



# Is it Wise to Fly Automotive Grade Electronic Parts in Space?

Are They an Affordable and Effective Option?

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# It Depends

- Mission
- Risk Posture
- Commercial Options
- Matching Parts to Applications
- Cost vs Benefit
- Architecture Factors
- The Value of Sharing Lessons Learned



Microsoft® Clip Art



[http://www.nasa.gov/directorates/heo/home/CubeSats\\_initiative.html#.VAhnWhDisY](http://www.nasa.gov/directorates/heo/home/CubeSats_initiative.html#.VAhnWhDisY)

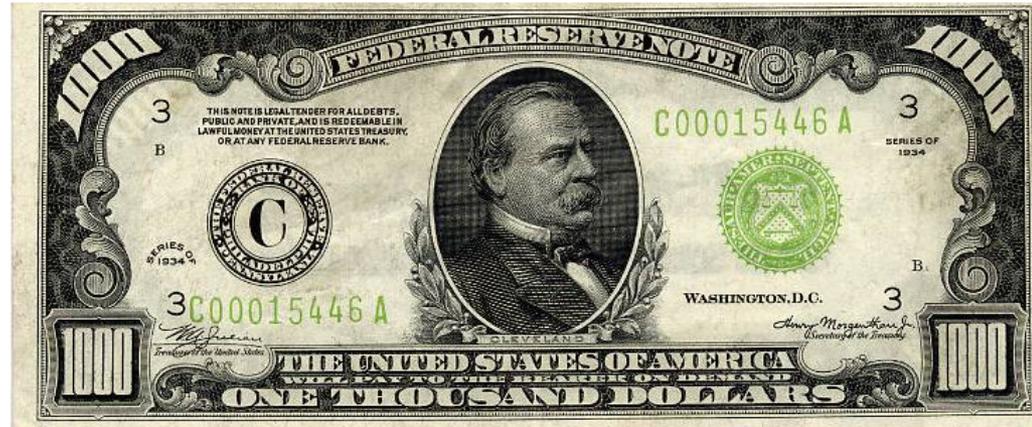
# Drivers

SIZE

WEIGHT

AND

PRICE



- Commercial electronic parts usually represent a more desirable combination than MIL parts
- How do automotive parts compare to catalog commercial?
- Size and weight are intimately linked

# Commercial Parts Options

- Manufacturers make parts to meet the needs of their chosen market(s)
- Automotive parts are unsurprisingly designed to meet the needs of sub-system suppliers to automobile manufacturers
- And there are subdivisions: Suppliers to luxury car makers probably select higher quality parts than suppliers to mass market vehicle manufacturers
- As usual, you get what you pay for

# So Why Consider Automotive Parts for Space?

- Parts from manufacturers that are qualified to the AEC Q specifications have advantages for the smallsat user
  - Similar parts from different manufacturers have to be capable of meeting the same qualification, so they can be expected to have similar performance and reliability
- Reliability problems are more likely to become public knowledge than similar problems for general purpose commercial grades (large, homogenous market)
- They are cost competitive to catalog COTS

# What do AEC Q Specifications contain?

AEC Q specifications are Qualification Requirements Only, Focused on:

- A One-Time INITIAL QUALIFICATION of a Device Family
  - Periodic Qualification Verification NOT REQUIRED
  - Guidance is given to define what constitutes a “Device Family”
    - Common Materials, Processes, Designs, Manufacturing Location, etc.
  - Specifies # of lots, qualification tests to perform and sample sizes
  - “Generic Data” may be used provided relevance of data can be demonstrated (e.g., less than 2 years old for passives)
- Requirements for REQUALIFICATION
  - Provides recommendations for requalification tests in the event of certain kinds of materials or process changes are made after initial qualification
- Requirements for process change notification to automotive customers (sub-system suppliers to automotive manufacturers)
- **THEY DO NOT PROHIBIT PURE TIN – Whisker mitigation recommended**

# CAPACITORS

# Tantalum Chip Capacitors



<http://www.bico.net.cn.img.800cdn.com/en/UploadFiles/200651510577614.jpg>

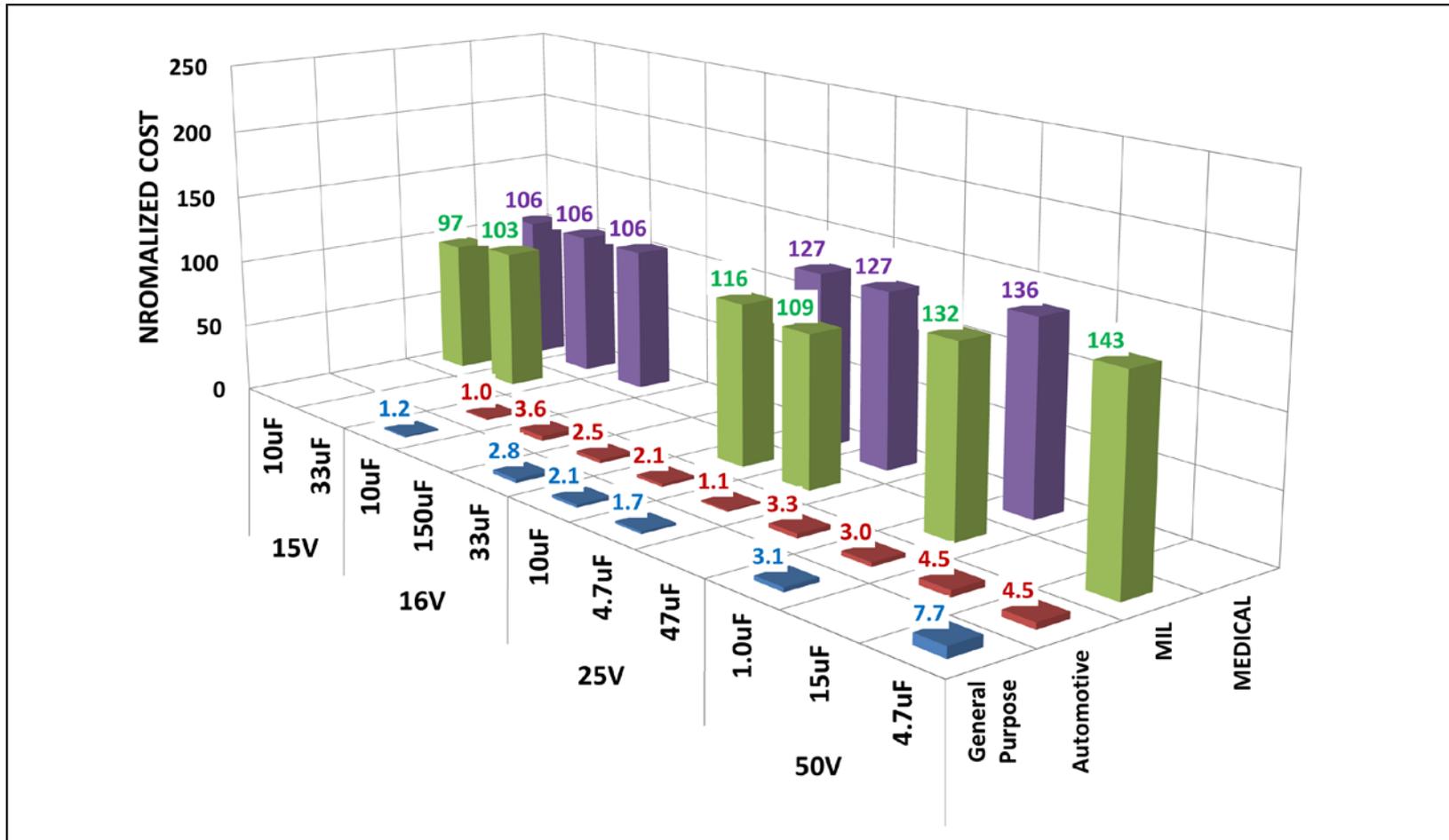


AVX Catalog S-TL0M714-C

To be presented by Michael J. Sampson at the at the Electrical, Electronic, and Electromechanical (EEE) Parts for Small Missions, Greenbelt, MD, September 10-11, 2014 and published on [nepp.nasa.gov](http://nepp.nasa.gov).

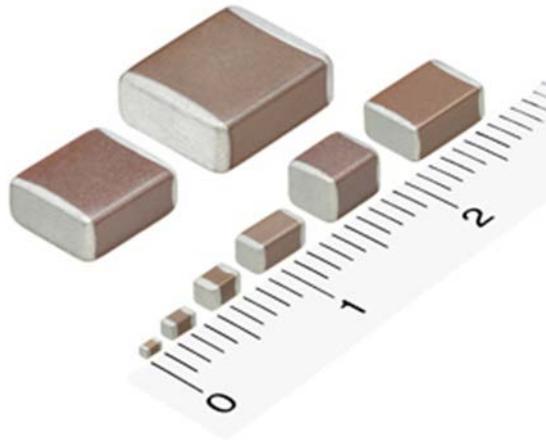
# Tantalum Chip Capacitors

## Normalized Cost Comparison for Selected Ratings



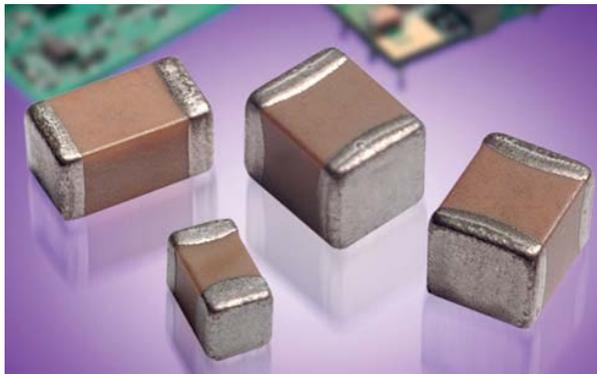
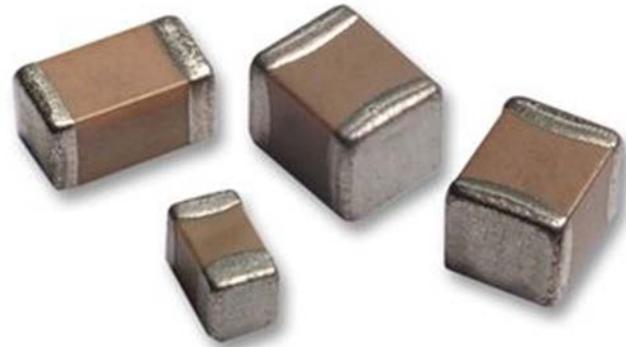
# Images of Ceramic Chip Caps

[http://www.global.tdk.com/news\\_center/press/img/20140424\\_01.jpg](http://www.global.tdk.com/news_center/press/img/20140424_01.jpg)



AVX Catalog S-MLCC0414-C

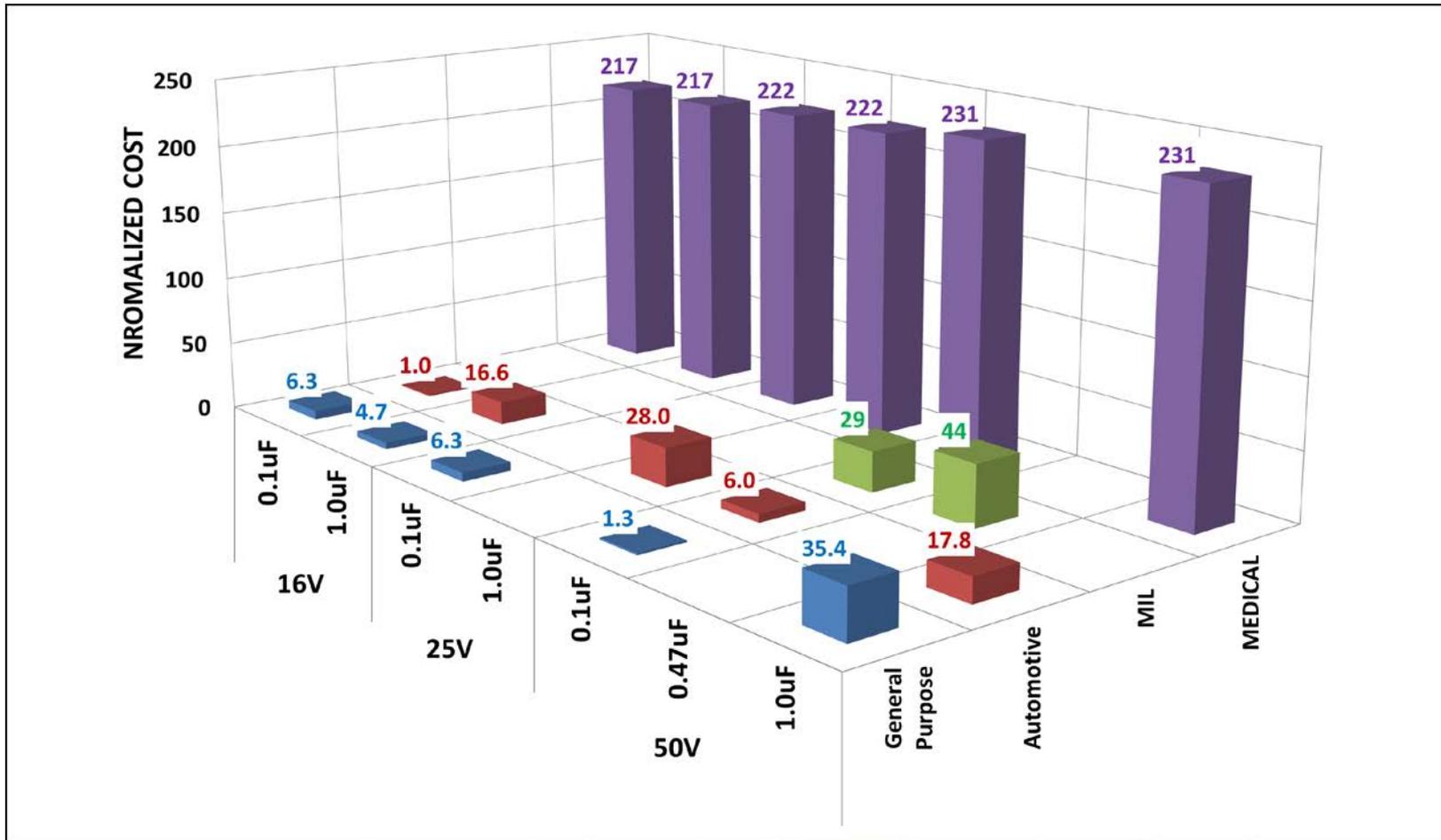
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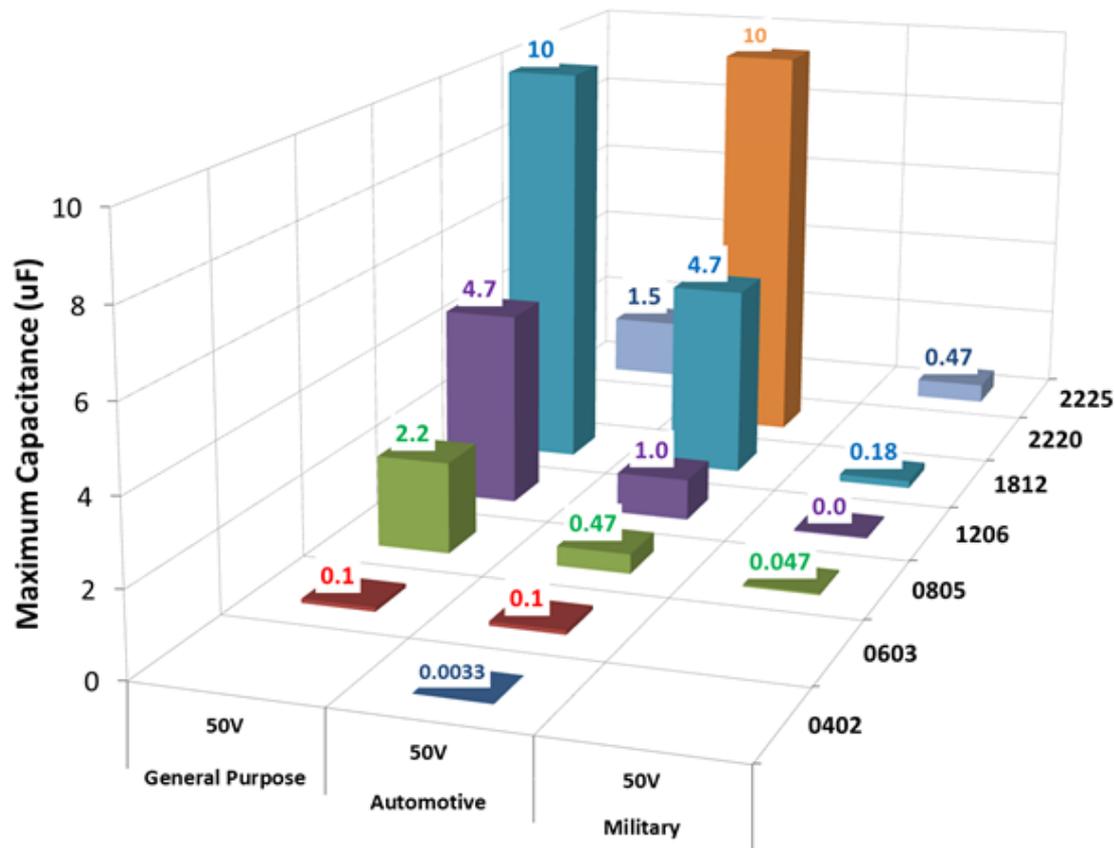
To be presented by Michael J. Sampson at the at the Electrical, Electronic, and Electromechanical (EEE) Parts for Small Missions, Greenbelt, MD, September 10-11, 2014 and published on [nepp.nasa.gov](http://nepp.nasa.gov).

# Ceramic Chip Capacitors

## Normalized Cost Comparison for Selected Ratings



# Size Comparison 50V Ceramic Chip Capacitors



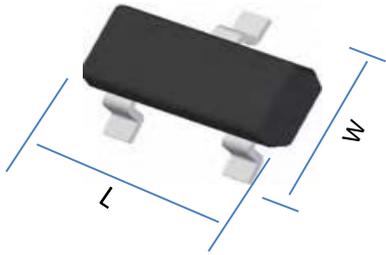
# DISCRETE SEMICONDUCTORS

# Discrete Semiconductor Cost Comparison

Part type	Commercial	Automotive	Medical	Military
Bipolar Transistor	1	1x	N/A	6x
Switching Diode	1	1.25x	N/A	28x
Schottky Rectifier	1	3x	N/A	2,416x
Optocoupler	1	0.25x	0.42x	1.62x

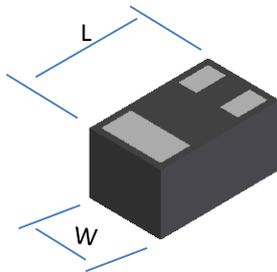
# Package Examples for 2N2222 Bipolar Transistor

## Automotive Grade



W = 2.5 mm/0.098 inch  
 H = 1.1 mm/0.043 inch  
 L = 3.0 mm/0.1181 inch

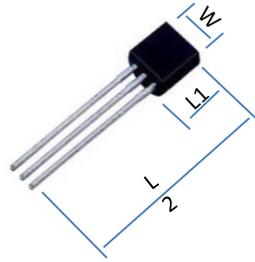
SOT-23



W = 0.65 mm/0.0255 inch  
 H = 0.4 mm/0.0157 inch  
 L = 1.05 mm/0.0413 inch

X2-DFN-1006-3

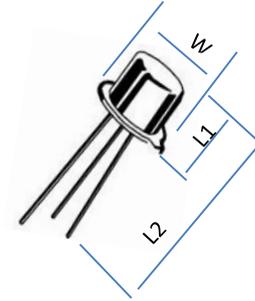
## Commercial Grade



W = 5.20 mm/0.205 inch  
 H = 4.19 mm/0.165 inch  
 L1 = 5.33 mm/0.210 inch  
 L2 = 17.02 mm/0.67 inch

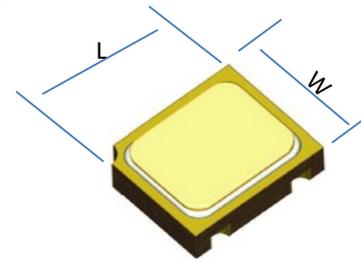
Plastic TO-92

## Military/Space Grade



W = 5.84 mm/0.230 inch  
 L1 = 5.33 mm/0.210 inch  
 L2 = 24.384 mm/0.96 inch

Hermetic TO-18

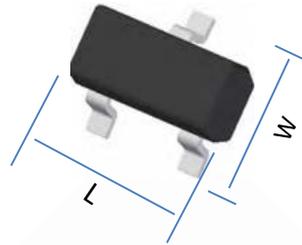


W = 5.84 mm/0.230 inch  
 H = 5.33 mm/0.210 inch  
 L = mm/ inch

Hermetic CerSOT – UB

# Package Examples for Switching Diode

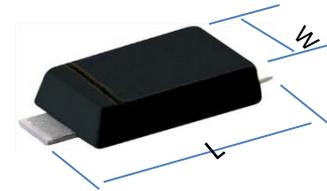
## Automotive Grade



W = 2.5 mm/0.098 inch  
H = 1.1 mm/0.043 inch  
L = 3.0 mm/0.1181 inch

SOT-23

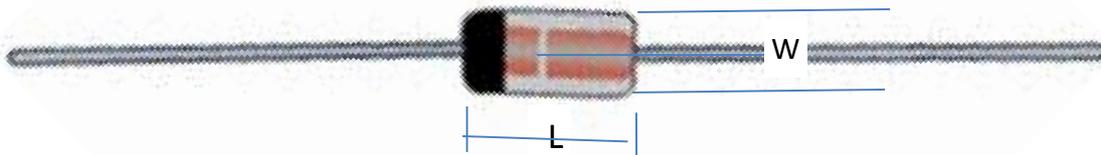
## Commercial Grade



W = 0.152 mm/0.006 inch  
H = 1.1 mm/0.043 inch  
L = 3.0 mm/0.1181 inch

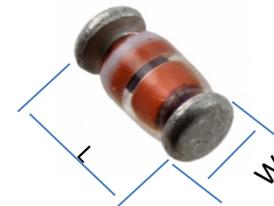
SOD-123

## Military/Space Grade



W = 1.91 mm/0.075 inch  
L = 4.57 mm/0.181 inch

DO-35

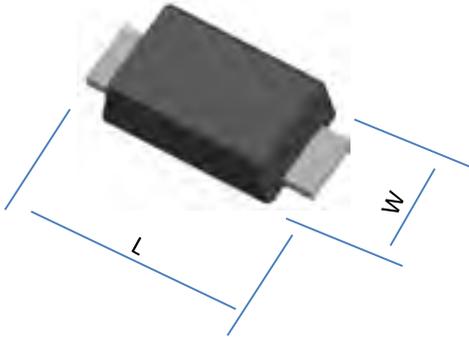


W = 1.70 mm/0.067 inch  
L = 3.71 mm/0.146 inch

UR – surface mount

# Package Examples for Schottky Barrier Diode

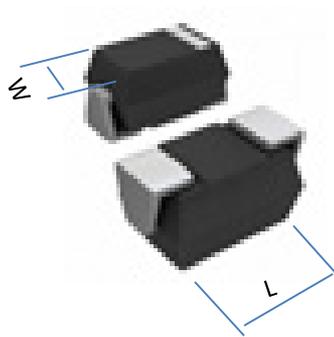
## Automotive Grade



W = 1.91 mm/0.039 inch  
 H = 1 mm/0.076  
 L = 3.90 mm/0.1535 inch

Powerdi123

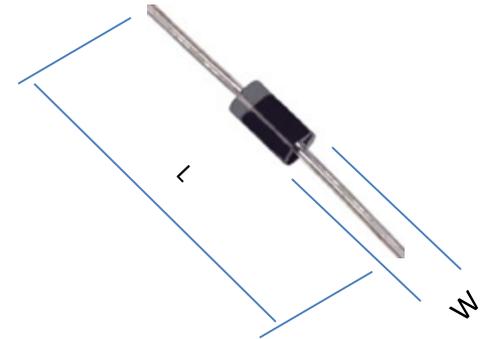
## Commercial Grade



W = 2.84 mm/0.112 inch  
 H = 3.15 mm/0.124  
 L = 4.57 mm/0.18 inch

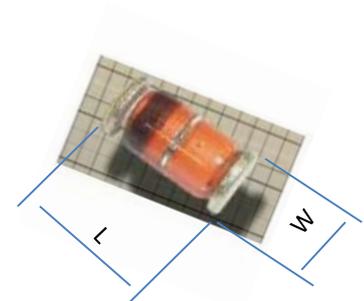
DO-214AC

## Military/Space Grade



W = 1.91 mm/0.075 inch  
 L = 78.10 mm/3.075 inch

DO-41

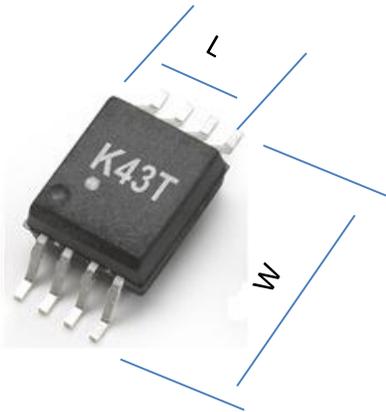


W = 2.67 mm/0.105 inch  
 L = 5.21 mm/.205 inch

DO-213AB – surface mount

# Package Examples for Optocoupler

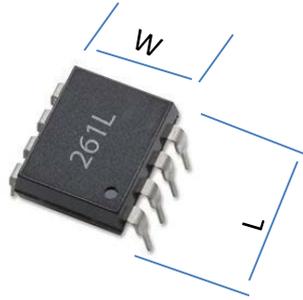
## Automotive Grade



W = 11.5 mm/0.453 inch  
H = 3.380 mm/0.133 inch  
L = 5.85 mm/0.230 inch

SO-8

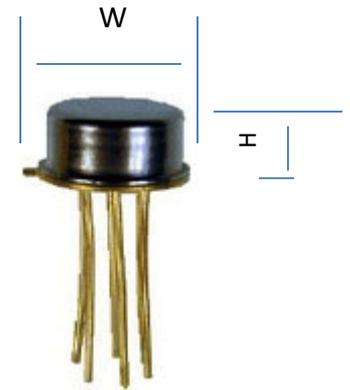
## Medical Grade



W = 9.00 mm/0.354 inch  
H = 5.01 mm/0.201 inch  
L = 11.15mm/0.442 inch

8 pin DIP

## Commercial/Military/ Space Grade



W = 9.40 mm/0.370inch  
H = 4.70 mm/0.185 inch

TO-78

# General Comments - Discretes

- Having two or more manufacturers of the same AEC Q101 part number does not translate to a form, fit, and function drop in replacement.
- AEC qualified discrete semiconductors are NOT MIL-PRF-19500 companies.
- Cost comparison did not factor in the additional costs due to upscreening devices to meet program requirements.
- For a lot of 100 pcs, upscreening of medium complexity auto grade parts to mil grade could cost \$15k-30k (which amounts to \$150-\$300 per unit). This was not factored into the cost comparison.
- In the small samples taken
  - Minimum buys typically in the thousands of devices required to be purchased.
  - AEC Q device finishes are 'pure Tin'.
  - Device packaging is typically molded plastic, "Green Molding Compound".
  - Automotive and commercial AEC Q101 devices have implemented the use of copper bond wires instead of gold bond wires.
  - Very difficult to find MIL and medical grade of AEC components
  - Cost of AEC and COTS are around the same

# MICROCIRCUITS

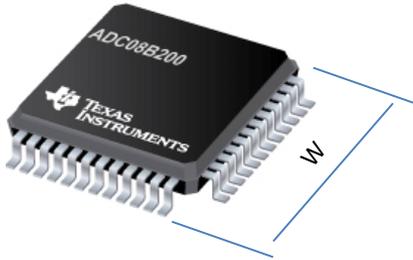
# Microcircuit Cost Comparison

	<b>General Purpose COTS</b>	<b>Automotive</b>	<b>Medical</b>	<b>Military</b>
IC A to D and D to A Converters	1.0	1.1	6.8	1200
DC/DC Cnvrtr	1.0	1.3	20.2	4700
Assorted ICs: Op amp, comparator, Diff Bus	1.0	2.7	????	60

Normalized to General Purpose Grade Commercial

# Package Examples for ADC

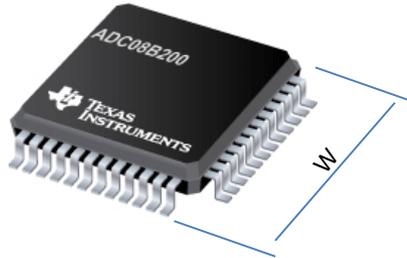
## Automotive Grade



W = 9.20 mm sq/0.362 inch sq  
H = 1.05 mm/0.041 inch

Plastic Quad Flat Pack

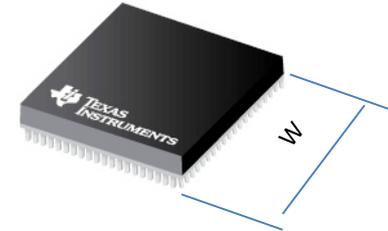
## Commercial Grade



W = 9.20 mm sq/0.362 inch sq  
H = 1.05 mm/0.041 inch

Plastic Quad Flat Pack

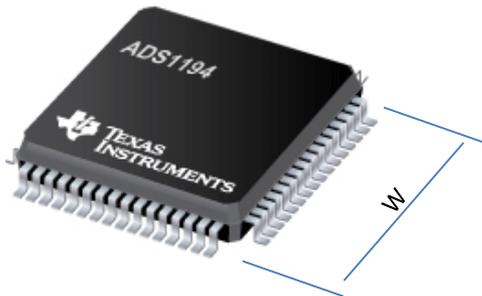
## Military/Space Grade



W = 27.94 mm/1.1 inch sq  
H = 3.22 mm/0.127 inch

Hermetic Ceramic Pin Grid Array

## Medical Grade



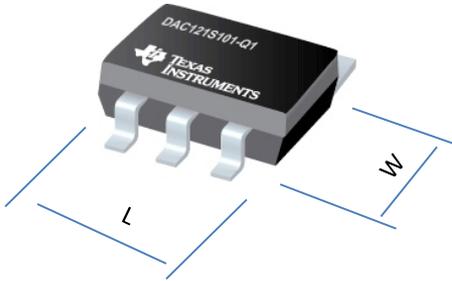
W = 12.20 mm sq/0.48 inch sq  
H = 1.05 mm/0.041 inch

Plastic Quad Flat Pack

Images courtesy of the following  
Manufacturers websites:  
Plastic Quad Flat Pack: TI.com  
Ceramic Pin Grid Array: TI.com

# Package Examples for DAC

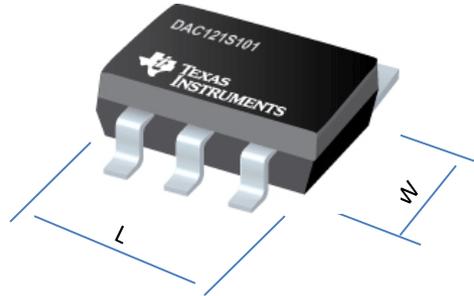
## Automotive Grade



W = 1.75 mm/0.068 inch  
L = 3.05 mm/0.120 inch  
H = 1.1 mm/0.043 inch

Plastic Small Outline

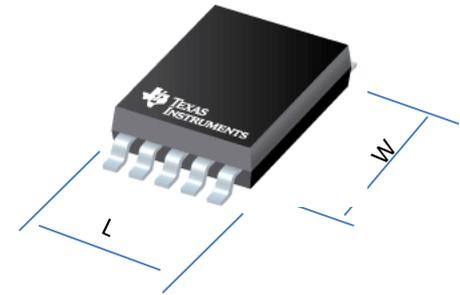
## Commercial Grade



W = 1.75 mm/0.068 inch  
L = 3.05 mm/0.120 inch  
H = 1.1 mm/0.043 inch

Plastic Small Outline

## Military/Space Grade



W = 6.12 mm/0.241 inch  
L = 6.86 mm/0.270 inch  
H = 1.78 mm/0.070 inch

10 Lead (CLGA) Ceramic  
Land Grid Array

Images courtesy of the following  
Manufacturers websites:  
Plastic Quad Flat Pack: TI.com  
Ceramic Pin Grid Array: TI.com

# General Comments - Microcircuits

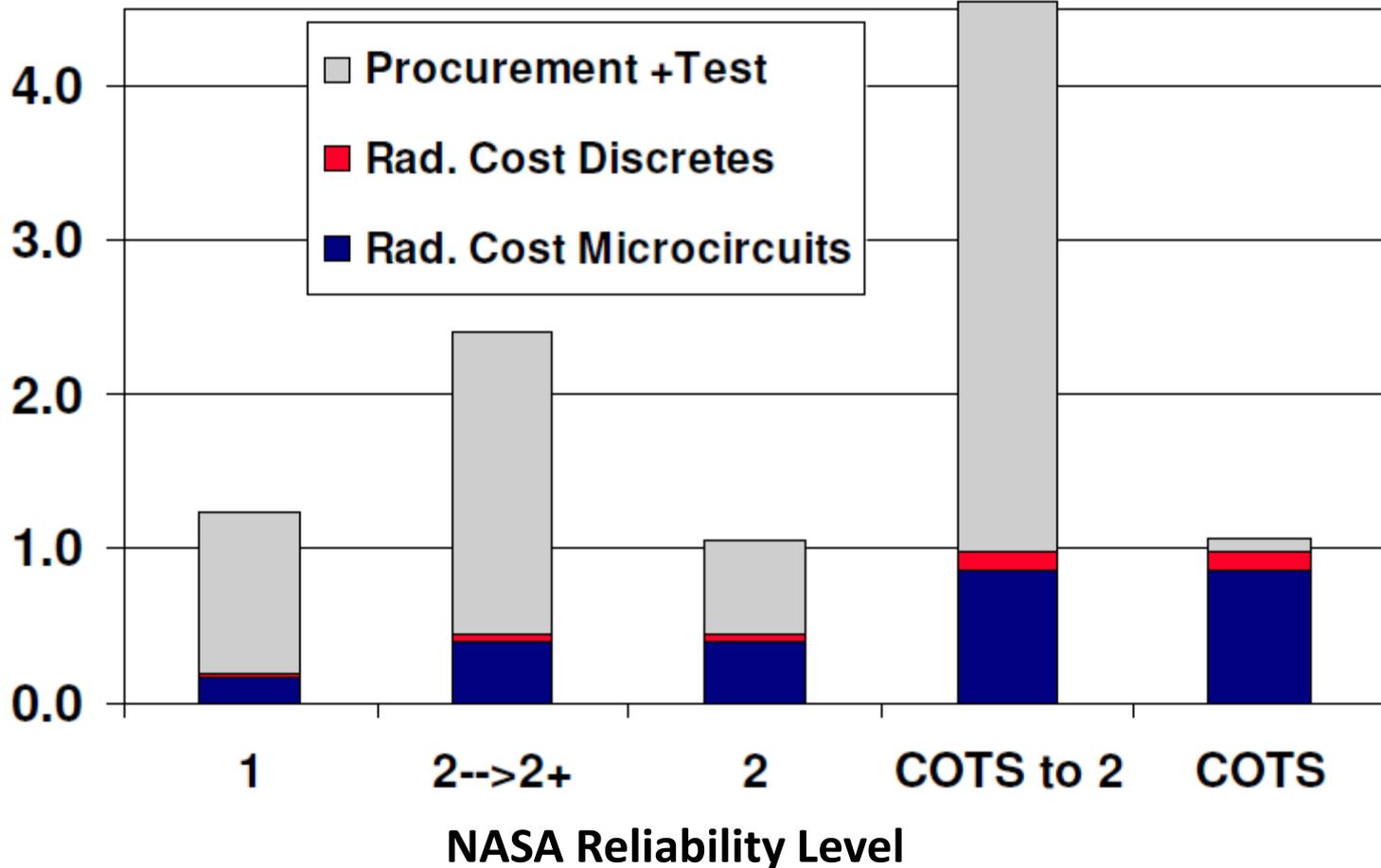
- AEC qualified “DC/DC Converters” aren’t MIL-PRF-38534 companies
  - Companies are MIL-PRF-38535
- Cost Comparison was done with out factoring in upscreening
- Radiation Assurance NOT included
- For a lot of 100 pcs, upscreening of auto grade parts to mil grade would cost \$25k-\$50k (which amounts to \$250-\$500 per unit).
- In the limited samples taken
  - AEC generally costs around the same as COTS
  - Very difficult to find MIL and medical grade level of AEC components
  - Pure tin finishes

# Lesson Learned

- Automotive “bus” is nominally 12 volt (~14 volts actual)
- Traditional spacecraft bus is 28volts
  - 40, 70, 120 volts have been used
- Limits applicability of some automotive parts in space applications
- Is there a typical bus voltage for smallsats and cubesats?
  - Does it provide adequate derating for automotive parts?

# Impact of Radiation Assurance

(From a >10 Year Old Study)



# **BACK-UP FOR DISCRETE SEMICONDUCTORS**

# Bipolar Transistor

- 2N2222 50 volt NPN small signal switching transistor chosen as baseline device
- AEC Part number – MMBT2222ALP4-7B
- Operating temperature range -55°C to 150°C
- Commercial part number – 2N2222CS-ND
- Operating temperature range -55°C to 150°C
- Military part number – JAN2N2222AUB
- Operating temperature range -65°C to 200°C
- Medical Part number – TBD
- COTS and AEC operating temperature range and power dissipation is less than military part number
- Comparable medical parts still being researched – Spoke with a couple of discrete semiconductor manufacturers and they said that they sell die to medical device assemblers.

# Switching Diode

- 1N4148 100 volt DC Reverse switching diode chosen as baseline device
- AEC Part number – SMMSD4148T1G
- Operating temperature range -55°C to 150°C
- Commercial part number – 1N4148WFL-G
- Operating temperature range -55°C to 150°C
- Military part number – JAN1N4148
- Operating temperature range -65°C to 200°C
- Medical part number – TBD
- COTS operating temperature range is less than military and AEC part number

# Schottky Barrier Diode

- 1N6761 100 volt DC Reverse voltage Schottky Barrier diode chosen as baseline device
- AEC Part number – DFSL1150-7
- Operating temperature range -55°C to 150°C
- Commercial part number – MBR1100G
- Operating temperature range -55°C to 150°C
- Military part number – JAN1N6761
- Operating temperature range -65°C to 200°C
- Medical part number – TBD
- COTS and AEC operating temperature range is less than military part number

# Optocoupler

- 4N49 chosen as baseline device
- AEC Part number – ACPL-K43T
- Operating temperature range -55°C to 150°C
- Commercial part number – 4N49
- Operating temperature range -55°C to 150°C
- Military part number – JANTX4N49
- Operating temperature range -65°C to 200°C
- Medical part number – ACNW261L-006
- Operating temperature range -65°C to 200°C COTS and AEC operating temperature range is less than military part number

# **BACK-UP FOR MICROCIRCUITS**

# A/D CONVERTER

- 12 Bit/200MSPS chosen as baseline
- AEC part # ADC08B200QCIVS/NOPB
  - Temp Range -40 to 105C
- COTS Part # ADC08B200CIVS/NOPB
  - Temp Range -40 to 105C
- MIL Part # ADC1201600CCMLS
  - 12 Bit/3.2GSPS
  - Temp range -55 to 125C
- Medical ADS1194CPAGR
  - 16 Bit/ 8KSPS
- Temp Range 0 to 70CEasy to find COTS equivalent of AEC part
- As medical and MIL parts are more specialized, part spec's had to change to find similar parts
- Prevents a direct 1→1 comparison

# D/A Converter

- 12 Bit chosen as baseline
- Temp Range -40 to 105C
- AEC part # DAC121S101-Q1
- COTS Part # DAC121S101
- MIL Part # DAC121S101QML
  - Temp range -55 to 125C
- DAC121S101 was found for all part levels except medical

# DC/DC Converter

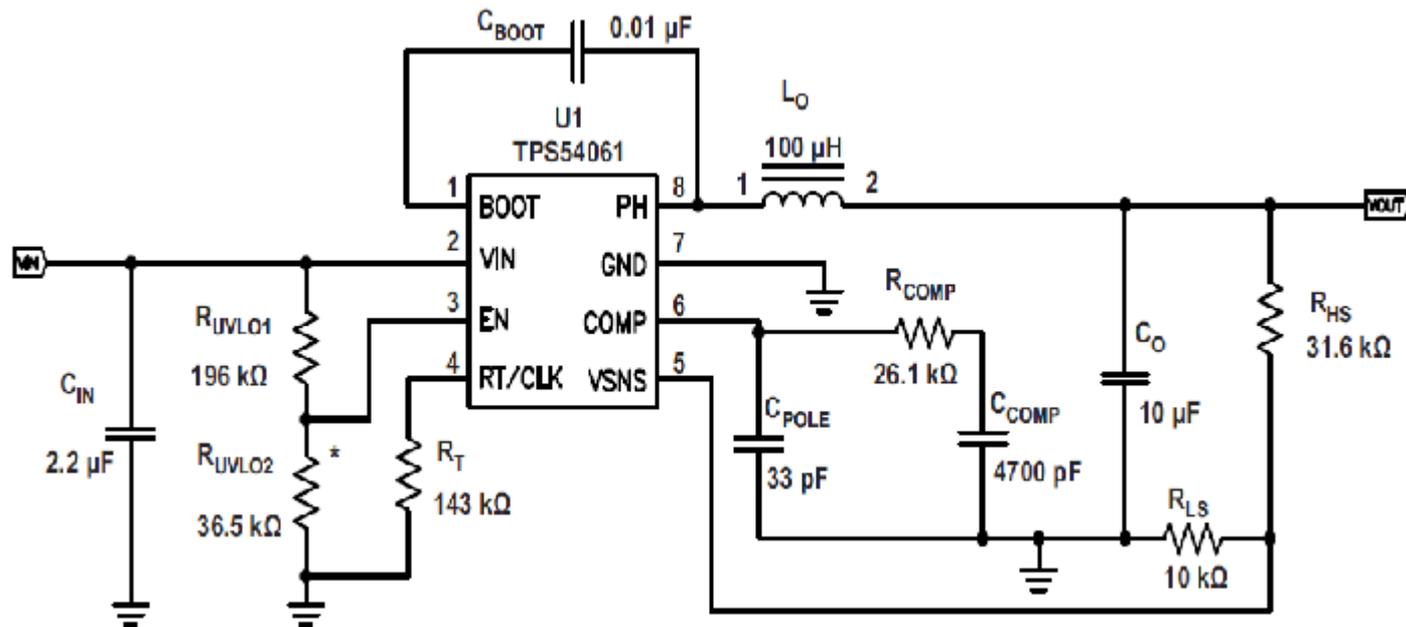
- Vin 28V, Vout 5V chosen as baseline
- AEC Part # TPS54061QDRBRQ1
  - Vin 4.7-60V
  - Temp range -40 to 150
- COTS Part # TPS54061DRBR
  - Vin 4.7-60V
  - Temp range -40 to 150
- MIL K LEVEL 2805S
  - Vin 15-50V
  - Rad Hard
  - Temp range -55 to 125
- Medical Part # MIHW1022
  - Vin 18-36V
  - Temp range -40 to 85
- Hi-Rel
  - Vin 28V
  - Temp range -55 to 100

# DC/DC CONVERTER

- There are no AEC qualified Hybrids
  - No AEC specification for Hybrids
- AEC part chosen was a “DC/DC Converter”
  - Fall under AEC Q100
  - Exterior components needed
  - Similar to a monolithic device
- MIL was a qualified hybrid
- A cost comparison between AEC and MIL/Medical is not 1→1
- AEC parts tended to be aimed around Vin 12V

# DC/DC CONVERTER

- AEC Qualified Component Circuitry



# Comparator

- AEC Part #'s
  - AD8468WBKSZ-R7
  - LMV7239QM7/NOPB
  - AEC Grade 1, -40 to +125C
- MIL Part #'s
  - No corresponding Numbers found
  - Manufacturer website lists the per unit cost of their military grade parts of stated functional complexity as less than or equal to a certain dollar amount
- These functions are not available as stand alone medical grade parts.

# Differential Bus

- AEC Part #'s
  - SN65LBC176QDRQ1
  - AEC Grade 1, -40 to +125C
- MIL Part #'s
  - No corresponding numbers found
  - Manufacturer website lists the per unit cost of their military grade parts of stated functional complexity as less than or equal to a certain dollar amount
- These functions are not available as stand alone medical grade parts.

# Op Amp

- AEC Part #'s
  - OPA2333AQDRQ1
  - AD8628WARZ-R1
  - AEC Grade 1, -40 to +125C
- MIL Part #'s
  - No corresponding numbers found
  - Manufacturer website lists the per unit cost of their military grade parts of stated functional complexity as less than or equal to a certain dollar amount.
- These functions are not available as stand alone medical grade parts.