

The Emulation and Substitution Minefield

Guide to replacing obsolete semiconductor components

What's the best technical approach to replace my "xyz" chip?

What's the best commercial approach to replace my "xyz" chip?

Custom package or Interposer?

ASIC or FPGA?

Have I considered ALL the available options?

What ARE the available options? If you have ever asked any of the above questions then you need to read this booklet



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Contents

	<i>Page</i>
Emulation and Replacement	1
The 3 Fs: Form, Fit and Function	3
The Form	3
The Fit	4
The Function	5
Or should that be the 4 Fs?	6
A balancing act	6
So where to now?	7
Direct Replacement - Salvage	7
Direct Replacement – New build	8
Direct Replacement – commissioned fabrication run	8
Indirect Replacement – COTS components	9
Newer IC designs	10
Indirect replacement – Second source or close match	10
Indirect replacement – but the wrong package style!	11
Reinvention – using an MCM or SiP approach	11
Who owns what?	12
Don't forget the Memory	13
Re-invention – using FPGAs, PALs or PLDs	14
Re-design – using the original mask sets or tapes.	14
Of ASICs, FPGAs and other things	15
Function migration ... VHDL and Verilog	16
FPGA or ASIC?	16
FPGA migration	17
IP Cores	18
ASIC migration	19
Partnerships and Relationships	19
Technical requirements	20
Technical considerations for a digital replacement part:	21
The inputs	21
The outputs	21
The power supplies	22
The AC performance and timing	22
The Function	22
Semiconductor processing	22
The device package	23
Technical considerations for an analogue or mixed-signal replacement part:	23
Typical “gotchas” on ASIC re-design	23
A simple checklist	25
A backward glance	26
Glossary	28

The publication is one of a series of booklets published by the Component Obsolescence Group, all of which are recommended as essential reading for organisations or individuals tasked with obsolescence management. This series includes:

The Obsolescence Minefield

The Obsolescence Minefield – Senior Executive Edition

The Date Coding Minefield

The Supply Chain Minefield

The Long-Term Storage Minefield

The Pb-Free Minefield

The Redundant Stock Minefield

The Hardware Design Minefield

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This booklet was written by Alun Jones TS2Micro in co-operation with members of the External Liaison Group of the Component Obsolescence Group (COG).

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Emulation and Replacement

Components become obsolete. For want of the component, the board couldn't be built, and for lack of the board the sub-assembly couldn't be finished. With no sub-assembly, the equipment couldn't be repaired, and without the equipment the plane couldn't fly. A scenario that shouldn't ever happen, but it does serve to emphasise that each position in the supply chain is reliant upon what it regards as a component.

One could also start from much further down the chain. The semiconductor foundry relies upon silicon wafers and specialist chemicals; the semiconductor assembly requires wafers, lead-frames, packages and lids, and so on.

So a component can be seen as different things to different industries, but for the purposes of this document, the discussion is mainly centred on semiconductor devices. This is primarily due to the fact that it was the initial withdrawal of many semiconductor devices that woke up large portions of industry to the question of obsolescence management.

This story has been told many times, with different emphasis, generally with the intent to scare. In practice, it would be most unusual for a scenario such as this to escalate so far upwards, as human ingenuity and engineering will generally solve the problem at an earlier stage. Components can be replaced, but a lot depends upon the replacement being really suitable. The original component requirements and operating environment should be reconsidered. The assumptions made in the original design may be overly pessimistic; there may be more "room for manoeuvre" than initially considered, permitting more "alternative" options.

If we're really serious about keeping our equipment alive in the future, maybe some planning should be

done early enough to salt away all the precious information on components, whilst it's still fresh in our collective memories, rather than wait until the proverbial manure hits the office air re-circulation equipment? This means archiving, or ensuring that your subcontractors archive all the necessary information to re-build your critical components ... and those are ...?

The 3 Fs: Form, Fit and Function

The phrase "the 3 Fs" is common parlance to describe the criteria required of a component designed as a replacement part. The answers to the 3 Fs will then determine the capability of a substitute component to act as a direct "drop-in" replacement.

Let's walk through each of these "3 Fs" in turn. Please remember that although we are initially discussing semiconductor ICs, the criteria is generally applicable to all "components".

The Form

Here we are generally considering the mechanical attributes of the component, such as size and shape, and the suitability to withstand and/or survive our assembly/embodiment processes. With an IC, we're typically looking at the package style and size, matching of the device footprint and the ability to use the same board assembly processes.

An IC package is generally designed to conform to a JEDEC outline, but as processes and materials evolve, so older packaging technologies are replaced. Packages can go quickly out of style, typified by the Dual-In-Line (DIL) package being marginalized once surface mount assembly techniques were perfected. There is currently little

issue with the availability of older package styles, but this may change significantly in the future. One example is of metal canning, such as the TO5 and TO18 cans. Prevalent in the 1960s and early 1970s, metal can assembly is becoming harder to find, and is now relegated to a few specialist assembly companies. Changes in the lead finish, due to environmental legislation, such as the Pb-free section of the European Union's RoHS directive, has led some packages and package styles to premature extinction.

Some of the latest-and-greatest "sexy" packages, sprouting pins in all directions, have been developed for the PC and the mobile phone-type market, so have a life or "fashion" expectancy of only a few years, and will be dropped just as quickly as they were introduced.

Please consider that re-engineering and re-tooling a package can be an expensive business. IC packages are not commonly "banked" yet, but this may become more relevant in the future. Ceramic packages generally "move" at a slower pace than their commercial plastic counterparts, but ultimately remain governed by the same supply and demand laws of their high-volume cousin. Currently, the plastic packaging performed by the major packaging houses are subject to high Minimum Order Quantities (MOQ's) or Minimum Order Values (MOV's) due to the nature of their volume business. Indeed, at least one company, based in the USA, offers to "reclaim" plastic packages in small volumes, effectively by "scooping" out the original die and bond-wires to leave a cavity within the plastic package that can be reused. Initial suggestions that this technique is only suitable for prototyping have given way to consideration that this option may be suitable for small to medium production runs.

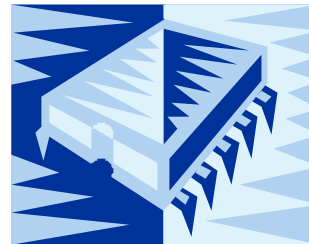
Chip- or die-scale packaging is interesting (from a technical viewpoint), as the package form and

connectivity will alter as the die changes, usually getting physically smaller. The implications for recreating the same footprint are, as you can guess, horrendous. But, *nil desperandum* ... read on.

The Fit

The Fit is concerned with the device specification, and its suitability to meet the system level requirement. This may include thermal and electrical characteristics, along with a whole host of other environmental, reliability and operational parameters.

The "Fit" really asks the two questions "Is it fit for purpose?", and "Will it fit in my application?"



Since the mid-1980s, many semiconductor manufacturers began pulling out of the high reliability / military markets that initially sustained them. The effort required to maintain a presence in a shrinking market was becoming an onerous burden to an increasingly commercially sensitive market. Specifications were re-targeted towards commercial, plastic encapsulated parts, and components were no longer rated nor characterised for the full military temperature range.

1994 saw the Perry report published by the US DOD, which sensibly questioned the military's need for "all things military". The report concluded that the prime criteria for component selection should be that components used should be fit for purpose. The IC's environment, amongst other parameters, should be evaluated against application, effectively

paving the way for the use of Commercial Off The Shelf (COTS) components in specific instances.

This then allowed the military market to take advantage of the wealth of semiconductor product available to the commercial market, and in doing so, sounded the death knell for many companies that specialised in producing high reliability product solely for the military market.

The Perry report is often misunderstood and misquoted. The report did not expressly say “use plastic” as some believe. The Perry report was also attempting to improve the military uptake of commercially available technology, so should be viewed as a functional drive as well. In practice, the initiative was intended to steer engineers away from expensive “special products” towards catalogue items. These could include full military specified devices as CECC or JANTX etc. The result, however, was a significant drop in demand for such suitable parts, resulting in their almost wholesale obsolescence.

Product suitable for harsh environments is harder to source, and often up-rating or up-screening is used to obtain the desired “paperwork”, but if the component was not designed for operation with these extended parameters, no amount of testing can improve the inherent reliability.

Would you worry that your new medical pacemaker actually came from a musical Christmas card, that your aircraft's guidance system had the same reliability as a “tamagochi” product, that a missile warhead was detonated by a commercial calculator chip, or the rail networks time keeping was controlled by a single cheap digital watch?

Component Engineering is a dying resource as is design support from conventional distribution channels.

So the burden is now firmly placed on the component engineers within the large military OEMs to ensure that the selected component meets the operational application targets with a commercial cost constraint; an often daunting, but not impossible, task.

The Function

The Function is exactly that ... does it perform the function in the same manner and as well as the component it is replacing? Does it perform the same operation as the original, and if so, does it replicate the same bugs, trips and traps as the original.

In the same breath, function addresses the electrical environment of the component. Does it have the same input and output characteristics, will it operate with the same supplies, and with the same electrical “ambience”, such as I/O filtering, line impedance, timing characteristics, power supply decoupling etc.?

The function is often the hardest criteria to successfully describe or fully define, but can also be the most critical. There is also the opportunity here for the replacement part to correct errors or omissions of the original part, but if so, is it really a replacement part or an upgrade? Even minor changes in function can be disastrous, as the “bug” in the original chip may have been “employed”, intentionally or otherwise, by the original designers!

Some changes in the operation of the replacement part may be necessary, due to unavoidable advances in processing and manufacturing technology, which may then lead to alterations in the embodiment of the replacing component.

A product requirement document, when written sensibly, is often the best point of reference when starting to analyse a device's function. Analysis of the functional test vectors, either at component or

board level, can also reveal some of the intended function.

It is the author's experience that many COTs devices with apparently identical functionality exhibit significantly reduced performance as one approaches the temperature and/or voltage extremes.

Caution should be exercised in assuming that, just because a part has a similar part number from the same manufacturer, the internal die is identical or even parametrically similar. The die source and design is entirely at the whim of the semiconductor manufacturer, his manufacturing plants and his subcontractors. Consideration that his customer may be "abusing" his parts outside his given parameters is not really his concern, he can now absolve himself of all contractual and warranty obligation.

Or should that be the 4 Fs?

In addition to the 3 Fs above, it is strongly felt that a 4th "F" should be added ... Finance.

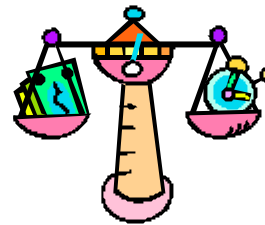
A replacement part may be all well and good, suitable in all aspects, but if the cost, either of purchasing or usage, is prohibitive, potentially rendering the final project or item unviable, then even the best replacement part in the world will remain unsold.

What the eventual customer wants is an economic and viable drop-in replacement that suits all the technical and environmental requirements.

A balancing act

Somewhere between the original 3 Fs of Form, Fit and Function, and satisfying the 4th F of finance lies

a solution that will solve everybody's problem. Sometimes not all the 3 Fs can be readily accommodated, as the original part relied upon



some unique feature or processing that cannot be viably replicated ... so something has to give. This compromise is often referred to as the "Threshold of Pain", i.e. what differences from the original component are

acceptable in the replacement component, what changes can the customer live with and tolerate within his given budget?

In considering this "compromise", some thought should be given to the compounding of changes, i.e. that compromising on more than one front can give rise to a "magnifying" effect, which may only become apparent during final test and integration.

There may still be a point at which the 3 Fs are overly compromised, and so the 4th F, finance, may have to give way. As sung by Mick Jagger of the Rolling Stones "You can't always get what you want ...", so we are often attempting to achieve "Best fit ... not perfect fit".



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