October 2015

Voltage Reference Applications

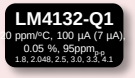
Interactive Selection Guide

Contents

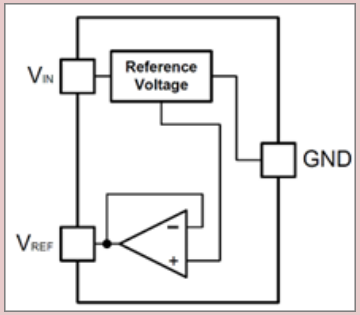
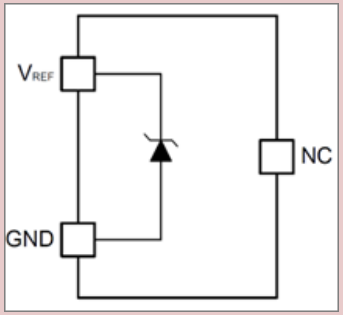
- User Guide
- Introduction to Voltage References
- Voltage Reference Parameters
- Market Sectors Menu (Home)
  - Application Overviews and Selection Guides

User Guide

- View in presentation mode for interactive experience
- Use embedded hyperlinks throughout guide to navigate between:
  - Sector home pages
  - Corresponding XY part-selection charts
  - Design parameter information pages

To view…	Click on…
Market Sector Menu	
TI.com sector home page to view end equipment block diagrams	
Application-specific parameters: higher priority	
Application-specific parameters: lower priority	
Parts to consider	
Product page on ti.com	

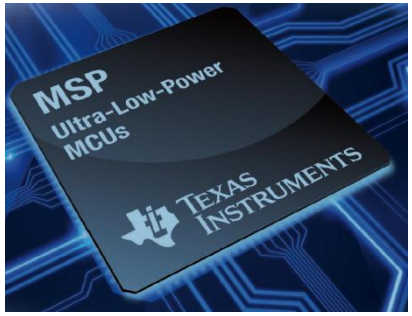
Introduction to Voltage References

	Series References	Shunt References
Diagram		
Number of Terminals	At least 3	At least 2
Advantages	• Significantly lower power dissipation • Generally higher precision • Lower dropout • Lower Iq	• No limit on maximum V_{IN} • V_{REF} not changing over V_{IN} • Can be used to create negative or floating reference voltages • Inherent current sourcing and sinking

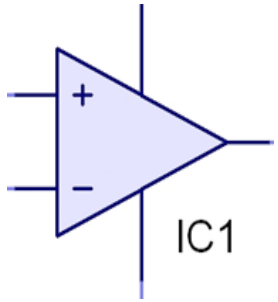
Common Vref Applications

OR

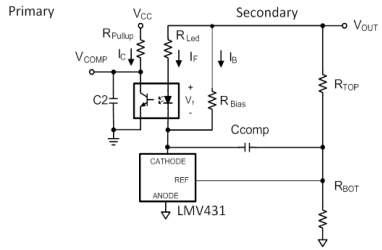
≥ 8 bits



MCUs or ASICs w/ integrated Data Converter

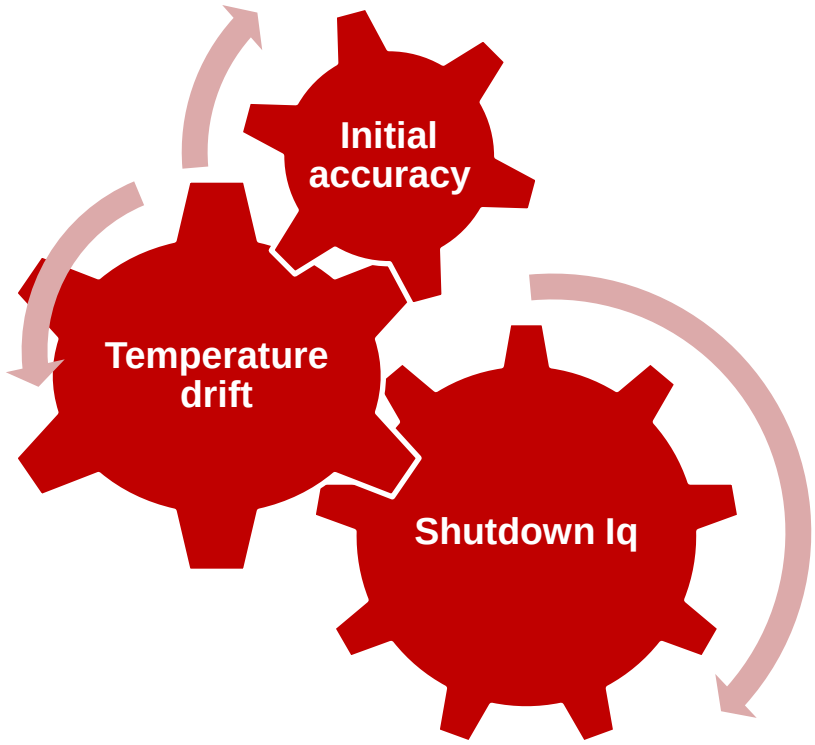


Comparators



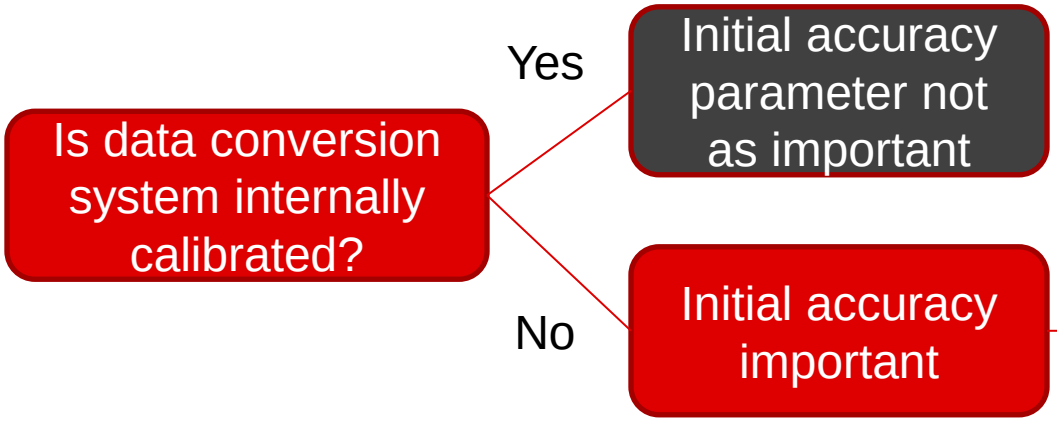
Flyback Opto-Isolator Circuit

Voltage Reference Parameters and Care-Abouts



Initial Accuracy

- How close to stated nominal voltage the reference voltage is guaranteed to be at room temperature
- Typically specified as percentage between 0.01-2.0% (100-20,000 ppm)



Accuracy	Range
Higher	<0.1%
Medium	~0.1-1.0%
Lower	>1.0%

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Temperature Coefficient/Drift (Tempco)

- Variation in Vref over temperature
- Specified in ppm/°C or can be calculated using V_{dev} (V_{max}-V_{min}) specification

$$Vref\ \left[\frac{ppm}{°C}\right] = \pm\frac{\left(\frac{Vmax - Vmin}{Vref\ (at\ 25°C)}\right) \times 10^6}{T_2 - T_1\ (full\ temp\ range)}$$

- Consider application's use case environment and practical user situations

Tempco	Est. range	Example applications
Very low	<10 ppm/C	Automotive, space/avionics/defense, building automation, factory automation, lab test equipment
Low	~10-50 ppm/C	Portable or hand-held equipment
Medium	~50-100 ppm/C	Portable or hand-held equipment
High	>100 ppm/C	Power supply

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Noise

- Internal noise (flicker noise 1/f) of voltage reference IC causes error

Noise type	Frequency range	Typical specification	Easy to filter out?
Low-Frequency Noise (LFN)	0.1Hz – 10Hz	V_{p-p}	No
Wide-Band Noise (WBN; broadband noise)	10Hz – 1kHz	V_{rms}	Yes

- Applications such as medical and lab instrumentation require low noise (<0.5uVp-p)
- Some series references (REF50xx) have additional trim/noise reduction pin to further adjust output voltage or create low-pass filter

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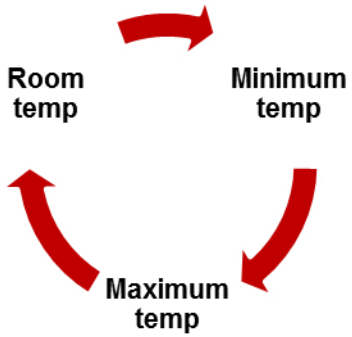
Stability Concerns

- **Long-Term Stability**
  - Shift in Vref after certain amount of continuous operation
  - Typically expressed in PPM after 1000hrs
  - Typically package dependent

- **Thermal Hysteresis**
  - Shift in Vref due to thermal cycles
  - Typically expressed in PPM
  - Typically dependent on package, material, IC layout



Thermal cycle

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Power Consumption

For the same performance, a series reference would consume less power than a shunt reference:

Shunt references	Series references
Designed for maximum (peak) current in system. If system does not need current, reference shunts this current towards ground.	Only draws current needed by system (plus current needed to operate reference). This results in lower average current consumption
	Some series references (LM41xx) have additional enable pin capability to shutdown reference when not in use
	Lower Iq results in lower average current consumption

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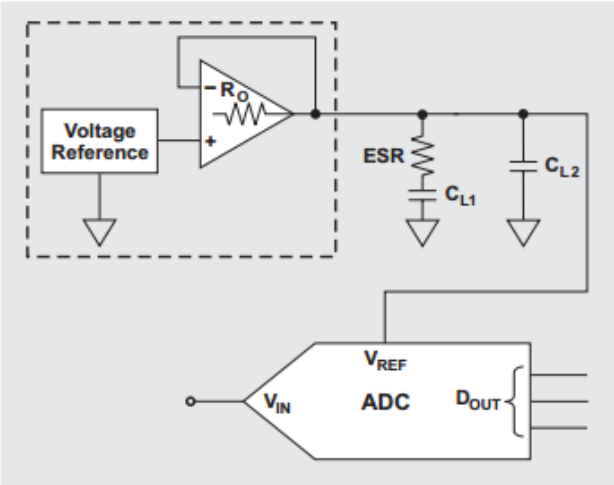
ADC Resolution

- External Vrefs are often used to achieve accurate data conversion measurements because internal ADC references may not offer the required precision
- ADC datasheets will specify voltage reference input (V_{REF} output) if external Vref option is supported

Resolution	Bits	Example applications
Higher	>16 bits	Lab-grade test instruments
Medium	12-16 bits	Precision instruments, factory automation, automotive, motor drives, medical instruments
Lower	<12 bits	Power supplies



Example configuration of external Vref as input to ADC

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Market Sectors Menu

Resources

Test & Measurement

Building Automation

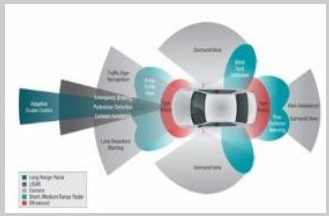
Factory Automation & Control

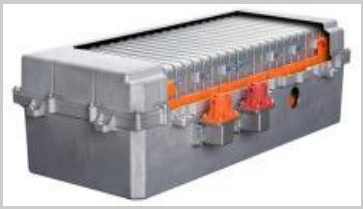
Motor Drives

Medical/Healthcare/ Fitness

Space/Avionics/ Defense

Automotive





Test and Measurement

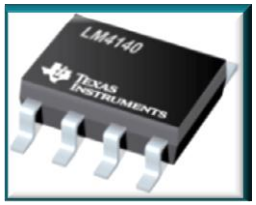
- Specific system care-abouts will depend on type of test and measurement equipment
- For example, lab bench equipment will have higher emphasis on low temperature drift and long-term stability, while portable instruments will have higher emphasis on low power consumption

Lab Equipment

- System care-abouts

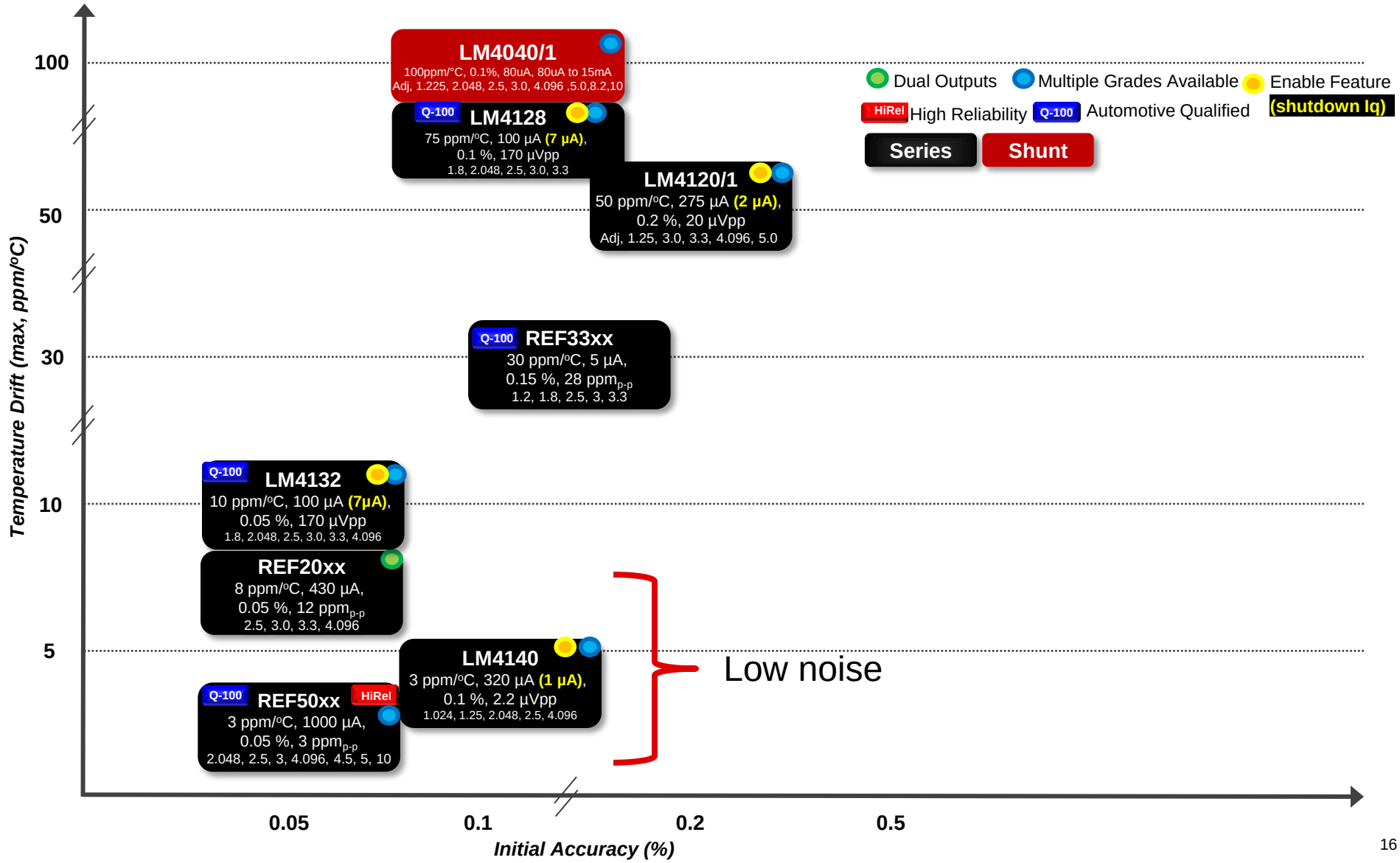
Initial acc [HIGH]	ADC res [MED-HIGH]	Power consumption
Temp drift [LOW]	Noise [LOW]	Long-term stability

- Example equipment
  - Vector signal analyzer
  - Spectrometer
  - Wireless communications tester
  - Bench digital multimeter
  - Oscilloscope weigh scale
  - Signal and waveform generator



Parts to consider

References for Lab Equipment



Back to Lab Equipment

Texas Instruments

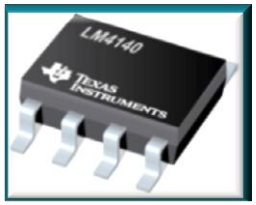
Portable Equipment

- System care-abouts

Power consumption [LOW]	ADC res [MED-HIGH]	Noise
Temp drift [MED]	Initial accuracy [MED-HIGH]	Long-term stability

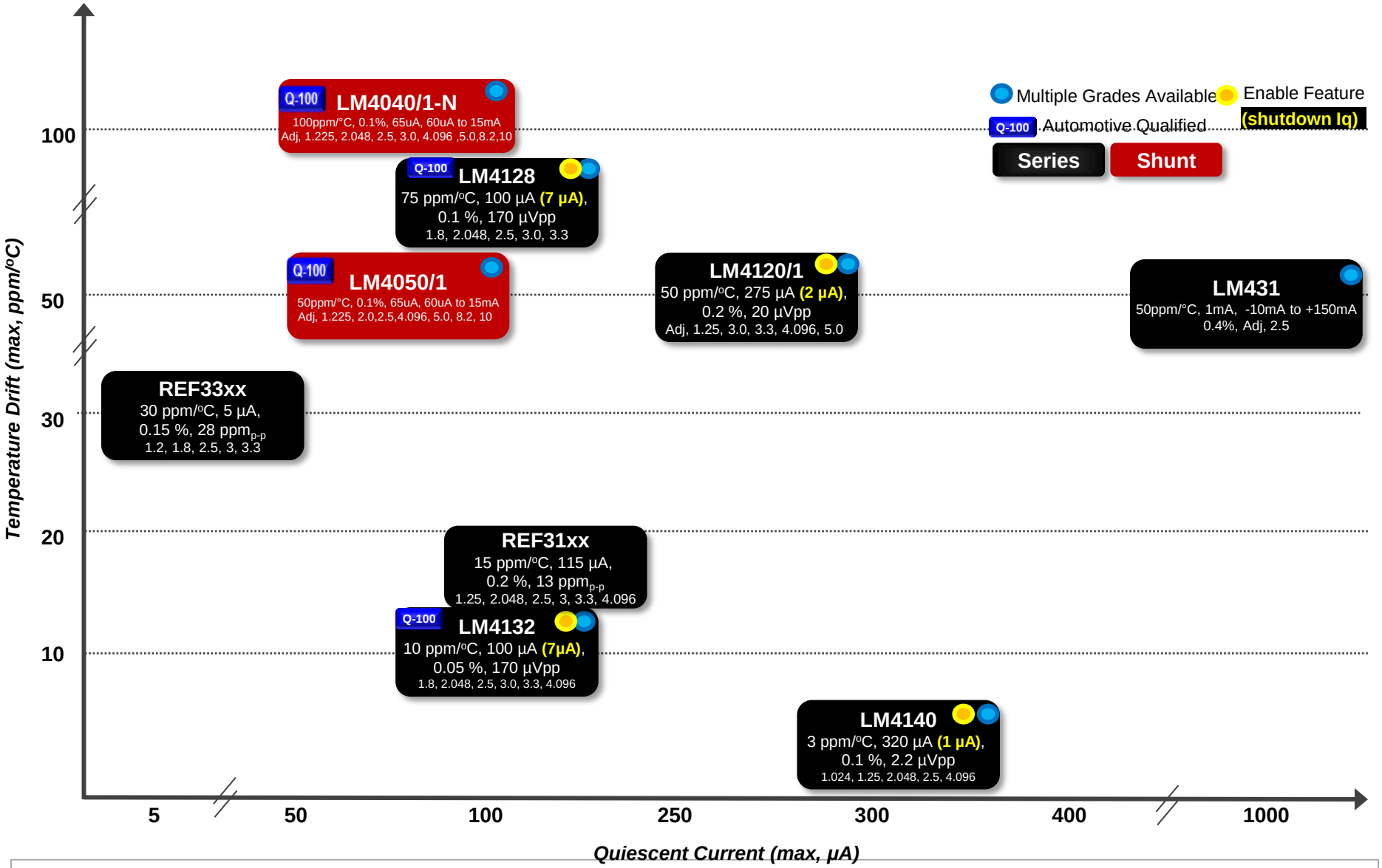
- For lower power and higher accuracy, consider series references. However, LM4040/1 C-D grades also work for medium-accuracy applications such as LCR testers

- Example equipment
  - Hand-held digital multimeter
  - Wireless communications tester
  - LCR tester



Parts to consider

References for Portable Equipment



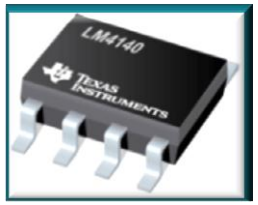
Back to Portable Test Equipment

Factory Automation & Control

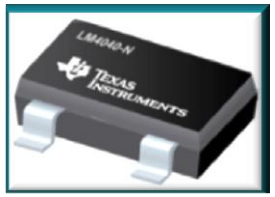
- System care-abouts

Initial acc [HIGH]	Power consumption [LOW]	ADC res [MED-HIGH]
Temp drift [LOW]	Noise [LOW]	Long-term stability

Examples of end equipment	Additional considerations
PLC: Analog I/O modules	Typ output voltages between 0-10V (consider adj Vout references); smaller packaging
PLC: Digital input modules	Typically have input voltages between 0-24V; need smaller packaging; consider shunt references for wide Vin requirements
Sensor transmitters	Low 1/f noise; low power consumption

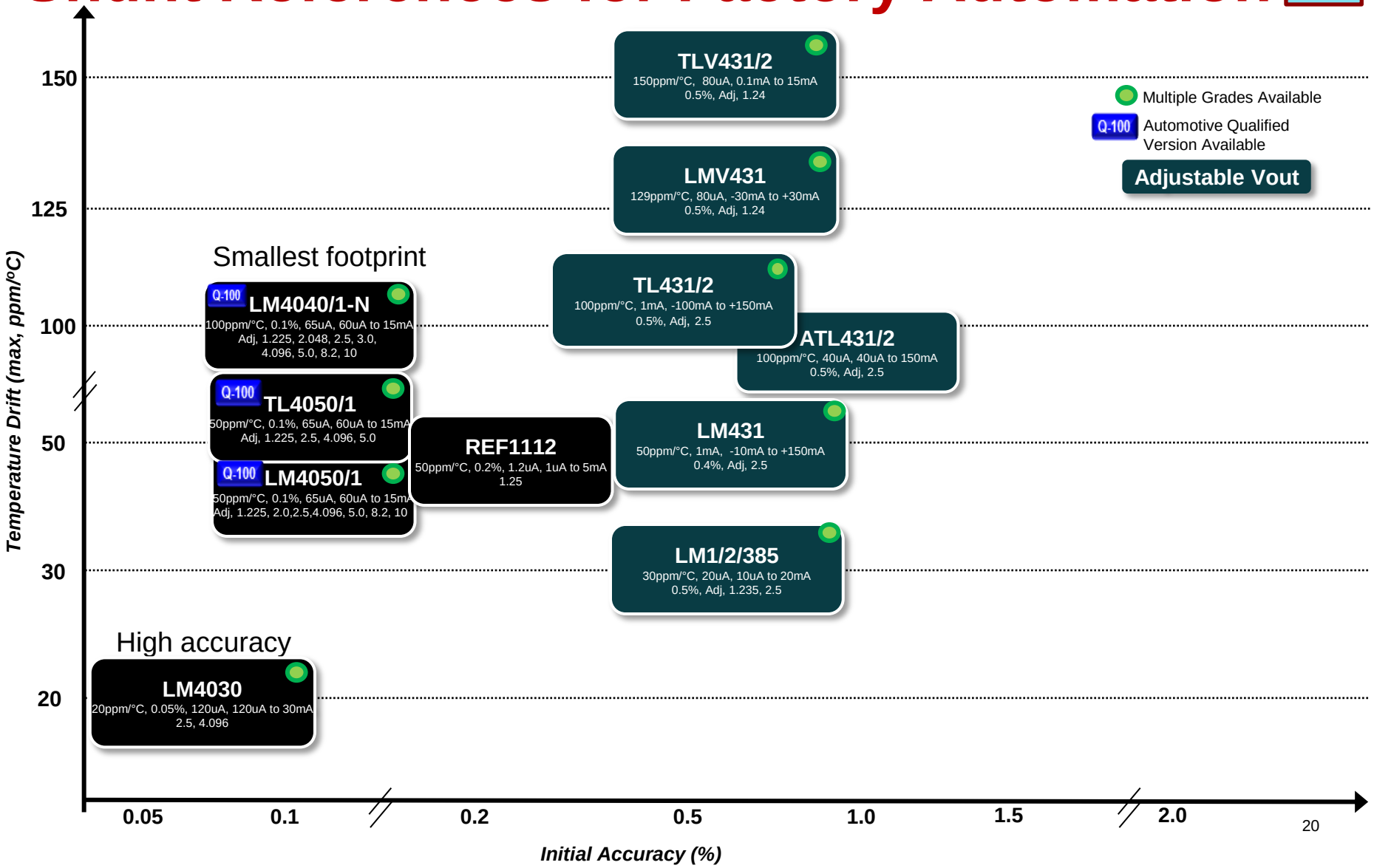


Series to consider



Shunts to consider

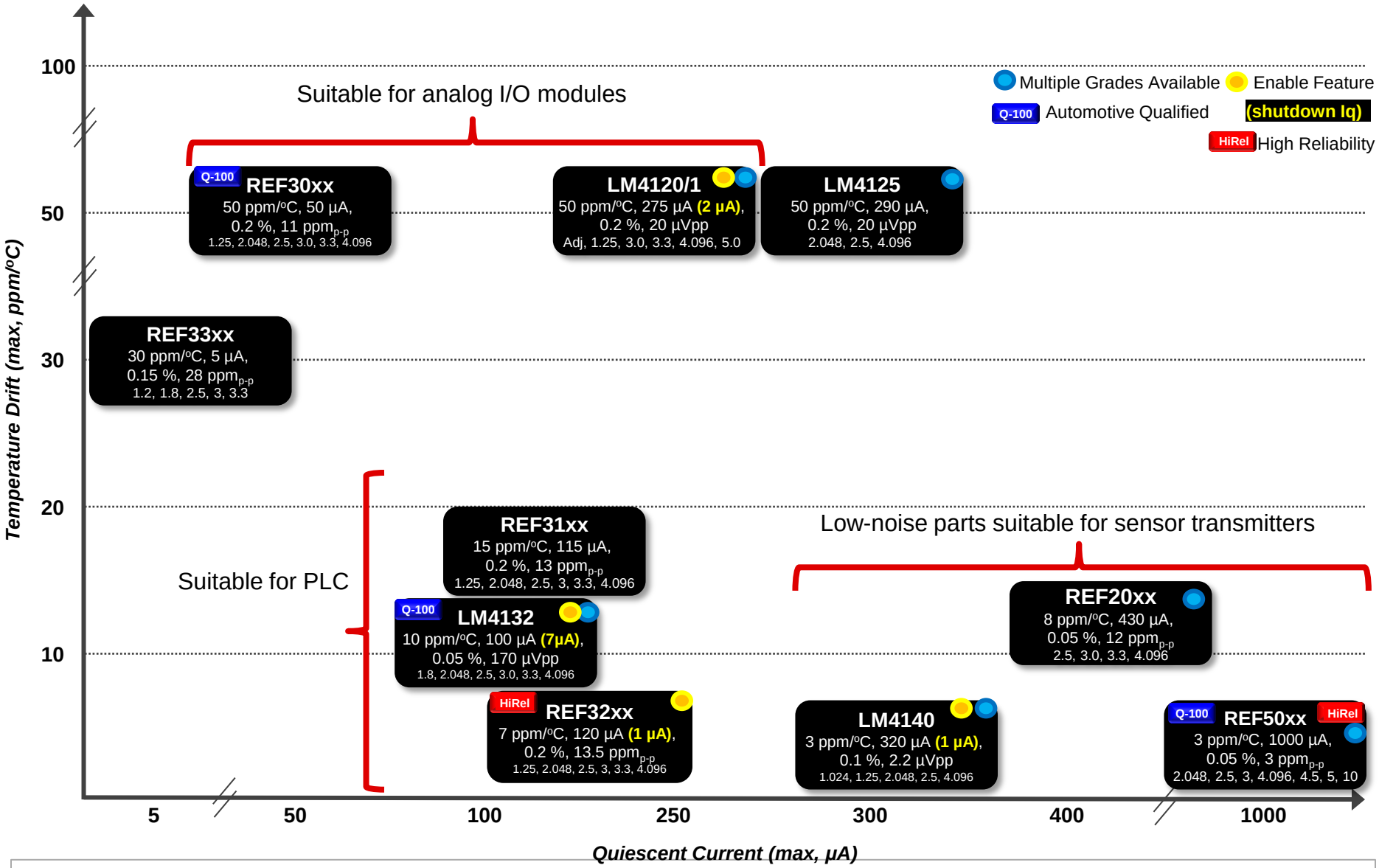
Shunt References for Factory Automation



Back to Factory Automation
Series References

Texas Instruments

Series References for Factory Automation



Back to Factory Automation

Shunt References

Texas Instruments

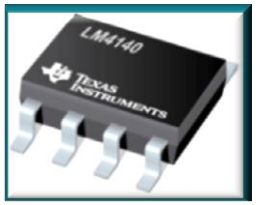
Medical Instrumentation

SBD

- System care-abouts

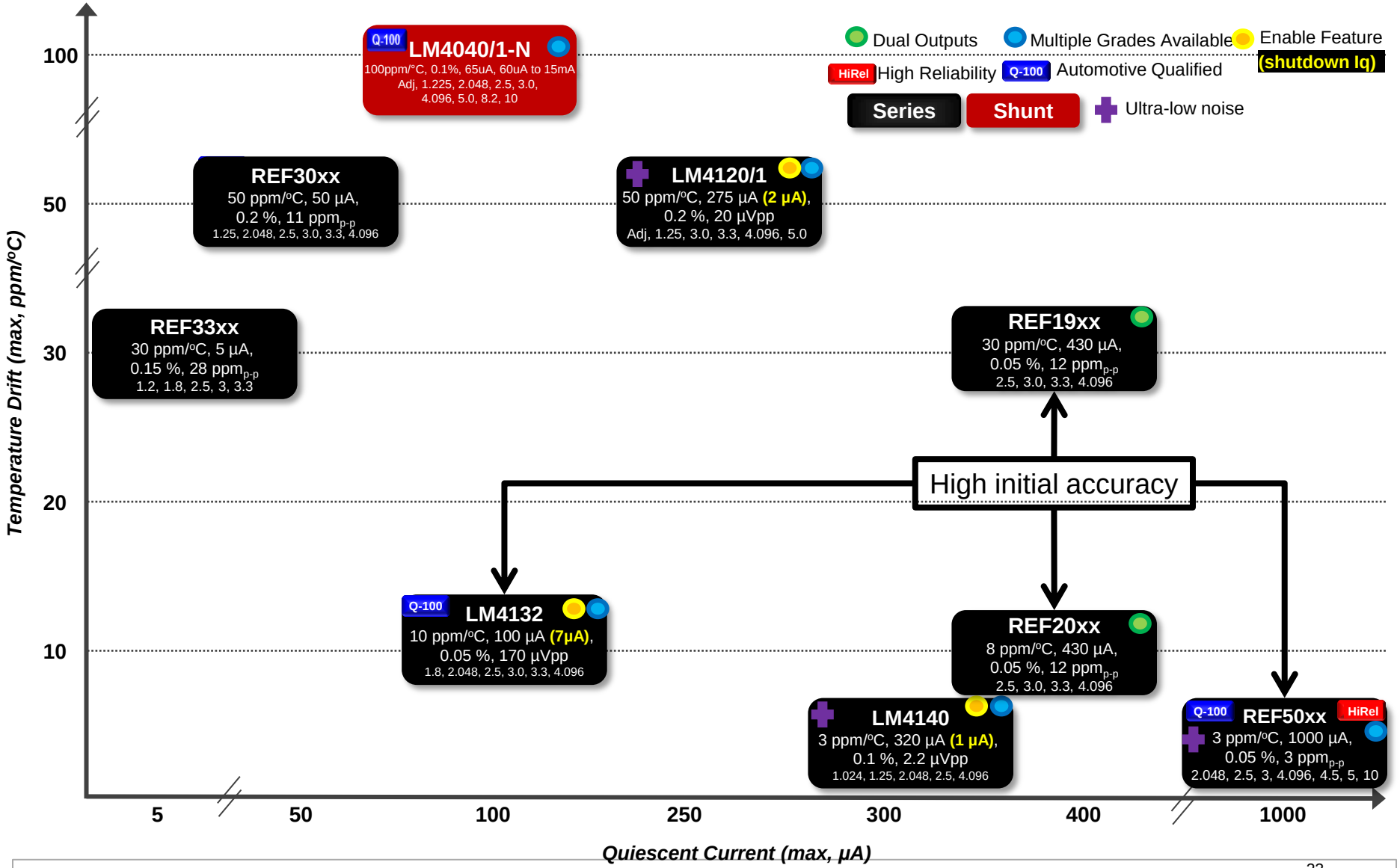
Initial accuracy [MED-HIGH]	Power consumption [LOW]	ADC res [MED-HIGH]
Temp drift [LOW]	Noise [LOW]	Long-term stability

	Examples of end equipment	Additional considerations
Portable	Patient monitoring, pulse oximeter, blood glucose	Low power consumption; medium accuracy
Hospital/lab	CT scanner, ultrasound equipment	Low noise, high accuracy



Parts to consider

References for Medical Equipment



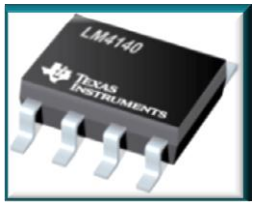
Building Automation

SBD

- System care-abouts

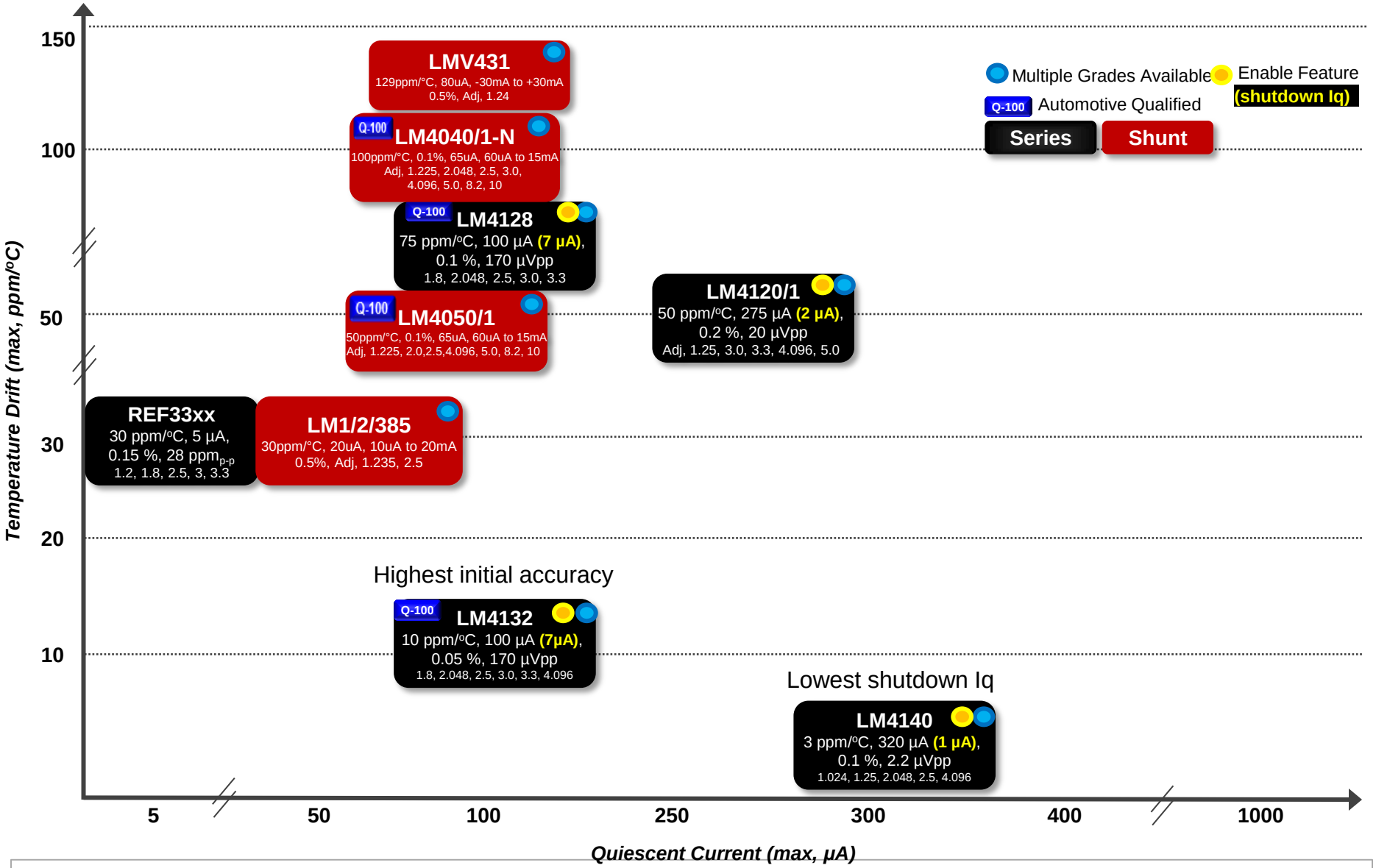
Power consumption [LOW]	Initial accuracy [MED]	ADC res
Temp drift [LOW]	Packaging [SMALL]	Long-term stability

- Example applications
  - Access control & security
  - HVAC
  - Video surveillance
  - Elevators/escalators
  - Building energy management



Parts to consider

References for Building Automation



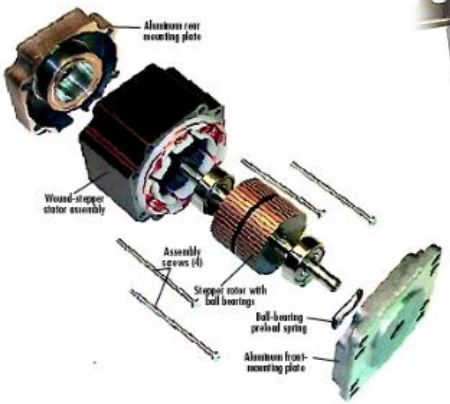
Back to Building Automation

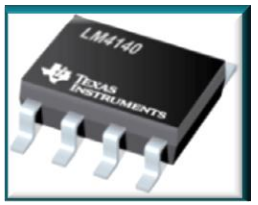
Motor Drives

- System care-abouts

Power consumption [LOW]	Initial accuracy [MED-HIGH]	Packaging
Temp drift [LOW]	ADC res [MED]	Long-term stability

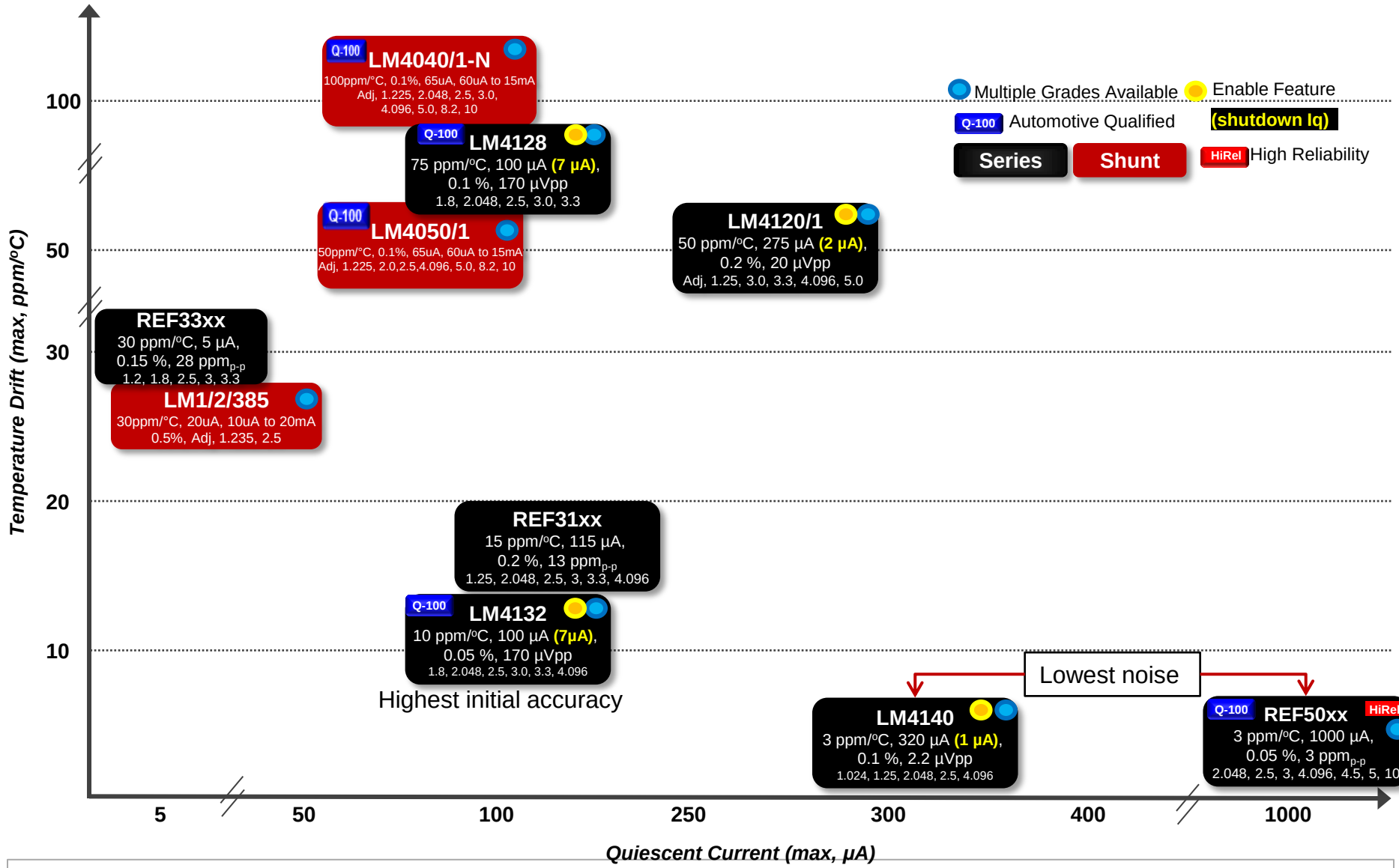
- Example equipment
  - Programmable logic controllers
  - Loop protection
  - Stepper motor





Parts to consider

References for Motor Drives



Back to Motor Drives

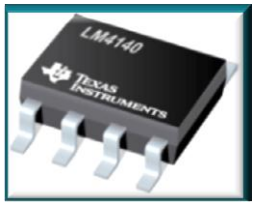
Space/Avionics/Defense

SBD

- System care-abouts

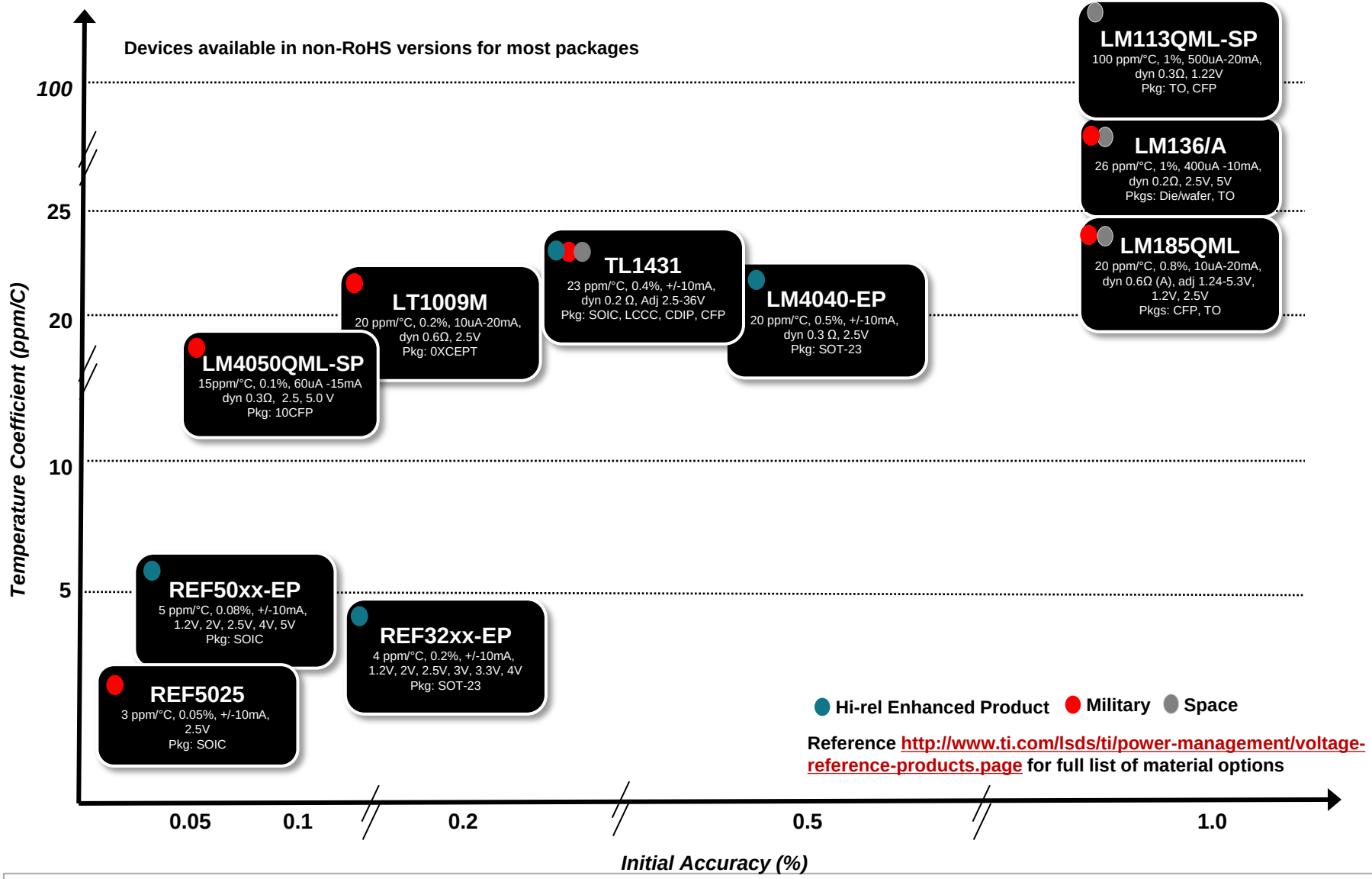
Noise [LOW]	Power consumption [LOW]	Packaging [SMALL]
Temp drift [LOW]	ADC res	Long-term stability

- Example equipment
  - Aircraft
  - Land defense
  - Satellite payload sensors
  - Military and avionics imaging
  - Munitions targeting



Parts to consider

References for Space/Avionics/Defense



Reference http://www.ti.com/lsds/ti/power-management/voltage-reference-products.page for full list of material options

Back to Space/Avionics/Defense

Automotive

- System care-abouts

Wide Vin	Initial accuracy [MED-HIGH]	Power consumption [LOW]
Temp drift [LOW]	Packaging [SMALL]	Long-term stability [HIGH]

SBD

XY Chart

Selection Grid

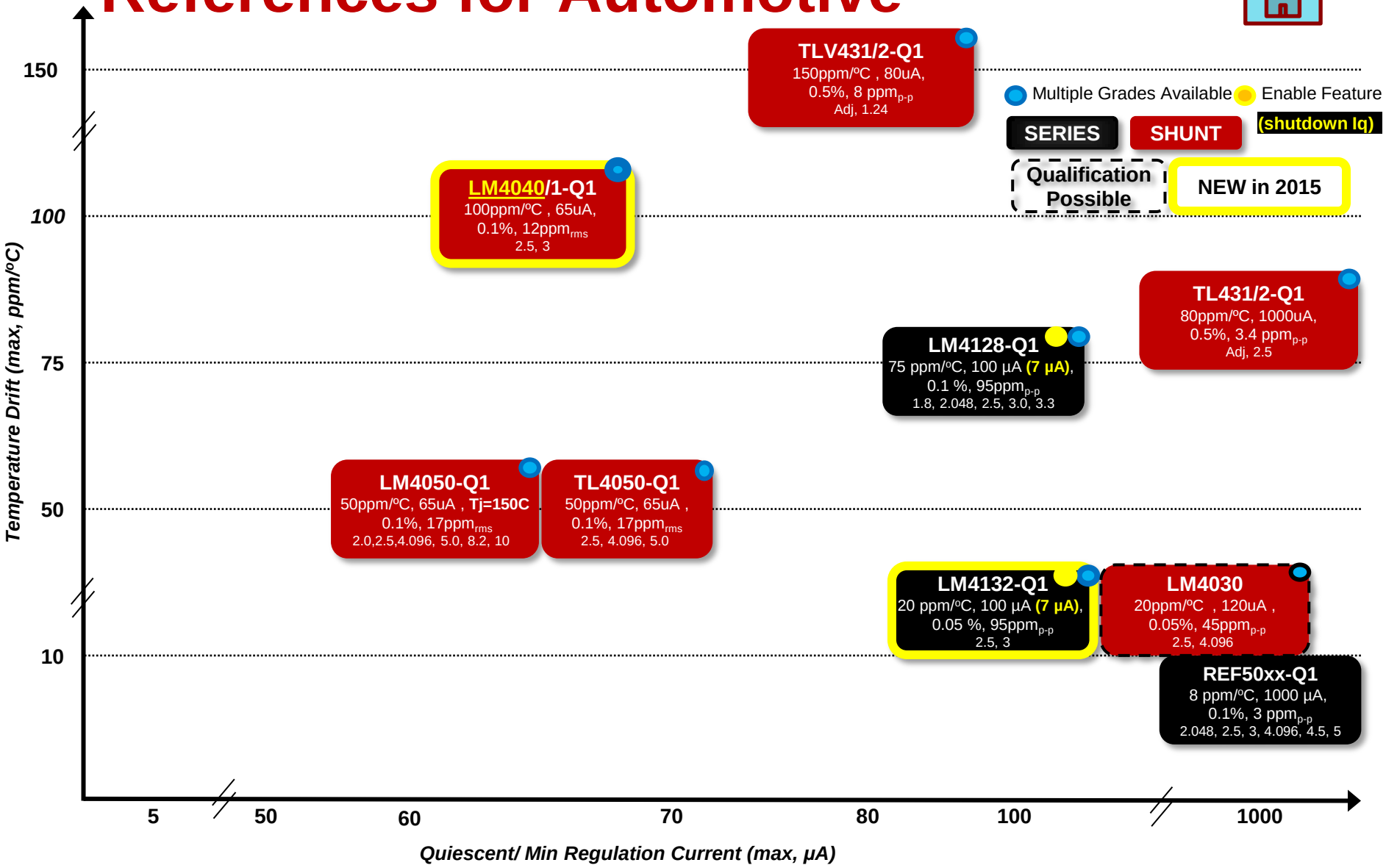
Application	Examples of end equipment	Considerations
ADAS	Camera modules (front, rear, surround), radar systems, ultrasonic park assist, LIDAR	Adjustable Vout, medium-high initial accuracy, small packaging
Infotainment/ cluster	Instrument cluster and LCD displays, touchpad, telematics, USB hub/charger, audio system, head unit, MCU attach	Medium initial accuracy, small packaging
HEV/EV	Start-stop voltage conditioning, fuel pump and injection, emission control/sensors, steering, inverters, engine and battery management	Medium initial accuracy, battery life and monitoring
Body	LED headlamps/lighting, HVAC controls, door sensors/locking	Low power consumption
Passive safety	Braking system, airbags	Medium-high initial accuracy

AEC-Q100 References by Voltage & Accuracy

	Part number	Voltage options [V]								Initial accuracy grades [+/- %]				
										A	B	C	D	E
Shunt references	LM4040-N-Q1			2.5	3.0					0.1	0.2	0.5	1.0	2.0
	LM4041-N-Q1	1.2							Adj	0.1	0.2	0.5	1.0	2.0
	LM4050-N-Q1		2.048	2.5			4.1	5.0	8.192	10.0	0.1	0.2	0.5	
	TL431/2-Q1			2.5					Adj	1.0	0.5			
	TLVH431/2-Q1	1.2							Adj	1.0	0.5			
Series references	LM4128-Q1	1.8	2.048	2.5	3.0	3.3	4.1			0.1	0.2	0.5	1.0	
	LM4132-Q1			2.5	3.0					0.05	0.1	0.2	0.4	
	REF50xxA-Q1		2.048	2.5	3.0		4.096	4.5	5.0	0.05*	0.1**			

Notes
* high grade (REF50xx)
** standard grade (REF50xx)

References for Automotive



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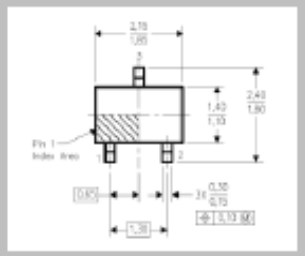
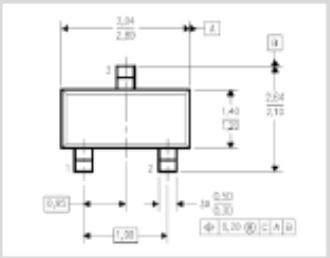
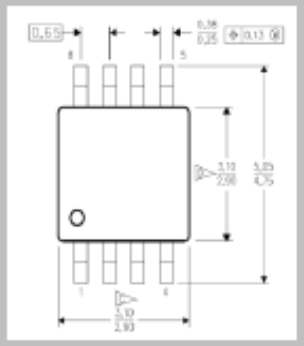
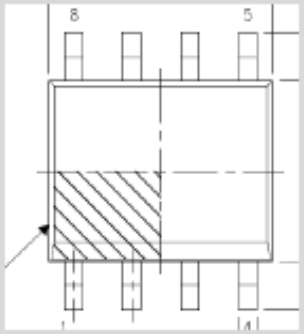
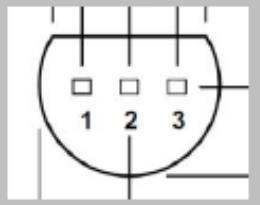
Texas Instruments

Packaging

SC70	SOT23	MSOP	SOIC	TO-92
				
REF33xx (3) LM4040 (5) LM4041 (5)	REF30xx (3) REF31xx (3) REF32xx(6) REF33xx (3) LM4120 (5) LM4121 (5) LM4125 (5) LM4128 (5) LM4132 (5) LM4030 (5) LM4040 (3) LM4041 (3) LM4051 (3) REF1112 (3)	REF50xx (8)	REF50xx (8) LM4140 (8) LM185 (8)	LM4040 LM4041 LM185

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Voltage Reference Resources

Find it all on the Vref landing page: www.ti.com/vref

Learn

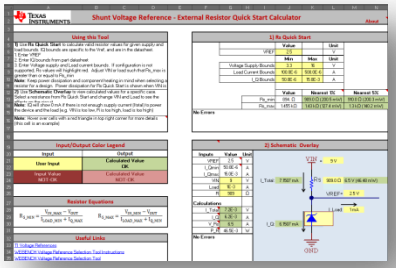
- *Voltage Reference Selection Basics* white paper
- Shunt vs. Series: How to Select a Voltage Reference Topology article
- Vref trick circuit blogs on Precision Hub and Power House

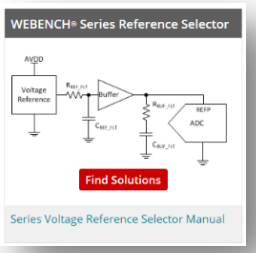
Design

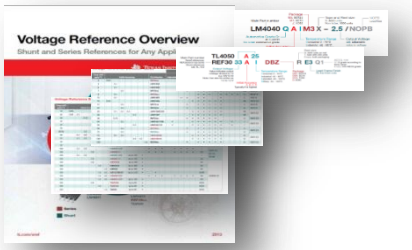
- Vref reference design library
- Webench ADC selector for series Vrefs
- Quick-start calculator for shunt Vref external resistor

Select

- Interactive application-based selection guides (industrial and automotive)
- Selection wheel (online & paper, LIT#: SLYW017)
- Vref overview brochure (LIT#: SLPT030)
- TI components for aerospace and defense brochure (LIT#: SLYC143)







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