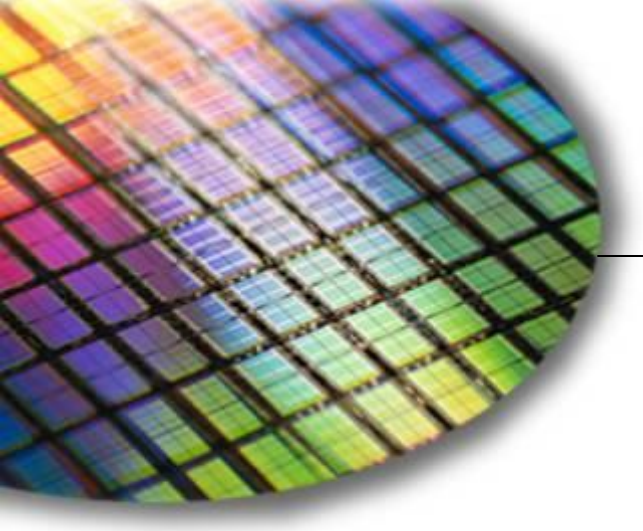
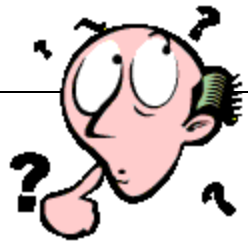


The World Leader in High Performance Signal Processing Solutions

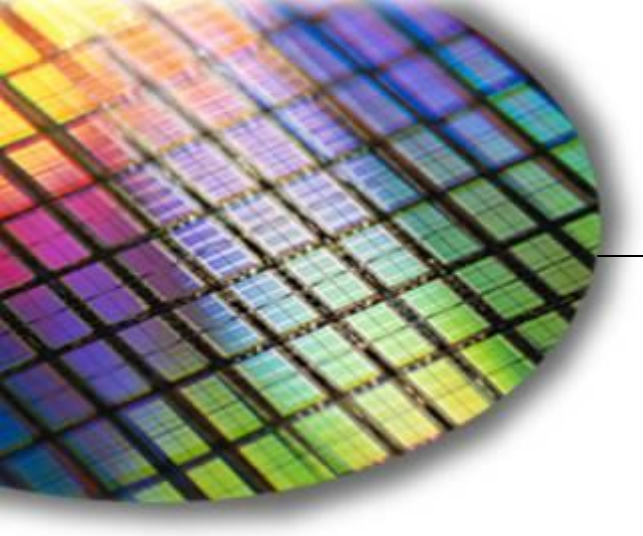
电压基准源产品

ANALOG DEVICES

What Is Going To Be Covered Today?



- What is a voltage reference?
- What is the difference between a shunt and series voltage reference?
- Key Characteristics of a voltage reference.
- What is the effect of voltage references in data converters.
- External vs. Internal voltage references.



What Is a Voltage Reference?

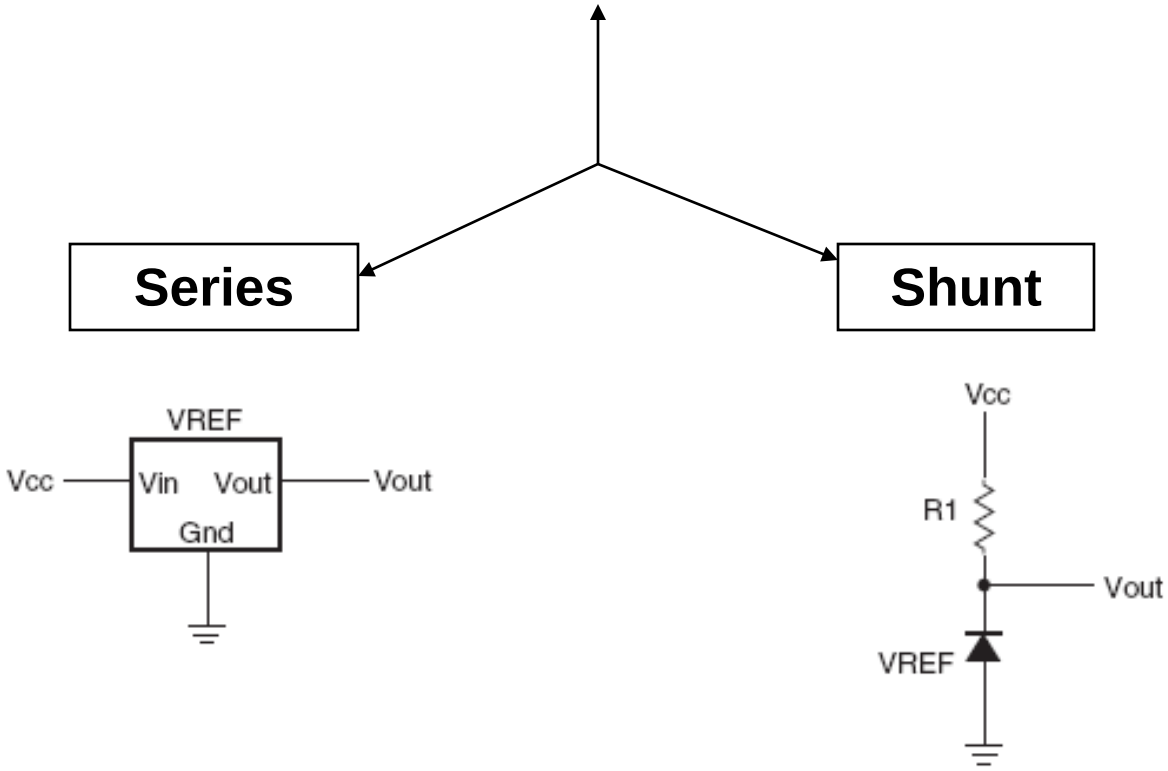
An ideal voltage reference is a device that provides a

precise output voltage
irrespective of
loading condition,
input voltage, and
temperature.

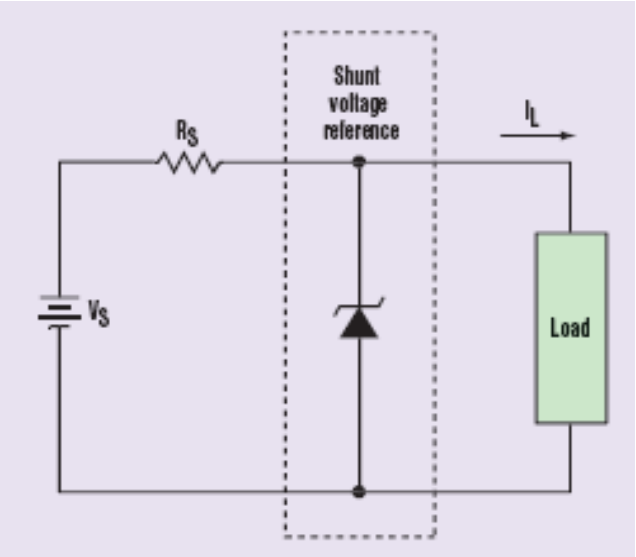
Parameter	*Voltage Reference*	*Voltage Regulator*
Initial Accuracy	Good/Excellent	O.K.
T.C.	Good	O.K.
Package Size	Small	Large
Thermal Shutdown	Usually Not	Yes
Long Term Stability	Usually Yes	Sometimes
Output Voltage	Fixed and Adjustable	Fixed and Adjustable
Configuration	Shunt and Series	Series
Output Current	Low	High

Types of Voltage References

Voltage References

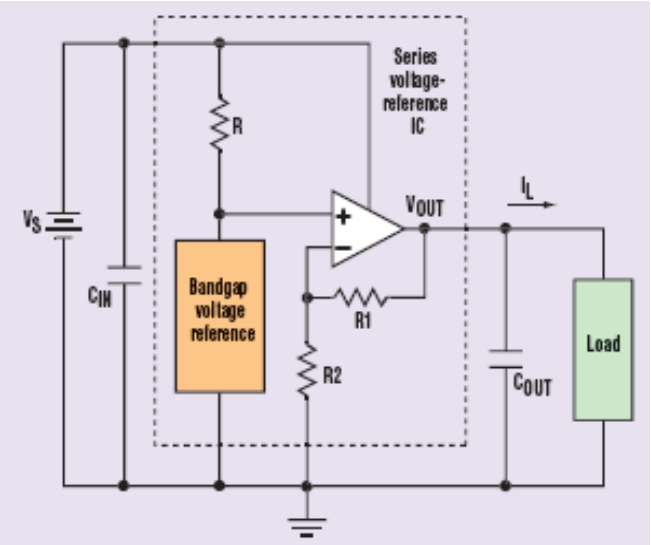


Shunt Reference



- A two-terminal Device
- Need for an extra resistance
- Need more board space

Series Reference

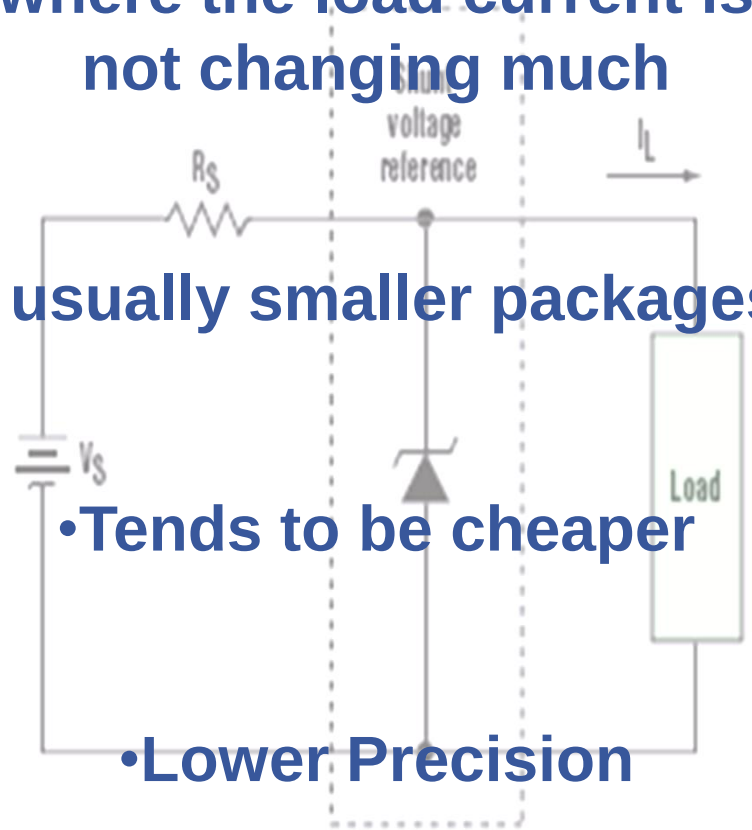


- A three-terminal device
- No need for an extra resistance
- Typically lower Vin range

ANALOG DEVICES

Shunt Reference

•Better in applications where the load current is not changing much



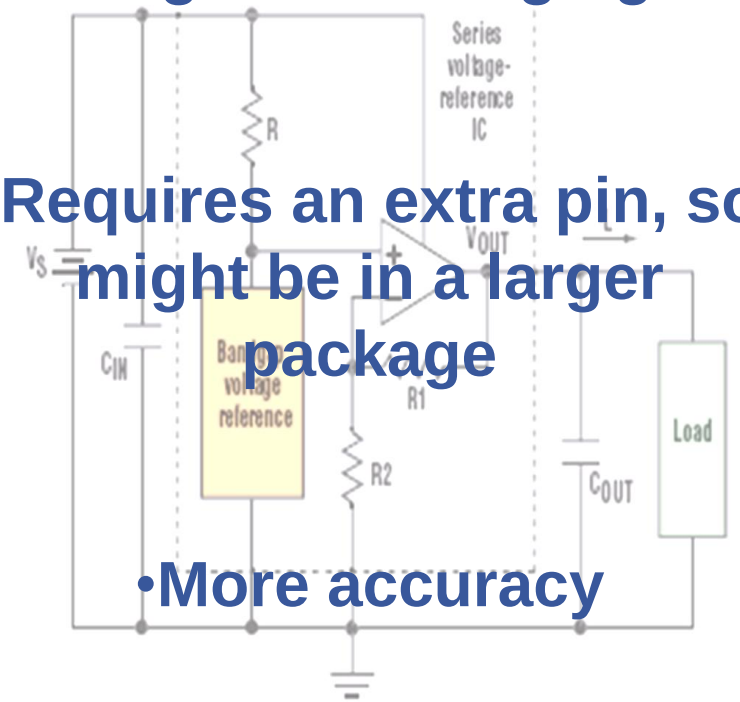
• usually smaller packages

•Tends to be cheaper

•Lower Precision

Series Reference

•Better in applications where the load current might be changing



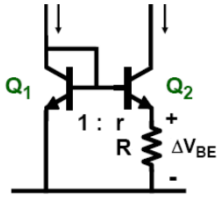
•Requires an extra pin, so might be in a larger package

•More accuracy

ANALOG DEVICES

4 Topologies of Voltage References that are offered by ADI.

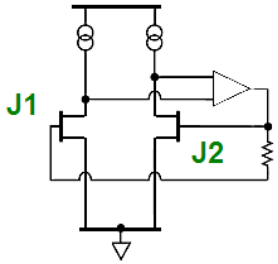
- **Bandgap: general purpose references**



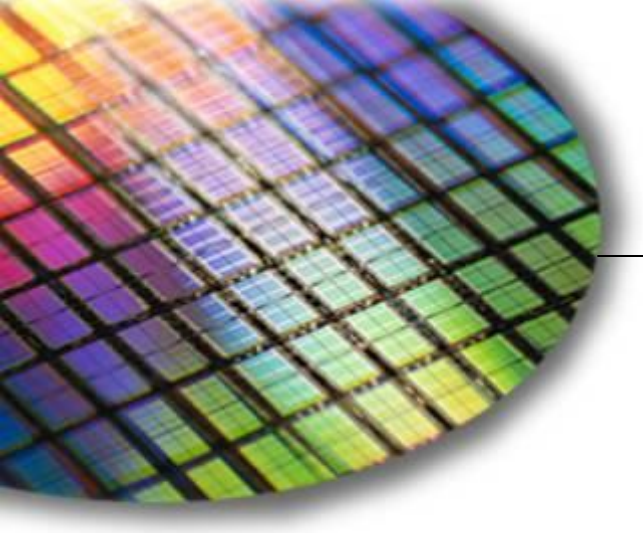
  - Best tempco in SOT and SC70
  - Suited for applications that require low Vref, Low operating current and medium temperature drift.

- **Buried Zener: Older high accuracy references**
  - Higher Current consumption than Bandgap references.
  - Suited in applications that require low TC and noise, higher operating current.

- **XFET: High accuracy, low noise references**
  - They depend on JFET instead of bipolar transistors



- **Zener: Low cost, low accuracy**



Characteristics of a Voltage Reference

Characteristics of a Voltage Reference

Initial Accuracy

The tolerance of your voltage reference expressed in %, mV, µV, or ppm.

To Convert From ppm to percentage

1 ppm = 1 millionth of Vout

10 ppm accuracy of 2.5V :

1 ppm = 2.5µV => 10 ppm = 25µV

(25µV / 2.5V) *100 = 0.001%

Characteristics of a Voltage Reference

Initial Accuracy

What is the use of the Trim Pin on series reference?

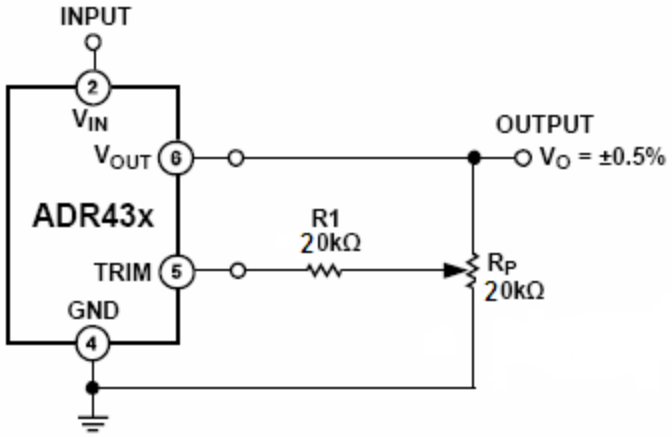


Figure 31. Output Trim Adjustment

Nominal+0.5% =5.02478V

Nominal=4.99978V

Nominal-0.5%=4.97478V

ANALOG DEVICES

Characteristics of a Voltage Ref.

Temperature Coefficient

Deviation of Reference output voltage due to change in temperature

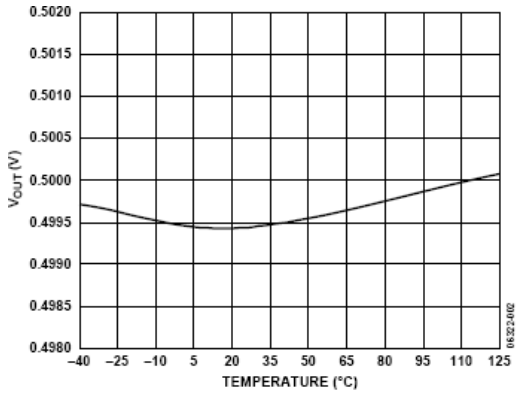


Figure 2. VOUT vs. Temperature, VOUT = 0.5 V

TEMPERATURE COEFFICIENT	TCV_O				
A Grade		$-40°C < T_A < +125°C$	2	10	ppm/°C
B Grade		$-40°C < T_A < +125°C$	1	3	ppm/°C

TC error in an application that runs between 0° C and 85° C

3ppm/° C*10^-6*2.048V*(85° -(-0°)) = 0.52mV

ANALOG DEVICES

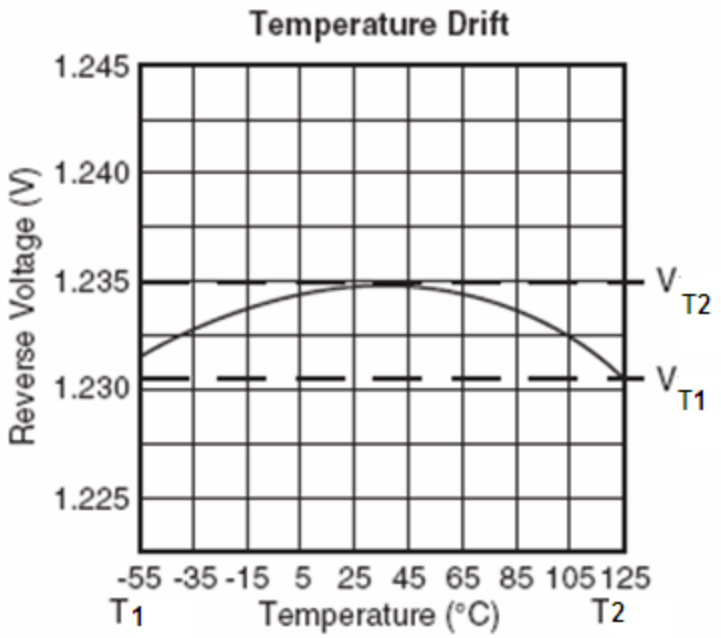
Characteristics of a Voltage Ref.

Temperature Coefficient

How do we specify this parameter?

"Box Method"

$$TCV_O[\text{ppm/°C}] = \frac{V_O(T_2) - V_O(T_1)}{V_O(25°\text{C}) \times (T_2 - T_1)} \times 10^6$$

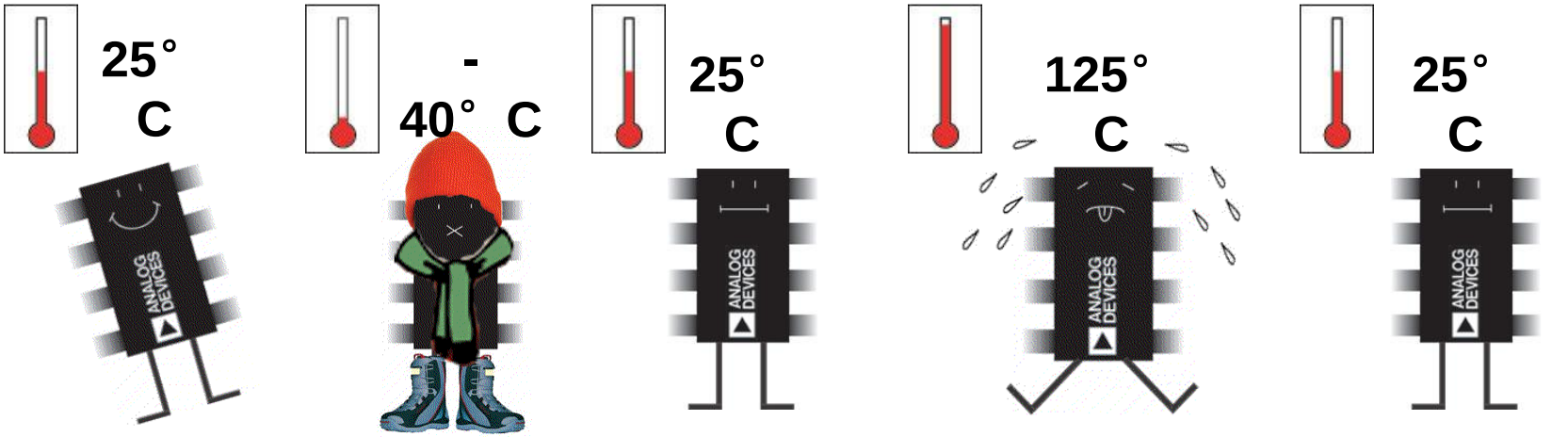


ANALOG DEVICES

Key Characteristics of a Voltage Ref.

Thermal Hysteresis

Total change in the output voltage after a temperature cycle.



OUTPUT VOLTAGE HYSTERESIS	V_{O_HYS}	20	ppm

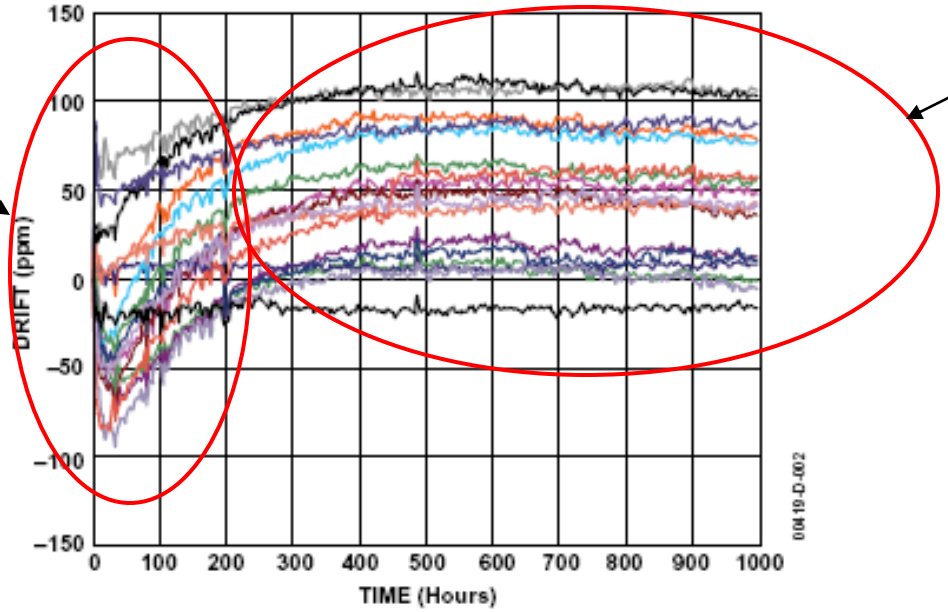
ANALOG DEVICES

Characteristics of a Voltage Ref.

Long-Term Drift

The parameter that tries to predict the amount of change in the output voltage over extended period of time.

Highest amount of changes happen in the first 100s of hours



The output stabilizes

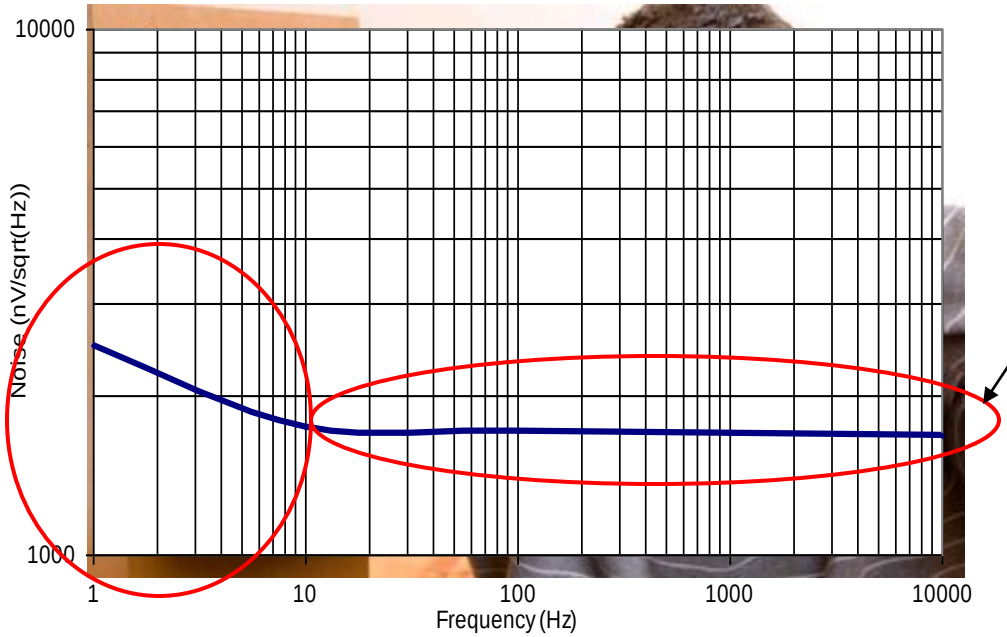
ANALOG DEVICES

Characteristics of a Voltage Ref.

Noise

Random unwanted signal which is specified as a peak-peak voltage for low frequency 0.1-10Hz BW and µVrms for 10-1KHz.

The noise is very hard to be filtered



The noise can be filtered

Key Characteristics of a Voltage Ref.

Line and Load Regulation

Line regulation: changes in the output with respect to changes to input.

Load regulation: changes in the output with respect to changes in the load.

Series(ADR280) (1.2V)

Line Regulation	$\Delta V_{OUT}/\Delta V_{IN}$	$2.55\,V < V_{IN} < 5.5\,V$, No Load		2	12	ppm/V

Shunt (ADR520)

Output Voltage Change vs. I_{IN}	ΔV_R	I_{IN} = 0.1 mA to 15 mA $-40°C < T_A < +85°C$		1 4	mV mV

12ppm * 1.2µV/ppm= 14.4µV

14.4µV/V * (5.5-2.55)V = 42.48µV

What is the effect of voltage reference on data converters?

ANALOG DEVICES

What is the effect of Voltage refs on Data Converters?

- **Effect of voltage reference on ADC**

$$\text{Digital output} \propto \frac{\text{quantized input}}{\text{“full scale” reference}}$$

- **Effect of voltage reference on DAC**

$$\text{Analog output} \propto \text{reference X digital input}$$

Example of Voltage Reference Effect on An ADC

- **Effects of Voltage Reference on ADC**

Δ Vref = Δ in full scale Vout, LSB size changes

Assume 12-bit ADC ➔ 2^12=4096 Bits.

Choosing ADR392B (4mV error accuracy)

1LSB = 4.096/4096 = 1mV with no errors from REF.

Now with REF error ➔ 1LSB = 4.100/4096= 1.001mV

Assume ADC input of 2.047V

Ideal LSB=1mV, 2.047V/1mV = 2047= 011111111111

Actual LSB= 2.047V/1.001mV=2045 = 011111111101

Characteristics of a Voltage Ref.

Temperature Coefficient(T.C.)

For System TC < 0.5 LSB

Resolution (BITS)	.5LSB for 5V Full scale (mV)	TC required (ppm/° C)
10	2.44	5.74
12	0.61	1.43
14	0.15	0.35

Over 0° C to 85° C

For a 12-Bit accuracy system:

2^12= 4096

5 / 4096 = 0.00122V 1 LSB

0.00122V / 2 = 610 µV 0.5 LSB

610 µV = 122 ppm

TC = 122 / 85 = 1.43 ppm/ ° C

Key Characteristics of a Voltage Ref.

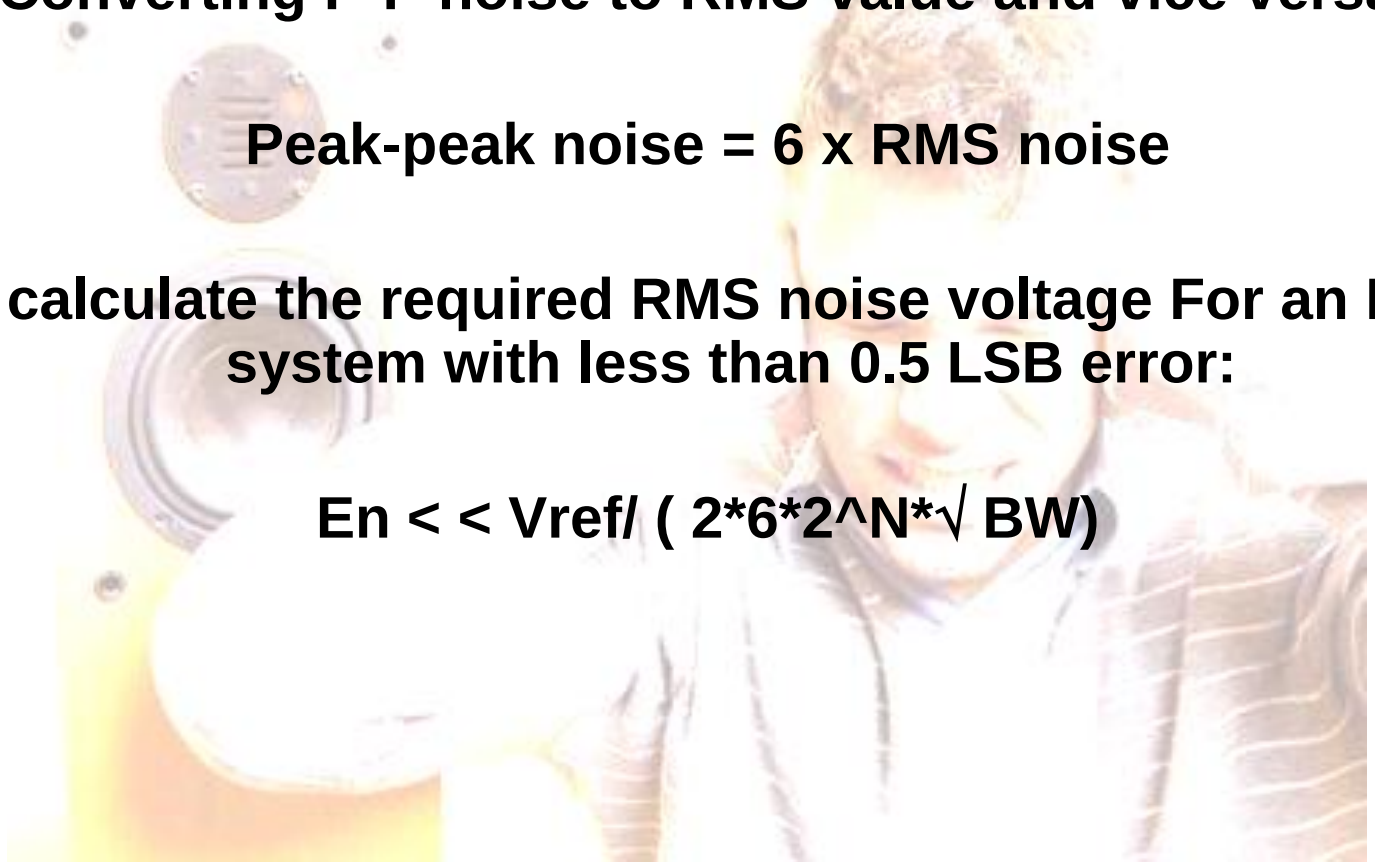
Noise

Converting P-P noise to RMS value and vice versa:

Peak-peak noise = 6 x RMS noise

To calculate the required RMS noise voltage For an N bit system with less than 0.5 LSB error:

En < < Vref/ (2*6*2^N*√ BW)



Example : 10 BIT system with 2.5V Ref operating at 0 to 50C

Total Error From Reference= Accuracy Error + T.C. + Noise

Total Error From Reference < 0.5 LSB

I will allocate:

0.2LSB to accuracy+.2LSB to T.C.+ 0.05LSB to Noise

➔ Total error =0.2 +0.2 +0.05 = 0.45

Example : 10 BIT system with 2.5V Ref operating at 0 to 50C Frequency(10Hz – 20KHz)

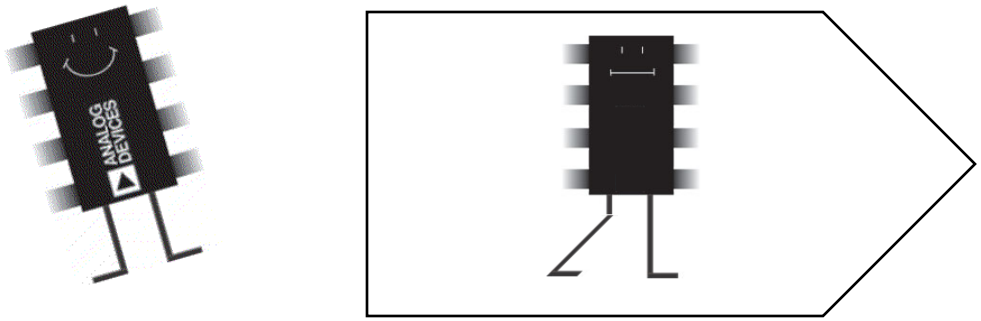
Accuracy Error(0.2LSB)	T.C. Error(0.2LSB)	Noise Error(0.05LSB)
2^10 = 1024 bits 2.5V/1024 = 2.44mV 1LSB 2.44mV*0.2 = 0.488mV 0.3LSB 0.488mV/2.5V*100 = 0.02 %	2.44mV 1LSB 2.44mV*0.2=488µV 244µV 0.1LSB 488µV*1ppm/2.5V= 195.2 ppm/50C=3.9 3.9ppm/C	En : 2.5/(6*2^10* √ BW) = 2.87 µV/ √Hz 1LSB 2.87 * 0.05 = 143nV/ √Hz

Recommendation: AD780

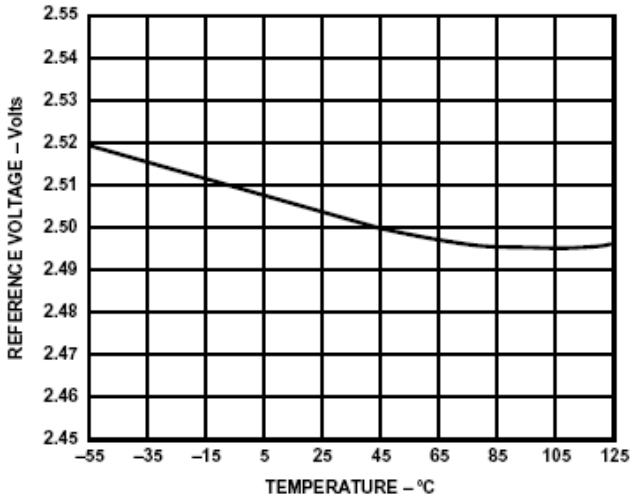
with 0.04% accuracy; T.C. 3ppm/C ; Noise 100 nV/ √Hz

External Reference vs. Internal Reference Use for Data Converters

- **Higher precision from ext. REF.**
  - **Ext. Ref can have a much better temperature coefficient.**
- **Triming feature on ext. REF allows exact converter output to be met which is not possible with on board Ref.**
- **Ext. REF. can provide common voltage to multiple converters increasing the overall accuracy.**



External Reference vs. Internal Reference Use for Data Converters



AD872A

Using the box method:

(2.516V-2.495V)/(125-(-40))C/2.5V*10^6=

= 51 ppm/C

Current Consumption= 500µA

Noise = 28 µVrms

ADR361

TEMPERATURE COEFFICIENT	TCV_O	A grade: $-40°C < T_A < +125°C$ B grade: $-40°C < T_A < +125°C$			25 9	ppm/°C ppm/°C
QUIESCENT CURRENT	I_{IN}	$-40°C < T_A < +125°C$		150	190	µA
VOLTAGE NOISE	$e_{N\,p-p}$	0.1 Hz to 10 Hz		9.3		µV p-p

ANALOG DEVICES

voltage reference check list for data converters

ANALOG DEVICES

- Output Voltage
- Input Voltage
- Initial Accuracy
- Ability to sink and source current
- Line and Load regulation
- Supply Current
- Temp Co.
- Turn-on Time
- Cost

Reference Market

- Three major voltage reference application areas

Signal Processing

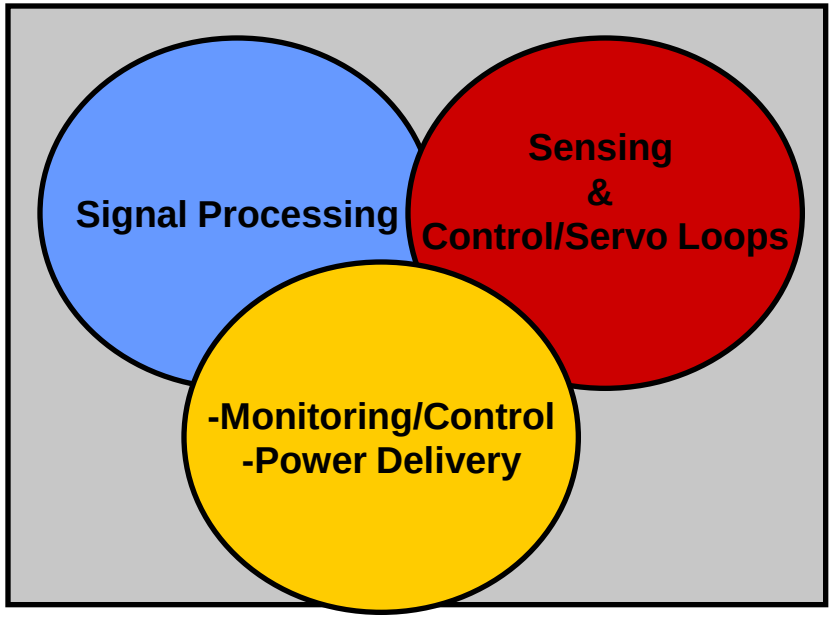
- Companion parts for data converters
- Sets system accuracy
- Utilizes the most accurate references

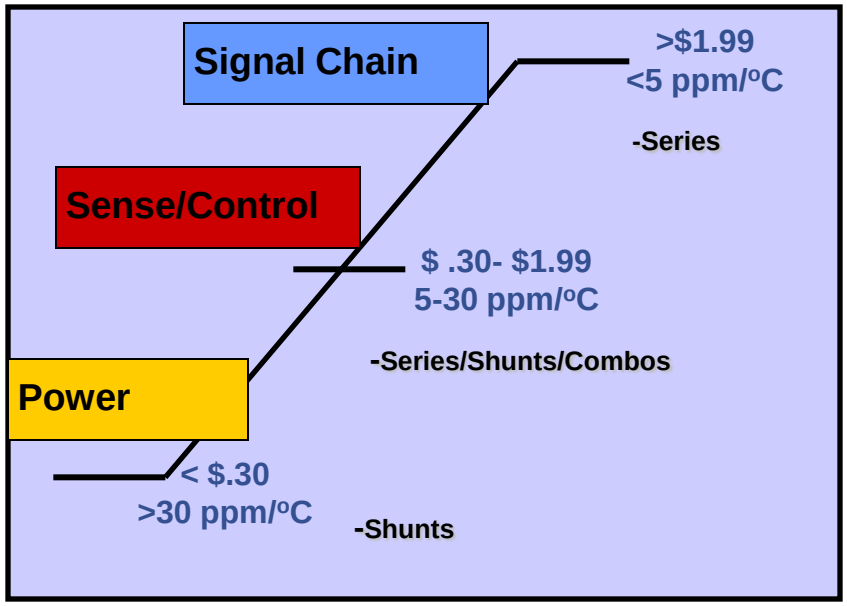
Sensing & Control Loops

- Higher precision at value prices
- Attack with combos (Amps, comparators + Refs)

Power

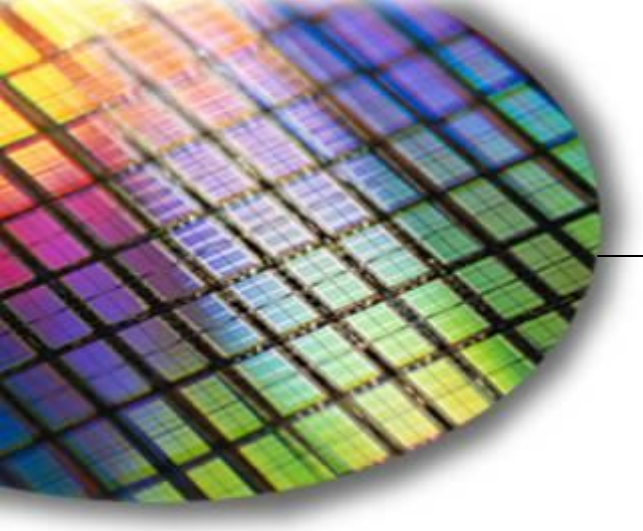
- Low voltage/power need more precision
- Fill gaps with shunts and value references
- Take advantage of NSM raising prices





Summary

- Shunt vs. Series Voltage references
- The effect of voltage references on data converters



Voltage reference products

ANALOG DEVICES

Recently Released Reference Products

- **ADR34xx – Low power, low cost precision references**
  - 10ppm/ºC max TC from -40ºC to +125ºC
  - 80µA supply current max
  - 1.25, 2.048, 2.5, 3.0, 3.3, 4.096, 5 volt output versions
  - SOT23-6 package

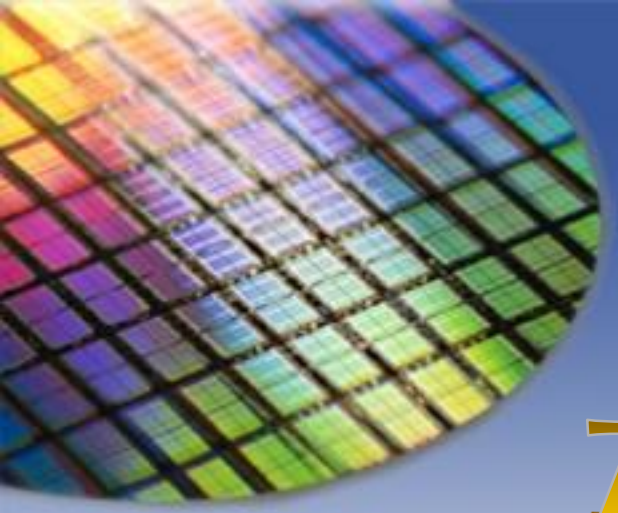
- **ADR45xx – Ultra low noise, high precision references**
  - 1µVp-p noise from 0.1Hz to 10 Hz
  - 2ppm/ºC max TC from -40ºC to +125ºC
  - 700µA supply current max
  - 2.048, 2.5, 3.0, 3.3, 4.096, 5 volt output versions
  - SOIC-8 and MSOP-8 packages

Product Specifications

Specification	ADR34xx
Temp Range	-40°C to +125°C
Quiescent Current	70 µA
Supply Voltage Range	(Vo + Dropout) -5.5 V
Output Voltage (Volts)	1.25, 2.048,2.5, 3.0, 3.3, 4.096, 5
Initial Accuracy	< 0.1 %
Temperature Coefficient	10 ppm/°C max
Drop Out Voltage (Vo-Vin)	400mV (Max Temp) @ 2mA
Output Noise (0.1 Hz to 10 Hz)	<10 µV p-p
Wideband Noise (10 Hz to 10 KHz)	40 µV rms
Output Current Source/Sink	+10/-3 mA
Output Voltage Hysteresis (0°C to +70°C)	50 ppm
Output Voltage Hysteresis with post cure	100 ppm
Long Term Stability	50 ppm
Package	SOT23-6

Product Specifications

Specification	ADR45xx
Temp Range	-40°C to +125°C
Quiescent Current	700 µA
Supply Voltage Range	(Vo + Dropout) -5.5 V
Output Voltage (Volts)	2.048,2.5, 3.0, 3.3, 4.096, 5
Initial Accuracy	< 0.01 %
Temperature Coefficient	2 or 3 ppm/°C max
Drop Out Voltage (Vo-Vin)	50mV (Max Temp) @ 2mA
Output Noise (0.1 Hz to 10 Hz) @ 2.048V	<1 µV p-p
Output Current Source/Sink	+10/-10 mA
Output Voltage Hysteresis	50 ppm
Long Term Stability	50 ppm
Package	SOIC-8



谢谢！

ADI中国地区技术支持热线：4006 100 006

ADI中国地区技术支持信箱：china.support@analog.com

ADI样片申请网址：http://www.analog.com/zh/sample

MAKEADIFFERENCE