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January 26, 2023

National Telecommunications and Information Administration
U.S. Department of Commerce
1401 Constitution Avenue NW
Washington, D.C. 20230

Attention: Public Wireless Supply Chain Innovation Fund Implementation
Docket Number 221202–0260
RIN 0693-XC053

MaxLinear, Inc. ("MaxLinear") is pleased to provide these comments to the Department of Commerce's National Telecommunications and Information Administration ("NTIA") in response to a Request for Comment on Public Wireless Supply Chain Innovation Fund Implementation ("Request for Comment" or "RFC")[1]. MaxLinear commends NTIA for swiftly implementing the important programs contained in the CHIPS and Science Act of 2022 to support the promotion and deployment of open, interoperable, and standards-based radio access networks ("ORAN"). MaxLinear strongly supports NTIA's efforts to promote the development and proliferation of a strong domestic ORAN-compliant supply chain infrastructure.

1 Introduction

Founded in Carlsbad, California in 2003, MaxLinear is a fabless integrated circuit design company which makes advanced communication systems-on-chip ("SoC") solutions that are widely used in broadband, mobile and wireline infrastructure, datacenters, and other applications. The company was started with founder capital and venture funding, and in the last 20 years we have grown from 8 cofounders to over 1800 full-time employees projected to generate over $1 billion USD in annual revenues in 2022.

MaxLinear achieved its success through pioneering work in integrating high performance radio systems on a chip using conventional CMOS process nodes. This produced innovations which arose by placing these radio frequency (RF) circuits together with mixed-signal circuits and digital signal processing (DSP) algorithms on a single silicon CMOS die. Markets responded with a proliferation of high performance, low-cost, and power-efficient communication systems products. In short, the company has played a key role in bringing Moore's Law to the world of communication systems. This has produced dramatic advances seen across a range of applications.

Today, MaxLinear's products – many of which are already ORAN-compliant – are found in products and systems that form the basis of our communication infrastructure, such as 5G base stations, wireless backhaul, wireline products such as ethernet and xDSL, and optical transceivers found in datacenters and optical networks. These products include 5G/ORAN-

[1] Docket No. 221202-0260; RIN 0693-XC053 (Dec. 7, 2022).

compliant base station transceivers, microwave and millimeter-wave wireless backhaul modems and transceivers, as well as optical transceivers for 5G fronthaul and backhaul applications.

However, nearly all our 5G access infrastructure products are sold to foreign Tier 1 original equipment manufacturers (OEMs[2]) for use in proprietary solutions because ORAN has yet to gain wide adoption, and the domestic 5G/ORAN ecosystem is nascent. Thus, while these products offer state-of-the-art circuits and algorithms, currently their primary customers are foreign companies. At the same time, the research, design and product development of cutting-edge semiconductor solutions has grown increasingly capital intensive with each successive generation of chip technologies, winnowing the field of available suppliers while putting such development out of reach for players with low market share such as new entrants to 5G/ORAN.

MaxLinear is one company capable of designing complex, high-performance SoCs while also being a key participant in the development of competitive products for the 5G/ORAN supply chain. It is from this unique perspective that we provide the enclosed comments.

[2] “OEM” is used within the telecommunication industry to refer to companies which develop and integrate hardware and software systems deployed by carriers and compliant with communication standards such as 5G.

2 Executive Summary

MaxLinear believes there are three crucial areas the Innovation Fund can focus on, in order to develop a fertile domestic ORAN ecosystem able to quickly reach competitiveness against incumbent proprietary solutions. These are:

1. Offer significant and early incentives for carriers to commit a meaningful percentage of their infrastructure investments to using domestically-developed ORAN solutions which meet agreed-upon KPIs
2. Level the playing field for domestic ORAN by supporting development of advanced custom ASIC solutions which can be used across a range of vendors to achieve best-in-class performance, cost and efficiency
3. Invest in world-class ORAN testbeds which give system integrators, domestic OEMs, and component developers commercially-focused, continuously-available facilities for validating interoperability, performance measured by KPIs, multivendor integrations, and scalability

The following sections address each of these recommendations in turn.

3 Carrier Incentives[3]

3.1 Background: System Integration and the "Silicon Gap"

5G equipment manufacturers, and the semiconductor companies designing the chips which power them, make R&D investment decisions based on clear commitments by carriers to bid for, and create systems compliant with carrier requirements. Carriers in turn make technology decisions on a complex set of factors including

1. Support for integration, deployment, and maintenance of systems
2. Overall network compliance, performance, reliability and security
3. Stable and broad supply chain
4. Total cost of ownership

ORAN does not yet have a mature ecosystem of companies capable of adequately addressing points 1 and 2, related to what we refer to as "System Integration", whereas non-domestic OEMs supplying proprietary systems have perfected such capabilities over the course of over two decades. This gap in System Integration expertise has contributed to a performance gap between initial ORAN deployments and Tier 1 OEM (none of which is domestic).

Concurrently, ORAN does not benefit from an open market for Application-Specific Integrated Circuit ("ASIC") components[4], due to the significant investment decision entailed in developing an ASIC supporting ORAN requirements, weighed against the low market penetration of ORAN. This "Silicon Gap" contributes to an additional penalty in cost and performance (as well as

[3] This section provides a response to *State of the Industry* (questions 1, 2, 4) as well as *Technology Development and Standards* (questions 6, 7, and 8).

[4] ASICs can include any complex chip designed for a particular purpose, such as a System-on-Chip (SoC)

energy efficiency) that ORAN equipment pays compared with Tier 1 equipment since ORAN vendors are compelled to design using FPGAs in lieu of ASICs. This acts as a barrier to achieving points 3 and 4 above. We discuss the Silicon Gap in greater detail in Section 4.1.

To summarize, vendors wishing to adopt ORAN face System Integration and Silicon Gap hurdles that are difficult to overcome without substantial resources and industry-wide coordination.

3.2 Recommendations to the Innovation Fund

We believe an important application of the Innovation Fund should be to help the ORAN ecosystem overcome System Integration and Silicon Gap hurdles by creating sufficient incentives for carriers to commit to the adoption of domestically-developed ORAN infrastructure. This could be made contingent on vendors being able to demonstrate agreed-upon key performance indicators (KPIs, discussed in Sections 4.2 and 5).

Such a commitment from carriers is, we believe, paramount to spurring the ORAN ecosystem to build products achieving these KPIs, as well as develop ORAN-compliant ASICs, knowing that the end market for their products was de-risked. The Innovation Fund incentive would also help underwrite workforce training and lead to the creation of high-skilled jobs. In view of this, offering substantial incentives to carriers *early* in the funding life cycle is much more valuable than even distributions over time, or delaying such incentives until later. In summary,

- The Innovation Fund should budget for a cash incentive to carriers, in exchange for their commitment to deploy domestically-developed ORAN infrastructure
- This commitment must result in deployment within a certain time period, over a certain percentage of the carriers' infrastructure
- The carrier commitment is contingent on system integrators and OEMs being able to achieve agreed-upon KPIs
- To get the most value out of such carrier incentives, they should be significant relative to the level of carrier investments, and they should be offered as early as possible

4 OEM Incentives and the Silicon Gap[5]

As introduced in Section 3.1 the Silicon Gap refers to the inability of subscale OEMs and new market entrants to afford the expensive, manpower-intensive process of developing competitive silicon solutions for ORAN when compared against incumbent systems. MaxLinear's product technologies help even the playing field by making the most advanced radio technologies available to the ORAN ecosystem for the first time. Nevertheless this only addresses a portion of the ecosystem.

4.1 Background: the challenge of bridging the Silicon Gap for new market entrants

One of the ways Tier 1 vendors are able to leverage their scale is to invest in custom ASIC development, which amortizes the high cost of such a development over the large volumes of shipments that Tier 1s deploy due to their incumbency. Custom ASIC solutions offer significant advantages because they consume far less power than FPGAs, ceteris paribus. These custom solutions can implement complex algorithms in a more advanced semiconductor process node than FPGA solutions, which makes such algorithms more efficient and cheaper. And, when amortized over larger volume of shipments, custom ASICs are considerably less costly than FPGA alternatives.

In many segments of the market, custom built ASICs are widely understood to be the reason Tier 1 incumbent OEMs are able to outcompete all other competitors. As a result, new entrants including aspiring domestic OEMs are unable to compete on important metrics such as output power, power efficiency, weight and size since they are compelled by economics to use FPGA-based solutions. RAN radio systems can benefit from custom ASICs in the transceiver and digital front end, where more sophisticated power amplifier (PA) linearization can substantially improve the power efficiency of 5G signal generation. PA power consumption is the dominant source of heat dissipation in the radio.

Another important way in which Tier 1 OEMs discourage competitor investment in custom ASICs is to create uncertainty in the ORAN standardization process, which in turn creates uncertainty in the feature set that such custom ASICs must implement to have a useful deployment life.

4.2 Recommendations to the Innovation Fund

In the face of such a competitive disadvantage, we suggest several ways that the Innovation Fund can level the playing field for domestic OEMs:

- First, partially subsidize investments that domestic OEMs make in developing their own custom ASICs, either with semiconductor design partners or on their own
  - This partial subsidy can be used to reduce mask set costs and other engineering costs required to customize ASICs.

[5] This section provides a response to *State of the Industry* (questions 1 and 5) as well as *Technology Development and Standards* (questions 6, and 7b).

  - Another approach would be to encourage domestic OEMs to pool their resources to develop custom ASICs which can be used across a range of interchangeable, ORAN-compliant hardware, and across usage scenarios
- The Innovation Fund should provide incentives to the ORAN community to establish clarity and stability in the specifications roadmap
  - This is important because it creates goals and timeframes for the entire ecosystem, while promoting multivendor interoperability
  - One way incentives could work is to fund ORAN development of clearly defined high level system KPIs for specific usage scenarios
  - System integrators offering multivendor systems could then benchmark against these KPIs, rather than coping with the uncertainty of a continuous flow of low-level feature implementations
  - One way to get industry consensus around KPIs would be to validate them in testbeds which fairly emulate field conditions and usage scenarios (discussed further in Section 5)
- Another way to drive consensus is to support the development of reference designs for both hardware and software stacks
  - This helps create economies of scale around ASIC components, while also reducing the cost and time required for new entrants to develop their differentiated products

5 Domestic ORAN Testbed Development[6]

5.1 Background: the importance of testbeds for successful real-world deployments

For any complex infrastructure system where many different subsystems interact, having access to a testbed for R&D is critical for a number of reasons:

- Testbeds allow vendors to demonstrate end-to-end functionality
- They allow measurement of performance of the system under controlled, reproducible conditions that reflect real-life field deployment scenarios
- In addition, they validates interoperability between equipment from different manufacturers
- They offer a facility for system integrators to debug and improve end-to-end performance
- Testbeds also enable adoption of acceptance criteria based on KPIs

For many of these reasons, ORAN established what are called Open Test and Integration Centres (OTICs) which are intended to serve as such testbeds for the ORAN community. There have also been private initiatives, such as MaxLinear's active role in testbed development with partner companies such as Dell and Meta. While this has been a step in the right direction, in our view there are shortcomings with the execution of OTICs:

[6] This section provides a response to *State of the Industry* (questions 1, 3, 5), *Technology Development and Standards* (question 6), *Integration, Interoperability and Certification* (question 12), and *Trials, Pilots, Use Cases and Market Development* (questions 14, 15), and *Security* (questions 16, and 17).

- For example, few OTICs are located in the US (only 2 in the North America, vs. 4 in EU)
- Implementations also appear to offer only limited scope for reproducing or modeling field scenarios, support for complete ORAN system implementations to validate end-to-end performance, and testing of operation at scale
- They are not always located on commercially-neutral facilities (e.g. some are sponsored by commercial entities)
- Some appear more geared toward long-term academic research topics than current product development
- ORAN compliance and interoperability are performed infrequently, and this serves as another barrier to rapid iteration necessary for speedy product development and the optimization of systems integration particularly within a multivendor ecosystem
- Testbeds should play a greater role in workforce development with respect to current and near-term industry needs in order to nurture domestic ORAN operational expertise

However, the steep cost of building and operating such testbeds is well beyond the individual budgets of most companies. We believe the Innovation Fund's stated goals are well-aligned to addressing these problems.

5.2 Recommendations to the Innovation Fund

Having considered the shortcomings in existing ORAN testbeds, we offer the following recommendations:

- The Innovation Fund should support the establishment of additional ORAN testbeds in the US
  - This is particularly vital for the West Coast where much wireless technology development takes place
- This funding should ensure that new testbeds focus on aiding commercial development and deployment
  - They must offer capabilities essential for developing, debugging, evaluating and optimizing commercial ORAN infrastructure and its component technologies
    - This should include studying and resolving issues related to brownfield integration of ORAN with proprietary solutions
  - The time horizon to field deployment for supported activities should be current to near-term, in the range of 3 years
  - Emphasis should be placed on reproducing realistic, challenging field deployment scenarios including virtualization of resources supporting network slicing
  - Critically they should offer KPI benchmarking, serving as objective means to evaluate performance and efficiency metrics across deployment scenarios
    - These testbeds should offer the ability for vendors to benchmark their products and integrations against proprietary systems
    - KPIs are necessary to serve as objective acceptance criteria by carriers

- Testbeds should be located on neutral facilities, and supported by funds not tied to any particular commercial entity
  - The most suitable sites may be academic institutions, particularly locations with a high density of universities and technology companies such as is readily found on the West Coast
  - They should secure spectrum licenses specifically for testbed use
- Testbeds should help companies assess performance issues with at-scale deployments
  - The Innovation Fund should consider supporting the development of network emulation and virtual infrastructure which can evaluate systems in a simulation environment rather than with physical deployments that are both expensive and constrained in scope
- They should serve as facilities which enable domestic innovation in products, systems and services for all parts of ORAN
  - Innovations often arise from experience with specific or novel use cases, so it is important for the testbeds to offer implementations of each 3GPP service type, and they should encourage exploration of applications by end users
  - Despite an ultimately commercial focus, we believe they should be accessible by all parties of the ORAN ecosystem including academic researchers
- Testbeds should support testing and improvement of end-to-end security and reliability by supporting
  - Security testing of field-deployed scenarios against cyberattacks
  - Stress tests to assess robustness to component and subsystem failures
  - Assessment of software and hardware stability, and the field-upgrade processes
- Finally, testbeds should help accelerate the development of domestic expertise in System Integration necessary in current and near-term commercial infrastructure (Workforce development)