THE FACILITATION OF SOLUTIONS TO OBSOLETE GATE ARRAY & ASIC DEVICES

Substitution and Emulation

One of the most common obsolescence issues concerns the use of: EPLD’s, CPLD’s and FPGA’s. These became very common in the 80s/90’s especially on military programs. This technology multiplied at an accelerated rate and many devices quickly became obsolete, especially military parts. Force have provided a range of solutions to these obsoleted parts by the introduction of FPGA and ASIC, emulations using alternative manufactured devices and the re-packaging of new parts to previous lower I/O count pin-out parts.

By working with the customer, Force have been able to continue the supply of working parts. Thus alleviating the need for major board re-design.

FPGA CONVERSIONS

An FPGA based design can be converted into an ASIC or an FPGA from an alternate source, which can then be used as a drop-in replacement. FPGA conversions can be used as a cost reduction, or as a solution to the problems of FPGA obsolescence.

DESIGN FILES AND SIMULATIONS

An FPGA conversion begins with the original design files. These can be the RTL used to generate the design, or the gate level FPGA netlist. FT converts these files into the library. We need to run simulations to make sure that the design has been correctly converted. Ideally, there are existing simulations that we can use. If not, then we will have to write them. We have the tools and can do a scan insertion. But while this is fine for production, it does not confirm the correct operation of the design.

When our design is done, we extract a test vector from the simulations. Then we program an FPGA with the customer programming data, and run our simulations against it. This confirms that our design works in the same manner as the original FPGA. It also confirms that we have been given the correct design files. The documentation on old FPGA designs may not have been kept up to date, and we need to make sure we are making the current design.

PROGRAMMING EMULATION

Our replacement can be ready for operation as soon as power is supplied. However, in some cases, it is desirable for our part to emulate the programming process. There could be existing firmware that needs to successfully load the FPGA before normal operation can begin. In these cases, FT can design a programming emulator into our design. We don’t actually use the data, but we can trick the rest of the system into believing that we do.
**ITAR**

We may have to get a license to make an ITAR design in our 0.35u technology in the UK. We have access to 0.6u technology and in many cases 0.35u.

**PROTOTYPES AND PRODUCTION**

When the design is complete, we program the new FPGA or in the case of an ASIC replacement we tape out, make masks, make wafers, and then assemble and test prototypes. We typically provide 10 prototypes, with production quantities available in two weeks after prototype approval.

Features:

- FPGA-to-FPGA
- FPGA-ASIC
- Emulation of existing program design to alternative sources
- Footprint emulation for FFF IO and power pins
- Increasing single source for multiple programs.
- Continuance of motherboard design
- Reducing cost of FPGA
- Reducing power

**FPGA Conversion Devices Allow for Quick Design**

- In today's market, cost reduction is a must to maintain competitiveness. FPGA and CPLD devices allow for quick design cycle and corrections or improvements during pre-production. As soon as the design is frozen and volume production starts, cost and manufacture ability becomes the most important criteria. No one wants to pay for programmability that is not required.
- Force Technologies offers a pin-to-pin drop-in replacement of your FPGA/CPLD generating immediate COST SAVINGS. Because WE HANDLE THE CONVERSION, the involvement of your engineering resources is limited. Delivered parts are IN-SYSTEM GUARANTEED thanks to our design techniques. You only pay if the part works in your application! For 15 years Force and our partners have successfully converted many FPGAs bringing cost-effective and easy solution to many customers in a wide range of applications. We have the technology to convert most devices (FPGA/CPLD) available on the market.
- FT also offer a solution for obsolete ASIC conversion.
ASIC HIGH TEMPERATURE SEMICONDUCTORS

FT now offers products based on special high temperature processes to meet the needs of the oil & gas, aerospace, automotive and industrial markets. While designed for ASIC and Mixed Signal Products, any of the FT microcontrollers or standard products can be made available using these processes.

225°C SOIS

FT can achieve 225°C operation by using our 1.0u SOI (Silicon-On-Insulator) process. With SOI processing to reduce leakage, Tungsten interconnect for reliability, and small lot processing, FT ASICs offer an affordable solution to 225°C requirements.

175°C / 150°C 0.35U

FT standard ASICs have been characterised for operation up to 175°C in ceramic packages, and up to 150°C in economical plastic packaging. This process also supports EEPROMs and 5 volt operation.

ASIC/FPGA RESCUE PROGRAM

The FT Rescue Program was created to help companies faced with ASIC or FPGA component obsolescence from their suppliers. A majority of the time, when a supplier issues an end of life, they will offer a chance for last purchase with increase in unit price; sometimes doubling or tripling the price. This results in a huge disruption in cash flow as well as an inflated inventory for the buyer. In order to help our customers to avoid this issue FT offers a low NRE, one-to-one, drop-in replacement of the existing ASIC or FPGA with the guarantee that it will work in the system. Our proven process and methodology ensures the replacement chip meets the most stringent requirements of the customer. FT can provide compliance with DO-254, Mil-, and ITAR standards and has a proven track record in converting designs from military, aerospace, industrial. FT’s unique ability to offer, Standard Structured cell and Custom Structured Cell provides the full spectrum of solutions, no matter what your objectives are. We offer technology nodes from 0.6um (5V IO compatible) all the way down to 65nm (40nm planned) to ensure your design can be converted seamlessly. We are dedicated to each customer to provide a long product lifecycle and low minimum order quantities.

Structured ASIC – the ideal solution

Structured ASIC is especially suitable for legacy designs because of the low NRE, rapid prototype, low MOQ, and silicon proven IPs. FT will target a product from its broad portfolio of Structured ASICs in 0.13u, 0.18u, 0.25µ, 0.35µ or 0.6µ. History shows that more than 95% of legacy ASICs or FPGAs can be mapped to one of these products. In case the design is too large to fit in a Structured ASIC, we
will propose a solution to migrate the design to a Standard Cell ASIC. Regardless of the current ASIC or FPGA, will offer a matching solution

**Experienced in:**

Aerospace, Factory Automation, Industrial Control, Medical Instruments, Military/Defence Systems, Telecommunications, Test & Instrumentation

**REPLACEMENT OF OBSOLETE ASIC OR FPGA**

**Benefits:**

FT will endeavour to provide a drop in replacement for obsolete ASICs or FPGAs with the following advantages:

- Minimal customer involvement limited to providing the list of deliverables and implementing a final test of the ASIC in the system to validate that the ASIC works exactly as the original component.
- Guaranteed to work in the system.
- Low minimal order quantities to support customers’ low annual usage.
- Long product life cycle.
- Low NRE with Structured ASIC.

In some cases, customers may have specific requirements that demand exact matching of the I/O behaviour in the system. FT will run SPICE models on contentious I/O buffers for increased confidence. If the results of this additional test is positive, FT will guarantee that the new ASIC will work in the customer’s system and, if necessary, we will re-spin it at no additional cost.

**Chip Replacement with IP and FPGAs: Example-68000 Processor**

The value of semiconductor intellectual property (IP) in saving time and cost while developing complex new Systems-on-Chip (SoC) designs is well understood. But IP also has a valuable role when old systems need updating.

Many processor or controller-based systems produced 10 or 20 years ago are still going strong. But several of the popular processor chips from that era have become impossible to purchase—they have reached “End of Life”—so replacing worn out system boards or manufacturing new copies becomes difficult.

Designers tasked with extending the life cycle of such systems have two choices:

- Replace the obsolete processor chip with a currently-available processor chip, writing new code that retains compatibility with the rest of the system, or
- Develop your own plug-in, instruction set compatible chip replacement for the existing processor, using an IP core implemented in an FPGA.
Using a new processor chip is a good approach in some situations. But we have found that exact replacement using IP in an FPGA is the best approach for many customer projects.

**Possible replacement with IP**

Replacing an obsolete processor or microcontroller chip with one that’s still available seems attractive and is in fact the best choice for certain projects (more on this later). The biggest challenge here lies in coding the new processor to work with the rest of the existing system as discussed in this EE article.

The customer initially might have considered replacing the original 68HC11 hardware with a completely different processor, but this approach would have required replacing the application software. That would have been a daunting task, because the software was written in tight relation to 68HC11 instructions and internal peripherals. Consequently, switching to a new processor would have required considerable effort and time just for the software redesign.

The challenge of new programming is especially burdensome for products that require certification or other formal approval. As examples, consider that any change in the software of an air flight control system in any country requires recertification by its Federal Aviation Authority."

Note this comment in a discussion of processor replacements:

The original customer for this design makes air data computers, and projects demand to continue well beyond when the "obsolete part stock" quantities of the Z8000 will be around. Since the software for this system has to be certified, changing even one line of code is horrendously expensive.

A variation on this approach is to take advantage of the extra capacity of a modern processor to run an emulation of the legacy device. This reuses the existing application software, but introduces new boot code and timing challenges. The effort to resolve these challenges can exceed the appropriate lifecycle extension budget, consuming any profit to be made in extending the product’s life.

In contrast, simply replacing the obsolete processor part with a new FPGA device that’s fully hardware and software compatible is usually significantly easier and less expensive.

Several customers have found this approach to work well in chip replacement applications. Some examples:

- The market life of an early Sega video game consoles by replacing their discontinued 68000 chip with a 68000 core in an FPGA.
- The same 68000 core was used to continue the 15-year-old stepper motor control system in a pharmaceutical printer. This move also gave them physical space and an effective platform to make improvements to later generations.
- The advantages of still running the considerable software for Intel® 80C188EC processors (e.g., Windows 3.1) were retained by using the 80188EC core and by another company in Australia with an 80186EB core.
- Fabless semiconductor providers cost-effectively developed new niche markets for 8051 and 80186 discrete chips implementing controller IP.
A system manufacturer intends to keep critical 68000-based traffic operation control systems functioning for several more years by replacing the end-of-life chips with FPGAs implementing the 68000 core.

Another benefit of the IP replacement approach lies in the new foundation for product improvement using an FPGA provides. Once software compatibility is proven, an FPGA with room for additional IP cores can present a great opportunity to improve that design. As written in a Chip Design article:

Finally, end-of-life conditions may force a designer to consider replacement hardware. Modern FPGAs are often ideal replacements for end-of-life FPGAs, CPLDs, and ASSPs like PCI controllers and physical-layer interfaces. A single-chip FPGA solution on the printed-circuit board is attractive, as it eliminates the need for an additional configuration device. Another issue is the European Union’s Restriction of Hazardous Substances (RoHS) directive, which is forcing system engineers to adopt modern lead-free devices.

Faster performance, better use of silicon, high-level programming languages, and modern debug tools help make it easier than ever to squeeze new features or quicker operation into an existing product or control system.

Choosing the Best Replacement Approach

Consider these issues when deciding between replacing an obsolete chip with a new discrete processor chip or with an IP core for the original processor.

- **End User Product Life** — How many more years do you expect to ship the product? The longer this life, the greater the chance your new processor chip will also become obsolete, and the more using IP makes sense.

- **Software Code Language and Volume** — How much assembler code must be rewritten to run with a new processor chip? If the system software is small and mostly written in C, for example, rewriting it for a new processor chip may be easier than using processor IP.

- **Licensee’s IC Units per Year** — If the product’s unit volume is very small (e.g., 10 or fewer each year), then the possible future revenue stream is unlikely to justify the expense of redesigning with a new processor.

- **Number of Peripheral Circuits** — Peripherals obtained with the original processor may also be nearing (or past) the end of their availability. If this is the case, and especially if there are many of them, then starting with a new processor and its modern peripherals probably makes the most sense.

- **End-User Equipment Cost** — possible future revenue will rarely justify the costs of switching to a new processor for very inexpensive products, unless their expected annual unit volume is very high.

- **Processor-Specific Chip and Programming Experience** — If the original programmers of the legacy processor are no longer available then continuing to maintain it will be difficult, possibly even more difficult than switching to a newer processor.

- **Experience using IP and FPGAs** — If your design team has little experience using IP cores and FPGAs, then using a discrete processor chip is likely the better approach.
These factors should weigh differently from application to application. For example, a long product lifetime of ten or more years shifts the decision towards using IP and an FPGA even if other factors suggest a new discrete processor chip makes sense (because a new discrete processor chip is also likely to go obsolete in that time).

**Using a Replacement Processor Core: the MC68000**

The M68000 series of CISC processors began with the MC68000 released by Motorola in 1979. The MC68000 used 32-bit internal and 16-bit external interfaces, making it more advanced than the 8- and 16-bit processors popular at the time. Its approach of "forward compatibility" and early 32-bit instruction set made it competitive even against later 32-bit processors.

It was originally produced with a 3.5 micrometer HMOS technology. Smaller feature sizes and faster speeds followed, reaching 16.67 MHz with the 12F version in the late 1980s. Equivalent chips were "second sourced" by several other chip manufacturers, including Hitachi (HD68000), Rockwell (R68000), and Thomson (EF68000 / TS68000). A better CMOS version, called the 68HC000, began appearing from Hitachi, Motorola, and others in 1985. Later family members included the 68010, 68020, and 68030.

The 68000 was a dominant processor in its heyday. Noteworthy products based on it include the early Unix workstations from Sun and Apollo, pioneering personal computers including the Amiga, Atari ST, and Apple’s Lisa and Macintosh, and the first laser printers from Apple and HP. Second sourcing helped spur this 68000 adoption; the Amiga 500 computer, for example, was built using Motorola, Hitachi, Syngentics, and Rockwell chips interchangeably.

Introduced in the spring of 2000, the 68000 IP core was one of the first such products available. The 68000 implemented in an FPGA works identically to the 68000 chip. It uses the same 16/32-bit architecture, runs 55 instructions, has 14 address modes, and includes interfaces to M68000 family peripherals.
In an improvement over the original, the core also supports IEEE1149.1 with a JTAG port. This lets designers use third-party commercial compiler/debugger tools.

**Planning a Replacement Chip Project**

Our experience with many customers successfully replacing obsolete chips with IP cores such as the 68000 suggests a two-step process is most effective:

1. Verify that the core is software-compatible.
2. Merge other functions from the board into the FPGA.

A cost-effective way to conduct these steps is by using an FPGA in a commercial or custom platform board.

For example, consider this 68000-based system:

![Diagram of 68000-based system](image)

Conceptually, the IP core just replaces the discrete chip.

In practice, you’ll also burn the system’s ROM image into the FPGA, and controlling its RAM through the FPGA.

The system I/Os should be initialised by the bootstrap code in ROM, and the system start functioning normally, verifying that the software executes correctly with the IP core.
With software compatibility proven, a next step is to integrate additional functions to take advantage of any remaining capacity in the FPGA. You might, for example, find that I/O 1 and I/O 2 perform well in the FPGA.

You can evaluate the feasibility of this approach by combining your system hardware with a low-cost commercial FPGA evaluation board. Because the voltage is different between the new FPGA and the original MC68000 chip, you’ll need to implement an adapter board with a level-shifter to plug in the FPGA. Additional pragmatic issues to be careful of include potential cross talk between the FPGA and the original hardware.

**Other Chip Replacement Opportunities**

We have focused here on MC68000 chip replacement, but similar benefits can be found in replacing several other obsoleted chips. For example, these IP cores are suitable for replacing older microcontrollers and other discrete chips:

- 8051 and 80251 Processors
- 80186XL and 80186EC Microcontrollers
- 6502 and 65C02 Processors
- 80188EC Microcontroller
- 68000 16- and 32-bit versions
- several UARTs
- 8254 Timer/Counter
- 8237 and 82380 DMA Controllers
- 32025 Digital Signal Processors
- Z80 CPU
- 387 Math Coprocessor

Family variations for any of these can also be effective solutions. When updating a 68020-based system, for example, you might buy and modify the 68000 core if you have considerable 68000 experience, or a 68929 version if not.
Conclusions

We have looked at some of the considerations behind replacing an obsolete processor chip with an IP core in an FPGA rather than using a new discrete chip processor. This approach is conceptually simple, but is likely to present real-world challenges for most designs. For many specific systems and projects though, extending product longevity with IP is still the smartest and most economical approach.