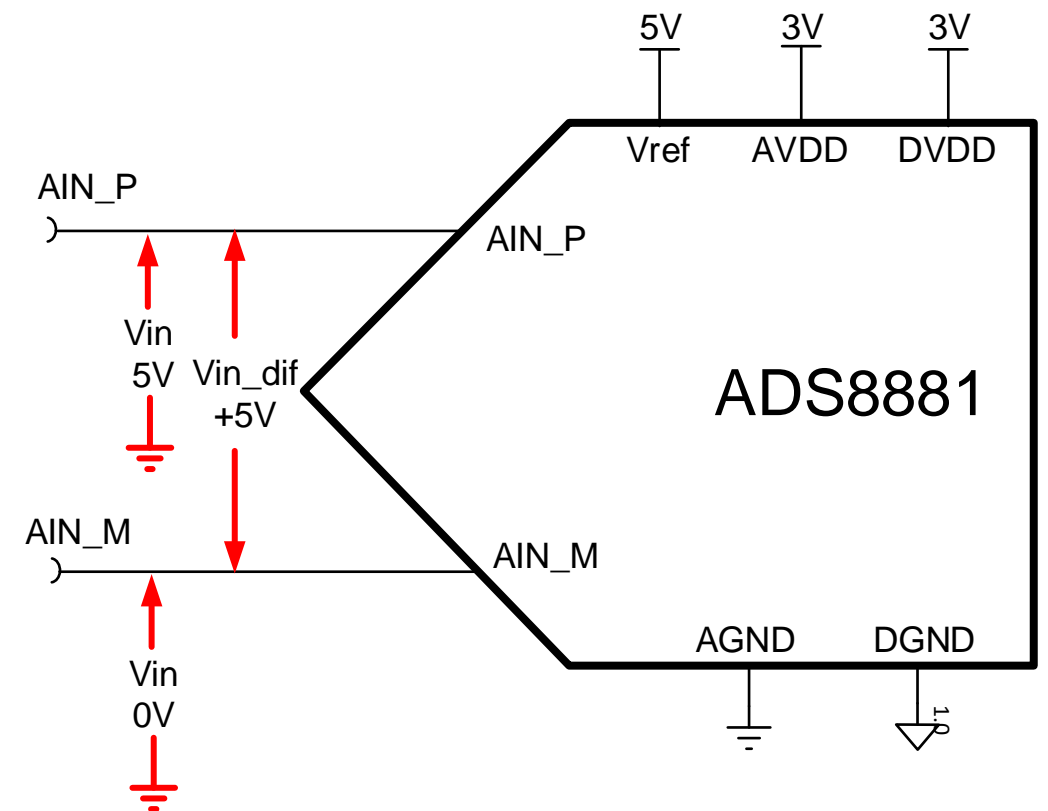
6. The circuit in the figure below has a _____.

   a. **Unipolar, differential input.**

   b. Bipolar, differential input.

Negative Full Scale Input

Positive Full Scale Input