



Micross Components Technical Paper

COTS, Commercial Off The Shelf

A brief discourse concerning semiconductor devices

The phrase “COTS”, an acronym for “Commercial-Off-The-Shelf”, would appear to mean something different to everyone involved, and there seems to be no single definition that satisfies all parties. The phraseology in which it’s mainly used applies to the purchasing or procuring of currently available commercial product to suit a “non-commercial” alternative application, generally without the additional relevant qualification or up-screening.

By example, many military and space/aerospace products relied on procuring semiconductor devices to a JAN-, MIL-, BS- or DSTAN specification. The majority of semiconductor manufacturers have long since pulled out of this military market, but often left the device “on the books”, but only as a commercial or industrial grade part. Other devices and device families vanished completely, leaving only a plastic packaged alternative. Consider the once ubiquitous 74xx/54xx logic family, pioneered in 1974 by Texas Instruments. Most, if not all, of the functionality of these parts still exist, but as fast CMOS parts, and not as the original bipolar fabrication ... technology families, such as the 74Sxx, 74Fxx and 74LSxx are now only found on the shelves of obsolete stockists. These newer CMOS parts are faster, consume less supply current, faster T_{PD} 's and sharper rise-times, and cost less ... but that doesn't mean to say they'll work in the same circuit as the original part, for those very reasons.

Commercial life-times are very short compared to military or avionics project life-times, and few people would nowadays design and develop a commercial electronic item to last more than 5 years, let alone the 25- to 40-years plus often demanded of high reliability electronics. And the assumption that this is only the problem of the military is also false. Most capital intensive infrastructures face the same dilemma, from railway transport, medical, road systems, nuclear power, shipping, commercial airlines through to fuel delivery, air traffic control, road signaling and domestic and industrial service delivery, to name just a few.

COTS in real life.

In the USA, the 1994 Perry directive clarified :

- Use Performance Based Specifications
- Use Commercial Specifications & Standards first
- Use MIL Specs & Standards when Commercial don't exist or when commercial doesn't meet the total need.

The Perry directive specifically did not say ...

- you must use Commercial parts.
- use parts outside the manufacturer's specification.

Paul Kaminski, former undersecretary of defense for acquisition and technology and a leading COTS proponent, warned in a March 1997 memo that "*we must be diligent in these initiatives to ensure that we don't invalidate technical requirements of our systems by the misapplication of microelectronics or other commercial products.*"

Common sense dictates systems must meet Mission and User needs.

So we can just pop round to the local electronic store, and use whatever I find on the shelves ?

The answer to that facetious question is somewhat complex, but the fundamental answer is yes, so long as what I'm using

- a). performs the function required
- b). will continue to perform that function throughout the equipment's life
- c). will continue to perform that function throughout the equipment's environment
- d). I have sufficient traceability to check backwards if it doesn't work.
- e). doesn't interfere with anything else

I can find out the answer to (a) as soon as I switch on (and thoroughly test my rig ...), and my customer is not going to be to happy with my answer to (d), but to answer (b), (c) and (e) I've got a bit of checking to do.

What's the lifetime of my equipment?

A really commercial part, such as a singing birthday card, lasts only a few moments, upto that point that someone rips the speaker out. And I expect my television to last at least 5 years, or 8 years if someone didn't keep changing channels!. But in the military world, real operational time of a round of munitions may be only a few seconds, with a storage expectancy of 20 years, or it might be an almost continuous 24-hr, 7 day week, for 25 years. Traffic light bulbs, for example, don't seem to blow their bulbs as half as quickly as those in my hallway at home, so I guess that their bulbs might cost a little bit more, and made to a higher standard.

Some modern equipment is inherently more reliable that it older counterpart, compare the expected life-time of an incandescent bulb with that of an LED lamp, but it's also care in the manufacturing process, thoughtful testing and an unstressful life that prolongs active life. I also note that my gas oven's inside light is still an incandescent bulb, I don't think that current batch LED technology will survive Gas Mark 5 ?

What's my environment like ?

If it's in my living room, and the TV won't work for a few days, too bad! But if this sits on the end of a wing-tip of a supersonic fighter, and is really, really important ... think again.

Knowing, or being able to control, the ambience of a device is very important. Vibration, temperature range, radiation levels and power supply tolerance are some of the key parameters that will permit accurate selection of the "correct" device ... cost-effective without being over-engineered.

What's the criticality of the component ?

Again, I can suffer my daughter, sans TV, for a few days, for the sake of a dud chip, but if this was my pacemaker, I think I'd like to know that this component, above all others, was smothered in Gold!!!

Establishing the mission-criticality of the overall product, and therefore the requirement on each individual device, also reflects upon the selection decision, and just because it's an avionics component doesn't automatically mean that it has to withstand the full -55°C to 125°C temperature range. Similarly, just because it's going into a cheap car, it might be part of the ABS system, and I really would like it to behave throughout the whole range of under-bonnet conditions, for the car's life-time. Still, plastic components in a fly-by-wire aircraft still give me cause for concern.

So it's horses for courses, almost.

The cost of fixing something once it's gone wrong can vary from negligible (I'll bin it, Sir, and give you our latest model ...) to astronomical (especially if it is in space). Plus your pride, reputation, future sales ...

It might just pay to sort through the stores' shelves a little bit harder, then test what we find a bit before we plug it directly into to our 10Gigawatt matter involutor. (You will of course have noticed that ALL the components fitted to USS-1701, the Enterprise, have been thoroughly tested and screened, especially those involved with the transporter, a.k.a. "beam-me up, Scotty" machine.)

But those hi-rel parts were made on the same lines as the new commercial ones.

Not really, those hi-rel parts were made on a source controlled, conservatively rated, stringently monitored, military technology funded line, with a process that could and would be "tweaked" at any stage to maximize and maintain the performance, sometimes at the expense of final product yield. And with exhaustively documented testing. And with traceable paperwork. Or they'd change the specification, and as a last resort, change the design!

Not so with modern commercial parts. So long as they operate within the commercial specification, they can be manufactured in a number of places, to a wide parameter tolerance spread, no guarantee of support, no longevity of supply, traceable paperwork?, etc., but in fairness, this is what you should expect in a commercial world, (do you have the source documentation and traceability on your washing machine?).

The truth is you have none of the equivalent guarantees, controls or documentation in the commercial world that used to occur as standard when obtaining high reliability components,

fundamentally because it costs time-effort-money to give those guarantees, maintain those controls and produce that documentation. And only you want it !

Many semiconductor manufacturers adopt the approach that COTS means :- “don’t ask me, that’s what my distributor is there for, ask him”. Any change request, even down to the colour of the package or selection of date-code, immediately implies that it is not a COTS device that is being requested. So if the distributor can’t help, then it’s not COTS.

But I can just up-screen them, can’t I?

Again, not a simple answer. Many users and manufacturers confuse the words “up-screen” and “up-rate”. Up-screening a part is just that, you take a part, and as a one-shot test (or series of one-shot tests) test the devices performance at elevated temperatures etc. This at least checks that the device is capable of operation beyond that manufacturers state limits, but offers no guarantee nor does it help or enhance the devices’ specification or reliability (it could have the reverse effect). Up-rating a part is actually re-writing the specification, effectively superceding the manufacturers specification.

There are some nasty implications, including legal and liability issues, that go with up-rating, and most semiconductor manufacturers strongly deprecate the whole scenario of up-rating. Up-screening has similar issues, but offers no guarantee, and it is the OEM’s responsibility to cover all liability and reliability issues ... all he has got going for him is that fact that the device did once work outside the semiconductor manufacturers specification. Care should be taken, especially with plastic commercial parts, as the screening routine could possibly do more damage to the device, leaving the device as a “walking wounded” part.

Assumptions of homogeneity of a single batch, therefore placing reliance on sample testing, again falls into the trap of assuming that the die and packaging were from the same source ... nothing of the sort is guaranteed in the commercial world, in fact, many manufacturers deliberately outsource the packaging to a number of assembly houses to insure against product delivery “disturbances”.

Plastic vs. Ceramic encapsulation

In most peoples minds, this means cheap versus expensive, which has some bearing in truth, but isn’t the whole picture by any means.

Plastic lets in moisture ... fact.

Plastic encapsulation has a higher thermal resistance ... fact.

High volume ceramic is relatively inexpensive ... also a fact.

Ceramic assembly implies hermeticity of the package ... fact, but only if done properly.

Consider why ceramic was used in the first place. It was used to provide a hermetically sealed, reliable, non-“active-surface” contact package that superceded canning due to lower assembly costs. The coefficient of expansion of the ceramic closely matched that of the silicon die, so robust die-attach methods could be employed. Inspection of the final package was straightforward both for side-brazed and “frit-sealed” or glass-sealed sandwich packages. Ceramic is also a reasonable conductor of heat, not as good as some metal alloys, but much better than that of plastic, hence most devices require to be thermally or power de-rated when used in a plastic package. The implication here is that plastic cannot be used as a drop-in replacement for ceramic without the design being completely re-analyzed.

But plastic is easily molded, is cheap, and is ideal for a low-cost item. The main problems with using plastic parts are from the ingress of moisture, which can give severe problems during board assembly if not properly prepared, and long-term stability of sensitive die. Ingress of moisture can also imply ingress of contaminants; some plastic packages use silicone release agents and plasticizers, and microscopic rubber spheres within the plastic ... excellent internal sources for long-term contaminants.

So plastic packaging is cheaper, and readily available.

But the attendant costs of "bringing" a plastic part upto a military specification (testing, qualification etc.), plus the additional liability and risk issues, often end up being substantially more than procuring or commissioning the original part from the outset. There are still many ceramic assembly houses that can package die product, and, with a full military or hi-rel screen, produce the right part for the right application.

And the internal silicon ?

If the life of the final consumer article is only to be around 5-10 years, why develop the silicon chip to have substantially longer life-time, especially if that means larger die area, more thorough characterization, more comprehensive testing, longer design cycle and ultimately with a higher cost ?

Many modern processes and design rules are not intended for use with military or industrial grade parts; the process may have characterized over an extended temperature, but this often does not translate into reliability or design data. There are many techniques available to the designer to cut corners in order to decrease effective die size, many of which seriously compromise the overall lifetime of the final product. Imbalanced thermal geometry, guard-ring removal, thinner current-carrying connections are all well documented techniques that potentially degrade the longevity and usage of an integrated circuit.

Shrinking Geometries

As silicon geometries shrink in order to permit increasing functionality per square millimeter of active die area, then other issues become relevant. Voltages drop throughout, and as chips speed up, the current consumption increases, thus more and more interconnections are required for the power supply, and additional connections are required for thermal management. As the voltages drop, the noise margins decrease, and more attention has to be given to the chip and system IO capability. The die itself will have an increasing susceptibility to external influences, such as electro-static fields and radiation effects, which then manifest themselves as single event upsets, (SEU). SEU's can be seen as temporary logic "glitches", or in the worst case, as permanently destructive events. Recent research highlights thermal neutron events as being particularly damaging, which is of increasing concern to space and avionic OEM's. Other related issues involved with sub-micro geometries include both metal / oxide failures and increased leakage paths due to quantum tunneling currents.

Micross Component's Viewpoint on COTS

Micross Components Ltd., has been assembling and testing semiconductor devices for more than 25 years, and in that time we have seen many device types; some good and some bad. For our own custom packaging operation, we would normally have to procure the only die/wafers available, i.e. commercial silicon, probe test then assemble into ceramic packages and test/screen the final device to a full military or space specification. Yields on electrical test varied from 0% to 99% but on average we achieved a final yield of around 80%.

These limitations and expectations similarly apply to commercial device up-screening. Without any further testing of COTS in hi-rel applications, it is reasonable to anticipate equivalent component failure rates once built into a system subject to similar temperature and environmental extremes.

For these reasons we would recommend any commercial devices procured to be use in harsh environment systems should undergo additional testing and screening to avoid costly system rework or system failure in service.

PRESS statements : IC makers worry about 'parts abuse'

In July 1997, National Semiconductor Corp.'s military aerospace unit (Sunnyvale, Calif.) issued a warning to its customers to stop "up-screening," or re-testing commercial ICs for use in military or aerospace applications.

"Using components in applications or environments [where] they were not intended can lead to component or system failure," National Semiconductor vice president Richard Cassidy warned. *"National does not authorize the use of its products beyond the published data sheet limits."* Cassidy added that National *"will not be responsible for any component or system failure [deemed] inappropriate use of its product."*

Texas Instruments Inc.'s military unit stated, also in 1997, that it has sent similar warnings to individual customers and is considering issuing a warning letter to all of its military and aerospace clients.

"It is a very significant concern," added Bob Kroeger, general manager of Texas Instruments' Military Semiconductor Products unit in Midland, Texas. *"We're not against [using commercial parts] in the right places. Our position is you need to use the right part for the right application."* *"The Perry directive absolutely does not say to use parts beyond the manufacturer's spec or in applications where either their long-term reliability [or] performance are questionable,"* said Kroeger.

Analog Devices Inc. is facing similar concerns, said John Hartman, military/aerospace business manager at the Wilmington, Mass., company. *"We're afraid a plane will fall on a playground,"* said Hartman. *"It's getting to the point where we've got to protect ourselves."*

Documented examples of commercial parts failures are scarce. The journal Aviation Week and Space Technology reported in December that an unmanned Federal Aviation Administration weather radar using commercial computers experienced "intermittent problems" while operating at a building temperature of 100°F. The temperature was lowered, fixing the problem.

While continuing to push for greater use of commercial electronics in weapons, the basis for the military's shift to commercial semiconductor devices is a 1994 directive from former Defense Secretary William Perry aimed at reforming the Pentagon's notorious acquisition practices. Military IC makers argue that the Perry directive does not require manufacturers to use commercial parts.

Meanwhile, chip vendors predicted the parts-abuse problem will grow as smaller manufacturers struggling to survive against defense giants like Lockheed Martin, Raytheon and Boeing are forced to use more commercial parts to hold down costs in contract competitions.

Some relevant follow-on web-sites :

www.analog.com/marketSolutions/militaryAerospace/cotsmu.html

www.national.com/appinfo/milaero/files/TF_Upscreen_letter_20010718.pdf

[focus.ti.com/docs/military/catalog/general/general.jhtml?templateId=5602
&path=templatedata/cm/milgeneral/data/quality](http://focus.ti.com/docs/military/catalog/general/general.jhtml?templateId=5602&path=templatedata/cm/milgeneral/data/quality)

nepp.nasa.gov

cots.jpl.nasa.gov/slides.html

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*Alun D Jones
Technical Director
Micross Components Ltd.,
Oriel Court, Omega Park
Alton, Hampshire, UK
GU34 2YT*

*Tel : +44 (0) 1420 594180
Email : alun.jones@micross.com
Web : www.micross.com*