Introduction to SAR ADC Component Selection

TIPL 4401
TI Precision Labs – ADCs

Created by Art Kay

Presented by Peggy Liska

Agenda – Next several videos

1. SAR Operation Overview
2. Select the data converter
3. Use the Calculator to find amplifier and RC filter
4. Find the Op Amp
5. Verify the Op Amp Model
6. Building the SAR Model
7. Refine the Rfilt and Cfilt values
8. Final simulations
9. Measured Results
10. SAR Drive Calculator Algorithm

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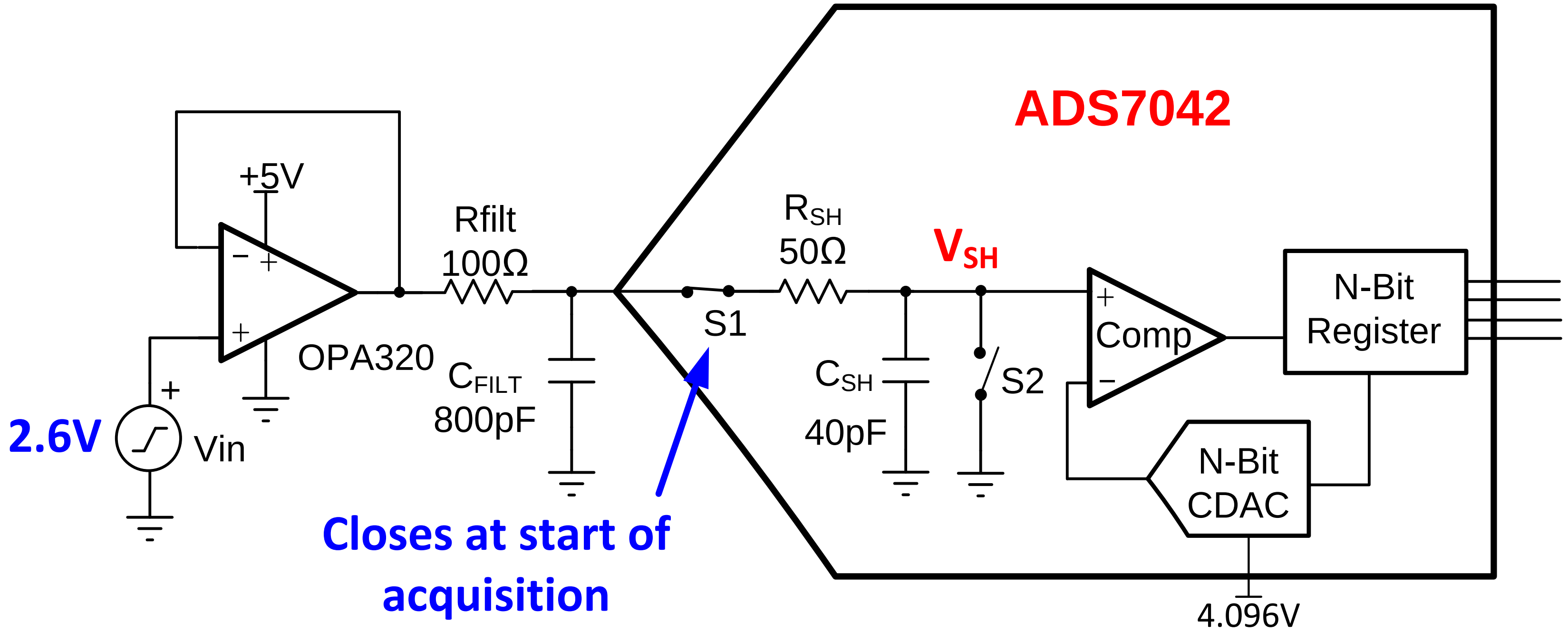
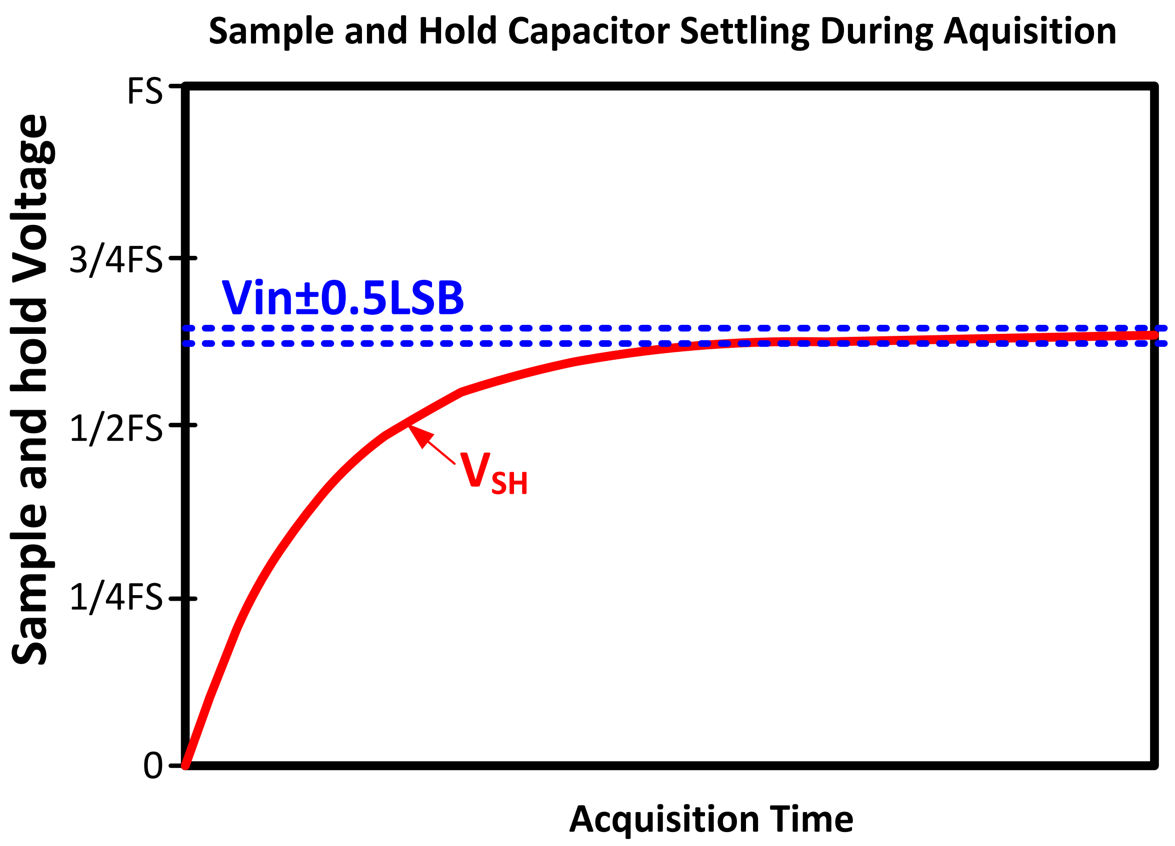
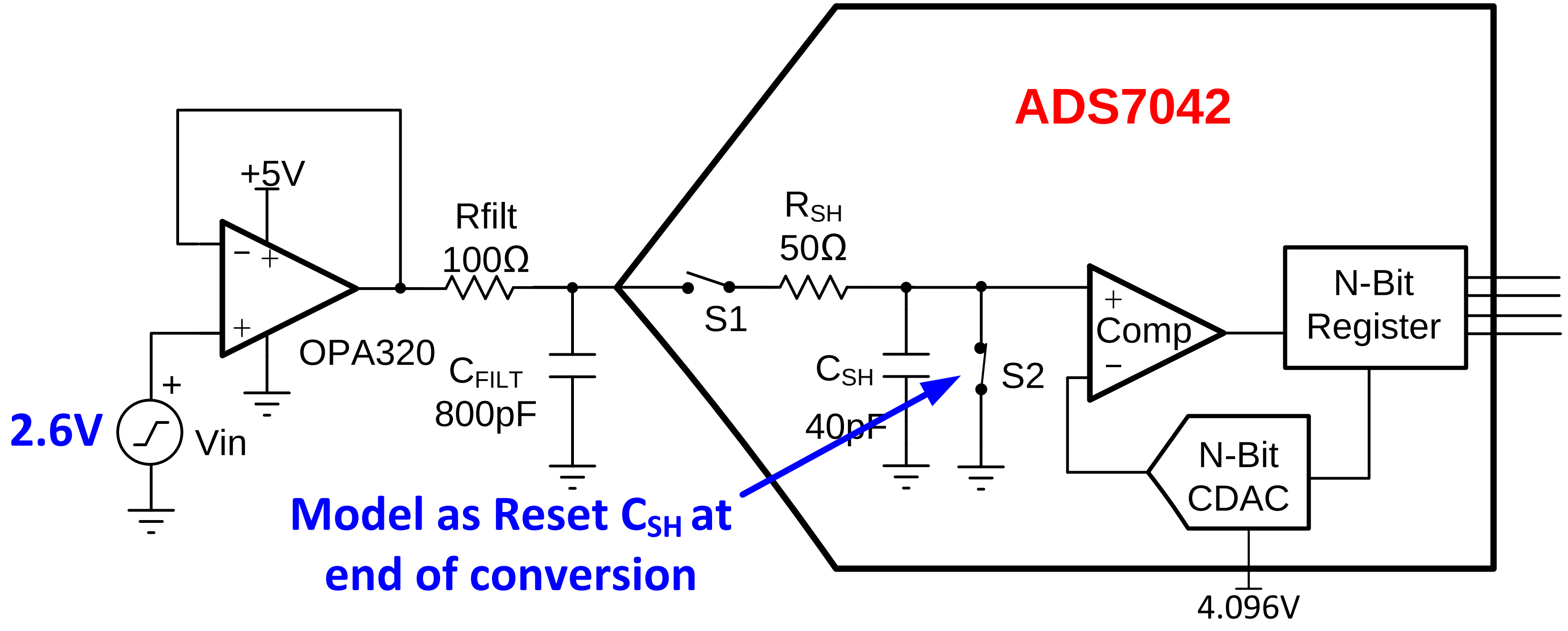
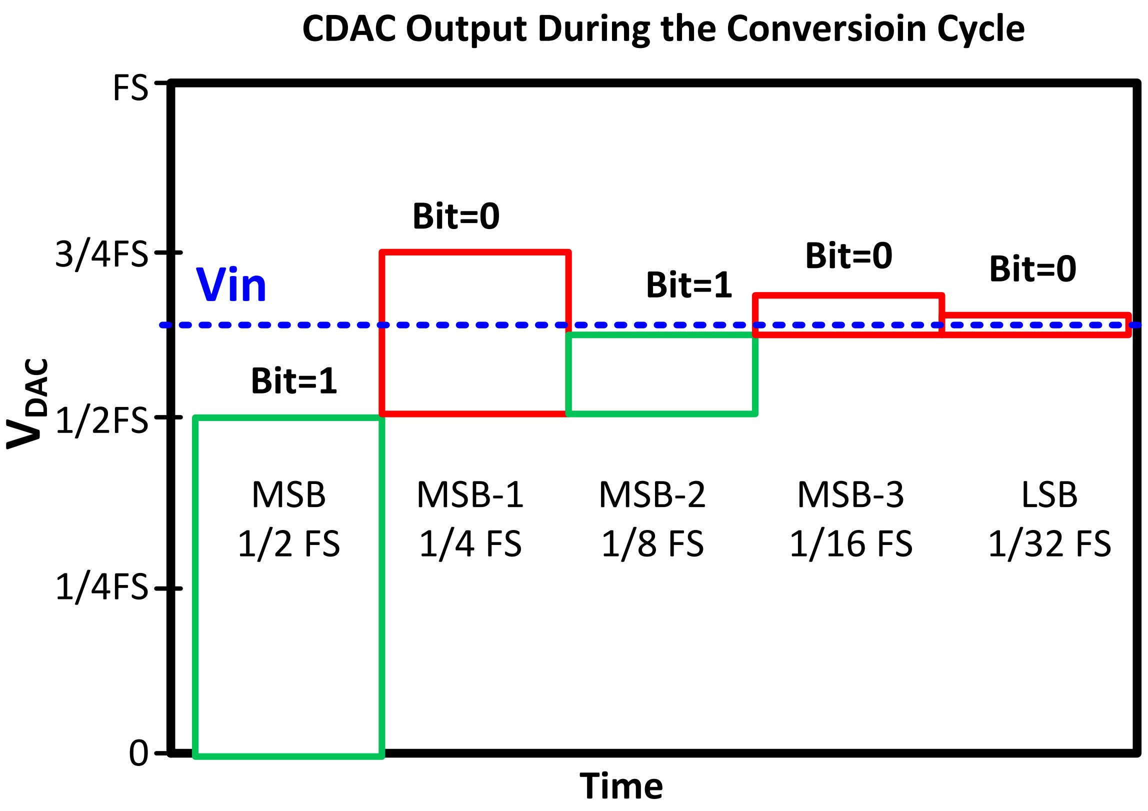
Acquisition phase





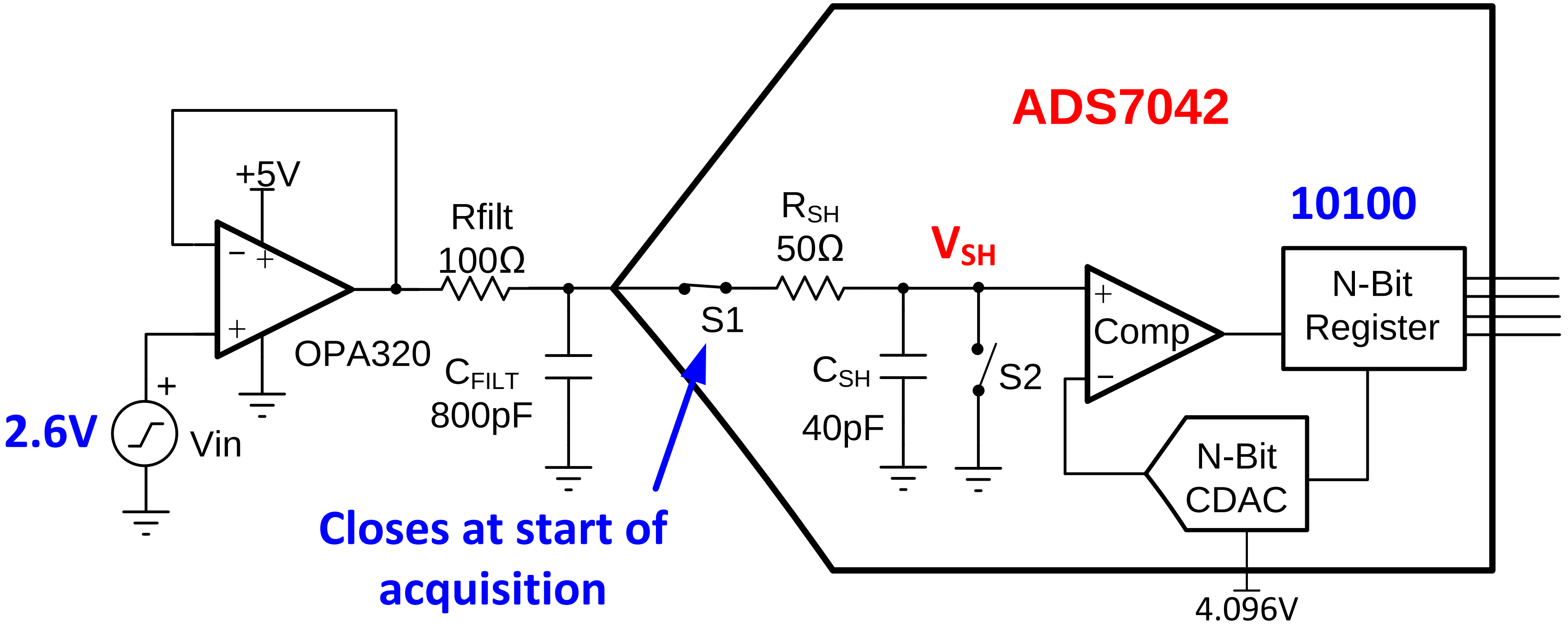
Conversion Phase

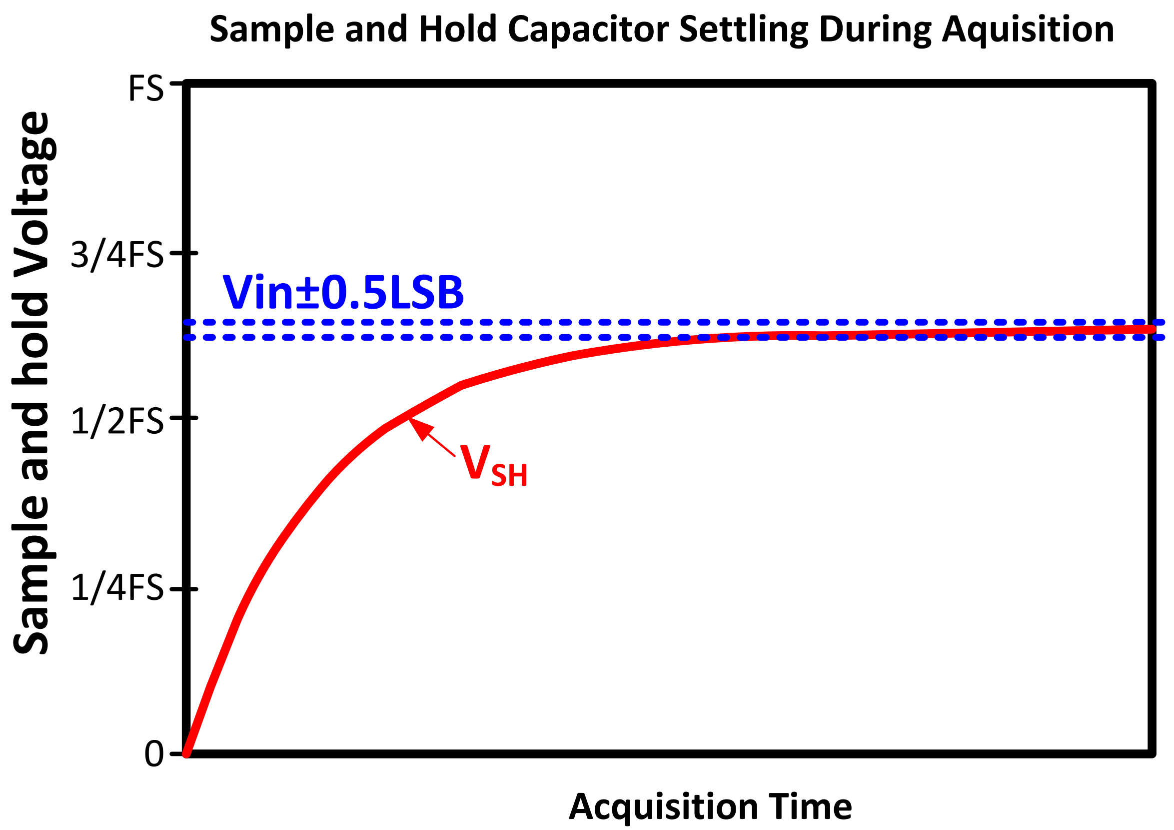




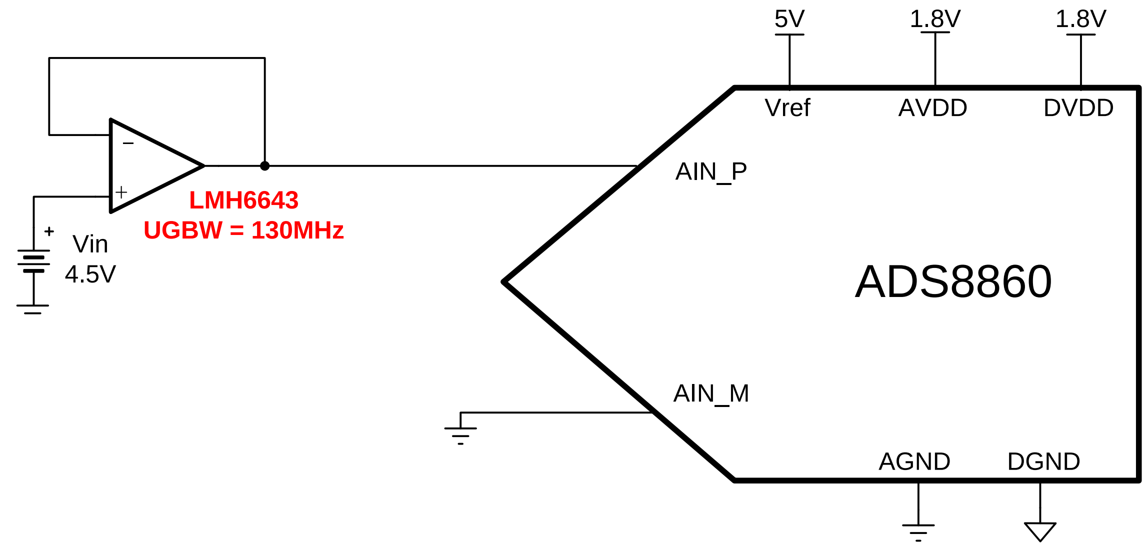
Overall Objective

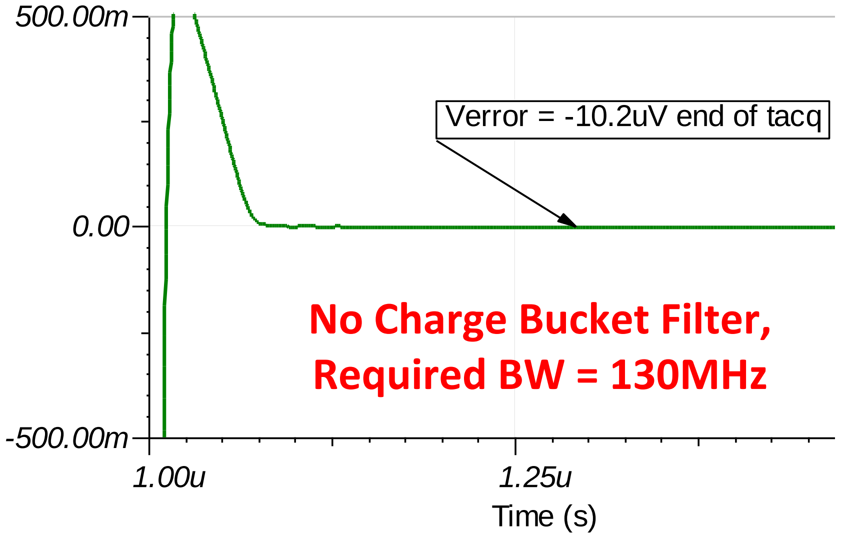
- Find Rfilt and Cfilt charge bucket filter that will optimize settling
- Find amplifier with bandwidth sufficient for settling
- Achieve final settling of 0.5LSB or better at end of tacq

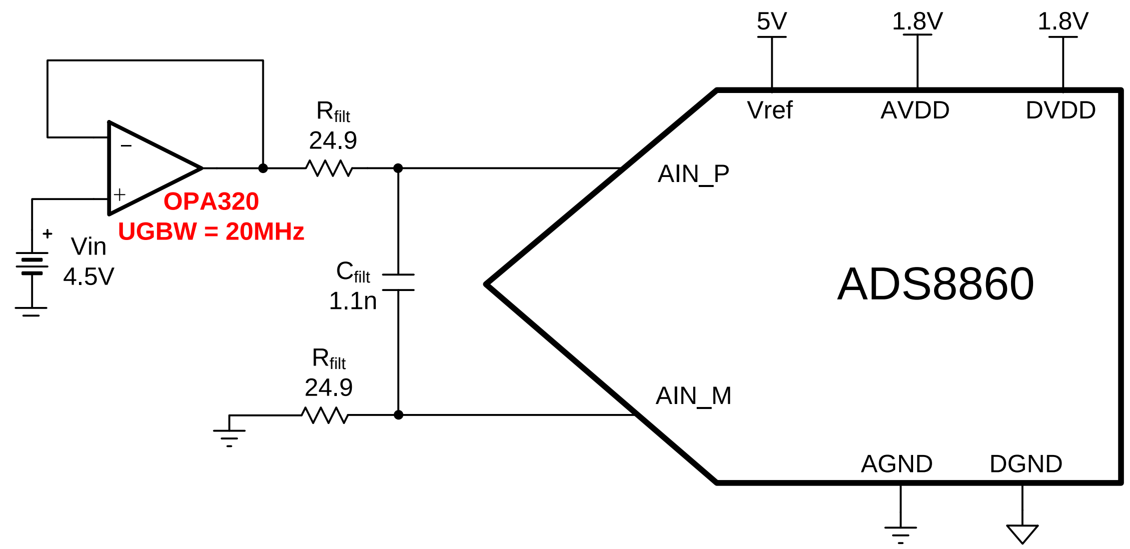


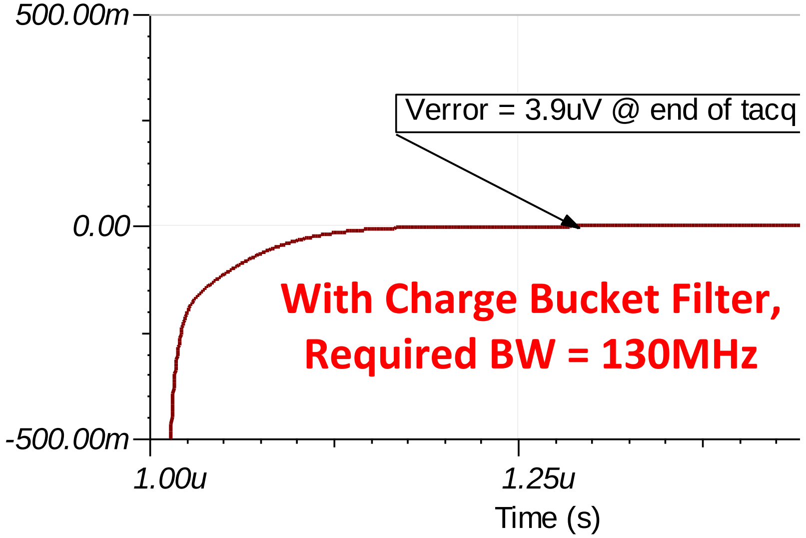


Is the charge bucket filter required?









Advantage of low BW Amp

- Lower Iq
- Better Vos, Ib
- Lower cost
- Less sensitive to stability issues

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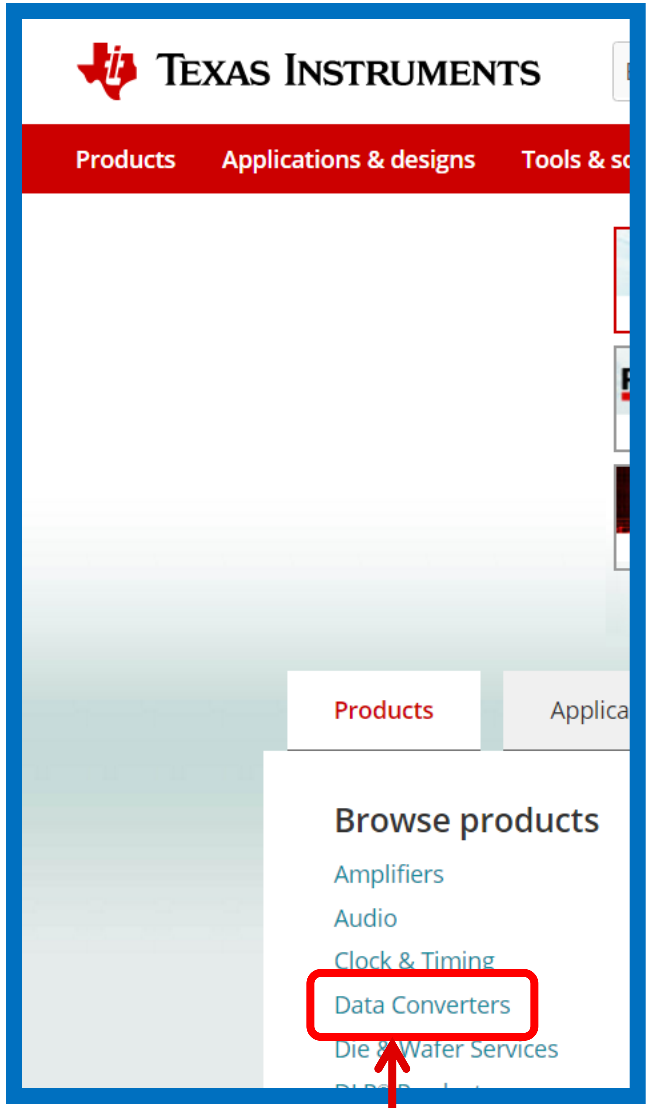
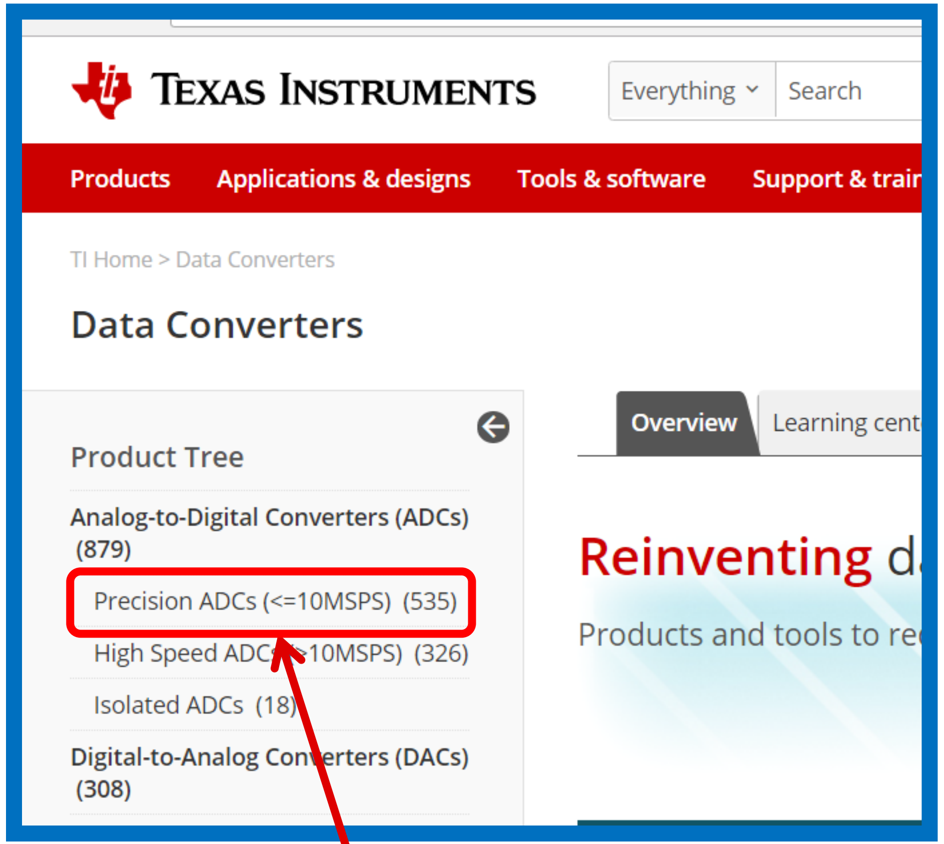
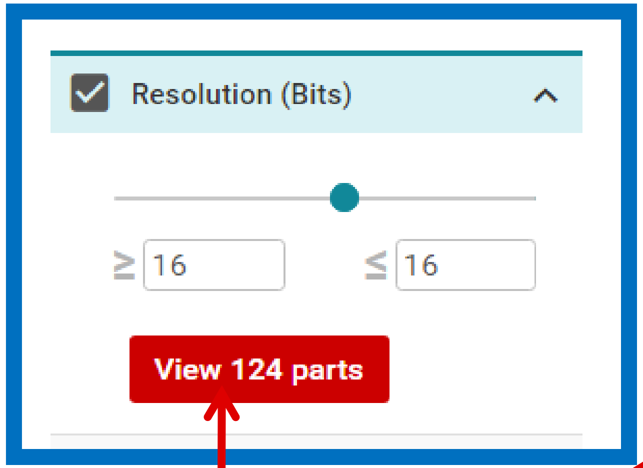
Find the data converter

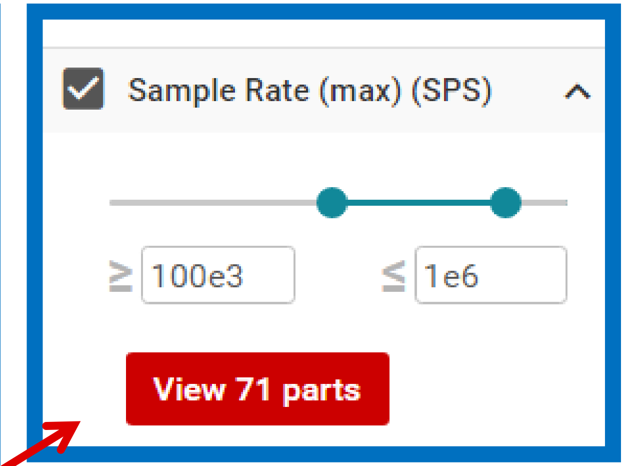


Select Data Converters



Select "Precision ADC"
Operational Amplifiers (Op Amps)
535 different choices!





Continue to refine selection

Design Goal:
#Bits = 16
100kSPS < Sample Rate <1MSPS
Single Ended Input
5V input range
SPI interface

Find the data converter

 # Input Channels

≥ 1 ≤ 1

View 42 parts

Input Range (Max) (V)

≥ 0.0195 ≤ 5

View 17 parts

Interface

- [ ] Byte Wide
- [ ] I2C
- [ ] Microwire (Serial I/O)
- [ ] Parallel
- [ ] QSPI
- [x] SPI
- [ ] Serial

View 11 parts

Input Type

OR

- [ ] Differential
- [ ] Pseudo-Differential
- [x] Single-Ended

View 4 parts

Continue to refine selection

4 matching parts out of 535 total parts

Part Number	Resolution (Bits)	Sample Rate (max) (SPS)	# Input Channels	Multi-Channel Configuration	Input Range (Min) (V)	Input Range (Max) (V)	Interface	Integrated Features	Analog Voltage AVDD (Min) (V)	Analog Voltage AVDD (Max) (V)	Architecture	Rating	Operating Temperature Range (C)	Package Group
ADS8866 - 16-Bit, 100-kSPS, Serial Interface, microPower, Miniature, Single-Ended Input, SAR Analog-to-Digital	16	100kSPS	1	N/A	0	5	SPI	Daisy-Chainable, Oscillator	2.7	3.6	SAR	Catalog	-40 to 85	VSSOP, VSON
ADS8864 - 16-Bit, 400-kSPS, Serial Interface, microPower, Miniature, Single-Ended Input, SAR ADC	16	400kSPS	1	N/A	0	5	SPI	Daisy-Chainable, Oscillator	2.7	3.6	SAR	Catalog	-40 to 85	VSON, VSSOP
ADS8862 - 16-Bit, 680-kSPS, Serial Interface, uPower, Miniature, Single-Ended, Differential Input SAR ADC	16	680kSPS	1	N/A	0	5	SPI	Daisy-Chainable, Oscillator	2.7	3.6	SAR	Catalog	-40 to 85	VSON, VSSOP
ADS8860 - 16 bit 1 MSPS, Serial, Pseudo-Differential Input, Micro Power, Miniature, SAR ADC	16	1MSPS	1	N/A	0	5	SPI	Daisy-Chainable, Oscillator	2.7	3.6	SAR	Catalog	-40 to 85	VSON, VSSOP

ADS8860
Choose the data converter with the highest sample rate from this group

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Information needed from the data sheet

Full Scale Range (FSR)	The range of voltage that is applied to the converter for valid conversions. Typically this is Vref or a multiple of Vref.
Resolution	The number of bits used to represent the digital equivalent of the equivalent analog signal. In this example we use a 16 bit converter that has 2^{16} or 65536 codes.
$\mathbf{C_{sh}}$	Sample and Hold capacitance. Sometimes called Cin. Typically between 10pF and 100pF.
$\mathbf{R_{sh}}$	On-resistance for sample and hold switch. Typically between 10 ohms and 100 ohms. Normally, this information is in the data sheet equivalent circuit.
$\mathbf{t_{acq}}$	Acquisition time. This is duration that the sample and hold switch is closed. A longer acquisition time makes it easer to settle. The data sheet provides a minimum acquisition time that corresponds to the maximum throughput (samples / second).

Example: Full Scale Range, Resolution, C_{sh}, R_{sh}

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
ANALOG INPUT						
	Full-scale input span[1]	AINP – AINN	0		V_{REF}	V
	Operating input range[1]	AINP	–0.1		V_{REF} + 0.1	V
		AINN	–0.1		+ 0.1	V
C_I	Input capacitance	AINP and AINN terminal to GND		59		pF
	Input leakage current	During acquisition for dc input		5		nA
SYSTEM PERFORMANCE						
	Resolution			16		Bits

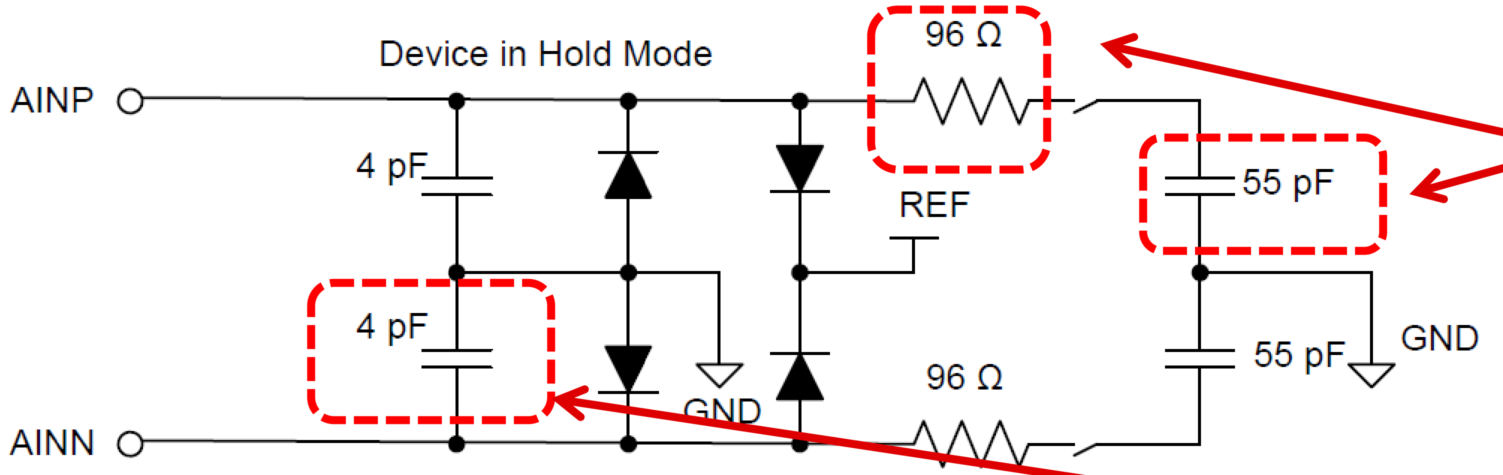


Figure 45. Input Sampling Stage Equivalent Circuit

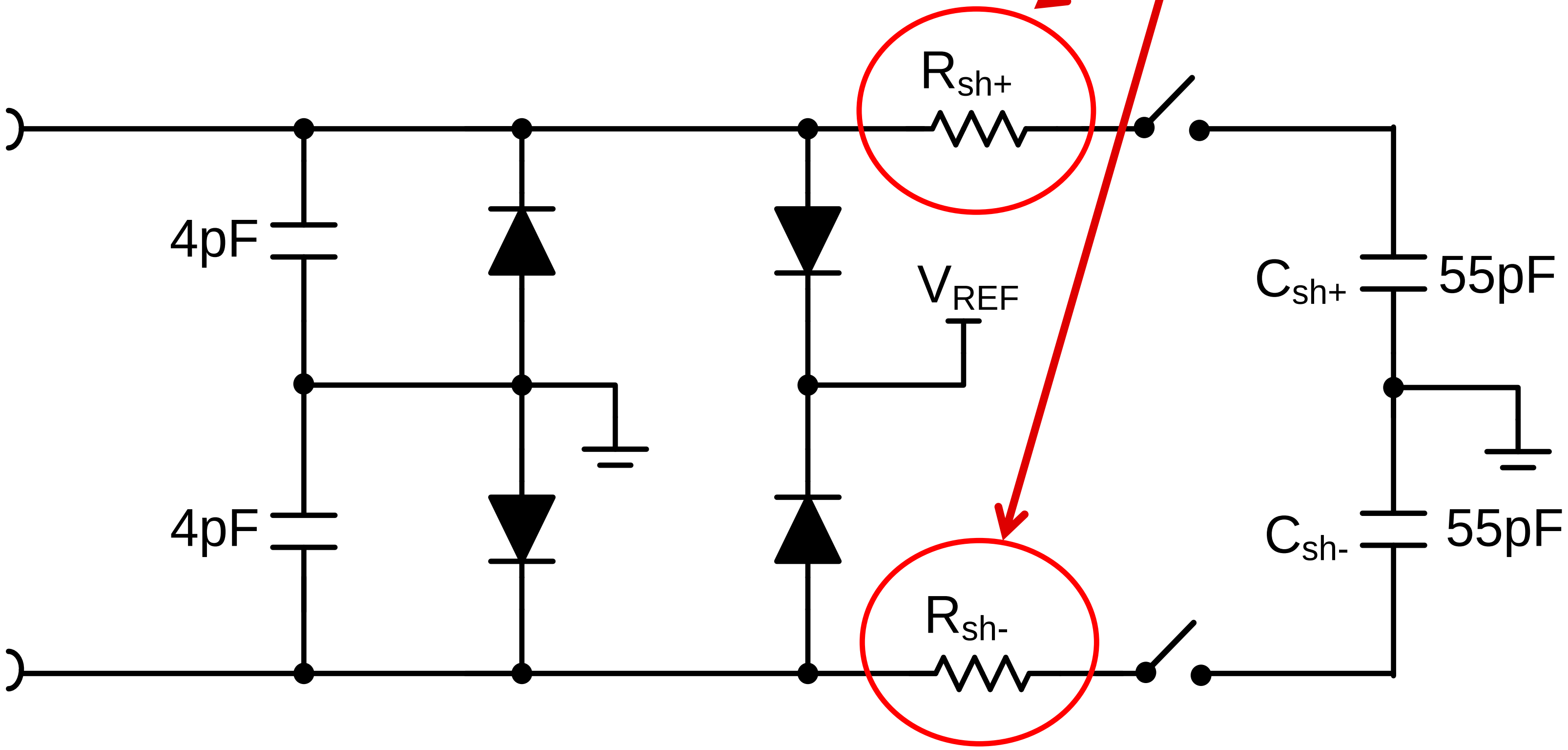
C_{sh} and R_{sh} can usually be found in the equivalent circuit.

Full Scale Range and resolution

Note: C_I from the table C_I = 55pF+4pF

If the data sheet doesn't provide R_{sh}

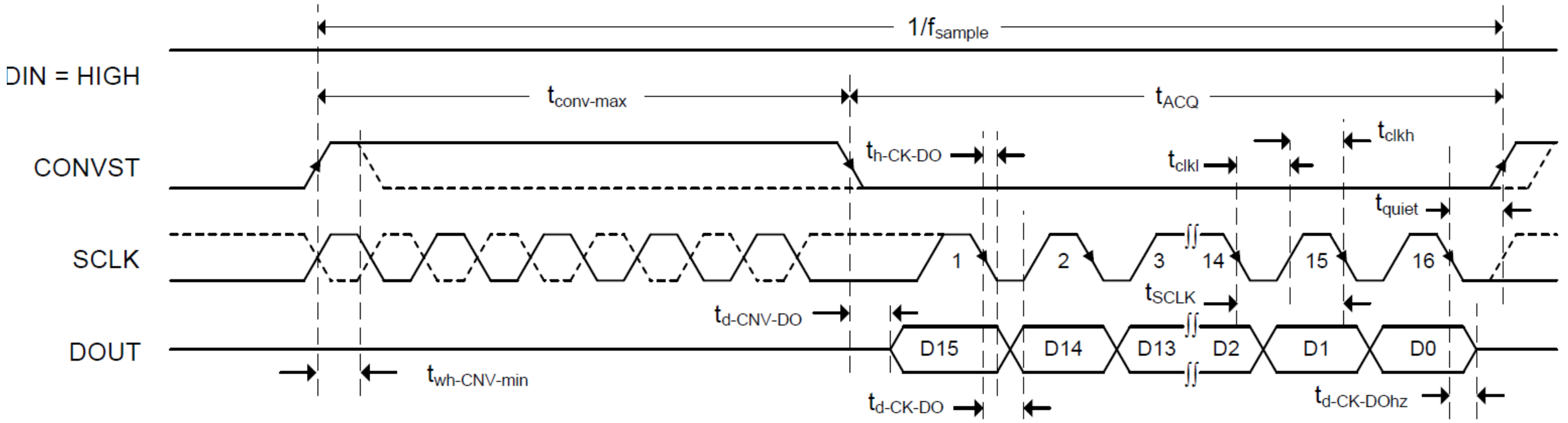
Not specified in data sheet



$$R_{sh} \approx \frac{t_{acq\_min}}{100 \cdot C_{sh}}$$

$$R_{sh} \approx \frac{290ns}{100 \cdot 55pF} = 53\Omega$$

For our example: acquisition time



Conversion time set by internal clock. The maximum time for conversion is 710ns.

PARAMETER		MIN	TYP	MAX	UNIT
t_{ACQ}	Acquisition time	290			ns
t_{conv}	Conversion time	500		710	ns

We are running at maximum throughput (1MHz)

$1/f_{sample} = t_{conv\text{-}max} + t_{acq\text{-}min} = 710\text{ns} + 290\text{ns} = 1\mu\text{s}$, or $f_{sample} = 1\text{MHz}$

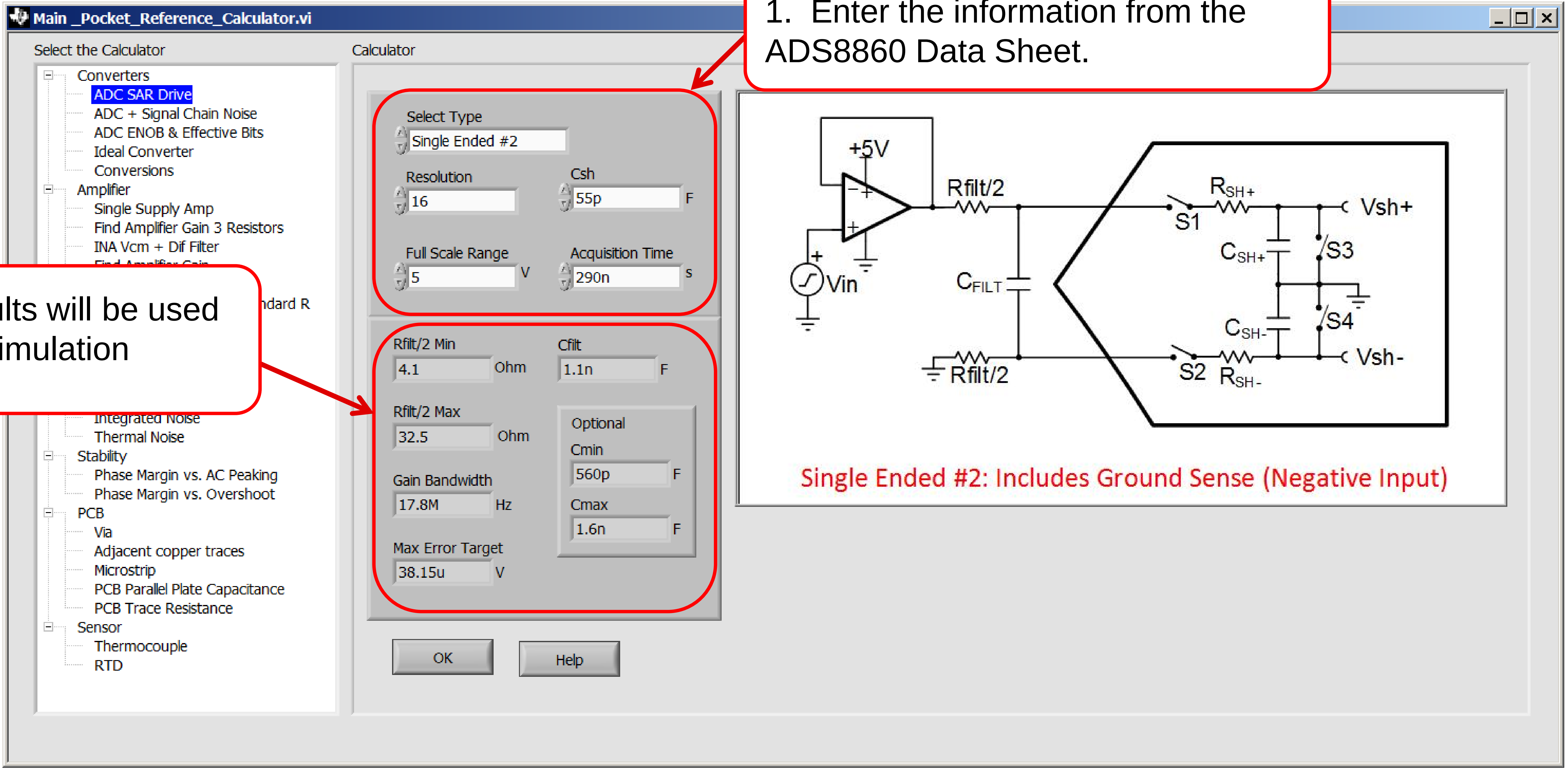
For cases where you aren't running at maximum throughput (e.g. 500kHz)

$t_{acq} = 1/f_{sample} - t_{conv\text{-}max} = (1/500\text{kHz}) - 710\text{ns} = 1290\text{ns}$

Run the "ADC SAR Drive" tool: ADS8860 Example

1. Enter the information from the ADS8860 Data Sheet.

2. Results will be used in the simulation



http://www.ti.com/tool/analog-engineer-calc

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Thanks for your time! Please try the quiz.

Quiz: Introduction to SAR ADC Component Selection

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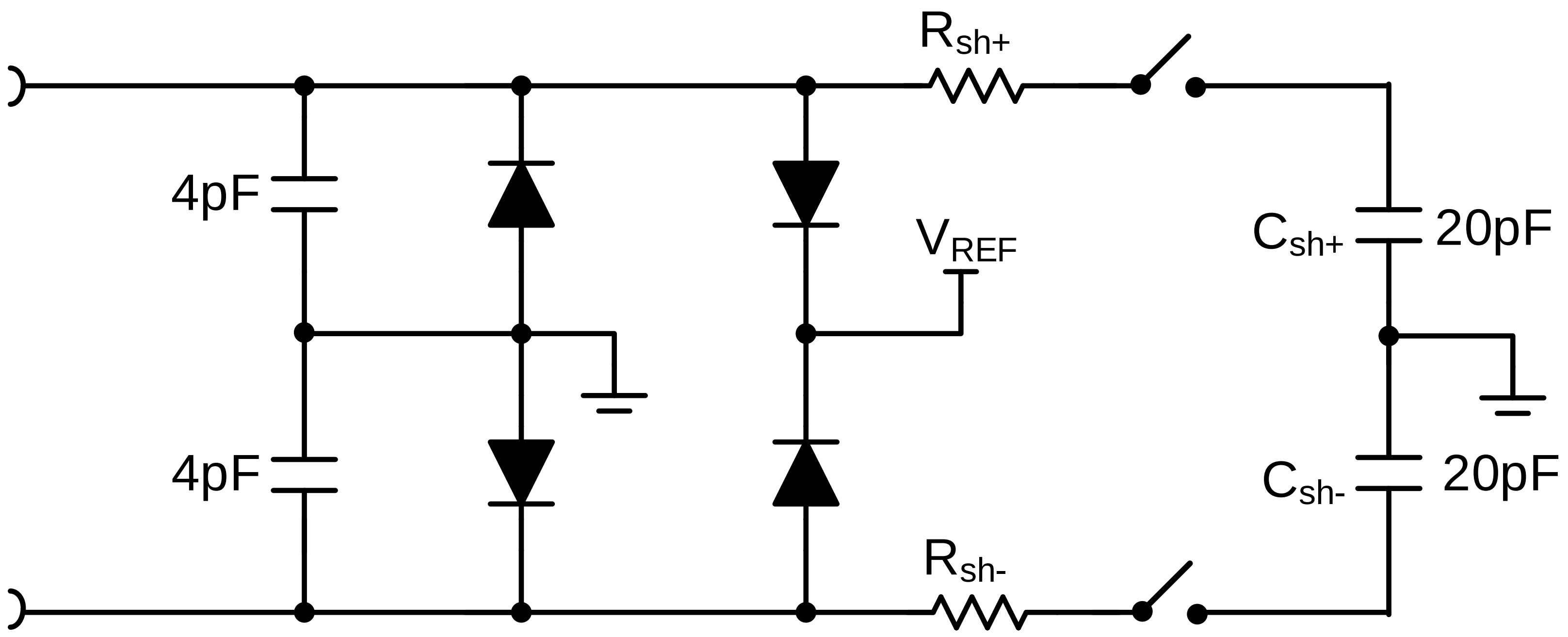
1. The SAR data converter throughput is set by the ___________________.
   a) Acquisition and communications phase.
   b) Reference and conversion phase.
   c) Acquisition and conversion phase.
   d) None of the above.

2. SAR data converters with short acquisition time will need a driver amplifier with ______.
   a) High bandwidth.
   b) High slew rate.
   c) Good output swing.
   d) Low noise.

Quiz: Introduction to SAR ADC Component Selection

3. The data sheet for the input circuit below does not specify Rsh. What is a good estimate for Rsh? Assume t_{acq_min} = 150ns.
   a) 25 ohms.
   b) 50 ohms.
   c) 75 ohms.
   d) 100 ohms.



Quiz: Introduction to SAR ADC Component Selection

4. Use the calculator to find an amplifier and RC range for a converter with the following specifications: ADS7056, Single Ended, 14 bit, 2.5Msps, t_{acq_min} = 95ns, FSR = 3.3V, and Csh = 16pF.

Solutions

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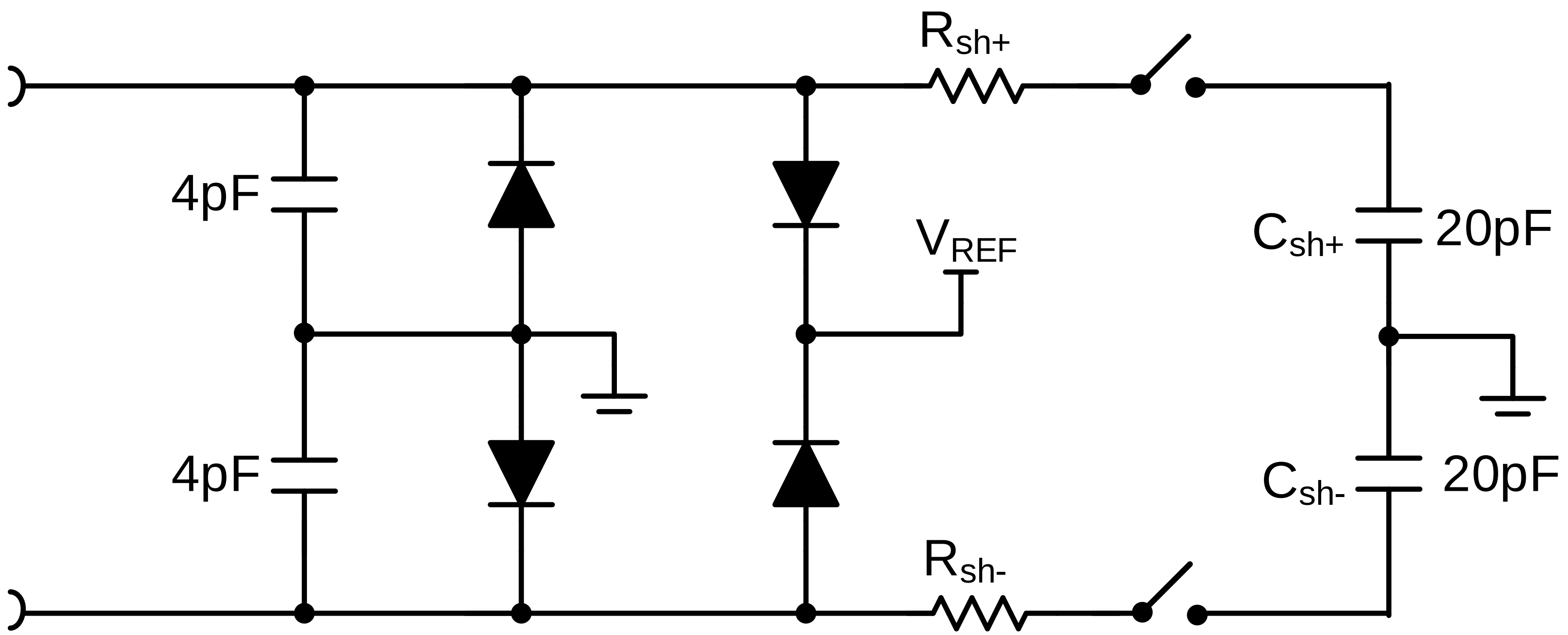
   c) **75 ohms.**
   d) 100 ohms.



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