



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

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



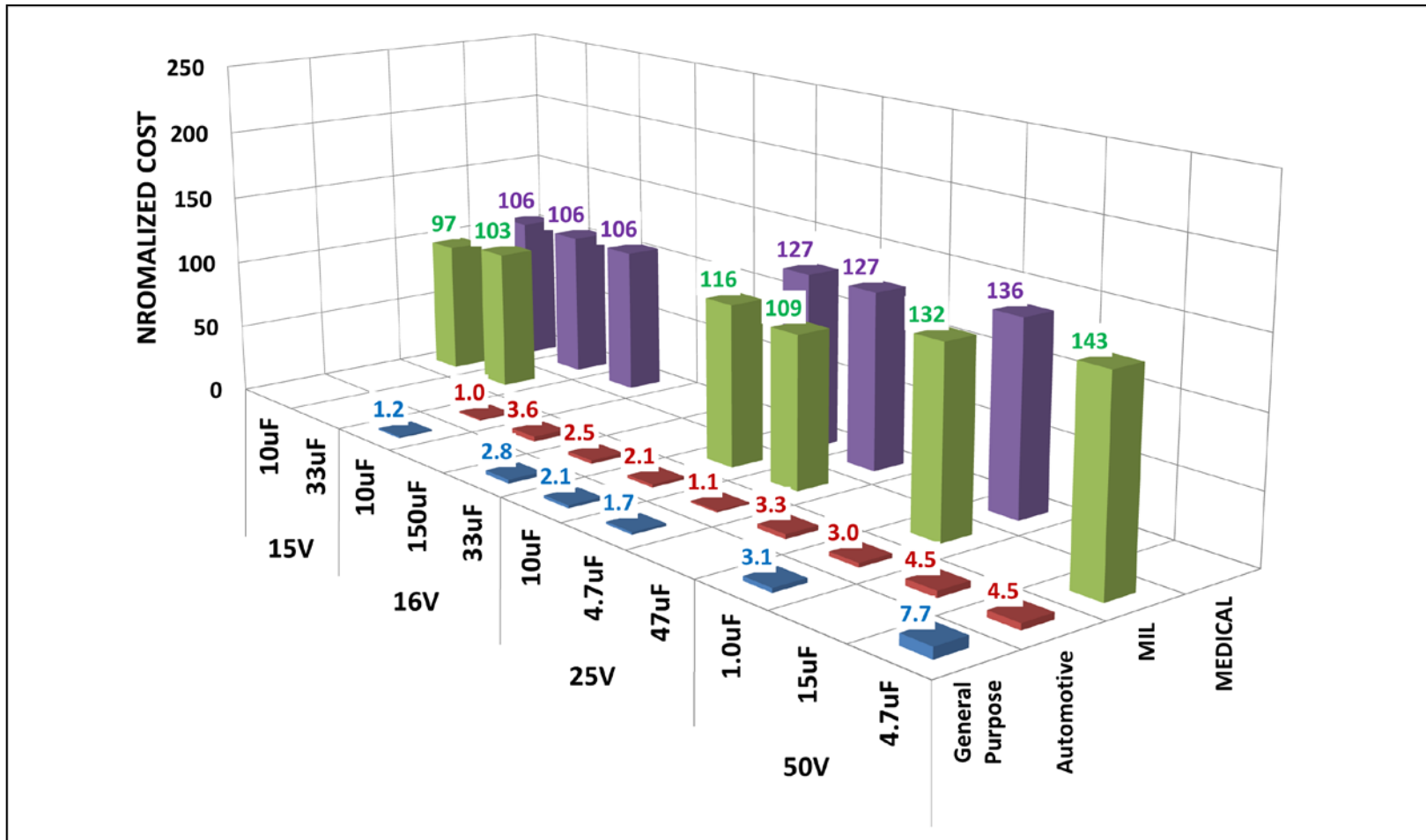
AVX Catalog S-TL0M714-C



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

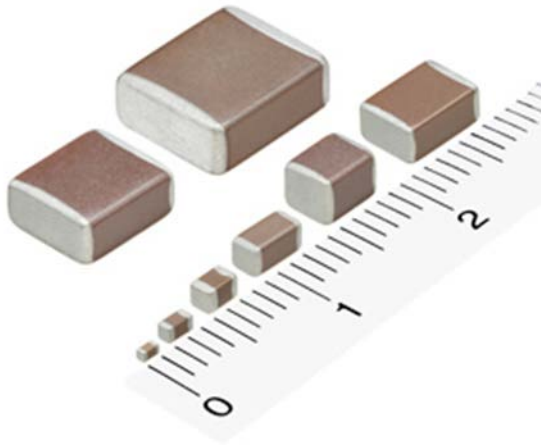
Tantalum Chip Capacitors

Normalized Cost Comparison for Selected Ratings



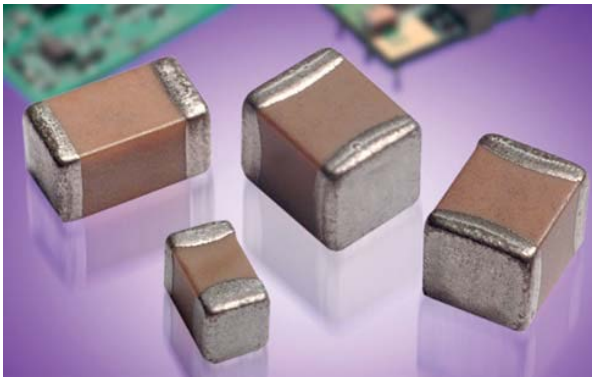
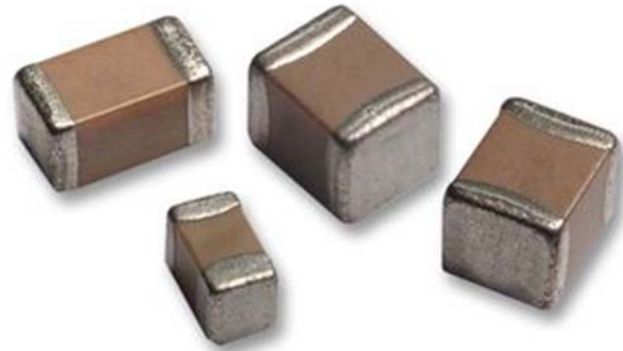
Images of Ceramic Chip Caps

http://www.global.tdk.com/news_center/press/img/20140424_01.jpg



AVX Catalog S-MLCC0414-C

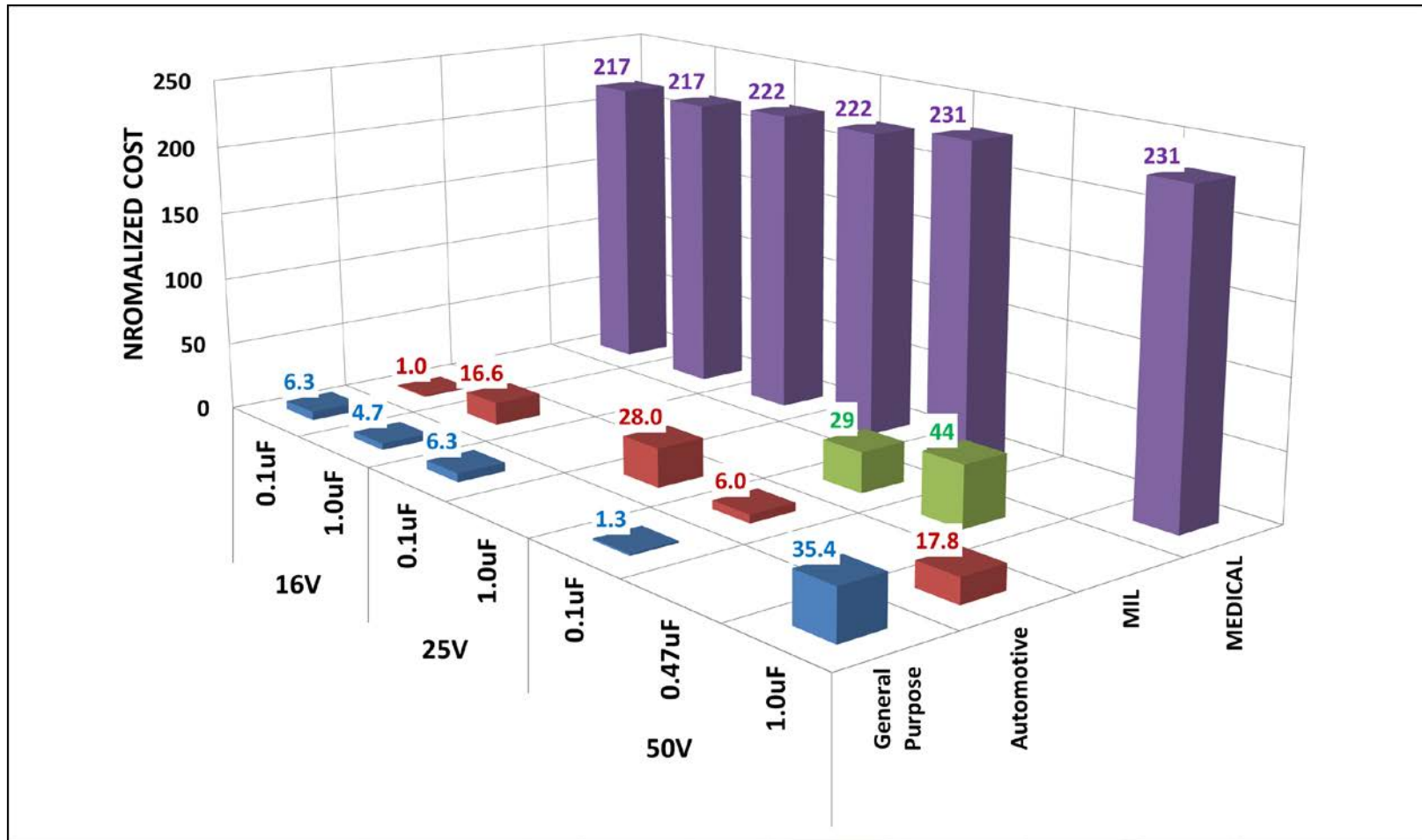
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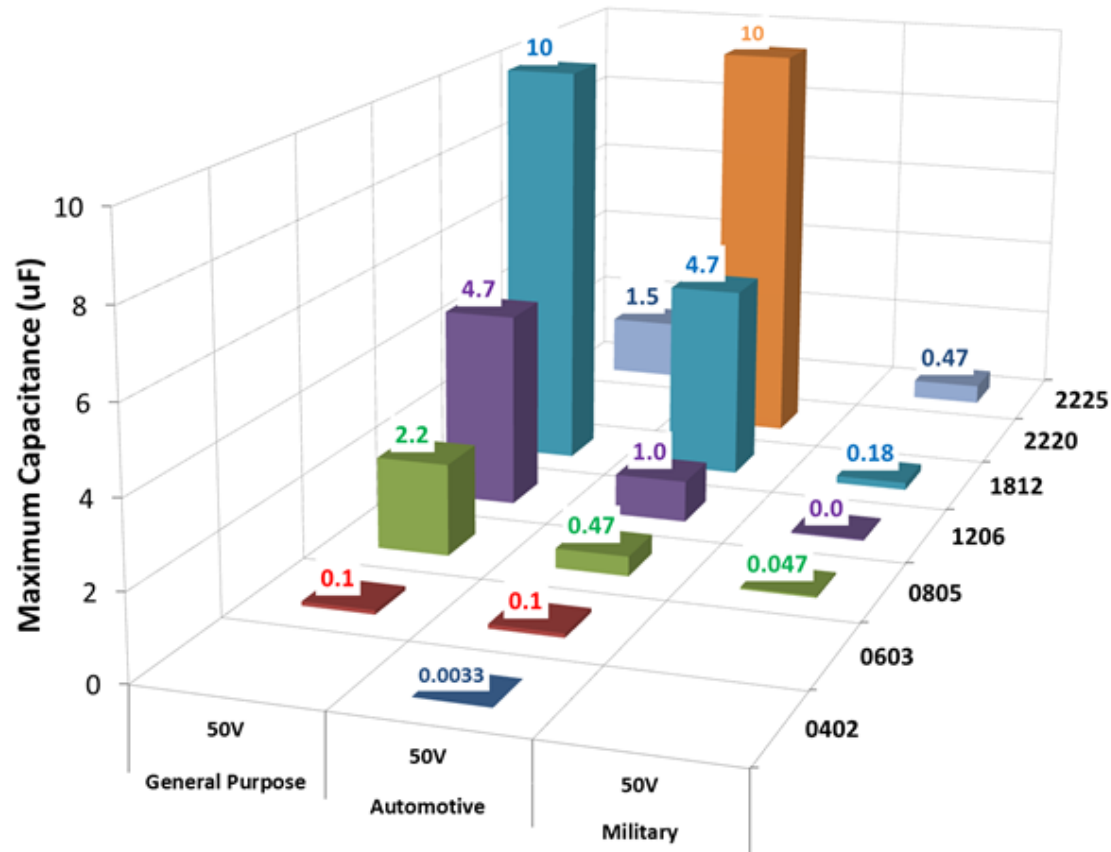
To be presented by Michael J. Sampson at the at the Electrical, Electronic, and Electromechanical (EEE) Parts for Small Missions, Greenbelt, MD, September 10-11, 2014 and published on nepp.nasa.gov.

Ceramic Chip Capacitors

Normalized Cost Comparison for Selected Ratings



Size Comparison 50V Ceramic Chip Capacitors



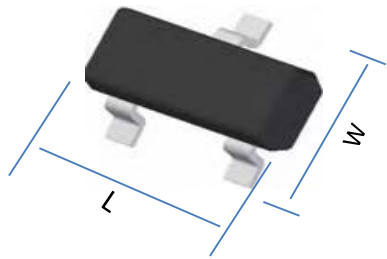
DISCRETE SEMICONDUCTORS

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

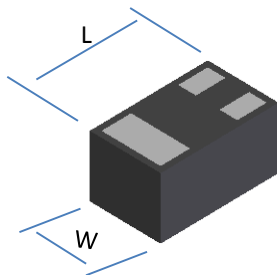
Package Examples for 2N2222 Bipolar Transistor

Automotive Grade



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

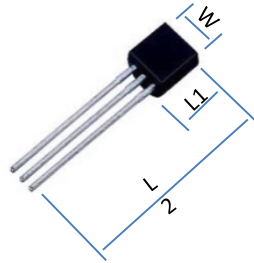
SOT-23



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

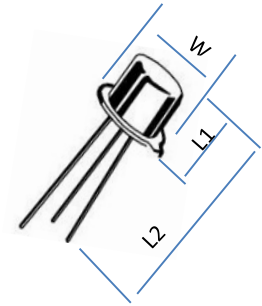
Commercial Grade



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

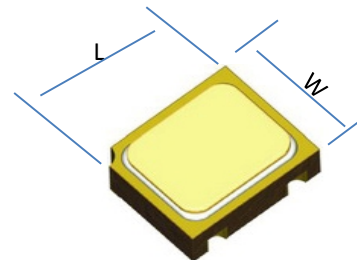
Plastic TO-92

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

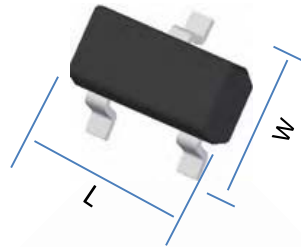


W = 5.84 mm/0.230 inch
H = 5.33 mm/0.210 inch
L = mm/ inch

Hermetic CerSOT – UB

Package Examples for Switching Diode

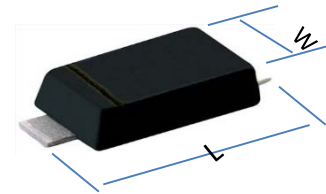
Automotive Grade



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

SOT-23

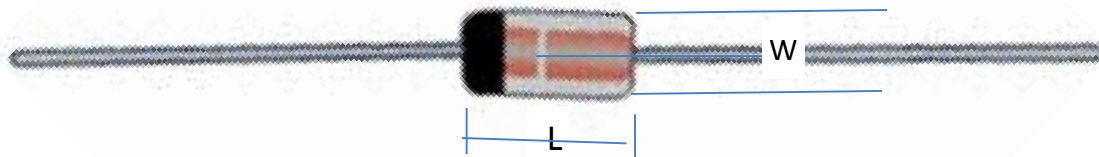
Commercial Grade



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

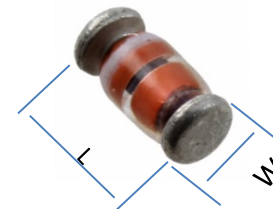
SOD-123

Military/Space Grade



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

DO-35

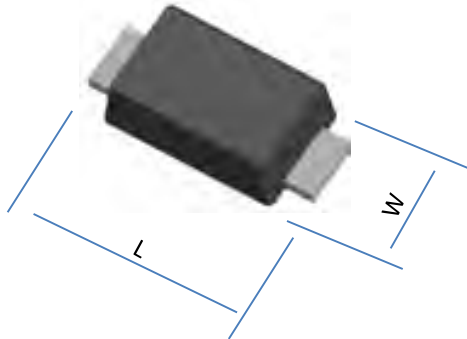


W = 1.70 mm/0.067 inch
L = 3.71 mm/0.146 inch

UR – surface mount

Package Examples for Schottky Barrier Diode

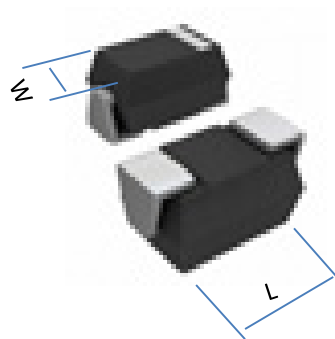
Automotive Grade



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

Powerdi123

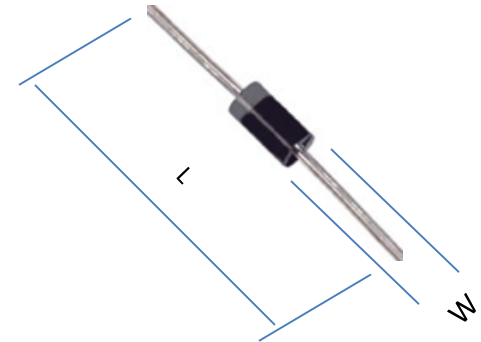
Commercial Grade



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

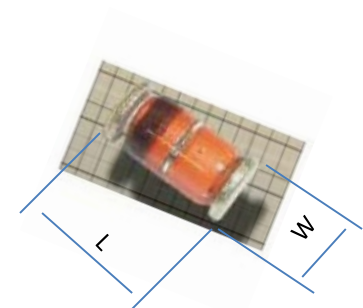
DO-214AC

Military/Space Grade



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

DO-41

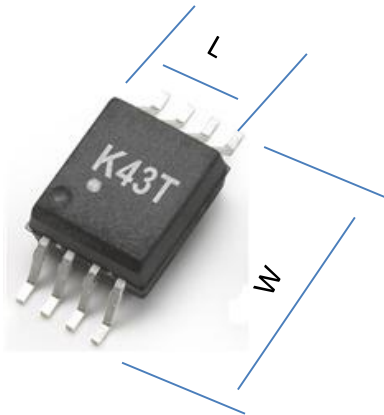


W = 2.67 mm/0.105 inch
L = 5.21 mm/.205 inch

DO-213AB – surface mount

Package Examples for Optocoupler

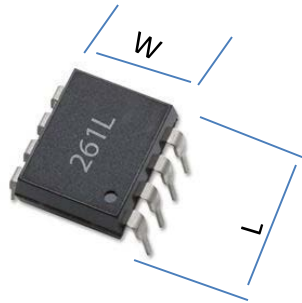
Automotive Grade



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

SO-8

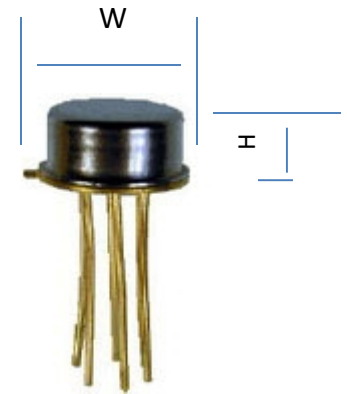
Medical Grade



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

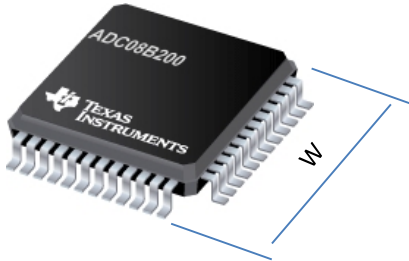
Microcircuit Cost Comparison

	General Purpose COTS	Automotive	Medical	Military
IC A to D and D to A Converters	1.0	1.1	6.8	1200
DC/DC Cnvtrtr	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

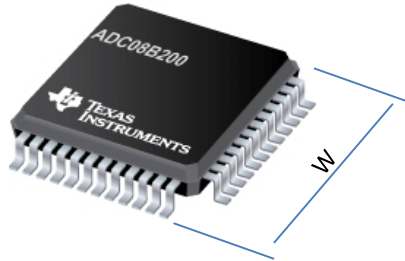
Automotive Grade



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

Plastic Quad Flat Pack

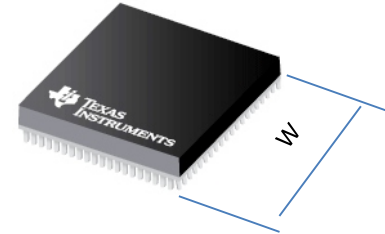
Commercial Grade



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

Plastic Quad Flat Pack

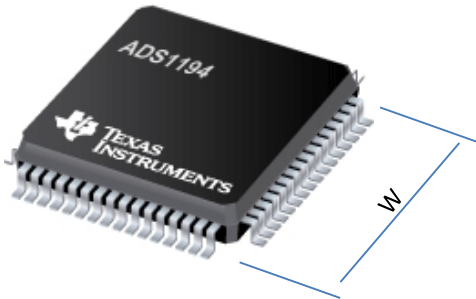
Military/Space Grade



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

Hermetic Ceramic Pin Grid Array

Medical Grade



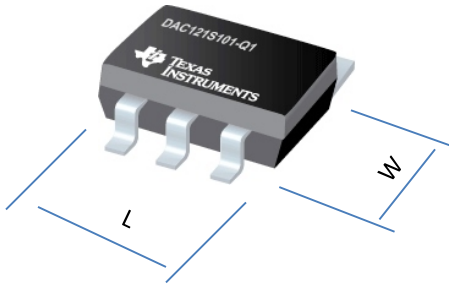
W = 12.20 mm sq/0.48 inch sq
H = 1.05 mm/0.041 inch

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

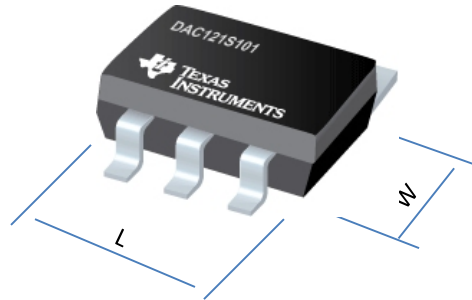
Automotive Grade



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

Plastic Small Outline

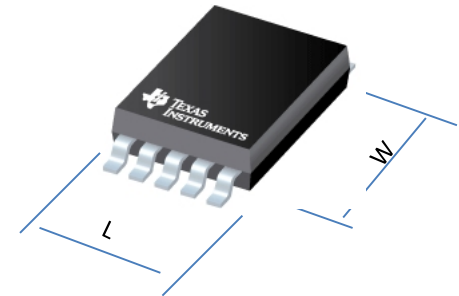
Commercial Grade



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

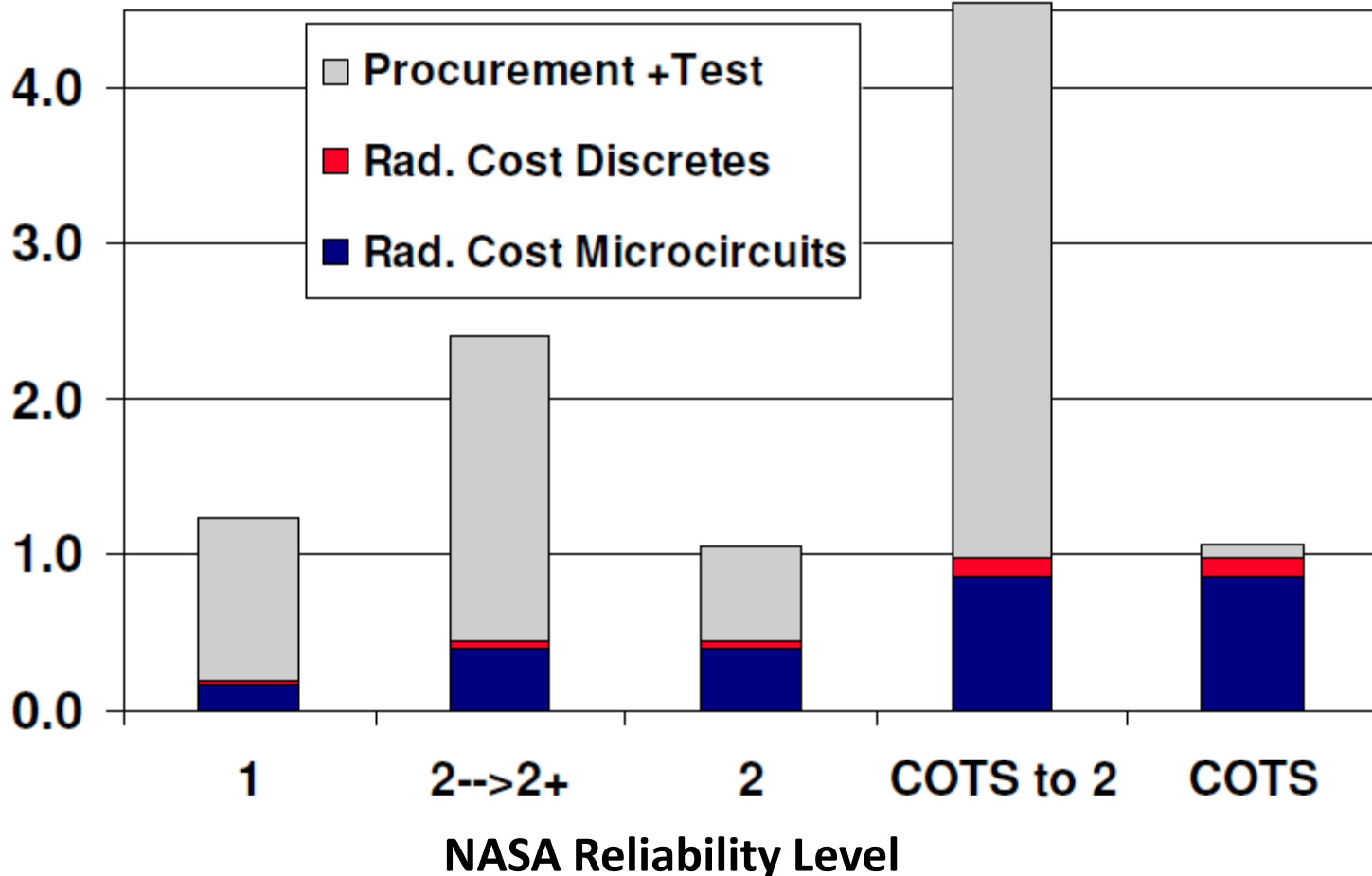
- AEC qualified “DC/DC Converters” aren’t MIL-PRF-38534 companies
 - Companies are MIL-PRF-38535
- Cost Comparison was done with out factoring in upscreening
- Radiation Assurance NOT included
- For a lot of 100 pcs, upscreening of auto grade parts to mil grade would cost \$25k-\$50k (which amounts to \$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 – JANTX2N2222AUB
- 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 – JAN4N49
- 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

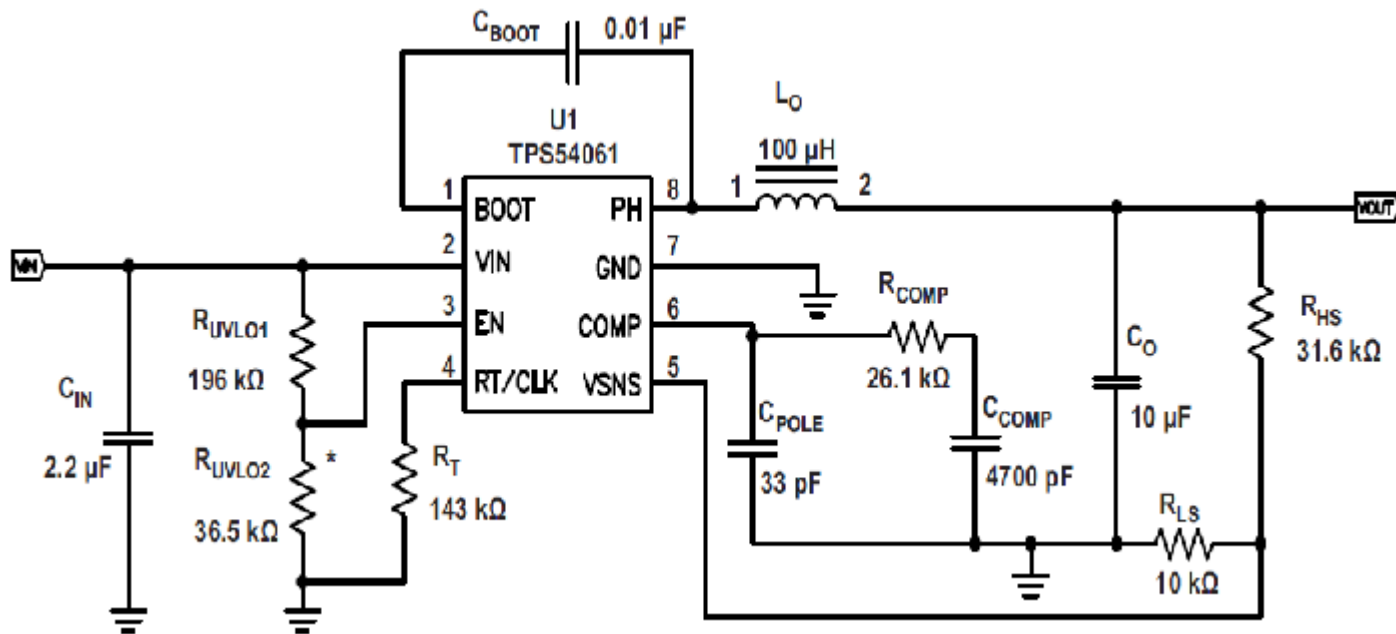
- Vin 28V, Vout 5V chosen as baseline
- AEC Part # TPS54061QDRBRQ1
 - Vin 4.7-60V
 - Temp range -40 to 150
- COTS Part # TPS54061DRBR
 - Vin 4.7-60V
 - Temp range -40 to 150
- MIL K LEVEL 2805S
 - Vin 15-50V
 - Rad Hard
 - Temp range -55 to 125
- Medical Part # MIHW1022
 - Vin 18-36V
 - Temp range -40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