

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

DELTA ELECTRONICS, INC.

Petitioner

v.

VICOR CORPORATION

Patent Owner

DECLARATION OF DR. PATRIZIO VINCIARELLI

I. BACKGROUND

1. My name is Patrizio Vinciarelli. I am the founder and CEO of Vicor Corporation. I am also the first-named inventor on Vicor's U.S. Pats. Nos. 10,199,950 ("the '950 patent"), 9,166,481 ("the '481 patent"), and 9,516,761 ("the '761 patent").

2. I am providing this declaration to explain the impact of the inventions of '950, '481, and '761 patents on Vicor's own products and the industry at large.

3. I graduated from the University of Rome, Italy, in 1970 with a Doctorate in Physics, engaged in research in field theory and elementary particle physics at SLAC (Stanford Linear Accelerator Center), CERN (the European Center for Nuclear Research), the Institute for Advanced Studies in Princeton and Princeton University, published over 40 articles in scientific journals and books, lectured at physics conferences and taught university courses in general physics and electromagnetic theory.

4. I founded Vicor Corporation in 1981 based on an innovative, patented power conversion technology that I developed and that advanced the state of the art in high density power conversion by a factor of ten. As of 1984, DC-DC converters were typically switching at less than 0.2 MHz and exhibited typical power densities of less than 2W per cubic inch. In 1984, Vicor introduced its first DC-DC converter operating at 1 MHz and providing a power density exceeding 20W per cubic inch.

5. As the CEO of Vicor Corporation, I have been actively and continuously involved in the design and development of power converters, power conversion topologies, and power distribution architectures since 1981, and am the named inventor of 216 U.S. patents relating to power conversion technologies. As a result of this work, I am familiar with the development of the art of power supply design from 1981 to the present time.

II. VICOR

6. Vicor Corporation is a NASDAQ-listed company founded in 1981. Vicor is a leading provider of high-performance power converter modules and systems for use in enterprise and high-performance computing, industrial equipment and automation, robotics, UAVs, vehicles and transportation, satellites, and aerospace and defense. Vicor is headquartered in the United States, and manufactures its power converter modules at facilities located in the United States. In all, Vicor employs approximately 1,100 people in the United States, with manufacturing facilities and offices in Andover, Massachusetts; Santa Clara, California; Lombard, Illinois; and Lincoln, Rhode Island.

III. RELEVANT INDUSTRY, PRODUCTS, AND HISTORY

7. The Vicor products most relevant to the '950, '481, and '761 patents are called Non-isolated Bus Modules, or "NBMs". Vicor's NBMs are typically used in data centers. These facilities house electronic equipment needing a substantial

amount of power. For example, a modern data center may use a large multiplicity of servers or AI processors whose aggregate power consumption may reach 100 megawatt (MW). Within data centers power is distributed at a high voltage, converted to a lower, intermediate bus voltage and utilized at a low voltage, as low as 0.7 V for contemporary logic circuits.

8. Earlier telecommunications facilities would also use a distributed power architecture. Power from utility main lines was provided at a high AC voltage. The high AC voltage was down-converted (lowered) and rectified, resulting in an internal power bus carrying power at negative 48 V DC and routed throughout the facility at this -48 V level to wherever it was needed. Close to the “Point-of-Load”, so-called DC/DC converters would convert power to the voltage levels required by the equipment. DC/DC converters would typically use a transformer, providing isolation and down-conversion of the voltage. DC/DC converters would also provide regulation of the output voltage, holding the output voltage at a required level with low variation, even when the input voltage or load demand changes.

9. Telecommunications facilities used a bus carrying power at negative 48 Volts to avoid electrochemical reactions with exposed copper wires and at battery terminals. (Ex. 2023, p. 5). Batteries were needed to provide backup power, and were typically available in parallel to the – 48 V source to back up a utility power failure.

10. The – 48 V telecommunications bus was the incumbent standard for adoption in high power racks within data centers around the time of the inventions of the '950, '481, and '761 patents (the 2010-2013 timeframe, hereinafter the “relevant timeframe”). Data centers viewed the telecommunications power systems as “tried and true”, and borrowed standard equipment and techniques from telecommunications systems. In articles concerning telecommunication and data center power infrastructure in that timeframe and earlier, people would sometimes refer to the negative 48 V power bus as simply a “48 V” bus. For example, in the attached Exhibit 2003 (an Ericsson design note), Fig. 1 is described as having a “-48 V telecom bus”, but in Fig. 1, the bus is simply shown as providing a “48 V input”. (Ex. 2003, p. 2).

11. About two decades ago, many telecommunications providers began to transition from Distributed Power Architecture to what is now known as an “Intermediate Bus Architecture” or “IBA”. In IBA, a so-called “bus converter” converts power from the -48 V bus to an intermediate bus, at e.g. +12 V. The change in polarity from -48 V to +12 V would be handled by reversing polarity through a transformer-isolated bus converter. The bus converter usually did not regulate its nominally +12 V output, because regulation would impact efficiency and power density. The +12V bus would route power to a multiplicity of loads, where individual Point-of-Load converters would down-convert from +12V to the voltage

level needed by the load, and provide regulation.

12. The implementation of IBA therefore called for two different power system components: a bus converter and a POL converter. The bus converter was usually a so-called “fixed ratio” converter, because it did not provide regulation. Instead, it would down-convert the input voltage in a fixed ratio, for example 4 to 1 (e.g. - 48 V to 12 V). Variations in the input voltage would affect the output voltage, at the fixed (e.g, 4:1) ratio. POL converters, on the other hand, were regulating converters designed to provide a regulated voltage directly to loads, typically processors or other digital components.

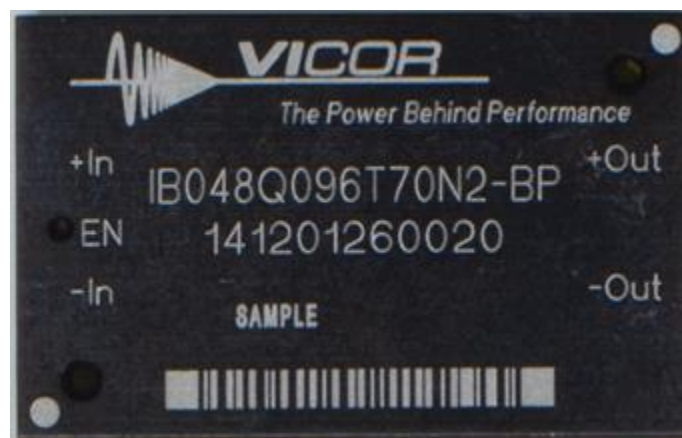
13. To compete with DC/DC converters that had the isolation and regulation functions all in one package, bus converters needed to be very efficient.

14. In general, both bus converters and POLs had certain characteristics that made them more attractive in the marketplace: for bus converters, primarily their efficiency and power density. Efficiency is the ratio of output power to input power. In general, processing of power (for example, by providing galvanic isolation, changing the voltage level or providing regulation) will result in some inefficiency, i.e., power dissipated as waste heat. Waste heat is a significant problem, because thermal management is a complex and expensive part of the infrastructure and operation of telecommunications facilities and data centers. Bus converters and POLs would also be assessed based on the amount of power they could process in a

given physical volume: a metric known as “power density” (Watts/in³). Power density was extremely important: power modules that could process more power in less space, within a server rack, were highly desirable.

15. Before the '950, '481, and '761 patents issued, Vicor offered bus converter products, called BCMs, based on a proprietary converter topology, known as “Sine Amplitude Converter” or “SAC”. The SAC was a significant improvement over prior art bus converters. Vicor’s SAC-based BCMs were able to reduce switching losses and provide high efficiency while operating at a much higher (e.g., 10X) switching frequency, which enabled smaller components and solutions. This led to an industry-leading power density.

16. As one example of this, a photograph of Vicor’s Bus Converter Module IB048Q096T70N2-BP (from 2012) is shown below:



17. This converter had a maximum power capacity of 750 W in a volume of 1.40 in³ (2.30 x 1.45 x 0.42in), for a power density of 535 W/in³. (Ex. 2024, pp.

6, 1). Such a converter would take up an area of 3.3 square inches on a mother board.

IV. IMPACT OF THE INVENTIONS

18. The '950, '481, and '761 patents had a significant impact on the efficiency and power density of such Vicor bus converters. These inventions redefined the role and structure of a “bus converter”, by enabling a tenfold increase in power density.

A. The '950 Patent

19. The '950 patent claims, among other things, a converter having a galvanic connection between the input and the output, as stated, for example, in the language of a claim that states “wherein the input circuit of the bus converter and at least a portion of the output circuit of the bus converter are galvanically connected in series across the source such that an absolute value of the input voltage V_{IN} applied to the input circuit is approximately equal to the absolute value of the DC source voltage V_S minus a number N times the absolute value of the output voltage V_{OUT} , where N is at least 1.” In simple terms, this means that a fraction (e.g., 25%) of the output power bypasses the converter’s power train (including a transformer and power semiconductors), and is provided directly to the output. This enables efficiency to be increased, as a fraction of the output power is effectively delivered to the output without any power loss.

20. A galvanic connection, i.e., loss of isolation, between the input and

output circuits of a bus converter was thought to be problematic in the relevant timeframe. This was for several reasons. First, operators of telecommunications facilities and data centers believed that a bus converter should be isolated. This was both for safety reasons and signal integrity that can be compromised by noise due to loss of isolation. With respect to noise, it was well-known in the relevant timeframe that input voltages to a facility could (and did) vary over a wide range of values, depending on the state of upstream generators, giving rise to voltage spikes which, without isolation, would be coupled directly from the bus converter input to its output.

21. Second, because the input voltage to a bus converter was negative (e.g., -48 V), galvanic isolation between input and output was deemed to be necessary.

22. For these reasons, the concept of a non-isolated bus converter replacing an isolated bus converter, was met with significant resistance from within Vicor and the industry at large. For example, Vicor's own Vice President of Marketing, Steve Oliver, reacted to the NBM concept of a Non-isolated Bus Module by asking "who would buy a bus converter without isolation?", and then stating that this would be a product without a market.

B. The '481 patent

23. The '481 patent is directed to a method for operating a Sine Amplitude Converter ("SAC") by controlling each switching event of the SAC to occur at a

cadence set by a digital clock providing zero voltage and zero current switching at a standard frequency and operating period. This is embodied in the entirety of claim 1 of the '481 patent, but in particular in those limitations requiring standard timing for primary and secondary MOSFETs (*e.g.* “generating timing control signals for each of a plurality of events based upon the clock signals in a (A) standard converter operating cycle, having a standard operating period and frequency” and “wherein the oscillator frequency is preset”), the limitations requiring zero-voltage and zero-current switching, and the limitation requiring independent control signals (“the timing of the timing control signals for one or more selected events may be set independently of other timing control signals and events.”).

24. The approach disclosed and claimed by the '481 patent was again contrary to the conventional wisdom. In prior generations of SACs, analog sensors were used in a closed-loop analog circuit to time the primary and secondary MOSFET switches. This was done to cause the SACs to operate at their resonant frequency, which depended upon transformer leakage inductance and resonant capacitance. These parameters vary between devices, between production runs, or with environmental conditions, particularly operating temperature. Variations in resonant frequency that could cause loss of zero voltage and zero current switching were thought to necessitate the use of analog circuitry to sense when switching should occur, and automatically adjust switch timing through a closed-loop control

methodology. This is explained in Vicor's prior U.S. Pat. No. 6,984,965 (Ex. 1009 in the '481 patent IPR, IPR2024-00187), which is incorporated by reference into the '481 patent at column 1, lines 13-20, and referred to as the "SAC patent". Our prior '695 patent states:

"One way of controlling the switches in the SAC is to turn them ON and OFF using signals whose frequency, relative timing and ON and OFF intervals are pre-determined. This, however, requires that the relative timing of the switch control signals be adjusted to compensate for variations in the characteristic resonant frequency due, for example, to component value variations in individual units. A preferred way to control the switches is to provide an 'automatic switch controller' which automatically turns the switches OFF at times when the sinusoidal component of the currents I_1 and I_2 (FIGS. 10C, 10D) returns essentially to zero and which provides an energy-recycling interval sufficient for ZVS at each switch transition prior to turning the complementary switch ON. The benefits of using an automatic switch controller include minimization of switching and conduction losses and maximization of converter efficiency; elimination of timing adjustments in individual SAC units due to variations in values of circuit elements resulting from component tolerances, optimization in current sharing accuracy among SACs in a parallel array, as discussed below; optimization of soft switching, i.e. primary ZVS and secondary ZCS and ZVS; and maximization of the spectral purity of the sinusoidal waveforms in the converter."

(Ex. 1009 in IPR2024-00187, 21:52-22:8).

25. In the above-referenced section of the prior SAC patent, the “automatic switch controller” is the analog circuitry that controls switching.

26. Furthermore, prior art analog control circuitry recycled the energy needed to charge and discharge the gate capacitances of the MOSFETs. This is described in the Background of the '481 patent at column 2, lines 13-22:

“One way to efficiently recycle the energy is to use a resonant technique. Apparatus and methods for resonant recycling of capacitive gate energy are described in: High Efficiency Floating Gate Driver Circuit Using Leaking Inductance Transformer, Vinciarelli, U.S. Pat. No. 6,107,860; Lossless Gate Driver Circuit for a High Frequency Converter, Steigerwald, U.S. Pat. No. 5,010,261; High Frequency Control of a Semiconductor Switch, Toile et al., U.S. Pat. No. 7,602,229; and Gate Driving Circuit, Inoshita, U.S. Pat. No. 7,091,753.”

27. In contrast to the traditional analog closed loop, the '481 patent teaches an open-loop digital-control methodology to switch MOSFETs. The digital controller (not relying on events that occur in the system on a cycle-by-cycle basis to control the MOSFETs) generates timing signals (to control the occurrence of each switching and other events) based on a preset cadence established by the digital controller's preset clock and preset registers. Although adjustments to the preset parameters may be made during manufacture or operation based upon observed circuit conditions, timing signals from the controller remain open-loop with respect

to the power train. This is reflected in claim 1 of the '481 patent as the ability to impose a standard operating frequency and period, as well as the ability to set signals to control primary and secondary MOSFETs independently in a converter that employs zero-voltage and zero-current switching in both primary and secondary MOSFETs.

28. Remarkably, the open-loop SAC controller methodology enabled higher SAC efficiency and power density. Variability in resonant frequency and the inability to recapture gate charge energy were offset by the speed with which we could charge and discharge the gate capacitances of the MOSFETs. The preset cadence allowed more precise timing than with traditional closed-loop control, allowing SACs to operate at a higher frequency, with higher power density while still achieving ZVS and ZCS. The area taken up by the digital SAC controller turned out to be less than the space needed by analog sensors and the automatic switch controller.

C. The '761 patent

29. The '761 patent is directed to symmetric layouts of power semiconductor devices of a power converter with a multiplicity of cells, to cut interconnect losses between transformer windings embedded within a PCB and the power semiconductor devices mounted on the top and bottom surfaces of the PCB, and to balance distribution of power dissipated by devices symmetrically arranged

on the top and bottom surfaces of the PCB. This is embodied in claim 1 of the '761 patent, in claim limitations that recite:

“a plurality of power semiconductor devices, a first set of the power semiconductor devices being mounted on the top Surface and electrically connected to dissipate power at a level, P_t , during operation of the converter, a second set of the power semiconductor devices being mounted on the bottom Surface and electrically connected to dissipate power at a level, P_b , during operation of the converter; wherein the power semiconductor devices are distributed between the first and second sets to distribute heat generation during operation of the converter Such that each level P_t , P_b is less than 150% of the other level P_b , P_t .”

30. This design approach was once again contrary to the conventional wisdom at the time, which called for the power semiconductor devices, the MOSFETs that generated the most heat, to be asymmetrically placed on the side of the converter module facing a heat sink. As Vicor's prior U.S. Pat. No. 7,361,844 (incorporated by reference into the '761 patent at 1:42-47), entitled, “Power Converter Package and Thermal Management” stated:

“In applications where heat is primarily removed by forced airflow or by an external heat sink coupled to the top surface 35, cooling of power dissipating components, such as MOSFET power switches 448, is enhanced by placing the devices on the top surface of the circuit board 442, in close proximity to the large top surface 35.”

(Ex. 2002 in IPR2024-00227, 11:17-23).

31. Surprisingly, however, placing MOSFETs of converter cells carrying current symmetrically at the top and bottom surfaces of the converter's PCB reduced winding interconnect losses, improved converter efficiency and increased converter power density. Placing MOSFETs symmetrically on the top and bottom surfaces of the of the PCB increased bus converter efficiency, because MOSFETs of complementary cells could split current carried through common VIAs to transformer windings within the PCB.

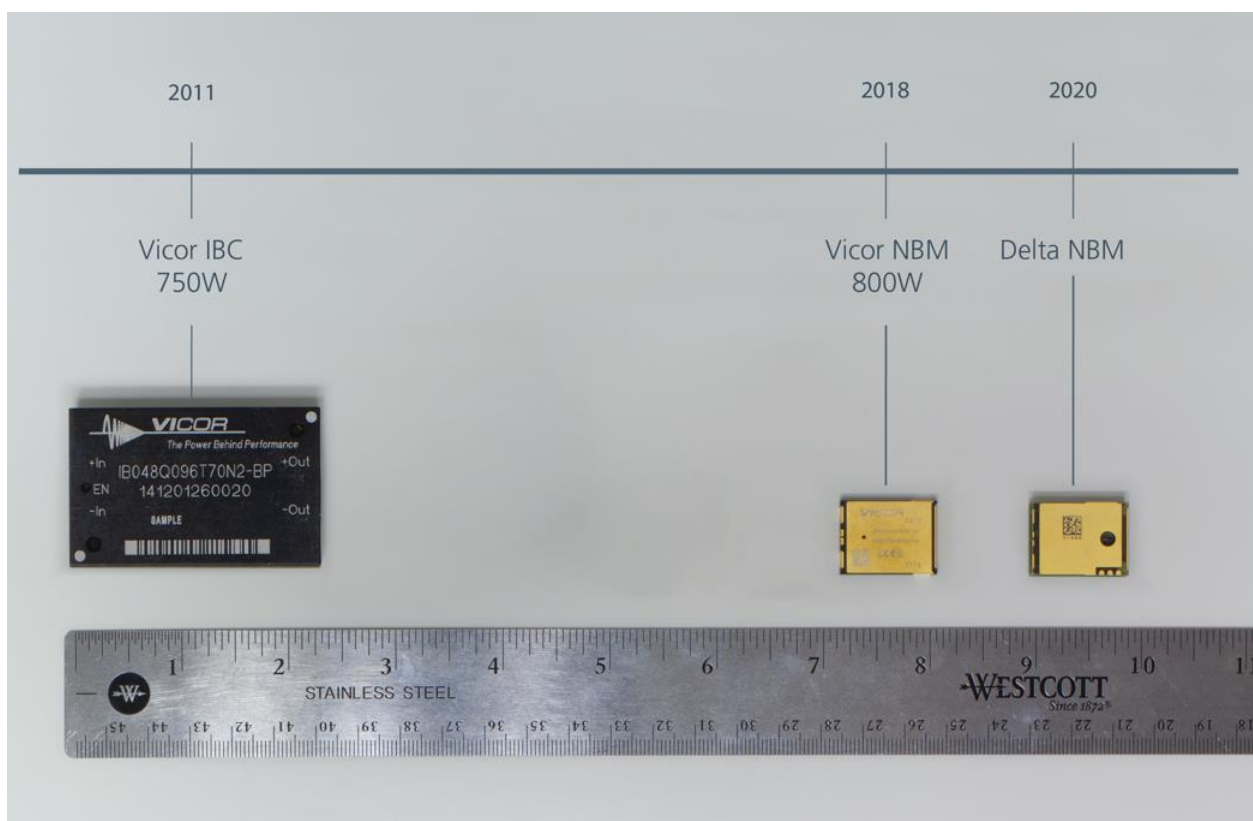
V. EFFECT OF THE INVENTIONS ON VICOR PRODUCTS

32. The inventions of the '950, '481 and '761 patents were conceived and developed at Vicor in the 2010-2013 timeframe, and ultimately led to Vicor's NBM line of products, the first of which were introduced in 2017. Vicor's NBMs derived significant performance advantages from the '950, '481, and '761 patents. The inventions led to gains in efficiency and savings in space, enabling an increase in power density over Vicor's previous generation of products by nearly a factor of ten (10X). For example, Vicor's NBM2317, introduced in 2017, processed 800 W within a volume of 0.12 in³ (0.90 x 0.68 x 0.20in), for a power density of about 6535 W / in³. (Ex. 2026, p. 1). This is a ten-fold increase in power density from one generation of bus converters to the next.

33. After the introduction of Vicor's NBM products, Petitioner Delta

introduced NBM modules copying each of the teachings of the three Vicor patents, as shown in the attached claim charts. (Ex. 2031).

34. The evolution of bus converter technology, as pioneered by Vicor, can be seen in the following image showing, to scale, the relative dimensions of Vicor's prior bus converter product (2011) on the left, Vicor's NBM 2317 (2018) in the middle, and on the right, a copycat product introduced by Delta in 2020, with added annotations at the top:



35. The NBM2317 module, shown above, uses the '950, '481, and '761 patented inventions, as articulated in the attached exhibits. (Ex. 2032).

36. Despite the increase in power density, Vicor's NBM products, and the

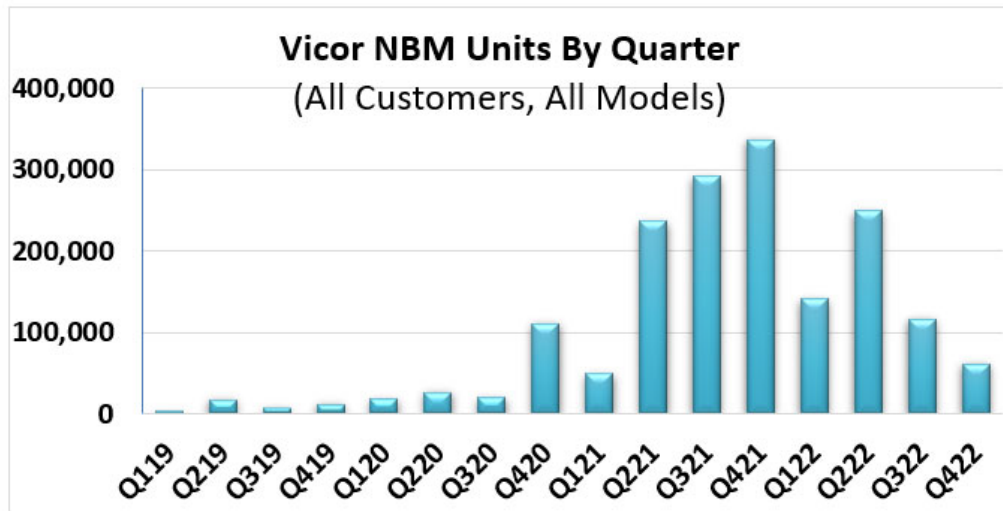
concepts behind them, however, were initially greeted with skepticism.

37. In April 2015, Vicor presented to a High Performance Computer and Data Center OEM its positive 48-volt power distribution architecture. Because of the stronghold of negative 48-volt power distribution, the industry was skeptical of using positive 48-volt without galvanic isolation, citing safety, reliability, and noise concerns.

38. Vicor, however, persisted in its effort to bring positive 48-volt power distribution and its benefits to market and ultimately broke through that skepticism. Major OEMs, including Google, first adopted Vicor's positive 48-volt distribution in the form of Vicor's patented Factorized Power Architecture ("FPA"). Still, despite success with early adopters, FPA was largely viewed as a niche technology, and skepticism about positive 48-volt power distribution in high-performance computing and data center cloud servers remained.

39. At the 2017 Applied Power Electronics Conference and the 2017 Open Compute Project, Google began to publicly laud the benefits of positive 48-volt distribution based on its experience with FPA and visibility of Vicor's Non-IBA with NBMs. Others followed in Google's steps, first by using Vicor's FPA and then by using its Non-IBA with NBMs. Notably, NVidia's "A100" was the first Artificial Intelligence GPU using FPA and positive 48-volt power distribution. And NVidia's next generation H100 GPU used Vicor's Non-IBA with NBMs.

40. While it is difficult to partition the contribution of each of the inventions of the '950, '481, and '761 patents to the tenfold increase in NBM power density, each one contributed to the increase in significant ways based on improvements to the design of the NBM converters claimed in each of the patents, as discussed above. The breakthrough in NBM power density enabled high-end servers and AI accelerators, and drove general adoption of a positive 48 V input bus infrastructure. Sales of Vicor NBM 2317 rose from a few thousand units in the fourth quarter of 2019 to over 300,000 in the third quarter of 2021. In 2021, a leading artificial intelligence (“AI”) OEM licensed Vicor’s patents and started paying royalties on NBMs sourced from third parties. However, unlicensed sales of infringing products by third parties began in earnest in late 2021, and had a serious impact on sales of Vicor’s NBM 2317 product, which had otherwise enjoyed an exponential growth curve, as shown in the chart below, which shows the number of units of NBM 2317 sold by quarter:



VII. OATH

41. This declaration and my opinions herein are made to the best of my knowledge and understanding, and based on the material available to me, at the time of signing this declaration. I declare under penalty of perjury under the laws of the United States of America that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true. I understand that willful false statements and the like are punishable by fine or imprisonment, or both (18 U.S.C. 1001) and may jeopardize the validity of the application or any patent issuing thereon.

Date: **2/19/2024**

Signed: ***Patrizio Vinciarelli***