# Choosing SAR or Delta-Sigma

## TI Precision Labs – ADCs

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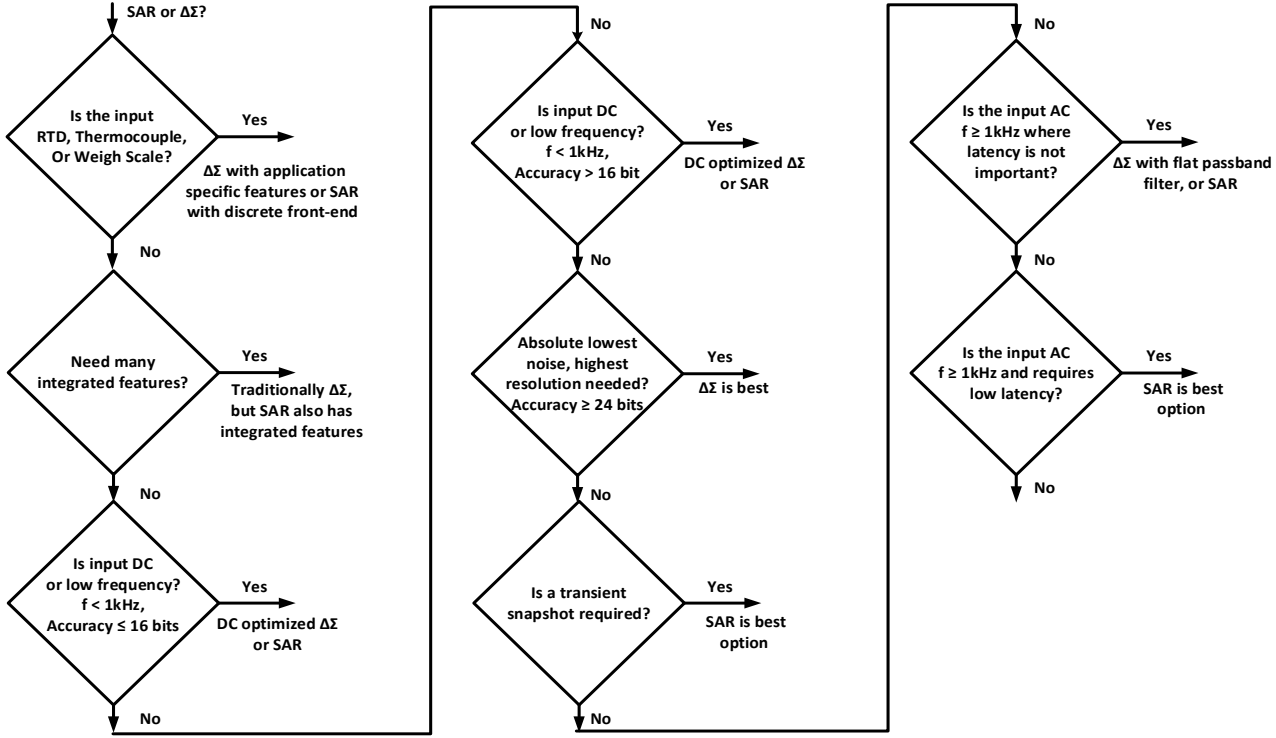
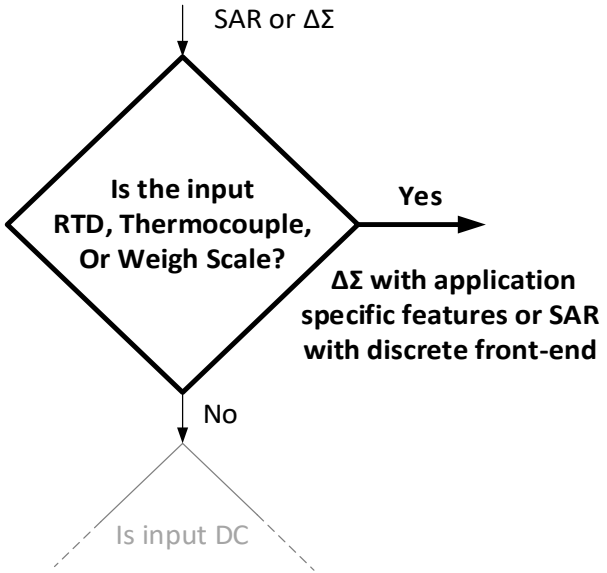
**Presented by Ryan Andrews**

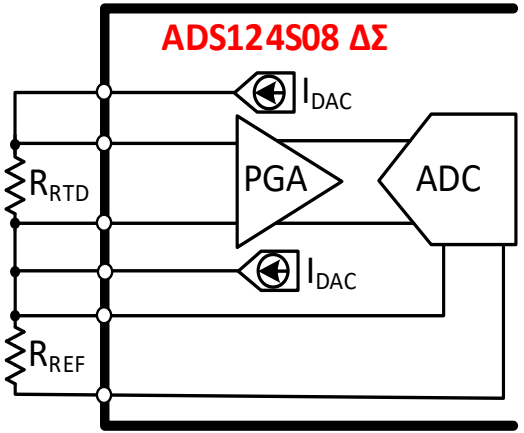
# Choosing SAR vs. delta-sigma decision tree



# Sensor specific input? delta-sigma option



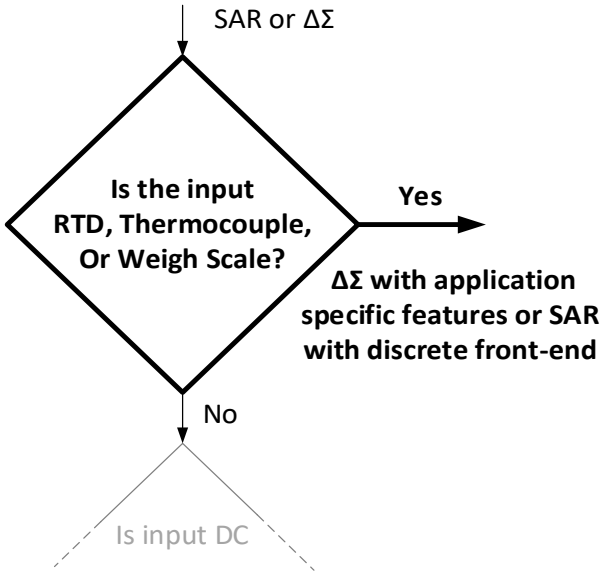

Optimized For RTD

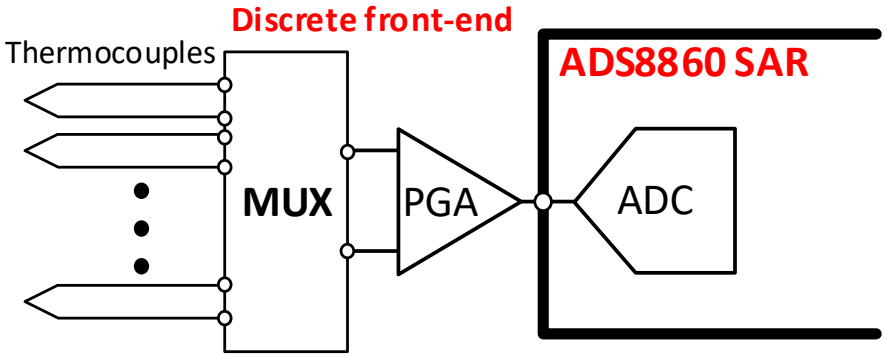



## ΔΣ Option

- Preferred solution
- Application specific integrated features (current sources, gain stage, open sensor detection)
- Resolution (16 to 32 bits)
- Typically lower sampling rate than SAR

# Sensor specific input? SAR option

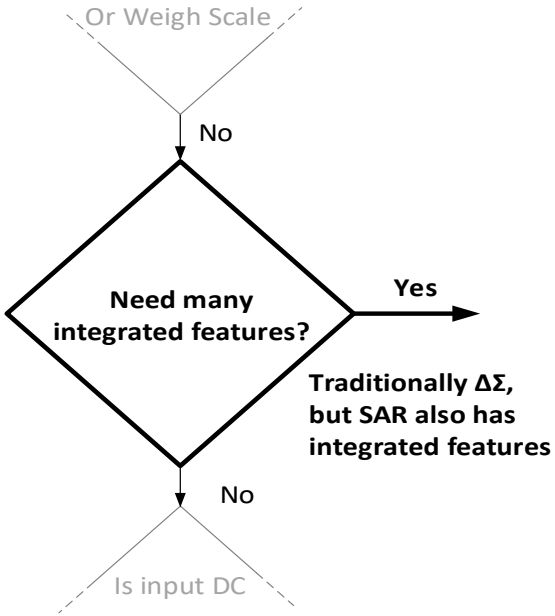


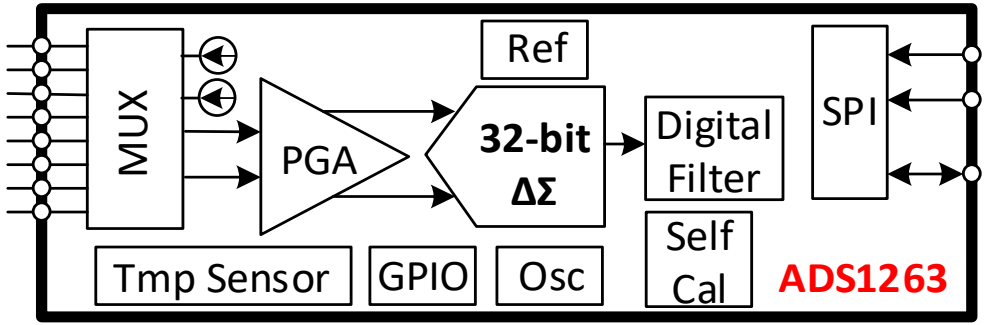




## SAR Option

- Usually requires discrete front-end
- Lower resolution (12 to 16 bits)
- Faster mux scan rate for sensors
- May have lower cost for low-end system
- Infrequently used for these applications

# Are integrated features of key importance?

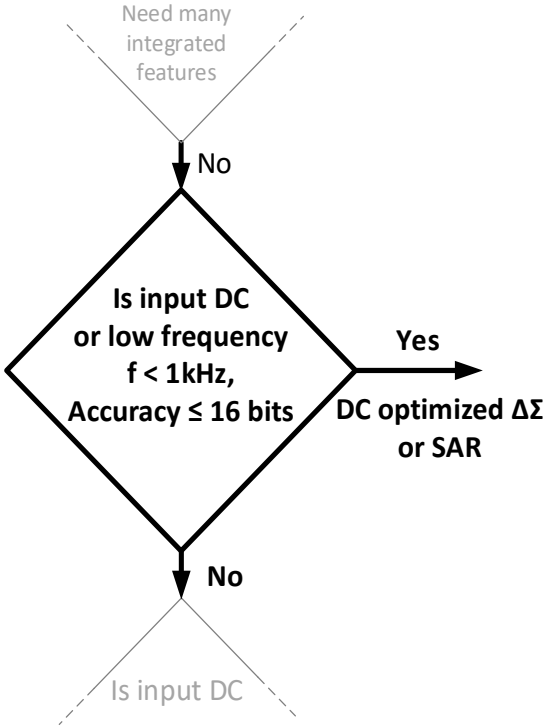


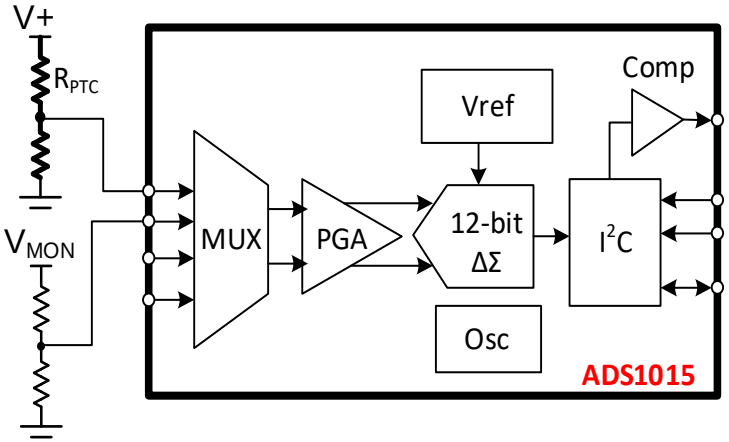

## Integrated Features

- ΔΣ often has strong integration, but SAR also can include features
- Examples include current sources, reference, digital filters, threshold detects, PGA, temperature sensors, self-calibration, multiplexer, oscillators, RMS calculation, CRC calculation

# DC, accuracy ≤ 16 bits: delta-sigma option



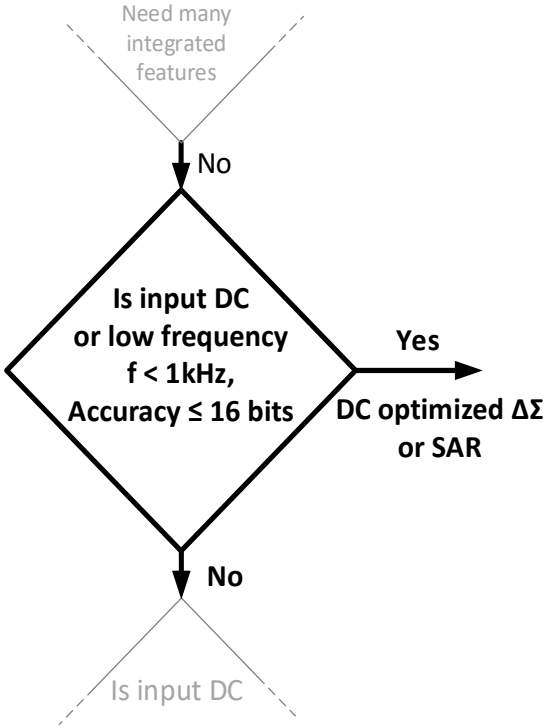

System monitor of slow signals

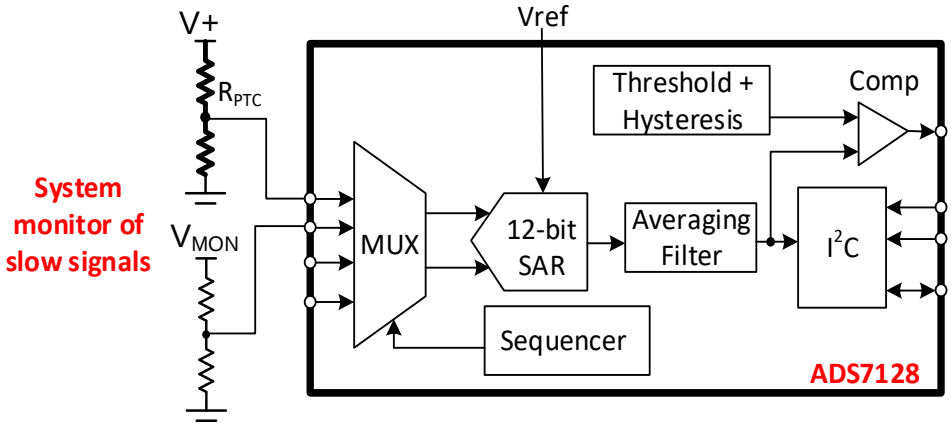



## ΔΣ Option

- Both SAR and ΔΣ have good options
- ΔΣ higher resolution (16 bits) than comparable SAR
- ΔΣ lower sampling rate (kSPS) than comparable SAR
- Small size available for both
- Single-cycle settling for multiplexed systems

# DC, accuracy ≤ 16 bits: SAR option

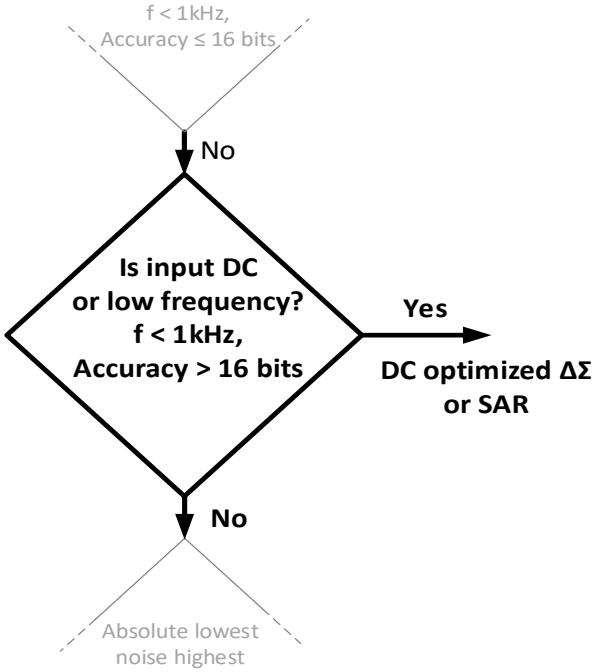


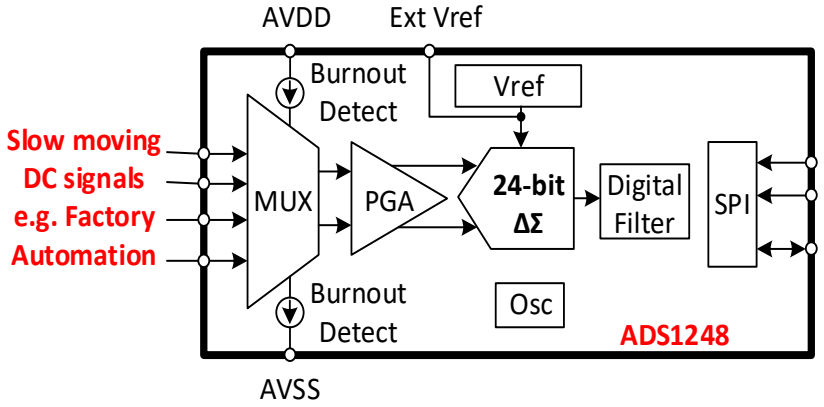




## SAR option

- Both SAR and ΔΣ have good options
- SAR may take a fast snapshot and remain dormant for low power.
- Same SAR ADC can work for both DC and higher frequency signals through MUX

# DC, accuracy > 16 bits: delta-sigma option

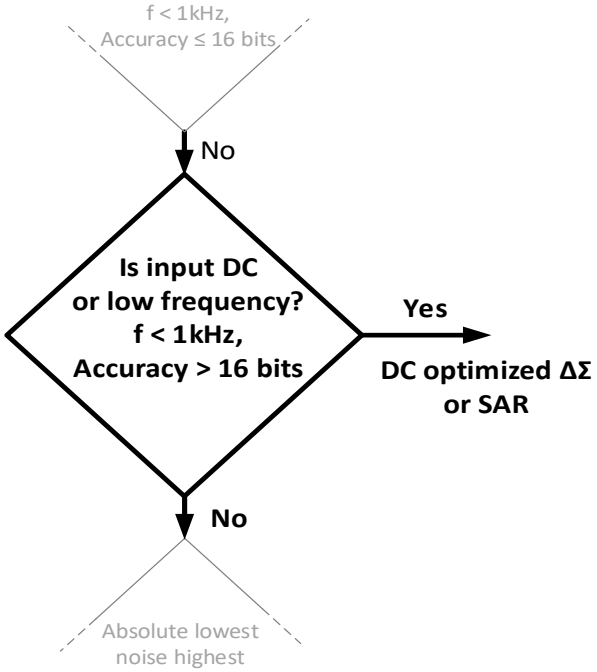


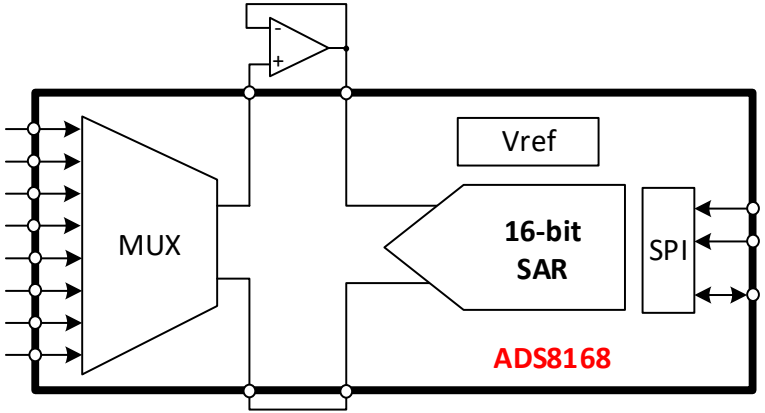

**ΔΣ is the best option for DC, high precision**

- Both SAR and ΔΣ have options
- ΔΣ typically has lowest overall noise
- ΔΣ may have integrated 50/60Hz filter noise rejection
- ΔΣ typically does not require external amplifier
- ΔΣ frequently has integrated PGA

# DC, accuracy > 16 bits: SAR Option



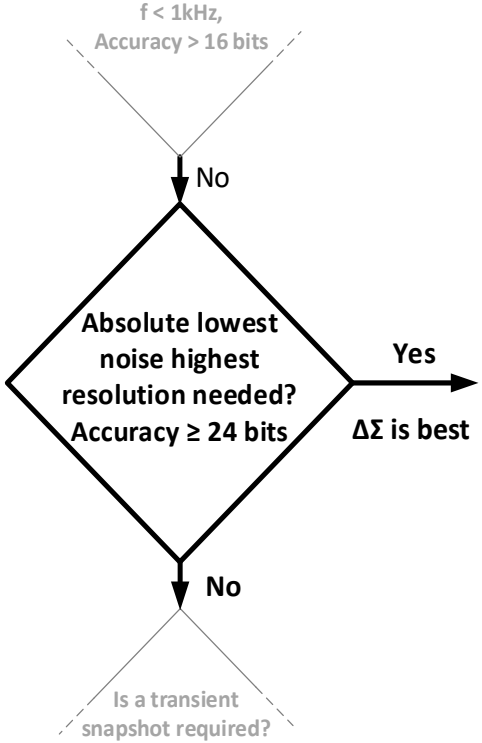

Slow moving
DC signals
e.g. Factory
Automation

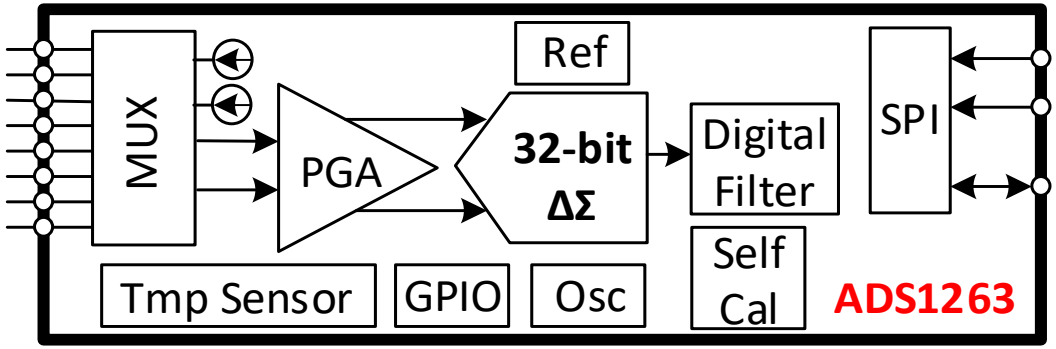



**High resolution SAR for some DC applications**

- Both SAR and ΔΣ have options (normally ΔΣ )
- One channel may be used for higher frequency
- SAR may take a fast snapshot and remain dormant
- May require external amplifiers
- SAR resolution up to 20 bits available

# DC, accuracy ≥ 24 bits, ultra low-noise: delta-sigma

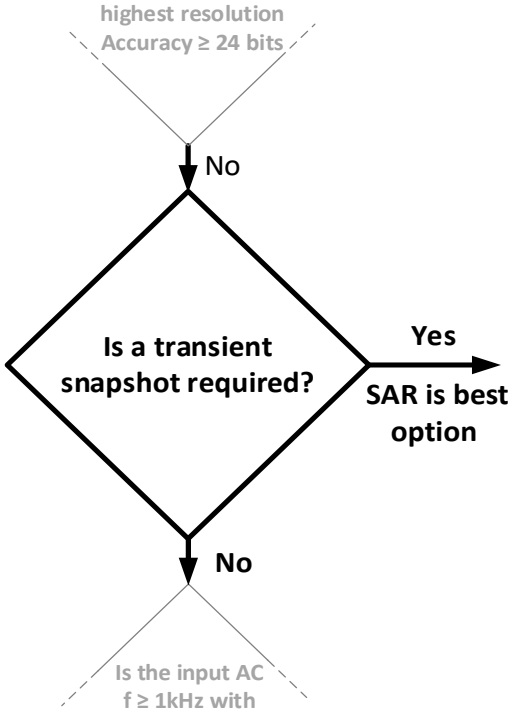


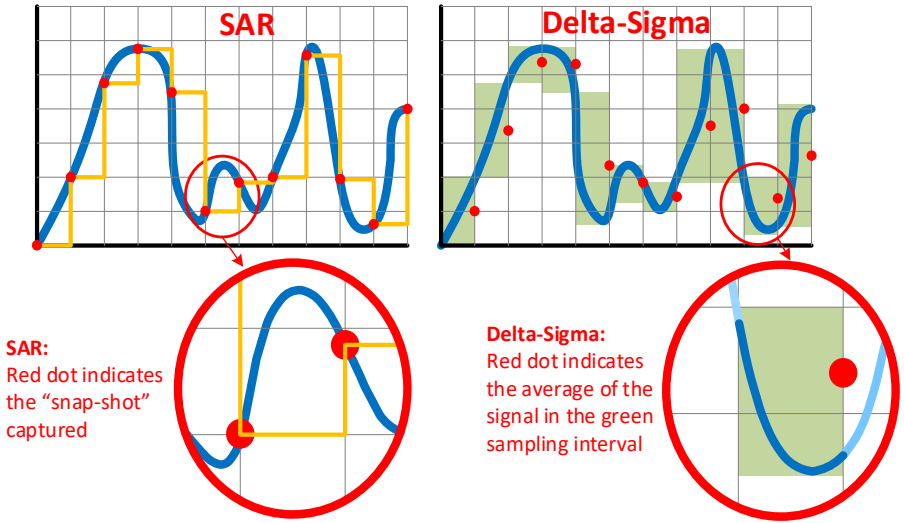




**High resolution SAR for some DC applications**

- ΔΣ is the best choice for highest resolution
- Up to 32 bits available
- Total integrated noise is 7 $nV_{RMS}$!
- Digital filter for lowest noise and 50/60 Hz rejection

# Is a transient snapshot required?

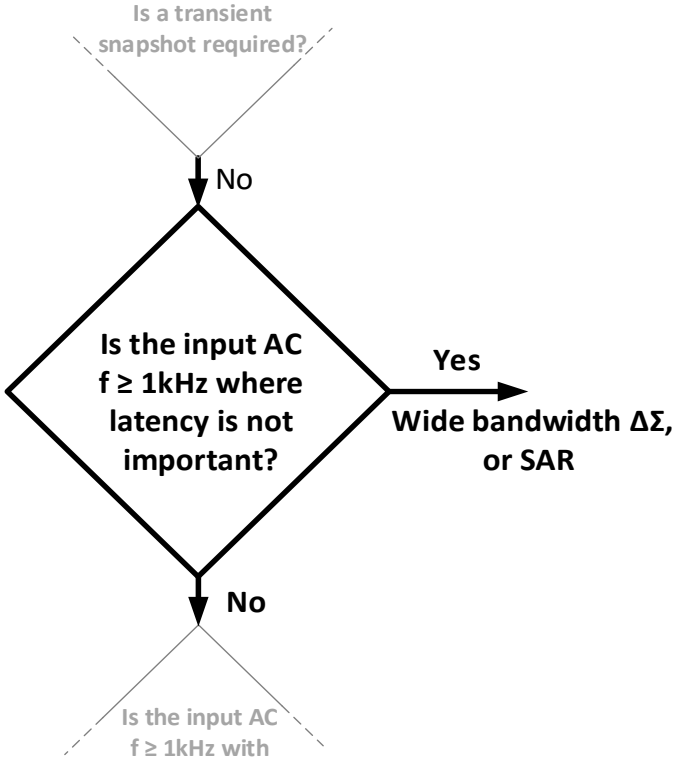


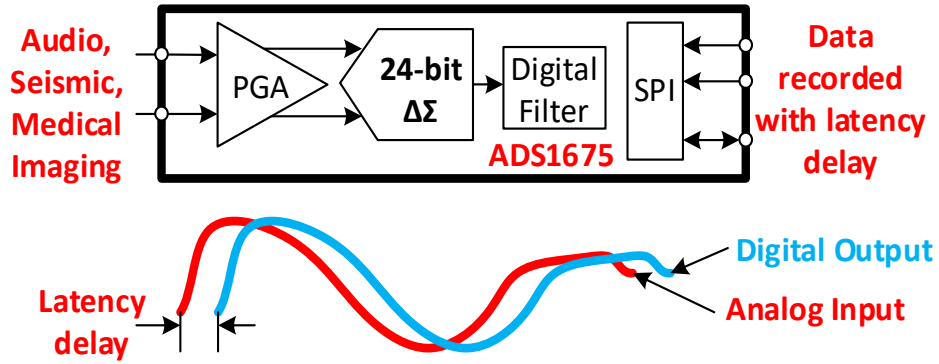




**Different sampling approaches**

- SAR uses sample-and-hold to take a snap shot of signal at an instant in time
- ΔΣ averages signal over a time interval

# AC, latency not important



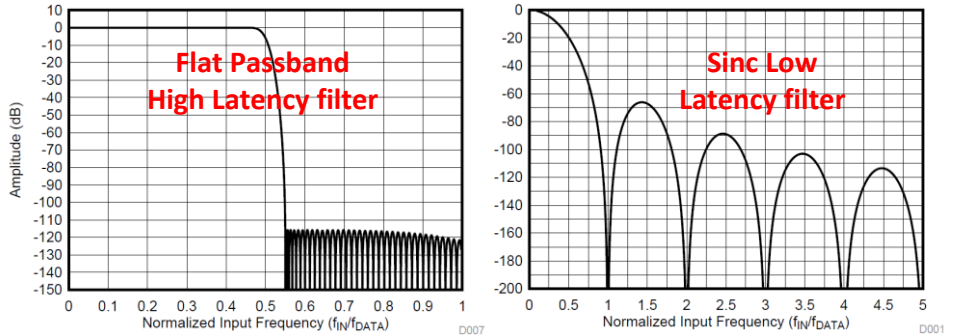

**Both SAR and ΔΣ can work**

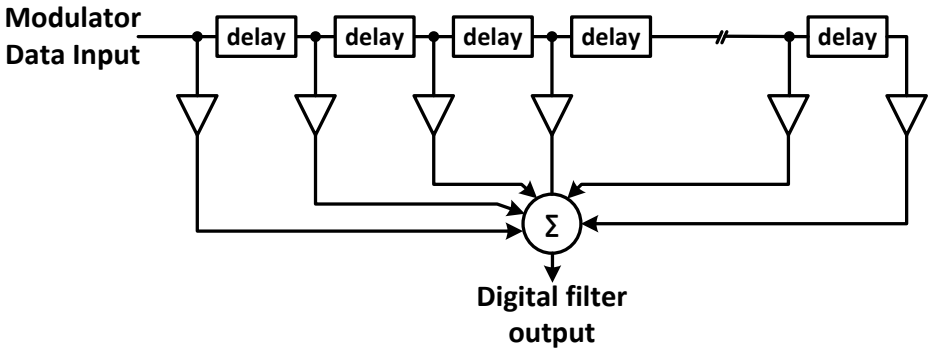
- Used in applications where a delay between input and recorded data is not an issue
- The natural choice for highest resolution is ΔΣ
- ΔΣ devices uses high latency flat passband digital filter

# How do you know how much latency is in a delta-sigma?

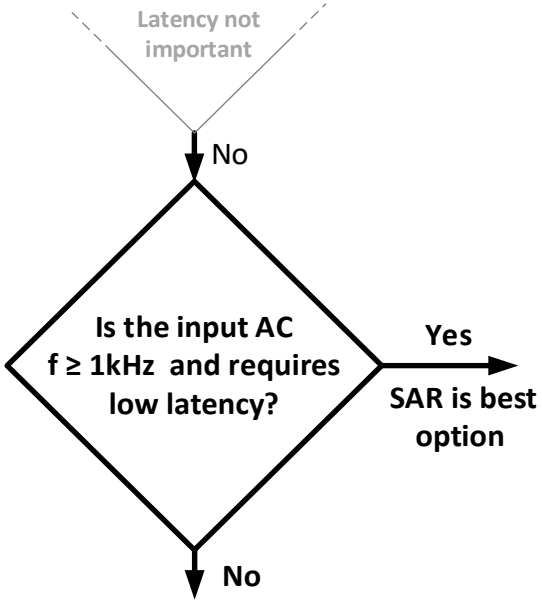
## ΔΣ Latency

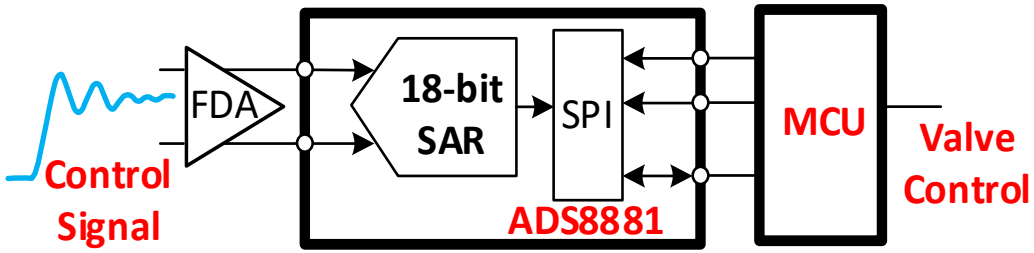
- Flat Passband type filter
  - ✓ High latency (e.g. 50 cycles)
  - ✓ AC in passband not attenuated
  - ✓ Stopband steep attenuation
- Sinc type filter
  - ✓ Low latency (e.g. 1-3 cycles)
  - ✓ Passes DC but attenuates AC
  - ✓ Can be used for 50/60Hz rejection



# AC, latency is important



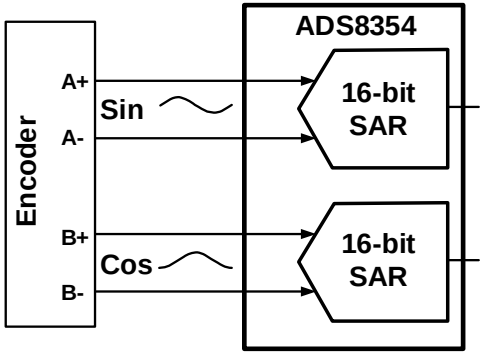

**SAR is best choice for low latency**

- AC or transient input that requires an immediate response (e.g. ≤ 1 cycle delay)
- Examples: control systems, safety relays, position sensors

# Still not sure?...
# Choosing between two equivalent options

- Solution size, or total power consumption
- Ease of use
  - Some SAR ADCs have simple configurations (No registers. Power-up and go.)
  - Delta-Sigma ADCs incorporate digital filters to simplify antialiasing design
- Are pin-for-pin upgrades available?
  - Device families offers options and future upgrade paths
- Integrated features (e.g. PGA, voltage reference, digital filters)
- External supporting circuitry required (e.g. driver amplifiers, voltage references, crystal oscillators)
- Key analog specifications: Noise, SNR, THD, linearity
  - SAR vs. Delta-Sigma is no longer the important comparison
- Performance is not always the key concern. Integrated ADCs in MCUs can offer greater convenience at lower cost.
  - SAR vs. Delta-Sigma topology selection is determined by the MCU

# Summary: SAR vs. delta-sigma ADCs

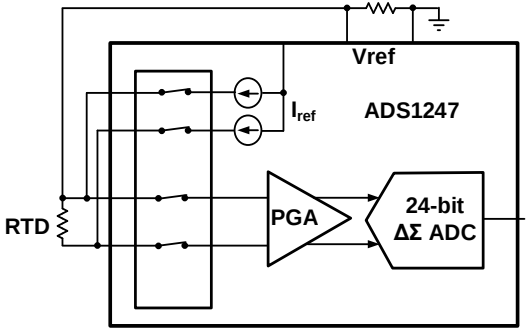



## SAR

- ❑ Low latency matters
- ❑ Needed to capture transient snapshots

**Example applications:**

- Motor control
- Power quality measurement
- Safety relays
- Test and measurement (scope)
- Mechanical shock
- Control loop systems

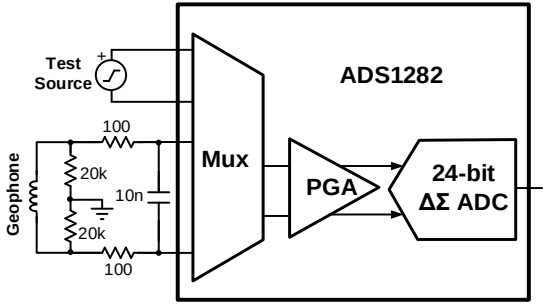



## DC Optimized ΔΣ

- ❑ Offset, drift, linearity, and noise
- ❑ Integrated features
- ❑ Sensor specific inputs

**Example applications:**

- RTD, thermocouple
- Weigh scale, pressure sensor
- Precision dc measurements




## Wide Bandwidth ΔΣ

- ❑ SNR, THD, SINAD
- ❑ Used when latency does not matter
- ❑ Selectable digital filter response

**Example applications:**

- Audio
- Imaging, ultrasound
- Seismic
- ECG, vibration analysis
- Test and measurement

# Thanks for your time!
# Please try the quiz.

# Questions: Choosing between SAR & delta-sigma

1. What kind of ADC is best for measuring an RTD or thermocouple temperature sensor?
   a. SAR
   b. DC optimized delta-sigma
   c. Wide bandwidth delta-sigma

2. (T/F) Wide bandwidth delta-sigma converters will always use a high-latency filter.
   a. True
   b. False

# Questions: Choosing between SAR & delta-sigma

3. Which of the following is true?
   a. SAR converters are used for low latency DC measurements
   b. SAR converters integrate current sources and PGAs.
   c. SAR converters take a snapshot of transient signals
   d. SAR converters use a high-latency, integrated digital filter

4. (T/F) A wide bandwidth delta-sigma converter would be a good choice in cases where low-latency AC measurements are required. For example, a controls system.
   a. True
   b. False