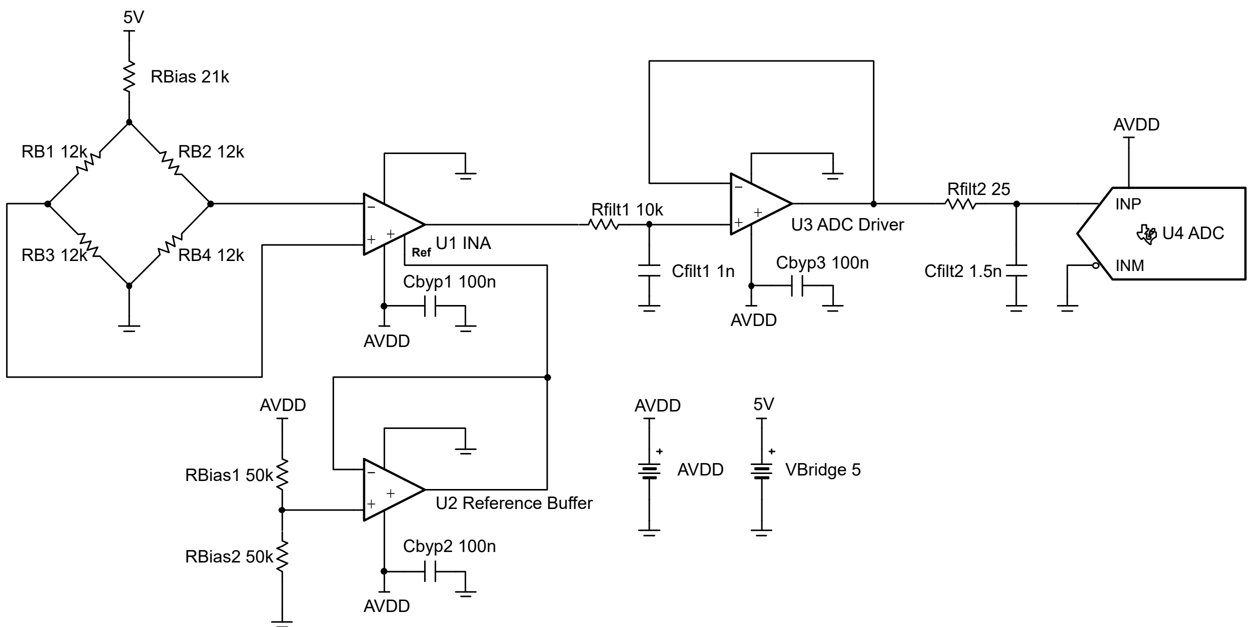
Product Overview

Bridge Sensor Solution

Instrumentation amplifiers (in-amp or INA) are a common way of translating low-level sensor outputs to high-level signals that can drive an analog-to-digital converter (ADC). INAs are well-suited for sensing applications because they offer high common-mode rejection and are able to match the high output impedance of many sensors with their high input impedance. They are typically optimized for low-noise, low-offset, and low-drift. A downside is that they often do not have enough bandwidth to achieve the settling time required for the sampling rate of an ADC. The solution for leveraging the benefits of an INA in a sensing application while still achieving a high sampling rate is to use a high-bandwidth ADC driver between the INA and the ADC. This overview shows how to achieve this solution for a bridge sensor, but this method could be used for a wide range of different sensors.



Bridge Sensor Signal Chain Solution

Design Considerations

1. An instrumentation amplifier (INA) circuit can be implemented discretely or integrated. The TI Precision Labs - Instrumentation Amplifier video series discusses the different use cases and topologies.
2. The bandwidth of instrumentation amplifiers is typically too low to drive SAR data converters at high data rates. Wide bandwidth is needed because the SAR has a switched capacitor input that needs to be charged during each conversion cycle. The OPA320 and OPA322 buffer was added to allow the ADC to run at full data rate (1 MSPS).
3. RBias is chosen to be within the common-mode range of the INA using the Common-Mode Input Range Calculator for Instrumentation Amplifiers software tool. In the above scenario, RBias is set to output ½ × AVDD to INA IN– to match the reference buffer output.
4. Select C0G-rated capacitors for Cfilt1 and Cfilt2 to minimize distortion.
5. The TI Precision Labs – ADCs training video series reviews methods for selecting the charge bucket circuit Rfilt and Cfilt. Refer to Introduction to SAR ADC Front-End Component Selection for details on this subject.
6. For calibration, see Understanding and calibrating the offset and gain for ADC systems for detailed theory on this subject.

Recommended Parts

The following table provides four different options with recommended devices for the components in the circuit. The *Good* low-voltage solution accuracy is a discrete implementation INA. The *Better* high-voltage solution accuracy is shown as it accompanies the existing Analog Engineer's circuit: *Circuit for driving a switched-capacitor SAR ADC with a buffered instrumentation amplifier*. The *Better* low-voltage solution accuracy offers mid-level precision, but is the most size and cost-optimized of the four.

Solution Accuracy	Total INA Vos in Gain of 50 RTI(1) (Typ)(2)	INA	Reference Buffer	ADC Driver	ADC	Estimated total(3)	
						Area	1 ku $(4)
Good (Low Voltage)	424.3 µV	TLV9064 (QFN RUC)		OPA322 (SOT-23 DBV)	ADS7040 (X2QFN RUG)	14.4 mm^2 (5)	$ 1.505
Better (Low Voltage)	200 µV	INA350 (WSON DSG)	TLV9041 (X2SON DPW)			**11.5 mm^2**	**$ 1.334**
Better (High Voltage)	22.8 µV	INA823 (VSSOP DGK)	OPA192 (SOT-23 DBV)	OPA320 (SOT-23 DBV)	ADS8860 (VSON DRC)	27.3 mm^2	$ 10.579
Best (Low Voltage)	**10.5 µV**	INA333 (WSON DRG)	OPA333 (SOT-SC70 DCK)		ADS8681 (WQFN RUM)	32.1 mm^2	$ 7.684

(1) Referred to INA Input
(2) Offset voltage may be calibrated out using *Design Consideration step 6*
(3) Estimated solution area and price only includes listed ICs
(4) As of April 2022, latest price available on ti.com product page
(5) Discrete implementation of INA with 7 0402 resistors

Design References

- Simulation files for this design: SBOMC56
- Analog Engineer's Circuits:
  - *Single-supply strain gauge bridge amplifier circuit*
  - *Three op amp instrumentation amplifier*
  - *Circuit for driving a switched-capacitor SAR ADC with an instrumentation amplifier*
  - *Circuit for driving a switched-capacitor SAR ADC with a buffered instrumentation amplifier*
- Additional resources:
  - Determining a SAR ADC's linear range when using instrumentation amplifiers
  - Calculating amplifier + ADC total noise: design examples
  - Introduction to reference noise in ADC systems
  - Reference noise affect on signal chain performance
  - Calculating the total noise for ADC systems
  - Analog Engineer's Calculator