

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

DELTA ELECTRONICS, INC.

Petitioner

v.

VICOR CORPORATION

Patent Owner

IPR2024-00134
Patent No. 10,199,950

DECLARATION OF PROF. JUAN RIVAS-DAVILA

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1. I, Dr. Juan Rivas-Davila, hereby declare as follows:

I. ENGAGEMENT AND COMPENSATION

2. I have been retained by Vicor Corporation (“Patent Owner”) as an expert in the *inter partes* review proceeding described above. I have been asked to provide my technical review, analysis, insights, and opinions regarding the references that form the basis for the alleged grounds of unpatentability set forth in the Petition for *inter partes* review of US 10,199,950 (the ’950 Patent). For this service, my billing rate is an hourly consulting fee of \$525 / hour, and I am reimbursed for actual expenses. My compensation in no way depends on the outcome of this matter.

3. This declaration sets forth my analyses and opinions based on the materials I have considered thus far and the bases for my opinions. I understand that this declaration will be used in the above mentioned *inter partes* review. In forming my opinions, I have considered the following documents:

Exhibit	Description
1001	U.S. Patent No. 10,199,950
1002	Certified File History of U.S. Patent No. 10,199,950
1003	Declaration of Douglas Hopkins
1005	Daocheng Huang et al., <i>Novel Non-isolated LLC Resonant Converters</i> , 2012 Twenty-Seventh Annual IEEE Applied Power Electronics Conference and Exposition (APEC) (Feb.

	2012) (“Huang”)
1006	U.S. Patent No. 7,307,857 to Yan-Fei Liu and Sheng Ye (“Liu”)
1007	U.S. Patent No. 9,166,481 to Patrizio Vinciarelli and Sergey Luzanov (“the ’481 Patent”)
1008	Fred C. Lee et al., <i>Design Challenges for Distributed Power Systems</i> , Asian Power Electronics Journal, Vol. 1, No. 1 (Aug. 2007)
2002	Morrison, D., “Distributed Power Moves To Intermediate Voltage Bus”, <i>Electronic Design</i> , Sept. 16, 2002, pp. 55-61.
2003	Ericsson, Design Note 023, “Selection of Architecture for Systems using Bus Converters and POL Converters”, May 2005.
2004	Bindra, “Two-Stage Conversion Redefines Distributed Power Architecture”, <i>Power Electronics Technology</i> , 2003.
2005	Petition for <i>inter partes</i> review in IPR2024-00187.
2006	Bel Power Products, “Intermediate Bus Architecture”, White Paper.
2007	“International Rectifier Introduces DC Bus Converter Chip Set Re-Defining Distributed Power Architecture for Networking and Communication Systems”, May 5, 2003.
2008	Bel Power Products, Bus Converter, Preliminary Data Sheet.
2011	U.S. Pat. No. 7,184,280.
2012	Huang, H, “Designing an LLC Resonant Half-Bridge Power Converter”, 2010 Texas Instruments Power Supply Design Seminar.
2013	McDonald, “Design and Optimization of a High-Performance LLC Converter”.
2014	Microchip, “DC/DC LLC Reference Design Using the dsPIC® DSC” (“AN1336”).

2015	Malik, R., “The Power System Challenge - Understanding the Total Picture”, IEEE 2003.
2016	Zhu, et al., “Three-Level Switching Cell for Low Voltage/High-Current DC–DC Converters”, IEEE Transactions on Power Electronics, Vol. 22, No. 5, Sept. 2007.
2017	Miftakhutdinov, Rais. "Improving system efficiency with a new intermediate-bus architecture." Texas Instruments Inc. Seminar. Vol. 2. 2009.
2018	Brush, “Distributed Power Architecture Demand Characteristics”, IEEE 2004.
2019	Xu, <i>et al.</i> , “Voltage Divider and its Application in the Two-stage Power Architecture”, IEEE, 2006.
2021	Intel® Xeon® Processor E5-2400 Product Family Datasheet - Volume One, May 2012
2022	Yan-Fei Liu, “Source Reactance Lossless Switch (SRLS) for Soft-Switching Converters with Constant Switching Frequency”, IEEE Transactions on Circuits and Systems-I: Fundamental Theory and Applications, Vol. 43, No. 4, April 1996.
2023	Salato, “Re-Architecting 48V Power Systems with a Novel Non-Isolated Bus Converter”, Vicor White Paper, 2018.

II. QUALIFICATIONS

4. I am currently an Associate Professor in the Department of Electrical Engineering at Stanford University and Fellow at the Precourt Institute For Energy. At Stanford, my research focuses on high-frequency power converters, such as the ones at issue in this matter. I was also responsible in 2023-2024 for teaching courses in the Electrical Engineering Department entitled “Power Electronics” and

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“Resonant Converters”. My laboratory at Stanford is the Stanford University Power Electronics Research Laboratory. I joined Stanford in 2014 as an Assistant Professor.

5. I hold a Ph.D. in Electrical Engineering from the Massachusetts Institute of Technology (MIT), awarded in 2006. My Ph.D. thesis was entitled “Radio Frequency dc-dc Power Conversion”. I also hold a Master’s Degree in Electrical Engineering from MIT (2003), and a Bachelor of Arts degree from the Monterrey Institute of Technology (1998).

6. Prior to joining Stanford, I was an Assistant Professor in the Electrical Engineering Department at the University of Michigan (2011-2013).

7. During the timeframe 2007-2011, I worked as the Lead Power Electronics Engineer for General Electric’s Global Research Center. My work there focused on the development of high-frequency power converters.

8. From 2018 to June 2021, I served as an Associate Editor for the IEEE Power Electronics Society Journal of Emerging and Selected Topics in Power Electronics. I am also a reviewer for the IEEE Power Electronics Society. From 2019 to 2021, I served as Vice Chair of the Technical Committee for Power & Control Core Technologies for the IEEE Power Electronics Society.

9. I am attaching a copy of my C.V. to this declaration. As shown in my C.V., I have authored dozens of papers in the field of Power Electronics and

the design of power converters. I am a named inventor on nineteen issued patents relating to power electronics.

III. MY UNDERSTANDING OF THE RELEVANT LAW

A. Claim Construction

10. I understand that a claim term in an *inter partes* review is to be interpreted according to standards applied by district courts. First, the language of the claims themselves is of primary importance in the effort to determine precisely what it is that is patented. The terms used in a claim are generally given the ordinary and customary meaning that the terms would have to a person of ordinary skill in the art in question at the time of the alleged invention, unless the term is expressly defined in the patent. The person of ordinary skill in the art reads the claim in the context of the entire patent, including the specification. Next to the language of the claims, the specification of the patent is the single best source for interpreting the claim terms. The claims may also be interpreted using the record of correspondence between the patent applicant and the Patent Office, and also with reference to other sources of evidence that can help to define the meaning of terms to a person of ordinary skill in the relevant time frame. I define the relevant time frame in ¶63, below.

B. Anticipation

11. I understand that a claim in an issued patent can be invalid if it is anticipated. In this case, “anticipation” means that there is a single prior art

reference that discloses every element of the claim, arranged in the way required by the claim.

12. I understand that an anticipating prior art reference must disclose each of the claim elements expressly or inherently. I understand that “inherent” disclosure means that the claim element, although not expressly described by the prior art reference, must necessarily be present based on the disclosure. I understand that a mere probability that the element is present is not sufficient to qualify as “inherent disclosure”.

C. Obviousness

13. I understand that a claim in an issued patent can be invalid if it is obvious. Unlike anticipation, obviousness does not require that every element of the claim be in a single prior art reference. Instead, it is possible for claim elements to be described in different prior art references, so long as there is motivation or sufficient reasoning to combine the references and a reasonable expectation of success.

14. I understand that a claim is invalid for obviousness if the differences between the claimed subject matter and the prior art are such that the subject matter as a whole would have been obvious at the time the alleged invention was made to a person having ordinary skill in the art to which said subject matter pertains.

15. I understand, therefore, that when evaluating obviousness, one must consider obviousness of the claim “as a whole”. This consideration must be from the perspective of the person of ordinary skill in the relevant art, and that such perspective must be considered as of the “time the invention was made”.

16. The level of ordinary skill in the art is discussed in ¶64 below.

17. The relevant time frame for obviousness, the “time the invention was made”, is discussed in ¶63, below.

18. I understand that in considering the obviousness of a claim, one must consider four things. These include the scope and content of the prior art, the level of ordinary skill in the art at the relevant time, the differences between the prior art and the claim, and any “secondary considerations”. I understand that these four things were specified by the U.S. Supreme Court in a case called *Graham v. John Deere*, and are therefore called the “*Graham* factors”.

19. I understand that “secondary considerations” include real-world evidence that can tend to make a conclusion of obviousness either more probable or less probable. For example, the commercial success of a product embodying a claim of the patent could provide evidence tending to show that the claimed invention is not obvious. In order to understand the strength of the evidence, one would want to know whether the commercial success is traceable to a certain aspect of the claim not disclosed in a single prior art reference (i.e., whether there

is a causal “nexus” to the claim language). One would also want to know how the market reacted to disclosure of the invention, and whether commercial success might be traceable to things other than innovation, for example the market power of the seller, an advertising campaign, or the existence of a complex system having many features beyond the claims that might be desirable to a consumer. One would also want to know how the product compared to similar products not embodying the claim. I understand that commercial success evidence should be reasonably commensurate with the scope of the claim, but that it is not necessary for a commercial product to embody the full scope of the claim.

20. Other kinds of secondary considerations are possible. For example, evidence that the relevant field had a long-established, unsolved problem or need that was later provided by the claimed invention could be indicative of non-obviousness. Evidence that others had tried, but failed to make an aspect of the claim might indicate that the art lacked the requisite skill to do so. Evidence of copying of the patent owner’s products before the patent was published might also indicate that its approach to solving a particular problem was not obvious. Evidence that the art recognized the value of products embodying a claim, for example, by praising the named inventors’ work, might tend to show that the claim was non-obvious.

21. I further understand that prior art references can be combined where there is an express or implied rationale to do so. Such a rationale might include an expected advantage to be obtained, or might be implied under the circumstances. For example, a claim is likely obvious if design needs or market pressures existing in the prior art make it natural for one or more known components to be combined, where each component continues to function in the expected manner when combined (i.e., when there are no unpredictable results).

22. I understand that when considering obviousness, one must not refer to teachings in the specification of the patent itself. One can, however, refer to portions of the specification admitted to be prior art, including the “Background” section.

IV. TECHNICAL INTRODUCTION

23. The following Technical Introduction is intended to describe concepts necessary to understand the '950 patent, and is not necessarily directed to any particular timeframe.

A. Voltage, Current, and Resistance

24. The '950 patent relates to power converters. Because the subject matter is complex, a brief introduction of the technology involved is appropriate.

25. Electricity concerns the flow of charged particles, such as electrons, through a material. Materials that allow easy flow of electrons are called

“conductors”, while materials that impede the flow of electrons are called “insulators”. The extent to which a material impedes the flow of electrons through it is called its “resistivity”. Some materials, like “semiconductors” can change their resistivities. An electrical component made from a material with resistivity, with a particular geometry, is said to have a “resistance”, which reflects its ability to impede the flow of electrons.

26. The flow of electrons (charged particles) per unit time is called “current”. Current is measured in Amperes and often represented by the letter “i” or “I”. The energy of electrons is called their “potential”, and is measured in Volts. A “voltage” is a difference between potential between locations, and often represented by the letter “v” or “V”. Current will tend to flow from higher to lower potential. When electrical current flows through a material that has a resistance (often represented by the letter “R”), it will lose some of its energy, creating a potential difference, or voltage, across the resistance. This is expressed as Ohm’s law: $V=IR$, or the voltage difference across the resistance (V) is equal to the current flowing through the resistance (I) times the resistance (R).

27. These basics of electricity can often be analogized to water in a pipe, where the electrical current is like the flow of water, the potential is like water pressure, and the resistance is the amount of resistance to flow (e.g. like sand packed in a pipe). Just as high water pressure can force a flow of water through a

pipe clogged with sand, a high voltage can force current to flow through a material that has resistance.

B. Alternating Current (AC) and Direct Current (DC).

28. Electrical current can be thought of as having two forms: Alternating Current (AC) and Direct Current (DC). Direct Current essentially means that the current flows in only one direction (imagine a steady stream of water leaving a pipe). Alternating current means the current flows back and forth, alternating directions (imagine water first leaving a pipe, and then being drawn back in, in alternating cycles).

29. Voltage can also be described as AC or DC. A DC voltage is one that typically points in only one direction (meaning that voltage is pushing/pulling electrons in one direction), while an AC voltage is one points in alternating directions (the voltage is pushing/pulling electrons in alternating directions).

C. Power

30. Electrical power is the amount of electrical energy that can be delivered in a unit time. Power is typically measured in Watts. When power is delivered to a device, the power can be expressed as the voltage across the device times the overall current through the device, or as V times I . Because power is equal to VI , the same power can be delivered by 1 Ampere of current at 10 Volts as 10 Amperes of current at 1 V.

31. Electrical power may often be used at different voltage levels. For example, a fan might be powered using DC at 12 V, whereas a modern microprocessor might require DC at less than 1 V. Furthermore, power can arise from sources at different voltage levels, and can be in AC or DC form.

D. Power Converters

32. The job of a power converter is to transform the characteristics of electrical power. This can mean changing voltage and current levels, changing between AC and DC, or both.

33. One simple power converting device that has been known for more than a century is called a “transformer”. A transformer has two separate wires that are usually electrically isolated from one another. Each wire is formed into a coil, having a series of loops (or “turns”). One coil of wire is called the “primary winding”, while another is called the “secondary winding”. The windings of each wire are placed in close proximity to one another, and are usually wound around the same “core” made of a magnetizable material. Then, when an alternating current passes through one of the windings (e.g. the primary winding), it will cause an alternating magnetic field that will induce an AC voltage in the respective other winding (e.g., the secondary winding). In an ideal transformer, the ratio of the voltage across the primary winding to the voltage induced in the secondary winding is equal to the ratio of the number of turns (loops) of wire in the primary

winding to the number of turns in the secondary winding. I say “ideal transformer”, because when using a transformer, usually some loss of power occurs. However, in a well-designed transformer, most of the power will be preserved. Transformers thus provide a very easy way to transform power to different voltage levels. However, transformers only work with AC power, not with DC power.

34. The utility power system in the United States works with AC power. This is to minimize the transmission losses in power lines. Transmission losses are approximately equal to the resistance of the power lines (which is low, but not zero) times the *square* of the current flowing through them (I^2R). Because losses increase with the square of the current, it is desirable to keep current low in power lines. Current can be kept low, but still deliver the same amount of power, by increasing the voltage of the power ($P=VI$). For this reason, utilities will use transformers to step up the voltage to a very high voltage for transmission along power lines, and then step the voltage back down, using another transformer near where the power is to be used. Because transformers only work with AC power, it is convenient to use AC power in utility power lines.

E. DC to DC Power Converters

35. Many power converters convert one DC voltage to another, for example, lowering or “downconverting” a high DC voltage to a low DC voltage.

36. Although transformers only work with AC power, transformers are often used when converting one DC voltage to another. To accomplish this, a DC voltage first needs to be changed to an AC voltage so that it will work with a transformer. Then, the transformer can be used to change the AC voltage level. Then, the transformed AC voltage needs to be changed back to a DC voltage. The process flow is indicated conceptually here:

DC voltage → AC voltage → Transformer → Transformed AC voltage → DC Voltage

37. To transform a DC voltage to an AC voltage, a power converter may use switches, often implemented as power MOSFETs. A MOSFET (Metal Oxide Semiconductor Field Effect Transistor) is a transistor. A MOSFET has a channel with source and drain terminals (connections), and a separate gate terminal. By applying specific voltage levels to the gate terminal, the MOSFET will change the resistance of its channel, effectively turning the channel ON and OFF. A MOSFET that has its channel turned ON will have low channel resistance, and current will be able to easily flow through the channel. A MOSFET that has its channel turned OFF will have a high channel resistance, and current will not be able to flow through its channel.

38. A MOSFET is a “power” MOSFET when it is designed to handle higher amounts of power, in part by making the MOSFET large in order to lower

the channel resistance (in the water analogy, by having a wider pipe for water to flow through).

39. MOSFETs usually have parallel body diodes. A diode is a semiconductor device that usually allows current flow in only one direction. A diode will begin conducting current in that direction if the voltage across the diode exceeds a turn-on voltage, called the “forward voltage drop”.

40. MOSFET switches can be used to convert a DC voltage to an AC voltage using specific circuit topologies. By topology, I mean the way in which circuit elements are connected to one another. One example topology is called a “full bridge”, and is shown in a portion of Fig. 4 of the '950 patent, which is reproduced here:

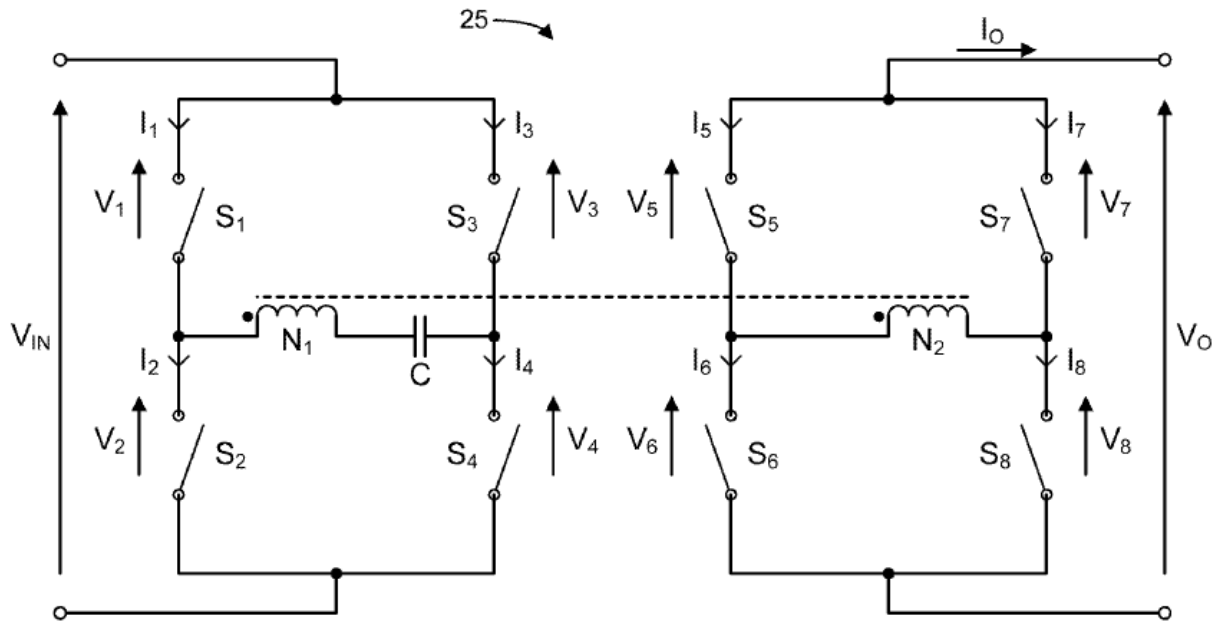
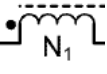
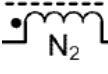


FIG. 4

(Ex. 1001, Fig. 4, 5:25-36).

41. This circuit has an input DC voltage on the left side, called “ V_{IN} ”, and an output DC voltage on the right side, called “ V_O ”. The object of this circuit is to transform the DC voltage V_{IN} to a different voltage level (V_{OUT}) without significant loss of overall power.

42. The circuit of Fig. 4 operates with a transformer, which is shown by the symbol  representing the primary winding near the left side, and the symbol  representing the secondary winding near the right side. While these two windings are separated by some distance in the circuit diagram of Fig. 4, in practice they would both be wound around the same magnetizable core. In

general, the side of the transformer that includes the primary winding is called the “primary side”, while the side of the transformer that includes the secondary winding is called the “secondary side”. The symbol “ N_1 ” usually indicates that the transformer has N_1 turns in its primary winding, and “ N_2 ” indicates that the transformer has N_2 turns in its secondary winding, such that the ratio of voltage across the primary winding to the voltage across the secondary winding should be N_1/N_2 , not accounting for non-idealities and losses in the transformer.

43. The DC input voltage V_{IN} is converted to an AC voltage across the transformer by the action of several switches, labeled S_1 , S_2 , S_3 and S_4 . For example, the converter might turn switches S_1 and S_4 ON at the same time, allowing them to conduct, while S_2 and S_3 are OFF. This effectively allows current to flow from left to right across the transformer winding N_1 (neglecting, for the moment, the action of the capacitor labeled “C”). A short time later, the converter may turn S_1 and S_4 OFF, while turning S_2 and S_3 ON. This reverses the flow of current across the transformer. By repeating this process at a frequency (called the “operating” or “switching” frequency), the DC input voltage can be changed to an AC voltage.

44. When an AC voltage is placed across the transformer primary winding, an AC voltage will appear across the transformer secondary winding (N_2) as well. This AC voltage will have a different overall voltage level, depending on

the ratio of the turns in each transformer winding, as explained above, and accounting "or any non-idealities and losses in the transformer.

45. The AC voltage in the secondary winding then needs to be converted back to DC output voltage. To do this, another set of switches are used: S_5 , S_6 , S_7 and S_8 . These switches are turned ON and OFF in alternation (S_5 and S_8 will be ON while S_6 and S_7 are OFF, and *vice versa*), in order to force the alternating current in the secondary-side circuit to flow in one direction. Obviously, the switches need to be turned ON and OFF with precise timing, in order for this process to occur. The process of turning AC into DC is called “rectification”.

46. When switches that need to be turned ON and OFF with precise timing are used for rectification, the process is often called “synchronous rectification”, and each switch (usually a power MOSFET) can be called a “synchronous rectifier”. There are other ways to perform rectification. For example, instead of switches, diodes can be used to perform rectification, because they only allow current to flow in one direction in most modes of operation. Diodes, however, experience a voltage drop when current flows through them, and so are less efficient than MOSFETs, which can be made to have very low channel resistance, and thus a very low drop in voltage across them, when they are ON.

47. The term “rectification” should not be confused with the similar-sounding term “regulation”, discussed in the next subsection.

F. Fixed-ratio converters and Regulating converters

48. A converter like the one shown in Fig. 4 above will provide an output voltage, V_{out} , that is a fixed ratio of the input voltage. Neglecting non-idealities and losses, this ratio (V_{out}/V_{in}) is equal to the ratio of transformer turns, N_2/N_1 . When the input voltage V_{in} varies, the output voltage V_{out} will also vary, always maintaining the ratio V_{out}/V_{in} approximately equal to N_2/N_1 .

49. These so-called “fixed ratio” converters have certain applications, but often the “load” (or the device attached to the output of the converter, which uses its output voltage) will require a precise voltage, like 1.00 V. This is especially true for microprocessors and other integrated circuits. In order to provide a precise and non-varying output voltage, many power converters will employ “regulation”. With regulation, the power converter in some way monitors the level of the output voltage. When the output voltage goes too high or too low, feedback into the power converter circuitry will change some aspect of the converter’s operation to counteract the deviation in output voltage. The change in operation can take a variety of forms, for example, the converter might change its operating frequency, in a technique called “frequency modulation”. A converter could also change the amount of time in a switching cycle that the primary-side or secondary-side MOSFETs are ON and OFF within a switching cycle, a technique called “pulse-

width modulation” or “PWM”. There are several other ways to provide a regulated converter output.

50. Because regulating converters hold their output voltage constant while the input voltage varies, the voltage transformation ratio $V_{\text{out}}/V_{\text{in}}$ is not fixed, but rather varies (because only V_{out} is fixed while V_{in} varies).

G. Isolation

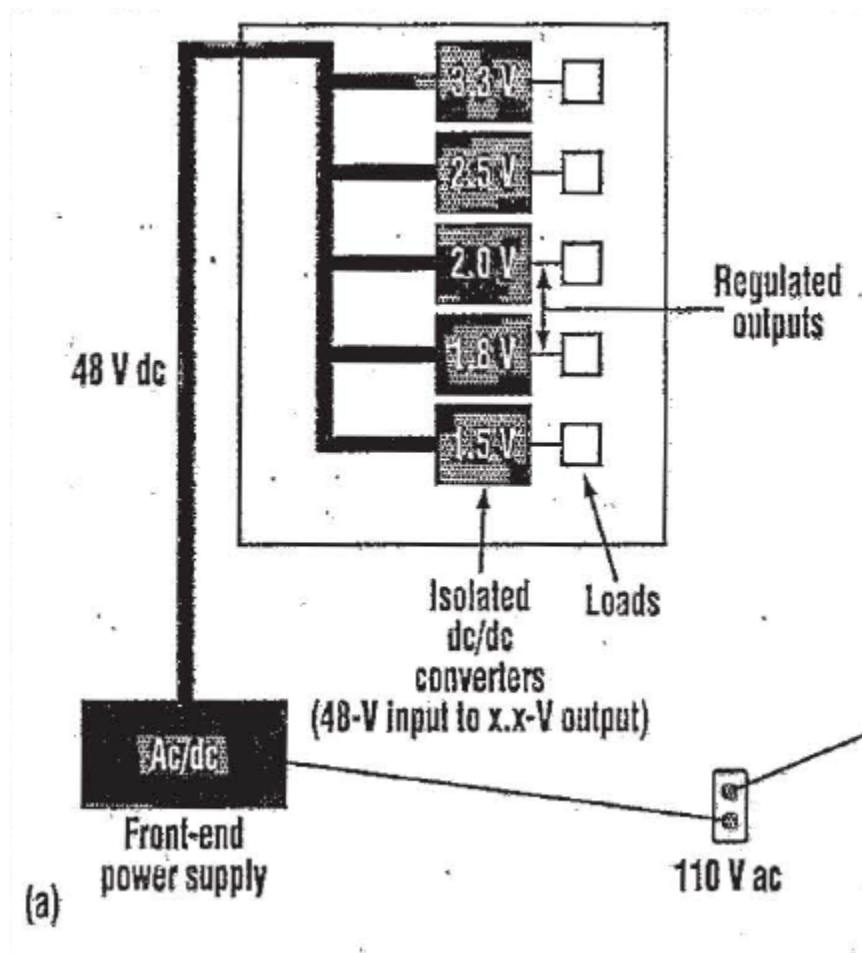
51. Transformers in power converters can provide galvanic isolation. This is because a transformer does not have a galvanic (wired) connection between its primary and secondary windings. Instead, the two windings are only magnetically coupled. For that reason, if no other galvanic connection is provided between the primary and secondary winding circuits, a power converter using a transformer is said to be “isolated” or “isolating”. Isolation can provide safety and noise-suppression benefits.

V. BACKGROUND OF THE '950 PATENT AND INDUSTRY

52. The '950 patent relates to power converters that can be used in data centers. Data centers can have thousands of servers. The servers are individual computers in racks that contain a motherboard. The motherboard supports the principal components of the server, including one or more processors and power modules, including those of the type at-issue here.

53. Providing power to a processor in a data center (or their technological progenitors: telecom central offices) is a complex task. Power needs to be supplied from power lines (providing high-voltage AC power) and ultimately converted to low-voltage (*e.g.* 0.7 V) DC power. The power delivered to a processor typically needs to be precisely regulated. For example, voltage rails supplied to Intel CPUs in the relevant timeframe needed to be regulated to a specific voltage level, with variations in voltage being limited to ± 0.015 V. (Ex. 2021, p. 152, and chart on pp. 155-156).

54. In a telecom central office, power was converted from utility power lines down to a lower voltage using a transformer, and then turned into DC power (“rectified”) using a so-called “front-end converter” or “rectifier”. Power from the rectifier, in the relevant timeframe, was typically distributed, at a negative 48 V DC, to individual telecom boards. Power distributed on the negative 48 V bus then needed to be converted to low, positive voltages needed within the equipment. The equipment would typically require a multiplicity of DC voltage levels for different components. For example, a fan might operate at 8 V DC, while a processor might operate at 1 V DC, while other components operate with 5 V or 3.3 V DC. This is shown in the following diagram (Fig. 1(a)) from Morrison 2002, where the boxes showing 3.3 V, 2.5 V, 2.0 V, etc., represent different regulated voltage levels delivered to loads:



(Ex. 2002, Fig. 1).

55. Converting the negative 48 V DC power to the various levels needed in a system required DC/DC converters. A DC/DC converter was a module that could convert power from one DC voltage level to another. A DC/DC converter typically included three functions: isolation, voltage transformation, and regulation. “Isolation” meant that the input and the output were “galvanically” isolated from each other, i.e., lacking a direct, wired connection that might compromise system safety and noise immunity, where “noise” means an irregular and unwanted variation in the voltage delivered. Isolation was usually provided

by a transformer, which *magnetically* couples its primary and secondary windings to avoid direct electrical contact. “Voltage transformation” meant changing the voltage level at the same power level. Because power is equal to voltage times current, a change in voltage typically meant an inverse change in current.

“Regulation” meant controlling the output voltage to a precise level, as the input voltage varied. In the 1990s, it was typical to use one DC/DC converter for each different voltage level required by a system on a board, as shown in the Figure from Morrison, above.

56. DC/DC converters were (and are) not 100% efficient. DC/DC converters in the 1990s achieved 80-90% typical efficiency. The remaining 10-20% was lost in waste heat. Waste heat is a problem: it increases input power and the heat itself needs to be removed. Currently, the United States uses about 2% of its total electricity in data centers, and nearly 33% of that goes to thermal management. Thermal management is required to keep equipment within an acceptable operating temperature range, typically thought to be below 85° C. Because of thermal management challenges, data centers tend to be sensitive to the efficiency of their power-supply systems. Specifically, the difference between 98% efficiency and 96% efficiency results in the lower-efficiency converter causing *twice* the waste heat (4% versus 2% inefficiency).

57. The solution of the 1990s—using one DC/DC converter for each DC voltage required in a system—worked for a while, but industry trends soon made it impractical. Specifically, system designers kept adding functionalities and components on circuit boards, and the components required different voltage levels. Additional components took up more space on the system board, which required more DC/DC converters, which in turn took up more space, cost more, and generated more waste heat. System designers could not easily increase the size of system boards, because the equipment had a standard size on which other vendors depended.

58. As a result, in the early 2000s, system designers revived an older power-supply architecture known as the “Intermediate Bus Architecture” or “IBA”. IBA relied on the ability to separate the isolation and regulation functions of a DC/DC converter. An upstream converter could provide isolation and voltage step-down without regulation, distributing power to a multiplicity of converters providing regulation without additional isolation. The isolated, unregulated converter was called a “bus converter”, and the downstream regulators were often called “POLs”, or Point-of-Load converters. In a typical IBA system, the bus converter would convert input power at negative 48 V DC to positive 12 V DC. The 12 V power was typically not regulated (or partially regulated), meaning that its output would vary in proportion to its input voltage. And the input voltages in

typical telecom / data center applications varied considerably. For example, a standard input voltage range for bus converters in data centers was from 40 V to 60 V. (Ex. 2023, p. 1). This implies that the output of the bus converter might be centered at 12 V, but would vary from 10 V to 15 V.

59. The bus converter output voltage would be carried by an “intermediate bus” to various loads, like processor chips. Near these loads, system designers placed POLs that would perform a final down-conversion (say from 12 V DC to 1 V DC), while regulating the output voltage. Such an IBA system is shown here:

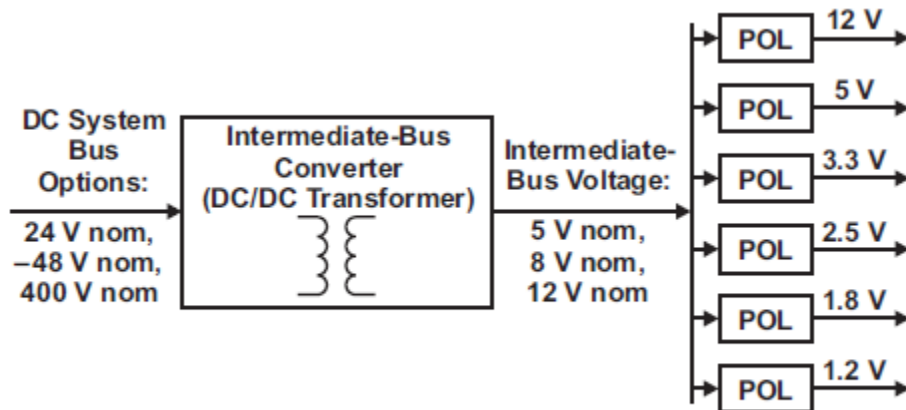


Fig. 4. Example of IBA.

(Ex. 2017, Fig. 4).

60. In the diagram above, the “Intermediate Bus Converter” is isolated, but not regulated, whereas the “point of load converters” are regulated, but not isolated. (Ex. 2017, p. 4). This allows power distribution from the bus converter to be isolated from the front end supply, while allowing each output (12 V, 5 V,

3.3 V, etc.) to be regulated at the required value, saving the power loss, space and cost required to make each converter be isolated *and* regulated. (Ex. 2017, pp. 6 and 4-4).

61. Demand for higher power density did not end there, however. In the past decade, the machine-learning revolution has driven the use of higher-power graphics processing units (GPUs) in data centers. Such GPUs demand more current (e.g., one thousand Amperes), at a lower voltage (below 1 V). Furthermore, to save power, modern GPUs can shift quickly into low-power modes and back again, creating extreme changes in loads (so-called “fast transients”) that the power system must cope with. At the same time, there is continued pressure for power supply components to use less board space.

62. Prior-art bus converters were known to convert an input DC voltage with a high absolute value (like 48 V), through a “power train” comprising a transformer and power semiconductors, to an output DC voltage with a lower absolute value (a process called “down-conversion”). Historically, bus converters would perform this DC voltage transformation using an isolating transformer driven from, and rectified through, power semiconductors. Transformers and power semiconductors give rise to a power loss. The ’950 patent improves upon bus converter efficiency and power density by using non-isolated transformer converter topologies to reduce power processing and power loss. Bus converter topologies

disclosed in the '950 patent enable a fraction of the DC power to efficiently flow through to the output, bypassing the power train's transformer and power semiconductors. For a 48 V input and 12 V output, 25% (i.e., 12/48) of the output power effectively bypasses the bus converter power train. Bus converter efficiency and power density are thus substantially improved.

VI. RELEVANT TIMEFRAME FOR DETERMINING OBVIOUSNESS

63. I understand that obviousness must be evaluated at the time the alleged invention was made. From the front page of the '950 patent (left column, field "(22) Filed"), I understand that the patent application was filed on July 2, 2013. I will assume for the purpose of this report that July 2, 2013, is the date the purported invention was made, with the understanding that my testimony will also be applicable to some time prior to July 2, 2013, approximately in the early-to-mid 2013. I may refer to this time period as the "relevant time frame", and my testimony concerning obviousness is directed to this timeframe, even if I occasionally do not explicitly use a past tense.

VII. LEVEL OF ORDINARY SKILL IN THE ART

64. I understand that the legal question of obviousness must be assessed from the perspective of a person having ordinary skill in the art ("PHOSITA") at the time of the invention. I understand that the Petitioner has stated that a person having ordinary skill in the art in the relevant timeframe "would have at least a

Master's degree in electrical engineering and two or more years of work experience relating to power electronics and the design of switching power converters, with more experience potentially substituting for education or vice versa." I will apply this definition at this stage of the proceeding.

VIII. REASONS FOR PATENTABILITY

A. Ground I (Huang).

1. Huang does not meet the language of the claims

65. In my opinion, Huang does not meet the language of the claims.

Claim 1 requires that the converter be "adapted to convert power from the input circuit to the output circuit at a substantially fixed voltage transformation ratio, KDC...wherein the substantially fixed voltage transformation ratio can be represented as $KDC = V_{OUT}/V_{IN}$..." Each of independent claims 9, 16, 29, and 31-33 has a similar limitation, as well as the remaining claims dependent on claim 22.

66. Huang is a regulating converter. As a regulating converter, Huang's converter produces an unvarying output voltage from a varying input voltage. Thus, *by design*, the ratio V_{out} / V_{in} in Huang's converter varies, because V_{in} varies while V_{out} remains fixed.

67. We know that Huang is a regulating converter for several reasons. As Huang states in its introduction "the non-isolated LLC resonant converter is

proposed as an alternative solution to future VR and POL converters.” (Ex. 1005, p. 1).¹

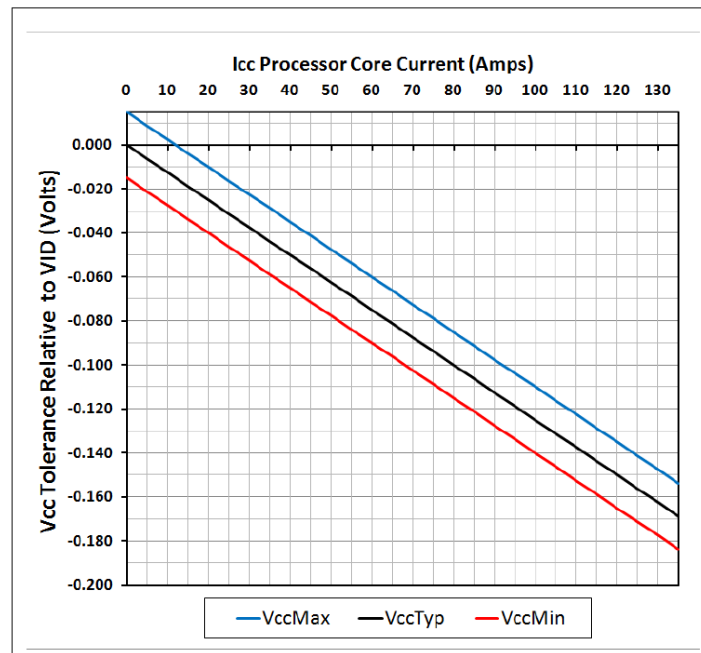
68. Both VRs and POLs are regulating converters. “VR” means “voltage regulator”. (Ex. 1005, p. 1). A Voltage Regulator, as the name suggests, is a converter that is used to supply power at a regulated voltage. A “POL”, in turn, is a specific type of Voltage Regulator, namely one that is placed close to the point-of-load it is driving, and typically implemented as a non-isolated buck regulator. (Ex. 2006, p. 2)(“**Nonisolated buck regulators commonly referred to as point-of-load (POL) converters** then generate each of the load voltages needed from this intermediate bus.”). As discussed in the Introduction, POLs are used in Intermediate Bus Architecture applications to provide the output, *regulated* voltage to a load (such as a CPU). (Ex. 2002)(“The intermediate voltage bus must provide isolation, but its regulation isn't critical because **the POL outputs are regulated.**”)(Ex. 2003, p. 3, left column, top)(“The individual **POL converters accomplish the regulation** of each of the output voltages.”)(Ex. 2004, p. 1)(“two-stage power conversion architecture aimed at 48V systems has been gaining momentum with an intermediate voltage bus. Because **the POL** can typically

¹ In all cases, this Preliminary Response will refer to the page numbers added by the Petitioner per 37 C.F.R. §42.63(d).

accept relatively wide input voltage and **provides the needed regulation**, this scheme does not require a tightly regulated intermediate voltage.”)(Ex. 2017, p. 4)(“nonisolated **POL regulators**”)(Ex. 2006, p. 2)(Ex. 2007, p. 2)(“the **POL provides the needed regulation** to the load....”)(Ex. 2008, p. 1)(“The downstream **POL converters will provide the precise regulation** required by the load.”).

69. Huang further confirms its regulating nature by stating that its converters are used to provide power to *processors*. (Ex. 1005, p. 1, left column, top). Providing power to processors was well-known at the time to require a highly optimized, *regulated* voltage. Regulation imposed strict specification requirements. For example, Intel’s 2012 Data sheet for its Xeon® Processor E5-2400 family of processors (processors for servers) explains that the processor will provide the power supply with a number, called VID, that indicates the level of voltage required (called “Vcc”) in 5 millivolt increments. (Ex. 2021, p. 152, and chart on pp. 155-156). Voltage tolerances were +/- 15 mV (0.015 V) around this VID level, as shown in the following chart from the datasheet, where the black line represents the desired voltage, the blue line represents the maximum allowable supply voltage, and the red line the minimum allowable supply voltage:

Figure 7-3. V_{CC} Static and Transient Tolerance Loadlines



(Ex. 2021, p. 167). Note that the required output voltage varies by output current, as is typical. This does not affect the analysis, because the claims of the '950 patent specify a substantially fixed voltage transformation ratio “at an output current”.

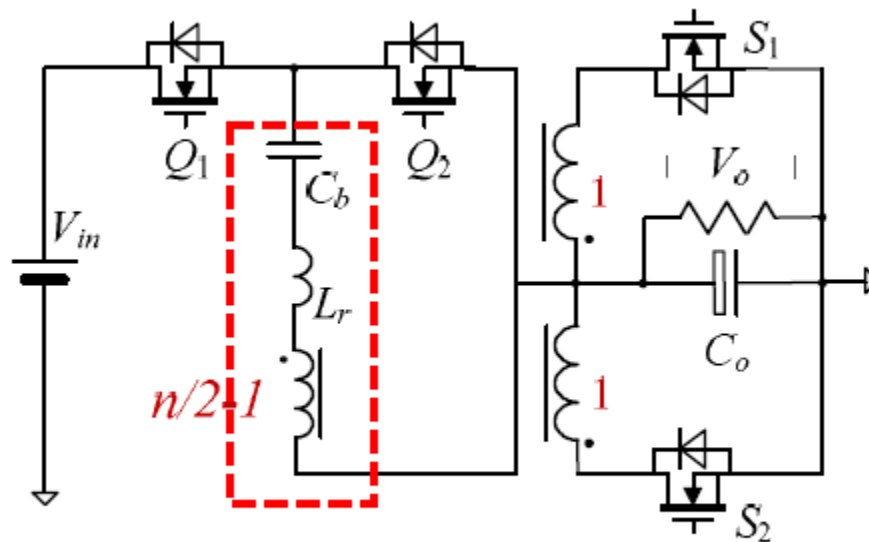
70. Regulators designed to supply such tightly-regulated supply voltages also needed to respond to fast-transient conditions, for example, when a processor changes state from a low-power state to an active state, which quickly increases current requirements. (Ex. 2021, p. 152, §7.1.9.2)(Ex. 1006, 1:38-64). For these reasons, power converters designed to feed processors tend to be specialized for that purpose, and sub-optimal for applications with different requirements. As Malik (IBM) wrote in 2003:

“The microprocessor voltage which is currently close to one volt needs **very tight regulation** and extremely small ripple. These

requirements are forcing use of **point of load regulators (POL)** which **have to be designed for very fast transient** response.”

(Ex. 2015, p. 2, left column)(Emphasis added).

71. The regulation function is built into the topology and operating protocol of LLC resonant converters like Huang’s. The converter of Huang’s Fig. 12(b), on which the Petition relies, is an LLC series resonant converter. The resonant components comprise a blocking capacitor labeled C_b , an inductor labeled L_r , and the primary magnetizing inductance of the transformer’s primary windings (unlabeled in Fig. 12(b)). These components are shown in the added red-dashed box in Fig. 12(b) of Huang, reproduced here:



(b) Type 2

The term “LLC” refers to the fact that two inductors (two “L”s) and one capacitor (one “C”) are critical to its operation.

72. The two inductors and capacitor in the “LLC” circuit are used to provide regulation. That is, the operating frequency of the LLC is varied across a range of frequencies, above the resonant frequency, to regulate the output voltage of the converter. Regulation is provided by frequency-dependent changes in relative impedances of critical LLC components.

73. At a high level, LLC resonant converters *change their switching frequencies to provide a regulated voltage output*. Delta’s U.S. Pat. No. 7,184,280 explains this operation as follows:

“The power switches S1 and S2 of the **LLC series resonant converter** operate under the condition of equal pulse width, that is, in the condition of 50%. A frequency adjustment controller 140 is therefore demanded because **the adjustment of the output voltage is obtained by changing the operation frequency.**”

(Ex. 2011, 1:60-65). Note that this discussion refers to the circuit of Fig. 1 of the ’280 patent, shown below, which (although it is an isolated converter) relies on the same series LLC principles as Huang:

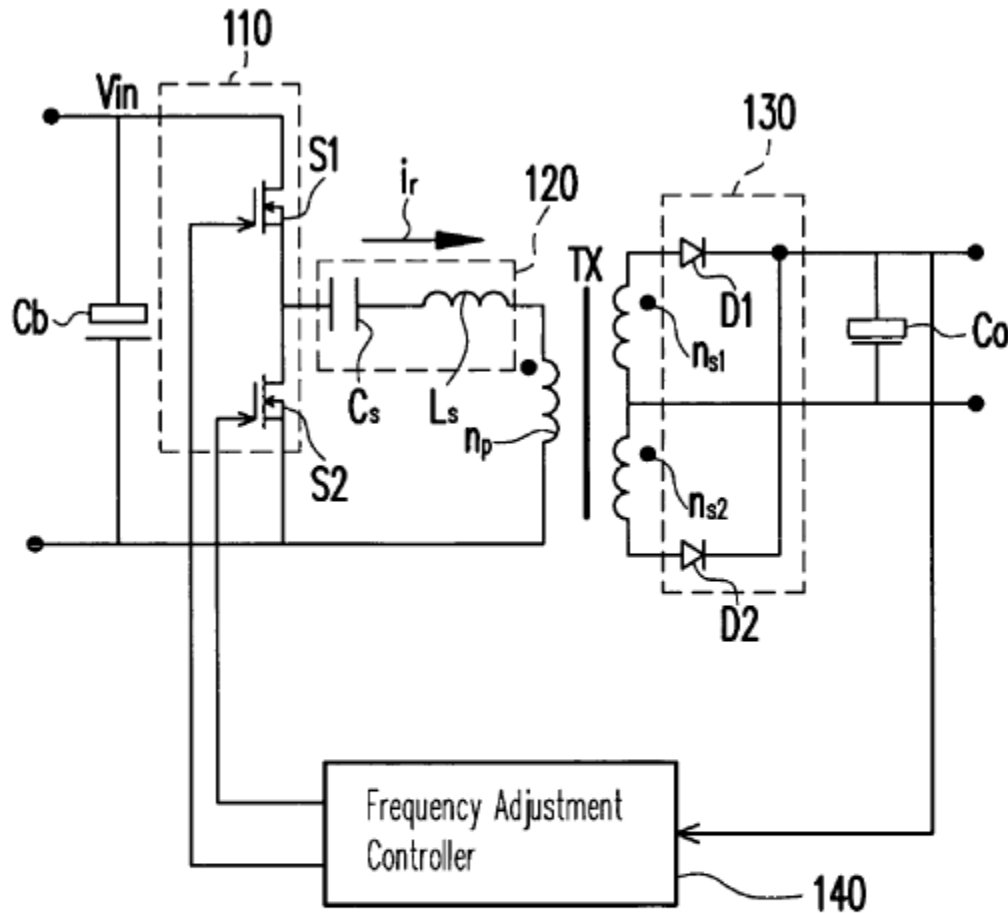


FIG. 1 (PRIOR ART)

74. The behavior of LLC resonant converters is explained in other documents. For example, in 2010 Texas Instruments published a white paper called “Designing an LLC Resonant Half-Bridge Power Converter”. In that paper, they explain:

“Among resonant converters, two basic types are the **series resonant**

converter (SRC), shown in Fig. 1a, and the parallel resonant converter (PRC), shown in Fig. 1b. Both of these converters regulate their output voltage by changing the frequency of the driving voltage such that the impedance of the resonant circuit changes. The input voltage is split between this impedance and the load.”

(Ex. 2012, p. 2)(Emphasis added).

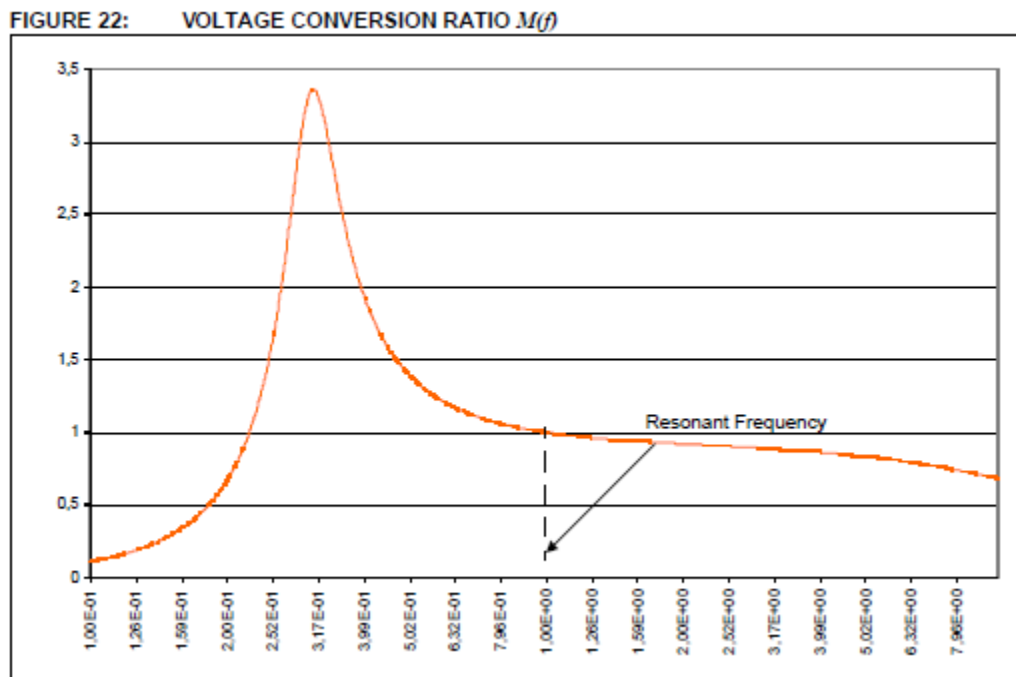
75. An extension of this paper from TI is found in the McDonald reference (Ex. 2013), which I understand that Delta submitted as the principal prior art in co-pending IPR2024-00187, and for which Delta asserted a publication date of 2012. (Ex. 2005, p. 2). McDonald, which is entitled “Design and Optimization of a High-Performance LLC Converter”, explains that for LLC Converters “[t]he **output voltage is commonly controlled** by using a fixed duty cycle (e.g., 50 percent) and a **variable frequency.**” (Ex. 2013, p. 3, right column, top)(Emphasis added). McDonald explains this in more detail, noting that when the input voltage to the converter varies, the converter changes its operating frequency to make sure the output voltage stays the same. (Ex. 2013, p. 5)(e.g. “The **input voltage is now reduced** so that **the system control effort changes the frequency** to something below the resonant frequency....”)(Emphasis added).

76. Another reference that I understand was submitted by Delta in the co-pending IPR2024-00187, called “AN1336”, explains:

“As presented in this application note, resonant converters – LLC resonant converters in particular – have all of the features mentioned above, resulting in a compact and highly efficient design. Their **ability to keep the output voltage regulated, over a very wide input voltage range**, contributes to reducing the overall system cost.”

(Ex. 2014, p. 1, left column)(Emphasis added).

77. When the input voltage varies, but the output voltage remains constant, the voltage-transformation ratio changes. A plot of the voltage conversion ratio (represented by M) versus a normalized operating frequency (the actual operating frequency divided by the resonant frequency) for an LLC resonant converter is shown in Fig. 22 of AN1336, reproduced here:



(Ex. 2014, p. 19). This curve has a characteristic shape for LLC resonant converters, and similar graphs can be found throughout the literature. (Ex. 2012, pp. 10, 12, 15)(Ex. 2013, p. 19).² As can be seen from these graphs, the voltage transformation ratio varies substantially with operating frequency. The operating frequency, in turn, is varied to counteract changes in input voltage.

78. Changes in input voltage, moreover, are quite common in processor applications, such as the Intermediate Bus Architecture that Ground I proposes. Variation in input voltages can arise from numerous sources. Power lines from a utility, for example, typically vary in voltage over 10-15% in the United States. Transformation and rectification from AC to DC may additionally introduce a voltage “ripple” (essentially, voltage waves on top of the DC voltage). Furthermore, power distribution infrastructure may vary its output voltage according to load, causing the voltage to fluctuate when the current demand is changing. In the relevant timeframe, it was not uncommon for large-scale applications in data centers to have input voltages varying over 40-60 V (Ex. 2026, p. 1), or in telecommunications from 36-75 V (Ex. 2016, p. 1).

² These graphs sometimes express the voltage transformation ratio as a “gain” function. (Ex. 2012, p. 8)(“the relationship between the input voltage and output voltage can be described by their ratio or gain.”).

79. Because Huang's converter is adapted to hold the output voltage fixed even as the input voltage varies, it is my opinion that Huang's converter is not "adapted to convert power from the input circuit to the output circuit at a substantially fixed voltage transformation ratio" as required by claim 1 and similar limitations in all other independent claims. The Petition makes no argument that it would have been obvious to modify Huang to alter its principle of operation. Nor do I believe that such an argument would be correct, given Huang's express statement that its converters are intended to be used as POLs and Voltage Regulators, to supply processors that require tightly-regulated voltages. (Ex. 1005, p. 2)(Petition, p. 51).

80. The Petition provides a discussion on pages 19-20—mirrored nearly verbatim by Dr. Hopkins—of the "substantially fixed voltage transformation ratio" limitation with respect to Huang, complete with a purported mathematical derivation of the transformation ratio. In my view, the Petition's analysis is incorrect.

81. The Petition incorrectly asserts that "[p]reliminarily, Huang discloses that the switching frequency of its converter may be at the resonant frequency. *Id.* at 1378" (Petition, p. 19). In fact, the cited page of Huang states:

"It is the same as type 1, the node voltage V_a is in phase with i_{s1} and i_{s2} when switching frequency is at or above resonant frequency."

(Ex. 1005, p. 7, left column, bottom). The Petitioner apparently mistook this statement to mean that operation could, or should, be fixed at the resonant frequency. But as discussed above, such a reading is contrary to Huang's teaching. In reality, Huang's converter depends on being able to change the switching frequency to correct for variations in input voltage and output load. The statement "when switching frequency is at or above resonant frequency" is not an invitation to make Huang's converter a fixed-frequency device, but rather a reminder that the observed behavior ("the node voltage V_a is in phase with i_{s1} and i_{s2} ") happens when the converter's variable frequency operation happens to veer into the range of frequencies above the resonant frequency.

82. The assumption that Huang can operate only at its resonant frequency, makes the Petitioner's reasoning on pages 19-20 incorrect. The Petitioner begins with the assumption that "the impedance of the resonant tank is zero", whereas in reality, the converters operation *depends* on the *variation* of the impedance within the resonant tank with frequency. The Petitioner's conclusion that "[b]ecause the impedance of the resonant tank is zero, the voltage gain is fixed for all load conditions" is similarly false, because the changing frequency of the Huang converter allows it to change its voltage transformation ratio to counteract changes in input voltage and output load. The calculations on pages 19-20 of the Petition are nothing more than a formalization of the Petitioner's error, because they begin

with the assumption that the voltage transformation ratio is simply equal to the transformer turns ratio. (Petition, p. 19). It is not, because Huang is changing the voltage transformation ratio to regulate the output voltage.

2. Ground I does not teach or render obvious using Huang as a “bus converter” or connecting to downstream regulators

83. In my opinion, the arguments of Ground I of the Petition are also insufficient to show that the claims were obvious, because they do not show that Huang teaches or makes obvious using Huang as a “bus converter” (per limitations 1(c) and 1(e)-1(h)), nor the entirety of limitation 1(e), which reads:

“1(e) a plurality of regulators, wherein each regulator comprises a regulator input connected to the power distribution bus to receive power from the output circuit of the bus converter and a regulator output connected to supply power to a respective load, the plurality of regulators each being separated by a distance from the bus converter.”

84. I note that independent claims 16, 29, 31 and 32 have similar limitations, and the assertion of Huang against each of every other remaining independent claim depends *entirely* on the assertion against claim 1. (Petition, pp. 32-33, 39-41) (referring only back to claim 1 for all remaining independent claims).

85. The Petition appears to rely on background teachings in the '950 patent to show that Huang is used, or would obviously have been used, as a bus

converter in an Intermediate Bus Architecture (IBA) that has regulators connected to the output of the bus converter. An Intermediate Bus Architecture is shown again below, with red-dashed lines indicating the “bus converter”, and green-dashed lines indicating the Point Of Load converters (downstream regulators), and an added blue arrow and label showing the Petition’s argument:

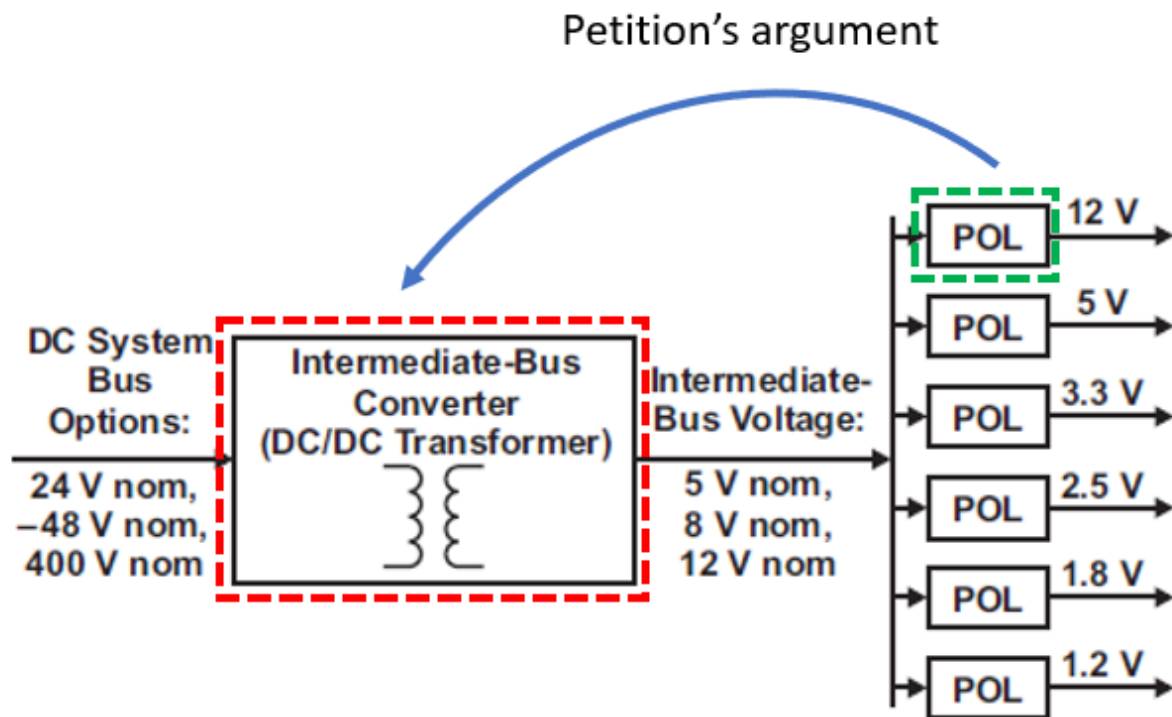


Fig. 4. Example of IBA.

(Ex. 2017, Fig. 4).

86. Assuming, for the sake of argument, that the Petition is making an obviousness argument based on admitted prior art in the ’950 patent, the obviousness argument is incorrect. There would have been no motivation to use

Huang's converter as a "bus converter" (the red position in the diagram above) in the Intermediate Bus Architecture described in column 1 of the '950 patent.

87. First, it would not have been obvious to use Huang's converter as a "bus converter" in an IBA system, because Huang's converter is non-isolated, and bus converters were commonly believed to require isolation.

88. In the relevant timeframe, bus converters were well-understood to provide galvanic isolation (usually through the use of a transformer). The '950 patent states this as follows:

"The **bus converter** 10 may include a DC Transformer which is a switching power converter that may provide voltage transformation from its input to output at an essentially fixed voltage gain and also **provide galvanic isolation between its input and output.**"

(Ex. 1001, 1:20-24)(Emphasis added). While the '950 patent states this somewhat permissively ("may provide"), the prevailing thinking indicated that bus converters *needed* isolation. Miftakhutdinov, in his 2009 article entitled "Improving System Efficiency with a New Intermediate-Bus Architecture", wrote that:

"**The advantage of IBA depends heavily** on an intermediate-**bus converter** (IBC) that generates an optimal intermediate-bus voltage **and provides electrical isolation.**"

(Ex. 2017, p. 1, left column, middle)(Emphasis added).

89. The company Bel-Fuse, in a 2004 white paper, noted the popularity of 48 V distribution buses for computing and networking applications, and wrote that “for most 48V systems, **isolation from the 48V bus** is a basic requirement.” (Ex. 2006, p. 1)(Emphasis added). The white paper continued:

“A new architecture currently emerging is what Bel has dubbed the **Intermediate Bus Architecture (IBA)**. In this approach, a **bus converter** is employed which serves two primary functions. First, **it provides the isolation from the 48V bus**. Secondly, it reduces the 48V bus to a level where non-isolated converters can operate with reasonable duty cycle without the need for a transformer. Nonisolated buck regulators commonly referred to as point-of-load (POL) converters then generate each of the load voltages needed from this intermediate bus.”

(Ex. 2006, p. 2)(Emphasis added).

90. David Morrison similarly wrote in a 2002 article that:

“The intermediate voltage bus **must provide isolation**, but its regulation isn't critical because the POL outputs are regulated.”

(Ex. 2002, p. 1, right column, top). Note that if the “intermediate voltage bus must provide isolation”, it must be provided by the bus converter.

91. In 2004, Brush wrote that:

“In an IBA, a ‘bus converter’ (typically 12Vdc output) **is employed to provide isolation** from the 48Vdc power distribution bus. It

reduces the 48V bus to a level where nonisolated Point-of-Load (POL) converters can operate with reasonable duty cycle without the need for a transformer.”

(Ex. 2018, p. 1, left column, middle)(Emphasis added).

92. This belief was predicated on fundamental requirements. First, galvanic isolation was believed to be necessary to provide safety. Second, galvanic isolation was believed to be necessary to reduce noise. Specifically, without galvanic isolation, power is directly coupled through a non-isolated transformer and *noise* may be coupled directly to the output. Third, power supply systems for telecommunications typically operated with a negative 48 V input. The negative 48 V input was used for equipment durability—copper wires and battery terminals experience less corrosion at a -48 V input. With an isolating transformer, *negative* 48 V input could be converted to a *positive* 12 V output. However, with a negative 48 V input, one could not simply let power bypass the transformer to a positively-referenced output bus. Thus, with a negative 48 V input voltage—as was common in telecommunications—there would have been no reason to expect that a non-isolated converter would produce any efficiency advantage.

93. While bus converters were believed to require isolation, Huang’s regulating converter is *non-isolating*. (Ex. 1005, Title, p. 1, Fig. 12, caption).

Because Huang's converters are non-isolating, a POSITA would have needed some specific motivation to use them in a role (that of the "bus converter" in IBA) thought to require an isolating converter.

94. The Petition provides no such motivation. The only motivation arguably provided by the Petition is the following argument on page 17:

"A POSITA would also have known, where the input and output of the converter both need to be DC, to use a DC-DC converter such as Huang's as the bus converter or part of the bus converter because the input to the converter is DC and the electronics downstream from the converter also use DC. Id., ¶64. A POSITA would have also known that, in the case of IBA, the bus converter should both be efficient and low cost. Id., ¶65. Huang's converter increases efficiency by, for example, achieving zero voltage switching, low turn off loss for switches, reduction in transformer turns, and reduction of current through transformer secondary windings. See Ex. 1005, 1373. Huang would thus be an attractive option to a POSITA seeking a high efficiency converter. Ex. 1003, ¶65."

(Petition, p. 17). Here, the Petition presents two arguments: (1) that both Huang and an IBA bus converter use DC voltages, and (2) that Huang's converter "increases efficiency". In my view, neither of these arguments provides a reason to use a non-isolated converter in a role that was thought to require an isolated converter. The Petition's argument that Huang's converter is a DC / DC converter, and therefore appropriate to use whenever DC voltages are involved, is a very generic rationale.

While the Petition's argument that Huang's converters "improve efficiency" is somewhat more specific, it suffers from a lack of context: the argument that Huang "improves efficiency" is an implicit comparison between Huang's converter and some earlier version of an LLC resonant converter without Huang's specific attributes. But this is the wrong comparison: the relevant comparison for obviousness would be between Huang's efficiency and the efficiency of common *bus converters* at the time of the invention because those are the converters the Petition seeks to replace. The Petition does not even attempt such an analysis. Even if it had, it would have failed: Answering the question of whether or not Huang's converter qualifies as "efficient" would not change the fact that Huang's converter is non-isolated, making it inappropriate to use as an IBA bus converter requiring isolation for safety and noise reasons, according to the prevailing mindset.

95. Second, there was also no motivation to replace bus converter in an Intermediate Bus Architecture with Huang's *regulating* converter. Huang's converters are designed to provide the tight regulation required by microprocessors. (Ex. 1005, p. 1). In contrast, an IBA bus converter does not need to regulate its output voltage, because downstream POLs provide the needed regulation. (Ex. 2002, p. 1)(Ex. 2003, p. 3)(Ex. 2004, p. 1)(Ex. 2007, p. 2)(Ex. 2008, p. 1). Because regulation is not required in a bus converter, adding regulation to a bus converter will needlessly lower the efficiency of the converter

(by providing a superfluous regulation stage) *and* make the bus converter larger (because of the burden of regulation), thus negatively impacting efficiency, power density and cost. While a few IBA applications did use regulated or partially-regulated bus voltages, by the relevant timeframe such applications were generally considered less desirable. (Ex. 2003, p. 4, left column)(Ex. 2017, p. 6, left column). Miftakhutdinov, in his 2009 paper, compared various degrees of regulation in intermediate bus converters (“IBCs”), concluding:

“The **unregulated IBC** provides the solution with the **highest efficiency and power density** and the **lowest cost** because it operates at almost 100% duty cycle at steady state.”

(Ex. 2017, p. 6, left column)(Emphasis added).

96. Thus, I am of the opinion that it would not have been obvious to use Huang’s regulating converter as a “bus converter” in IBA applications, because it would have been expected to negatively impact the efficiency, power density and cost.

97. Third and finally, there would have been no motivation to use Huang’s converter as a bus converter in an IBA application, because Huang’s converter was designed as a POL converter. (Ex. 1005, p. 1). Bus converters and POLs perform fundamentally different functions and are not interchangeable.

98. Bus converters and POLs occupy different roles in an IBA system, as shown (again) in the following diagram, which was shown above previously, but now adds a blue arrow and the label “Petition’s argument”:

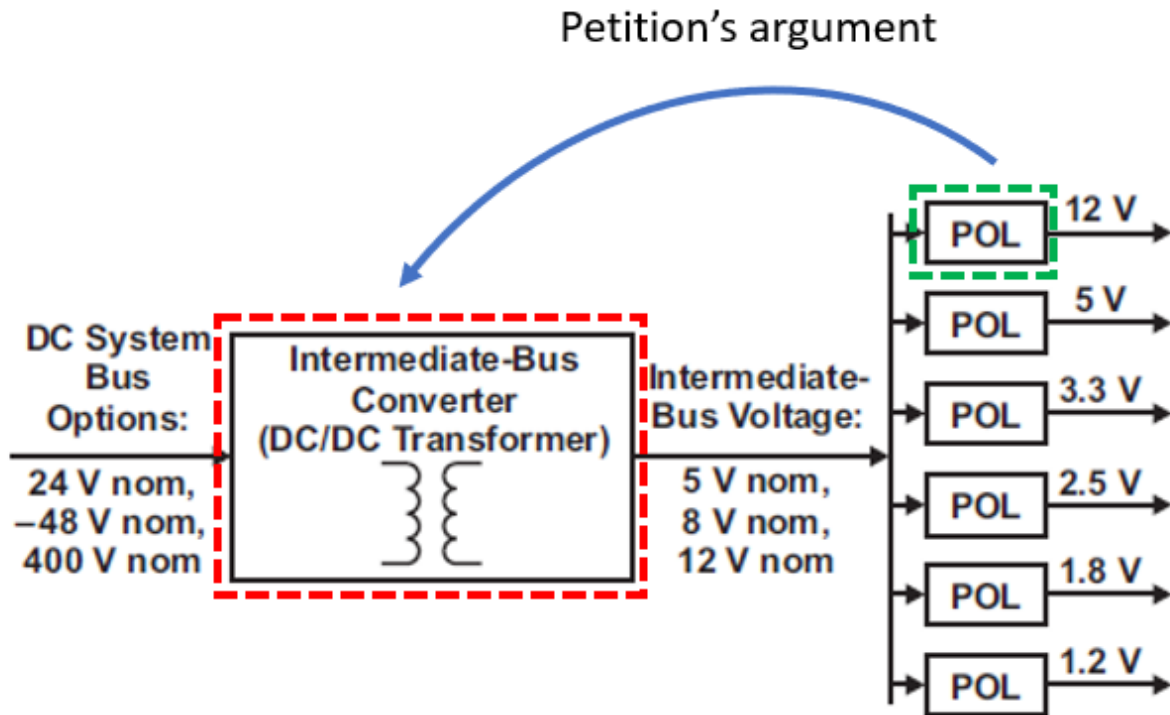


Fig. 4. Example of IBA.

(Ex 2017, Fig. 4)

99. Huang’s converters are designed to serve as POLs (Point of Load converters), (Ex. 1005, p. 1)(“the non-isolated LLC resonant converter is proposed as an alternative solution to future VR and POL converters....”). The Petition argues that Huang’s converter could be re-assigned to a different stage in an IBA system, the bus converter. But bus converters and POLs have different requirements. POLs supply the load, which is typically a microprocessor or

similar component. Such components demand high currents at low voltages. The low voltages also need to be tightly regulated. This tight regulation, moreover, needs to be provided over large variations in load current, occurring quickly. (Ex. 2007, p. 1). Bus converters, in contrast, do not need to provide regulation, and thus can sacrifice the ability to regulate to gain other advantages, namely high efficiency, high density and low cost. (Ex. 2017, p. 4)(“IBC designs can be simple because there are no strict regulation requirements for the intermediate-bus voltage.”). This turned out to be important for the relative advantage of IBA as versus other architectures. As Miftakhutdinov explained in 2009:

“The intermediate-bus converter must have the highest efficiency and power density to provide a competitive edge for IBA versus DPA.”

(Ex. 2017, p. 4).

100. In my view, there is no reason why a PHOSITA would have been motivated to take a converter designed for POL applications and use it to replace an IBA bus converter with fundamentally different constraints and priorities. The Ground I combination with the background of the '950 patent would thus not have been obvious.

B. Grounds III and IV (Huang and Lee)

101. In my opinion, Grounds III and IV (relying on Huang, AAPA and Lee) would not make the claims obvious. First, these grounds do not address the

arguments under Ground I relating to the “substantially fixed voltage transformation ratio” or the arguments that it would not have been obvious to use Huang’s regulating POL converter in the role of a high voltage bus converter.

1. A PHOSITA would not have been motivated to use Huang’s converter in Lee’s system.

102. Furthermore, I am of the opinion that it would not have been obvious to use Huang’s converter in Lee’s system. The Petition argues that “[i]t would have been obvious to a POSITA to use the resonant converters disclosed in Huang, as is or as modified by the ’481 Patent, in the intermediate bus architecture disclosed in Lee in place of Lee’s ‘voltage divider.’” (Petition, p. 51). The Petition provides four separate arguments for this motivation on pages 51-52 of the Petition.

103. The Petition’s arguments are, in my view, incorrect. First, even with the introduction of Lee, Huang’s converters are still designed to be regulating converters, for the role of a POL. It would not have been obvious to take a (regulating) POL converter and redesign it to be a bus converter analogous to Lee’s “non-isolated bus converter”, for the same reasons I discussed above.

104. Second, Lee’s proposed bus converter is advertised as “magneticless”, meaning that it does not have magnetic core components including a transformer. (Ex. 1008, p. 13, left column top). Lee’s “magneticless” converter avoids magnetic components by using a “capacitive divider”. Lee’s capacitive divider

transforms voltages by selectively reconfiguring an array of capacitors from series to parallel. (Ex. 2019). Lacking a transformer, Lee's "magneticless" converter teaches away from transformer-based bus converters with, or without, isolation.

105. In my view, Lee's capacitive divider also did not change the prevailing thinking concerning the need for bus converters to be isolated. For example, three years *after* Lee was published, Miftakhutdinov wrote "[t]he advantage of IBA depends heavily on an intermediate-bus converter (IBC) that generates an optimal intermediate-bus voltage and provides electrical isolation." (Ex. 2017, p. 1, left column, middle).

106. Third, even leaving aside these considerations, Delta's proposed motivations are not persuasive. Delta first argues that "POSITA would understand that the 'non-isolated bus converter' of Lee's proposed architecture is a power converting circuit that **could take many forms**" (Petition, p. 51)(Emphasis added). Here, Delta relies on power converter circuits taking "many forms" to demonstrate obviousness. But Delta seems to contradict itself a two sentences later, arguing that "there **were limited options** for non-isolated converters" (Petition, p. 51)(Emphasis added), implying that the limited number of options reduces the choice available to a PHOSITA, and relying on this limited number of choices for obviousness.

107. Delta’s argument that “Huang’s nonisolated LLC resonant converters were specifically designed for the same purpose as Lee’s voltage divider, namely, increasing overall circuit efficiency” is also incorrect. As I discuss above, Huang was designed to play a fundamentally different role in an IBA system than that of a bus converter, namely the role of a downstream, tightly-regulating POL. (Ex. 1005, p. 1).

108. Delta next argues that there would have been a reasonable expectation of success because “as shown in Lee Figure 43, it was contemplated that the non-isolated bus converter would be a modular, and thus replaceable, component.” (Petition, p. 51). Nothing around Figure 43, however, says or shows this. In fact, Lee’s *specific* non-isolated bus converter is proposed in Fig. 43 because it is “magneticless”, and would not need bulky magnetic components on the circuit board. (Ex. 1008, p. 13, left column, top). One consequence of being “magneticless” is that Lee’s converter is not galvanically isolated. When viewing these teachings against a consistent prior-art background counseling the use of isolated, transformer-based bus converters, a PHOSITA would have drawn the conclusion that Lee’s non-isolated bus converter was at odds with the prior art by removing the magnetic core of a transformer. Because Huang’s converter has a transformer *and* is non-isolating—viewed as detrimental at the time—a PHOSITA would not have seen Huang’s converter as a viable replacement for Lee’s.

109. Delta next argues “a POSITA would be counseled to improve the efficiency of the circuit design in other ways, such as including Huang’s improved converters in Lee’s improved architecture design to improve the overall power conversion efficiency.” (Petition, p. 52). Delta, however, presents no analysis showing how efficiency would change when Huang’s converter is used in place of Lee’s. Lee claims that its non-isolated bus converter obtains 98% efficiency. (Ex. 2019, p. 2, left column, bottom). Huang does not state the efficiency for its Fig. 12(b) circuit, but Huang’s experimental section shows a peak efficiency for the Fig. 12(a) circuit of about 88%—much less than Lee’s. (Ex. 1005, p 8, Fig. 18). The lower efficiency of Huang’s circuit is to be expected because Huang’s converter provides a low voltage output and a regulation function that will produce additional waste heat. A PHOSITA would thus have expected to see a *decrease* in efficiency if somehow Huang were used to replace Lee. An expected loss of efficiency teaches away from the combination.

110. Lastly, Delta argues “use of Lee’s intermediate bus architecture with the resonant converters disclosed in Huang would have involved mere substitution of one known element (Lee’s “voltage divider” as the non-isolated bus converter shown in Figure 43) for another (Huang’s non-isolated LLC resonant converters as the nonisolated bus converter) to obtain predictable results (more efficient power conversion).” (Petition, p. 52-53). This argument is incorrect. While Huang and

Lee are “known elements”, their converter species (“magneticfull” vs. “magneticless”) and functions (POL vs. bus converter) are different, as explained above. A PHOSITA would not have found them to be known or natural substitutes for one another. Furthermore, the allegedly predictable result (more efficient power conversion) is incorrect, because a PHOSITA would have expected *lower* efficiency with Huang’s converter, as discussed immediately above.

111. I am therefore of the opinion that it would not have been obvious to use Huang’s converter in Lee’s Fig. 43 system.

C. Grounds V and VI (Liu)

112. Grounds V and VI, involving the Liu prior art, fail for reasons similar to those of Grounds I-IV.

1. Liu does not teach the language of the claims

113. I am also of the opinion that Grounds V and VI (Liu and AAPA, or Liu with Lee and the AAPA) do not make the claims of the ’950 patent obvious.

114. Like Huang, Liu (even if modified by AAPA or Lee) does not meet the claim language. Liu is not “adapted to convert power from the input circuit to the output circuit at a substantially fixed voltage transformation ratio, KDC...wherein the substantially fixed voltage transformation ratio can be represented as $KDC = V_{OUT}/V_{IN} \dots$ ”. Liu is a regulating converter, and thus V_{out} will be held constant while V_{in} changes.

115. Liu explains that the invention relates to DC/DC converters to supply power to CPUs, and that these are regulating circuits. Liu states first that:

“The invention relates to DC-DC converters. More particularly, it relates to such converters for low voltage central processing unit applications.”

(Ex. 1006, 1:15-17). Liu next explains that DC-DC converters are voltage regulators:

“A DC-DC converter (often referred to as a voltage **regulator** module or VRM) is used to convert the 12V DC into the lower voltage required by the CPU.”

(Ex. 1006, 1:42-46).

116. Furthermore, Liu’s converters are expressly designed to supply power to processors. (Ex. 1006, 1:15-17, 1:37-46). For example, Liu states that with respect to the Fig. 3 embodiment, on which the Petition relies, that:

“The converter 301 can be used to meet the stringent power requirement of the next generation CPU. The circuit topologies described herein are able to achieve high efficiency, fast dynamic response and provide high current to the CPU.”

(Ex. 1006, 13:3-6).

117. As I discuss above, processors in the relevant timeframe required stringent regulation of their input supply voltage. (Ex. 2021, pp. 152, 155-156)(Ex. 2015, p. 2, left column)(Ex. 1006, 1:56-64, 13:3-5, 14:65-67).

118. The regulating function (holding the output voltage fixed) is built into Liu's devices. Two embodiments of Liu are discussed in the Petition: Fig. 3 as implemented in Fig. 15, and Fig. 68A as implemented in Fig. 80.

119. With respect to the embodiment of Figs. 3 and 15, the Petition relies, under limitation 1(h), on the version of Fig. 15 that uses "phase-shift PWM control". (Petition, p. 73). Phase-shift PWM, is a control method to regulate the output voltage. (Ex. 1006, 7:46-49)("phase shift control to **regulate** output voltage")(Emphasis added)(*see also* Ex. 1006, 30:38-45, 31:27-41). The phrase "PWM" (pulse-width *modulation*) describes a varying operation of the circuit to effect "control"—in Liu, control to achieve regulation the output voltage. (Ex. 1006, 7:46-49).

120. To accomplish the regulation of the Fig. 15 circuit, the primary-side transistors (Q1-Q4) in Fig. 15 are driven such that Q1 and Q3 are on for overlapping periods. This overlap is shown in Liu's Fig. 20, which provides example waveforms for the Phase-shift PWM control technique in Fig. 15 (Ex. 1006, 8:49-52), and is reproduced below with an added red-dashed box and label ("overlap") to show the overlapping ON times of transistors Q1 and Q3:

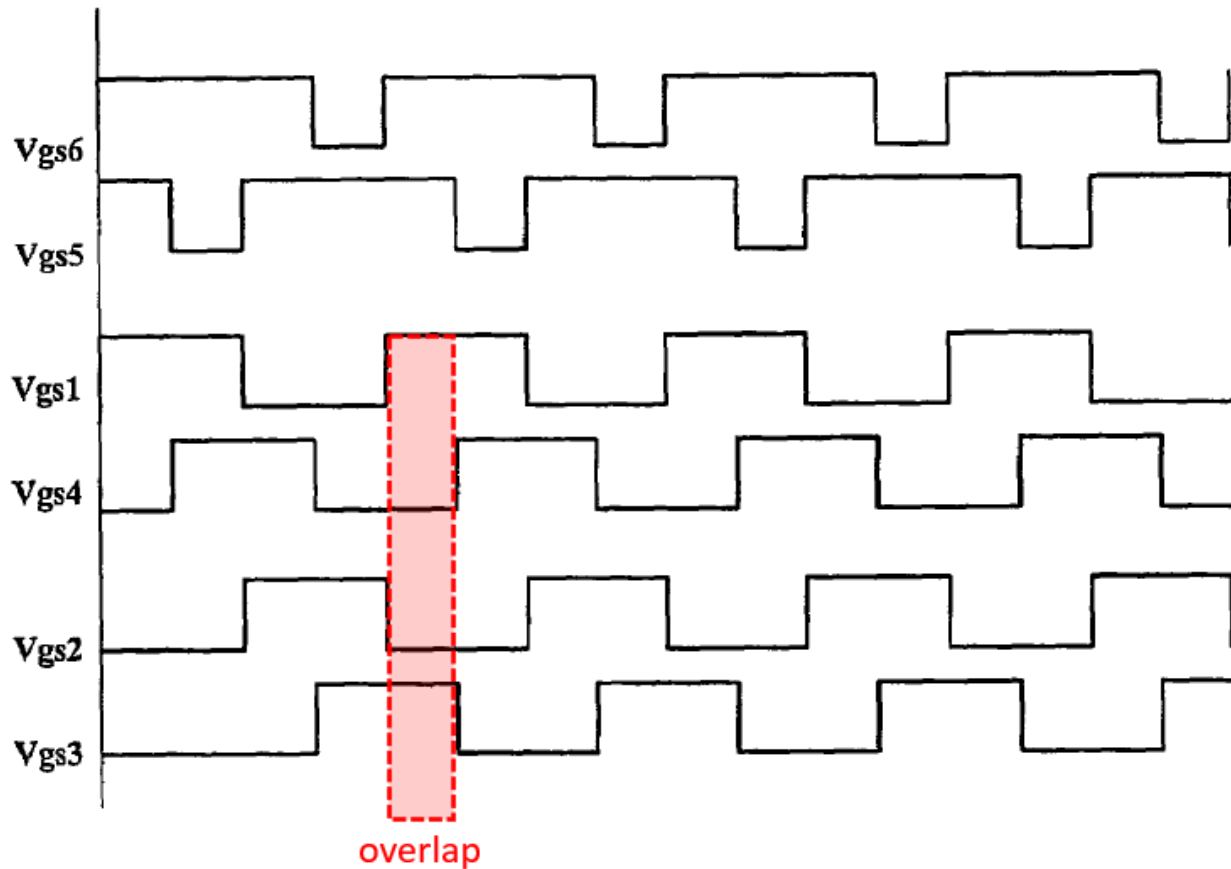


Fig. 20

(Ex. 1006, Fig. 20, *see also* 13:17-24 (explaining signal names), 18:17-31 (explaining phase-shift PWM gate drive)).

121. During the overlap period, when both Q1 and Q3 are ON, the primary windings of the transformer T1A are short-circuited, as shown here in Liu's Fig.

15, with added red-dashed lines to show the short-circuit path:

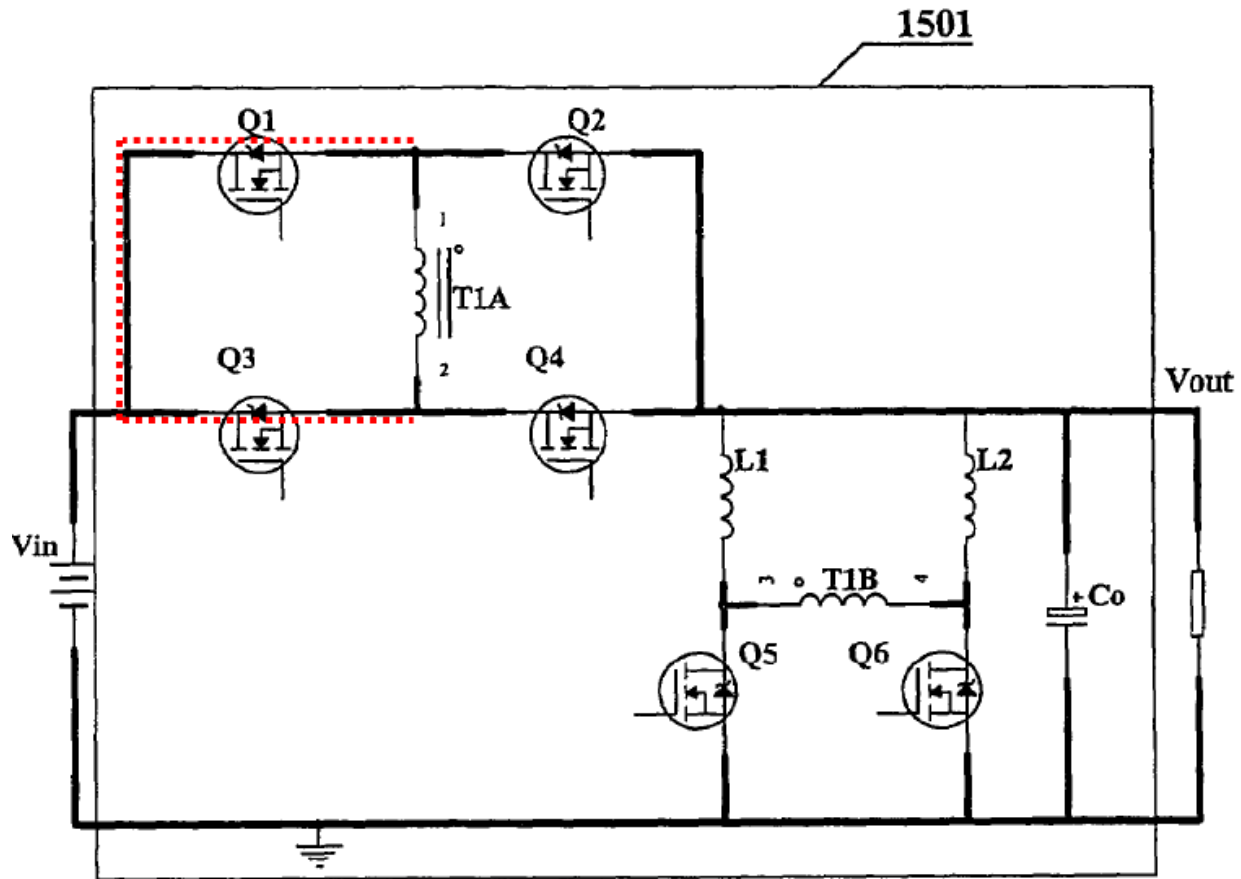


Fig. 15

(Ex. 1006, Fig. 15, 18:21-24). This short-circuiting allows the voltage across Q2 or Q4 to be reduced. Thus, by controlling the *length* of the overlap period, the circuit regulates the output voltage. As Liu explained in a prior paper (referred to in the Liu patent at 30:44-58):

“The PWM controlled resonant converters [13]-[19], also refer to as constant frequency clamped-mode resonant converters and **phase-controlled** resonant converters, have been proposed to keep the switching frequency constant. A **dead time** is introduced during which the **resonant tank is short circuited**. The output voltage is

regulated by changing the dead time.”

(Ex. 2022, p. 1, bridging left and right columns)(Emphasis added).

122. The phase-shift PWM control embodiment of Figs. 3/15, on which the Petition relies under limitation 1(h), is a converter that regulates its output voltage,³ as would be expected, given the intended application of delivering tightly-regulated supply voltages to processors. Because the output voltage V_{out} is held fixed while the input voltage V_{in} varies, ratio of V_{out} to V_{in} varies, and the converter of Figs. 3/15 is not “adapted to convert power from the input circuit to the output circuit at a substantially fixed voltage transformation ratio, KDC...wherein the substantially fixed voltage transformation ratio can be represented as $KDC=VOUT/VIN....$ ”.

123. The embodiment of Figs. 68A and 80, on which the Petition also relies, likewise regulates its output voltage. The Fig. 80 circuit is, like Huang, an LLC series resonant converter. (Petition, p. 68)(“The circuit depicted in Figure 80 is a series resonant LLC circuit”). The converter circuit diagram (Fig. 80) is reproduced below, with the two series inductors (the two “Ls”) and series capacitor (the “C”) shown inside an added red-dashed box:

³ Note that the other implementation, using standard PWM control as shown in Fig. 19, is also regulating.

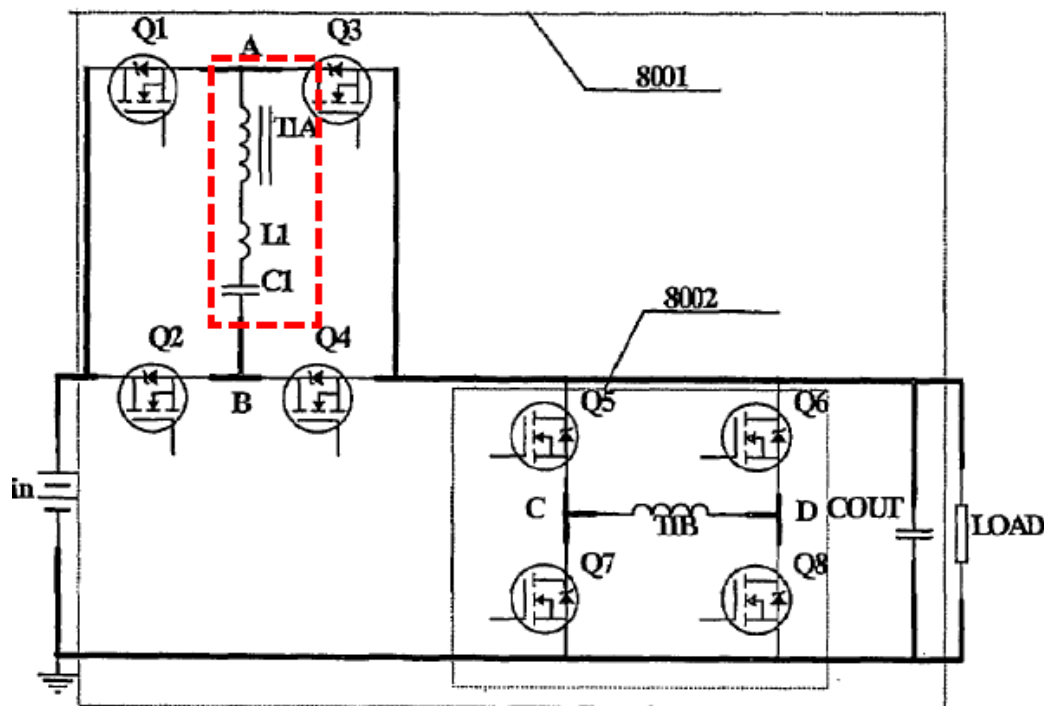


FIG. 80

(Ex. 1006, Fig. 80)

124. Liu teaches that this circuit is regulated in one of three ways. (Ex. 1006, 30:38-46). First, one can use a variable switching frequency (*i.e.* exactly the same way Huang's circuit is regulated). (Ex. 1006, 30:38-46). Second, one can use phase-shift control, like the embodiment of Figs. 3 and 15. (Ex. 1006, 30:38-46). Third, one can combine the two techniques. (Ex. 1006, 30:38-46). Liu states:

“Those skilled in the art will appreciate that **switching frequency control** can be used for all switches in the converters 9601 to **regulate the output voltage** across the load. Similarly, **phase shift control** can be used for high side switches in any full-bridge high side circuit (for example, the high side circuits in FIGS. 68B through 81 as will be described) in the converter 9601. Switching frequency

control and phase shift control may be used alone or in combination.”

(Ex. 1006, 30:38-46)(Emphasis added).

125. As with the embodiment of Figs. 3 and 15, regulation of the output of Figs. 68 and 80 is consistent with the purpose of Liu’s converters, namely to provide tightly-regulated output voltages to processors. (Ex. 2021, pp. 152, 155-156)(Ex. 2015, p. 2, left column)(Ex. 1006, 1:56-64, 13:3-5, 14:65-67).

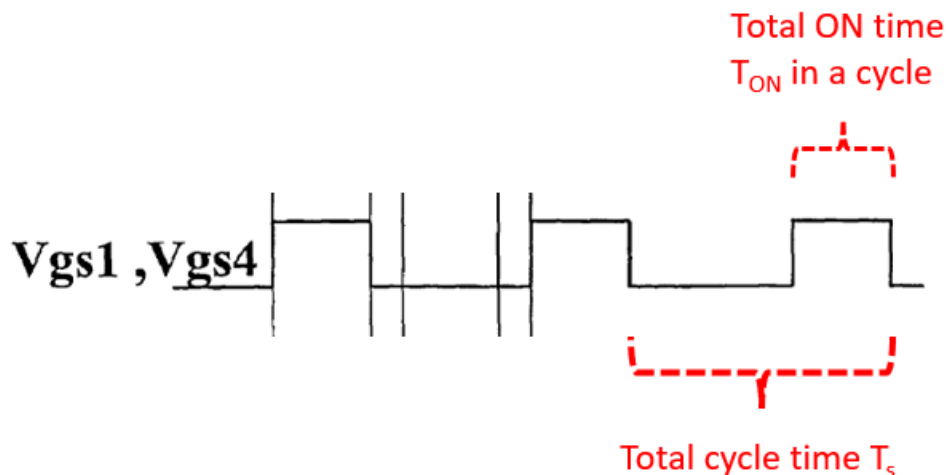
126. Because the output voltage V_{out} is held fixed while the input voltage V_{in} varies, the ratio of V_{out} to V_{in} varies, and the converter of Figs. 68A/80 is not “adapted to convert power from the input circuit to the output circuit at a substantially fixed voltage transformation ratio, KDC...wherein the substantially fixed voltage transformation ratio can be represented as $KDC=V_{OUT}/V_{IN}....$ ”.

127. The Petition provides an analysis of the “substantially fixed voltage transformation ratio” on pages 67-68. The reasoning in this section is incorrect.

128. With respect to the embodiment of Figs. 3 and 15, the Petition refers to equation (1) of Liu, namely
$$V_{out} = \frac{V_{in} * N * D}{(2 + N * D)}$$
. (Petition, p. 67)(citing Ex. 1006, 18:36-46). However, this equation is inapplicable; equation (1) applies to the implementation of Fig. 15 with the “regular PWM gate drive” described in 17:37-18:16 and Fig. 19, not the implementation that the Petition actually relies on to

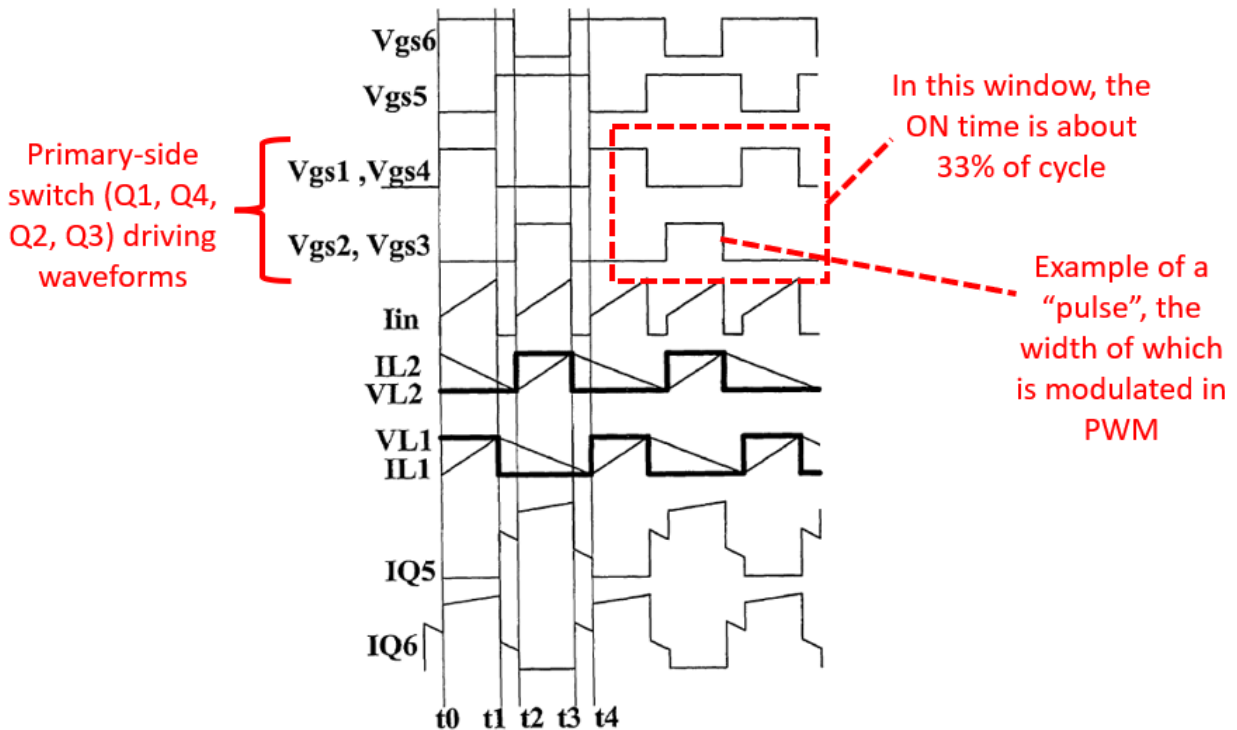
meet limitation 1(h), namely the “phase-shift PWM control” described at 18:17-35 and Fig. 20.

129. Even so, the Petition is also wrong when it quotes Liu at 17:5-15 as teaching a 50% duty cycle. (Petition, pp. 67, 68). The “duty cycle” in Liu is the length of time that the primary-side transistors are ON, compared to the length of the entire switching cycle, as shown in the illustration below, taken from the driving waveforms of Q1 and Q4 in Fig. 19 of Liu, with added elements in red. (Ex. 1006, 18:40-42):



(Ex. 1006, Fig. 19). In a pulse-width modulation scheme, the “pulses” that are being modulated are usually the ON times in the driving waveforms of the primary side transistors. By varying the ON times, the time during which the input voltage V_{in} is connected to the transformer is varied, thus changing the amount of power transmitted to the secondary side of the transformer. In the Fig. 19 implementation (regular PWM gate drive), one can immediately see that the duty cycle is not fixed

at 50%, and is closer to 33% This is shown in the reproduction of Fig. 19 of Liu, below, with added red-dashed elements and labels:



(Ex. 1006, Fig. 19). As shown above, the duty cycle in Fig. 19 is about 0.33. This is not to say that the converter is fixed at that duty cycle, but rather it is an illustration that the duty cycle is changing as the input voltage and load conditions change. Liu does not suggest to use a fixed 50% duty cycle in the portion of the specification cited by Delta, but rather states that “[w]hen the duty cycle is *around* 0.5, the performance of the converter is optimized.” (Ex. 1006, 17:14-15). Here, Liu is saying that although the duty cycle is changing, having the changes be *around* (centered at) 50% helps with efficiency. But because the duty cycle is changing as

the pulse width is modulated, the duty cycle “D” cannot simply be replaced with a constant 0.5, as Delta does on page 68 of the Petition. The Petition’s reasoning with respect to Figs. 3 and 15 is thus incorrect.

130. The reasoning for the embodiment of Figs. 68A and 80 is also incorrect. For this embodiment, Delta argues that “[w]hen the switching frequency of the circuit depicted in Figure 80 is at the resonant frequency, the voltage across the primary winding (as well as inductor L1 and capacitor C1) is $V_{in} - V_{out}$.” (Petition, p. 68). But as I discuss above the LLC series resonant converter either varies its switching frequency to regulate the output voltage (in which case it is not operating at the resonant frequency), or uses phase-shift PWM control. In either case, the purported voltage transformation ratio $K_{DC} = \frac{V_{out}}{V_{in} - V_{out}}$ is not substantially fixed, because V_{out} is held constant even while V_{in} changes. (Ex. 1006, 30:38-46).

131. For these reasons, I am of the opinion that Liu’s converter is not “adapted to convert power from the input circuit to the output circuit at a substantially fixed voltage transformation ratio, KDC...wherein the substantially fixed voltage transformation ratio can be represented as $KDC = V_{OUT}/V_{IN}....$ ”.

2. There is no motivation to use Liu's converters as bus converters in IBA

132. I am also of the opinion that there was no motivation to use Liu's converters as bus converters in IBA. The Petition alleges, in language essentially copied from Ground I, that a PHOSITA would have known from the alleged admitted prior art to use Liu's converter as a bus converter in an intermediate bus architecture. (Petition, pp. 65, 69). But Liu's converter is both non-isolating (Ex. 1006, Title) and regulating. Thus, it would not have been obvious to use Liu's converter as a bus converter in an intermediate bus architecture for the same reasons discussed above with respect to Huang's non-isolating and regulating converter.

133. Furthermore, Liu teaches away from intermediate bus architecture. Specifically, Liu states that:

“[I]n North America, power for a personal computer is typically drawn from a 120V AC wall outlet. This AC voltage is converted into a 12V DC voltage by an AC-to-DC converter. The 12V DC is distributed to a motherboard where the CPU is located. This 12V DC voltage cannot power the CPU directly. A DC-DC converter (often referred to as a voltage regulator module or VRM) is used to convert the 12V DC into the lower voltage required by the CPU. **This power system architecture is currently preferred from a performance and cost point of view.**”

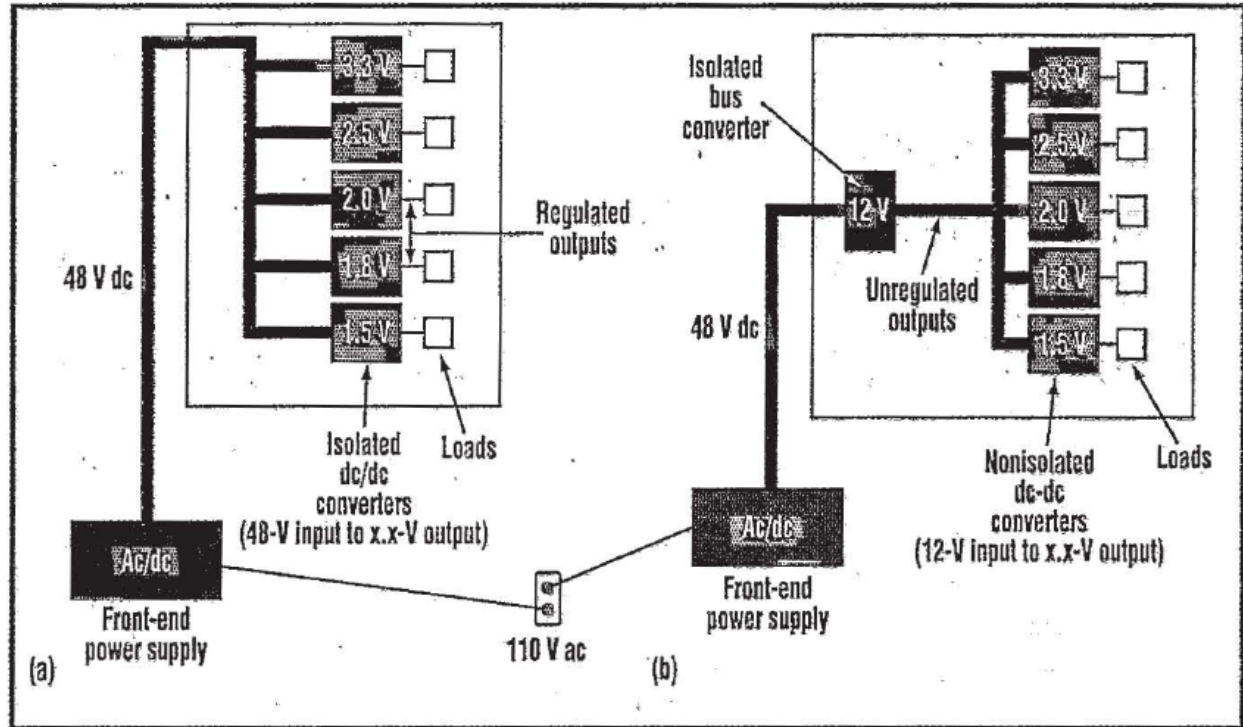
(Ex. 1006, 1:37-47)(Emphasis added). The “preferred” architecture described by

Liu is not IBA, because it lacks an intermediate conversion stage. In IBA, the AC voltage would normally be converted in a “front-end” converter to a relatively high DC voltage, like 48 V, *then* converted by a bus converter to a 12 V DC intermediate bus voltage, and only then converted to the voltage required by the CPU. (Ex. 2017, Fig. 4, p. 4-6)(Ex. 2002, p. 1, Fig. 1(b)). Liu instead suggests form of distributed power architecture (DPA), where power is downconverted *directly* from the output of AC/DC converter (a front-end converter) to the individual voltage levels needed by on-board components, using a separate DC/DC converter for each voltage level. (Ex. 1006, 1:37-47). This approach avoids both an intermediate bus and a bus converter. Thus, Liu has two conversion steps, while IBA has three, as shown conceptually here, where each converter used is in blue typeface:

Liu: AC/DC converter → DC/DC converter

IBA: AC/DC converter → Bus Converter → POL

134. The difference between the two approaches can also be seen by comparing Figures 1(a) and 1(b) from in Morrison’s 2002 article “Distributed Power Moves To Intermediate Voltage Bus”, reproduced here:



(Ex. 2002, p. 1, Figs. 1(a) and (b)). On the left side is a Distributed Power Architecture (DPA), where the Front-end power supply (the AC/DC converter) provides a 48 V input directly to isolated DC/DC converters to power loads. On the right, in contrast, is an IBA system, where the Front-end power supply (the AC/DC converter) provides a 48 V input to an isolated, non-regulating bus converter (see “Unregulated outputs”), which in turn provides an unregulated 12 V DC input to supply non-isolated POL converters. (Ex. 2002, p. 1)

135. Liu states that downconverting the voltage from the output of the AC/DC converter (*i.e.* the “front-end power supply”) directly to processor voltages (Fig. 1(a), above) is “preferred from a performance and cost point of view”, thus

teaching away from the use of Liu's converters in an IBA system (Fig. 1(b), above).

3. Ground VI (Liu and Lee)

136. In my view, Ground VI also does not render the claims obvious. Ground VI is essentially identical to Ground III, but with the word "Huang" replaced with "Liu". Thus, the discussion above with respect to Ground III applies similarly to Liu.

137. Three differences in the arguments should be addressed. First, Huang specifically states that it is designed to be used as a POL (a downstream regulator in an IBA structure) or Voltage Regulator, while Liu does not use the word POL. However, Liu is clearly directed at supplying tightly-regulated voltages, under fast-transient conditions, to a processor. As such, the role of Liu's converter is the same as that of Huang's converter, and equally inappropriate for a bus converter.

138. Second, Huang provides data concerning the efficiencies his converter achieved, while Liu does not. However, a PHOSITA would nonetheless have expected Liu's converter to reduce the efficiency of Lee's converter, because Liu's converter provides a low, processor output voltage and adds regulation, whereas Lee's converter is unregulated. (Ex. 2003, p. 4, left column)(Ex. 2017, p. 6, left column).

139. Third, as I discuss above, Liu teaches away from its use in an Intermediate Bus Architecture, instead stating that its DC/DC converters should be used directly to transform voltages from the AC/DC converter to the voltage needed by processors.

140. For these reasons, I am of the opinion that the Grounds stated in the Petition for inter partes review do not make the challenged claims of the '950 patent unpatentable.

IX. OATH

141. 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.

February 17, 2024
Date


Dr. Juan Rivas-Davila