FPGA ISSUES and Concerns: A Real Danger and a Call to Action

The reality of a brittle supply chain could mean harsh consequences for failure to deliver. **by MARTIN HART**

A field programmable gate array (FPGA) is an integrated circuit configurable by customers in the field, making such devices desirable for space and defense applications. A fortified version, known as a Radiation Hardened (RadHard) FPGA, can withstand attacks from electromagnetic and particle radiation in outer space.

Columns, rather than solder balls, are a critical subcomponent in the final assembly of FPGA packages.

A sudden shortage of mission-critical FPGA devices could result in warfighters not flying and rockets not launching. This is not an exaggeration. But how could this be? Quite simply, makers of ruggedized FPGA devices depend on a single subcontractor to provide services to attach copper-wrapped solder columns.

Past production shortages in the semiconductor industry have been short-lived because multiple vendors have been able to quickly step in to fill voids in the supply chain. Today, only a single subcontractor is designated on the Qualified Manufacturer List (QML-38535) as a provider of copper-wrapped solder column attachment services for the entire FPGA industry. Any supply chain dependent on a single supplier is inherently vulnerable. Action is needed to develop a solution to resolve this vulnerability.

Business continuation can become an issue for any number of reasons, ranging from natural disasters to the loss of a key manager due to death or retirement. An existential threat could materialize if a hostile foreign actor acquires or otherwise takes control over a single-source supplier, particularly if production is offshore. In terms of repercussions, a facility relocation typically results in the loss of QML status, pending requalification. It can take up to 24 months for a new candidate to undergo the arduous approval process prior to attaining QML status to provide column attachment services. A prolonged production shutdown of FPGA devices directly impacts US national security, affecting thousands of downstream customers who would be unable to complete systems and black box builds. Proactive steps taken now to identify and monitor the risks can mitigate such a threat.

The US Department of Defense (DoD) provides guidelines to help industry identify and mitigate dependency on services from single-source subcontractors. The Defense Standardization Program Office publishes a helpful document, SD-22, titled, "Diminishing Manufacturing Sources and Material Shortages (DMSMS), a Guidebook of Best Practices for Implementing a Robust DMSMS Management Program." It is a useful resource to aid FPGA device makers seeking to broaden their supplier base for components critical to the welfare of national security. The DMSMS guidebook presents the concerns and recommended remedies to mitigate the risk of loss, or impending loss, of manufacturers or suppliers of items, software, and raw materials.

The Under Secretary of Defense for Acquisition and Sustainment delivers an annual report to Congress titled "Industrial Capabilities" stating the mission of the Office of Industrial Policy (INDPOL), to ensure a robust, secure, resilient, and innovative industrial capabilities upon which the DoD can rely.

Eight companies making the majority of the world's FPGA devices may consider issuing forward-looking cautionary statements to stakeholders, citing their reliance on a single QML vendor to attach copper-wrapped columns. These statements disclose potential risks from the perspective of management's reasoning or beliefs.

Fabrication of copper-wrapped solder columns is not trivial and requires the correct know-how, manufacturing equipment and proficient operator skills to properly attach columns to FPGA packages. Solder column attachment services are not available from your friendly catalog distributor.

Risk of an FPGA production shutdown is preventable by taking prudent action now. The most direct solution is to qualify multiple vendors for critical processes, including column attachment services. This remedy requires a relatively low investment by FPGA device makers.

Supply Chain Resiliency

A production stoppage of critical FPGA devices could result in the failure of the defense industry to fulfill commitments for delivery of warfighters. Furthermore, failure to deliver RadHard FPGA packages could disrupt mission schedules.

Several risk archetypes for achieving a robust and resilient production of FPGA devices include a diminishing domestic manufacturing base and a fragile market. FPGA packages with solder columns are produced in a low-volume manufacturing environment; as such, around 75,000 individual FPGA devices spread over 100 different outline packages are produced annually.

Total annual volumes of FPGA and ASIC devices, with as much as 70 million copper-wrapped solder columns, are minuscule compared to volumes of commercial off-the-shelf (COTS) FPGA devices consuming billions of solder balls. Attaching solder columns to FPGA packages is substantially different from attaching solder balls that dominate the COTS market.

Solder columns are cylindrically shaped pins that must be held vertically in place by precision fixtures without slanting or falling over during the attachment and reflow process. A final assembly step requires the entire matrix array of up to 1,752 columns be planarized without damaging a single column. No manufacturing defects are allowed. Talented operator skills must be employed during every step in the process of attaching columns to FPGA packages. Attaching copper-wrapped solder columns to FPGA packages is fundamentally a nonautomated, artisan process.

Royalty-free, US-manufactured copper-wrapped solder columns are readily available today in the supply chain. But starting from scratch, it could take 24 months for multiple subcontractors to undergo the arduous process of attaining QML status to provide column attachment services.

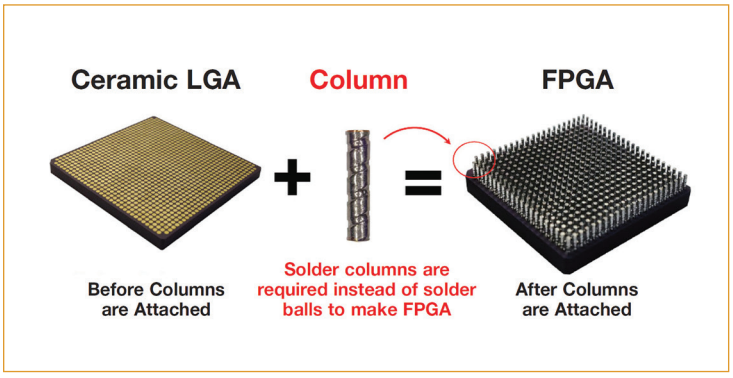

FIGURE 1. Sequence of FPGA package assembly with solder columns.

Monetary considerations. Companies that produce FPGA devices are not required to voluntarily qualify multiple subcontractors to attach copper-wrapped solder columns to their products. A lack of funding by FPGA manufacturing is most often cited as the primary reason for not qualifying a second source. Multiple microelectronic subcontractors in the US supply chain are ready, willing and able to provide column attachment services, provided funding is available to pay for the cost of QML qualification. An accelerated initiative by FPGA makers to mitigate risk and qualify multiple subcontractors to attach copper-wrapped solder columns requires a sizable investment. FPGA makers must take the lead in initiating the qualification of alternative subcontractors. As a practical matter, subcontractors cannot independently apply for QML status without the support of the FPGA maker.

The DoD speaks. The Department of Defense published an unclassified report titled, "Assessing and Strengthening the Manufacturing and Defense Industrial Base and Supply Chain Resiliency of the United States," in fulfillment of Executive Order (EO) 13806, which describes risks that threaten America's manufacturing and defense industrial base.

The 10 "risk archetypes" described in the report are as follows: 1) sole source; 2) single source; 3) fragile supplier; 4) fragile market; 5) capacity constrained supply market; 6) foreign dependency; 7) diminishing manufacturing sources and material shortages (DMSMS); 8) gap in the US-based human capital; 9) erosion of US-based infrastructure; and 10) product security.

Most of the risk archetypes described in the report apply to FPGA manufacturing. Risk archetypes lead to a variety of impacts upon America's industrial base. These include reduced investment in new capital and R&D; reductions in the rates of modernization and technological innovation; potential bottlenecks across the many tiers of the supply chain; and lower quality and higher prices resulting from reduced competition.

Sole source vs. single source. A sole source risk exists when only one supplier can provide the required capability. Fortunately, manufacturing capability for producing copper-wrapped solder columns exists today in the US. Also, multiple subcontractors capable of providing column attachment services for FPGA packages currently exist in America.

A single source exists when only one supplier is qualified to provide a required capability. EO 13806 draws a key distinction between sole source and single source. Multiple suppliers may exist, but only a single source for copper-wrapped solder columns is qualified, according to the Qualified Manufacturing List (QML-38535) published by the Defense Logistics Agency (DLA). Companies that produce FPGA devices are not required to voluntarily qualify multiple subcontractors. It could take 24 months for an alternative candidate starting from scratch to attain QML status should a single source supplier unexpectedly shut down.

Other risks. A fragile supplier is an individual firm that is financially challenged or distressed, and this potentially includes most subcontractors in the US microelectronics industry today. A fragile market occurs when domestic markets have structurally challenging economics and face the potential to move toward foreign dependency.

Presently, a capacity-constrained supply market may not be thought of as problematic. However, a single-source supplier may not be able to keep up with a sudden surge in market demand. Foreign dependency on wafer foundries could become an elevated risk, especially when a domestic foundry does not produce a critical item.

Diminishing manufacturing sources and material shortages risk are often associated with obsolescence that might result

when a relevant supplier issues end-of-life warnings.

Gaps in US-based human capital are an ongoing concern. Think the "graying" of Silicon Valley. The industry needs to keep fresh science, technology engineering and math (STEM) talent in the pipeline, especially within the microelectronics assembly base. Attaching copper-wrapped solder columns to FPGA packages is fundamentally a nonautomated, artisan process, requiring highly developed operator skills. Erosion of US-based infrastructure, including the loss of specialized capital equipment, is a risk, since attachment of solder columns to FPGA packages requires precision tools and fixtures that are difficult to fabricate. Last, product security could be of heightened concern under circumstances where FPGA packages require an assembly step overseas, opening the risk of reverse engineering or embedding trojans by hostile foreign actors.

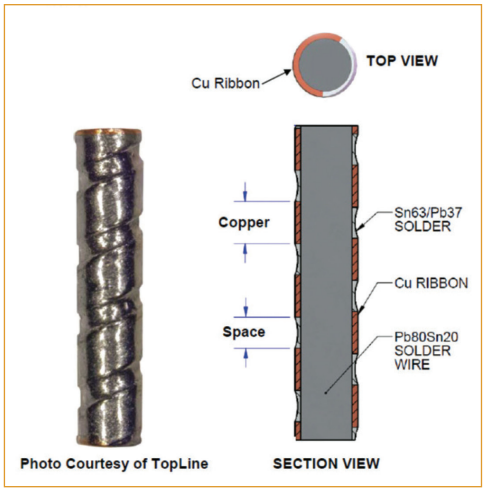

FIGURE 2. Cutaway of copper-wrapped solder column.

FIGURE 3. Braided solder column developed and patented by Topline.

Supply base recovery? FPGA devices used in defense and aerospace applications must be produced by suppliers on the QML. Multiple contractors are at various stages of tooling up, awaiting DLA certification to provide copper-wrapped column attachment services on FPGA and ASIC packages. Six-Sigma, based in Milpitas, CA, is already QML-38535-approved for attaching copper-wrapped columns. VPT Components and Micross Components have also demonstrated the capability to perform these services, and other suppliers, including Golden Altos, plan to offer them. By the end of 2021, it is probable five contractors will be qualified to attach columns to FPGA packages, pending certification.

Most recently, the Covid-19 pandemic has introduced risks not previously considered that can potentially derail America's dominance in warfighter technology. An early casualty of Covid-19 was an advisory to halt travel to conduct QML-38535 audits by DLA employees. DLA audits scheduled in March 2020 were abruptly cancelled. This unexpected event blocks new suppliers from participating in the QML market. The stoppage of DLA field audits means an indeterminate delay in qualifying additional qualified suppliers to make QML FPGA devices. Would DLA consider conducting virtual QML audits using video platforms, such as Zoom or Microsoft TEAMS, to support the supply chain?

The copper-wrapped column attachment service business is currently dominated by a single-source monopoly. Historically, monopolies, left unchecked, tend to drive up costs, extend delivery times, and generally dampen customer satisfaction. The introduction of fresh competition to perform column attachment services is expected to establish competitive pricing and speed deliveries. Multiple vendors offering copper-wrapped column attachment services increases the likelihood that a strong, resilient manufacturing and defense industrial base and supply chain in the United States will result. Original device makers (ODM) have noted FPGA and ASIC packages are suspended in financial limbo for more than a year, while products remain in a state of work-in-process (WiP) before generating cash flow.

Many manufacturing steps are required to produce ceramic FPGA devices. In the first stage, it takes a minimum of six months to procure and produce land grid array (LGA) packages, consisting of ceramic housings, along with necessary die bonding and lid sealing.

Then, it takes a reported additional six months for the current monopoly supplier to attach solder columns to convert the LGA package into a column grid array (CGA or CCGA). Finally, it takes months to perform final testing before the customer receives delivery. This lengthy procuration and production cycle can be significantly reduced by having multiple capable vendors, because they collectively have the bandwidth to perform column attachment services in weeks rather than many months.

New markets imminent. Emerging markets for AI and 5G utilize supersized organic packages, components too large for reliable BGA packaging. Alternative interconnects, other than solder balls, are needed to ensure reliability. This is a burgeoning market sector wherein solder columns can reduce stress caused by mismatches in the coefficient of thermal expansion (CTE) in the package and connection to PCBs. A new type of solder column utilizing copper braid, rather than copper wrapping, has the potential to dissipate more heat, while offering compliancy to extremely large AI and 5G base station packages.[1]

It's time for advocacy stakeholders to initiate a shared vision to ensure a robust, resilient, and sustainable supply chain for FPGA devices. Domestic manufacturing of copper-wrapped solder columns is already available. The next step is to qualify multiple microelectronic subcontractors ready and willing to

provide this process. A prudent investment today can mitigate the risk of waiting for an unexpected disaster to strike, potentially costing the defense industry hundreds of millions of dollars. A production stoppage of critical FPGA components could ultimately diminish market readiness. US manufacturing of copper-wrapped solder columns is available today. By the end of 2021, it is anticipated several subcontractors will offer column attachment services to the industry, once DLA is able to resume auditing and certifying new QML suppliers of column attachment services. Greater US government support to help fund programs to strengthen this critical area will result in enhanced readiness, greater security of supply, and fewer program delays caused by the potential inability to deliver FPGA components in a timely manner.

Where we go from here depends on raising the amplitude for a call to action. Not just rhetoric, but the successful execution of deliberate steps. The speed to which the current brittle market can be fortified depends on judicious access to funding, which will drive the next steps in the roadmap. For example, step one is the US Department of Defense funding an industry effort to strengthen the supply chain for attaching copper-wrapped solder columns to FPGA devices. Step two requires the engagement of subject matter experts (SME) with intimate knowledge of components used in the defense industry to vet proposals from the supply chain. If neither step is initiated, then step three should be initiated. In this step, the eight dominating ODM producers of FPGA components allocate reasonable funding to aggressively encourage multiple subcontractors to qualify solder column attachment services in preparation for certification by DLA. If none of those steps occurs, then we have step four, in which independent subcontractors in the supply chain deploy their own sources of funding to develop processes to attach solder columns to prepare for DLA certification. Step five follows, a proactive discussion with stakeholders, including the DoD, SMEs, FPGA makers and downstream customers to gain momentum for developing a resilient, robust supply chain for column attachment services. This course of action is much more desirable than waiting for calamity to strike. □

REFERENCES

1. Topline Corp., New Copper Braided Solder Columns for FPGA and Large Ceramic Modules, Jan. 1, 2020; www.topline.tv/pdffiles/Braided_Column_Introduction.pdf.

MARTIN HART is chief executive officer of TopLine Corp. (topline.tv) and holds a US patent related to CCGA assembly; hart@topline.tv.