

**UNITED STATES PATENT AND TRADEMARK OFFICE**

---

**BEFORE THE PATENT TRIAL AND APPEAL BOARD**

---

TEXTRON SPECIALIZED VEHICLES INC.,

Petitioner,

v.

SZ DJI TECHNOLOGY CO. LTD.,

Patent Owner.

---

Case IPR2023-01198  
Patent No. 10,640,224

---

**DECLARATION OF DR. REGAN ZANE, PH.D. IN SUPPORT OF  
PETITION FOR INTER PARTES REVIEW OF  
U.S. PATENT NO. 10,640,224**

## TABLE OF CONTENTS

|       |                                                                                                             |    |
|-------|-------------------------------------------------------------------------------------------------------------|----|
| I.    | INTRODUCTION .....                                                                                          | 6  |
| II.   | SUMMARY OF OPINIONS .....                                                                                   | 8  |
| III.  | BACKGROUND AND QUALIFICATIONS .....                                                                         | 9  |
| IV.   | MATERIALS CONSIDERED .....                                                                                  | 14 |
| V.    | LEGAL UNDERSTANDING .....                                                                                   | 16 |
| A.    | Anticipation .....                                                                                          | 17 |
| B.    | Obviousness .....                                                                                           | 17 |
| C.    | Claim Construction .....                                                                                    | 20 |
| VI.   | LEVEL OF ORDINARY SKILL IN THE ART .....                                                                    | 21 |
| VII.  | BRIEF OVERVIEW OF THE '224 PATENT .....                                                                     | 23 |
| A.    | Summary of the '224 Patent .....                                                                            | 23 |
| B.    | '224 Patent Prosecution History .....                                                                       | 26 |
| C.    | Challenged Claims of the '224 Patent .....                                                                  | 26 |
| VIII. | OVERVIEW OF THE PRIOR ART REFERENCES .....                                                                  | 31 |
| A.    | Takashi .....                                                                                               | 31 |
| B.    | Onishi .....                                                                                                | 34 |
| C.    | Kim .....                                                                                                   | 36 |
| IX.   | CLAIM CONSTRUCTION .....                                                                                    | 39 |
| X.    | A REASONABLE LIKELIHOOD EXISTS THAT THE CHALLENGED<br>CLAIMS ARE UNPATENTABLE .....                         | 39 |
| A.    | Grounds 1A and 1B: Claims 1-8 and 12-17 are (1A)<br>Anticipated by or (1B) Obvious in View of Takashi ..... | 39 |
| 1.    | Claim 1 .....                                                                                               | 40 |

|     |                                                                                                                                                                                                                                                                                                                                               |    |
|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| 2.  | Claim 2: The method according to claim 1, wherein the present electrical parameter includes at least one of a present charge quantity of the battery, <b>a present voltage of the battery</b> , a present output electrical current of the battery, or a present internal resistance of the battery. ....                                     | 50 |
| 3.  | Claim 3: The method according to claim 2, wherein the control signal includes at least one of <b>a control signal configured to control a rotation speed of the motor</b> or a control signal configured to control an output power of the motor.....                                                                                         | 51 |
| 4.  | Claim 4.....                                                                                                                                                                                                                                                                                                                                  | 52 |
| 5.  | Claim 5: The method according to claim 4, wherein modifying the control signal includes: modifying, at a present time point, the control signal according to the compensation amount. ....                                                                                                                                                    | 57 |
| 6.  | Claim 6.....                                                                                                                                                                                                                                                                                                                                  | 60 |
| 7.  | Claim 7.....                                                                                                                                                                                                                                                                                                                                  | 61 |
| 8.  | Claim 8: The method according to claim 7, wherein the compensation amount of the voltage is determined according to a difference between a full voltage of the battery and the present voltage of the battery.....                                                                                                                            | 68 |
| 9.  | Claim 12: An apparatus for controlling a motor comprising: one or more processors configured to: obtain a present electrical parameter of a battery; calculate a compensation amount of a control signal of the motor according to the present electrical parameter; and modify the control signal according to the compensation amount. .... | 70 |
| 10. | Claim 13: The apparatus according to claim 12, further comprising: an electrical parameter detection circuit electrically coupled to the one or more processors and configured to detect the present electrical parameter. ....                                                                                                               | 73 |
| 11. | Claim 14: The apparatus according to claim 13, wherein the electrical parameter detection circuit includes at least one of a coulometer, <b>a voltage detection circuit</b> , an electrical current detection circuit, or a resistance detection circuit.....                                                                                 | 75 |

|     |                                                                                                                                                                                                                                                                                                                                                                                     |     |
|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 12. | Claim 15.....                                                                                                                                                                                                                                                                                                                                                                       | 75  |
| 13. | Claim 16: The apparatus according to claim 14, wherein the one or more processors are further configured to: calculate in real time the compensation amount of the control signal of the motor according to the present voltage of the battery. ....                                                                                                                                | 76  |
| 14. | Claim 17: The apparatus according to claim 16, wherein the one or more processors are further configured to: calculate in real time a compensation amount of a voltage outputted to the motor according to the present voltage of the battery; and modify an original voltage outputted to the motor according to the compensation amount of the voltage outputted to the motor. .. | 77  |
| B.  | Grounds 2A and 2B: Claims 9-11 are (2A) Anticipated by or (2B) Obvious in View of Onishi .....                                                                                                                                                                                                                                                                                      | 78  |
| 1.  | Claim 9.....                                                                                                                                                                                                                                                                                                                                                                        | 79  |
| 2.  | Claim 10: The method according to claim 9, wherein the present electrical parameter of the battery includes at least one of a present charge quantity of the battery, a present voltage of the battery, a present output electrical current of the battery, or a present internal resistance of the battery.....                                                                    | 91  |
| 3.  | Claim 11 .....                                                                                                                                                                                                                                                                                                                                                                      | 92  |
| C.  | Grounds 3A and 3B: Claims 9-11 are (3A) Anticipated by or (3B) Obvious in View of Kim.....                                                                                                                                                                                                                                                                                          | 94  |
| 1.  | Claim 9.....                                                                                                                                                                                                                                                                                                                                                                        | 94  |
| 2.  | Claim 10: The method according to claim 9, wherein the present electrical parameter of the battery includes at least one of a present charge quantity of the battery, a present voltage of the battery, a present output electrical current of the battery, or a present internal resistance of the battery.....                                                                    | 101 |
| 3.  | Claim 11 .....                                                                                                                                                                                                                                                                                                                                                                      | 102 |
| XI. | CONCLUSION.....                                                                                                                                                                                                                                                                                                                                                                     | 106 |

## LIST OF EXHIBITS

| <b>Exhibit</b> | <b>Description</b>                                                                                                                                                                                                             |
|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>1001</b>    | U.S. Patent No. 10,640,224 (“the ’224 Patent”)                                                                                                                                                                                 |
| <b>1002</b>    | Declaration of Dr. Regan Zane                                                                                                                                                                                                  |
| <b>1003</b>    | File History for the ’224 Patent                                                                                                                                                                                               |
| <b>1004</b>    | Certified English Translation of Japanese Patent Application No. H05-39875 (“Takashi”)                                                                                                                                         |
| <b>1005</b>    | Japanese Patent Application No. H05-39875 (“Takashi”)                                                                                                                                                                          |
| <b>1006</b>    | Certified English Translation of Japanese Patent Application No. 2011-193653 (“Onishi”)                                                                                                                                        |
| <b>1007</b>    | Japanese Patent Application No. 2011-193653 (“Onishi”)                                                                                                                                                                         |
| <b>1008</b>    | U.S. Patent No. 8,330,419 (“Kim”)                                                                                                                                                                                              |
| <b>1009</b>    | Complaint, <i>SZ DJI Technology Co. Ltd. v. Textron Specialized Vehicles Inc.</i> , Case No. 1:23-cv-00055 (DE), Dkt. 1, filed January 17, 2023                                                                                |
| <b>1010</b>    | Defendants’ Opening Brief in Support of its Motion to Dismiss for Failure to State a Claim, <i>SZ DJI Technology Co. Ltd. v. Textron Specialized Vehicles Inc.</i> , Case No. 1:23-cv-00055 (DE), Dkt. 18, filed April 3, 2023 |
| <b>1011</b>    | Amended Complaint, <i>SZ DJI Technology Co. Ltd. v. Textron Specialized Vehicles Inc.</i> , Case No. 1:23-cv-00055 (DE), Dkt. 21, filed May 17, 2023                                                                           |
| <b>1012</b>    | AUSTIN HUGHES, ELECTRIC MOTORS AND DRIVES: FUNDAMENTALS, TYPES AND APPLICATIONS (3 <sup>rd</sup> ed. 2006)                                                                                                                     |
| <b>1013</b>    | DAVIDE ANDREA, BATTERY MANAGEMENT SYSTEMS FOR LARGE LITHIUM-ION BATTERY PACKS (2010)                                                                                                                                           |

I, Regan Zane, Ph.D., declare as follows:

**I. INTRODUCTION**

1. I have been retained as a technical expert on behalf of Petitioner Textron Specialized Vehicles Inc. (“TSV” or “Petitioner”) in connection with the above-captioned Petition for *Inter Partes* Review (“IPR”) of U.S. Patent No. 10,640,224 (“the ’224 Patent”) before the Patent Trial and Appeal Board (“PTAB”). Although I am being compensated at my usual rate of \$460 per hour for the time I spend on this matter, no part of my compensation depends on the outcome of this proceeding, and I have no other interest in this proceeding.

2. I understand that this proceeding involves the ’224 Patent, and I have been asked to provide my opinions as to the patentability of Claims 1-17 of the ’224 Patent. I understand that the application for the ’224 Patent was filed on August 29, 2018, as U.S. Patent Application No. 16/116,279, and is a continuation of International Application No. PCT/ CN2016/075097 filed on March 1, 2016. I also understand that a copy of the ’224 Patent has been provided as Exhibit 1001 to the Petition for *Inter Partes* Review.

3. I am familiar with the technology at issue, including during the period prior to March 1, 2016. I have reviewed the Petition for *Inter Partes* Review of the ’224 Patent, including the exhibits attached thereto. I make this Declaration in support of the Petition.

4. I have been asked to consider whether Claims 1-17 of the '224 Patent (the "Challenged Claims") are unpatentable under 35 U.S.C. §§ 102 and 103 in view of the prior art references identified in the Petition. Specifically, I have been asked to provide my technical opinions regarding the following grounds:

| Ground | Claims          | Basis for Challenge                                  |
|--------|-----------------|------------------------------------------------------|
| 1A     | 1-4, 6-8, 12-17 | Claims 1-4, 6-8 and 12-17 are Anticipated by Takashi |
| 1B     | 1-8, 12-17      | Claims 1-8 and 12-17 are Obvious Over Takashi        |
| 2A     | 9-11            | Claims 9-11 are Anticipated by Onishi                |
| 2B     | 9-11            | Claims 9-11 are Obvious Over Onishi                  |
| 3A     | 9-11            | Claims 9-11 are Anticipated by Kim                   |
| 3B     | 9-11            | Claims 9-11 are Obvious Over Kim                     |

5. In reaching the opinions stated herein, I have considered the '224 Patent and the prior art references identified above in Grounds 1A-3B in the context of my own education, training, research, knowledge, as well as my personal and professional experience.

6. In reaching the opinions stated herein, I have also considered the materials identified in Section IV in the context of my own education, training, research, knowledge, as well as my personal and professional experience.

7. I make this Declaration based on my own personal knowledge and, if called upon to testify, would testify competently to the matters contained herein.

Specifically, this Declaration is a statement of my opinions that the Challenged Claims are unpatentable based on the relied-upon references and above-identified grounds.

## **II. SUMMARY OF OPINIONS**

8. After studying the materials listed in Section IV of this Declaration, I reached the conclusions discussed herein.

9. It is my opinion that Claims 1-4, 6-8, and 12-17 of the '224 Patent are anticipated by Takashi. To the extent it is argued that Takashi does not expressly or inherently disclose one or more limitations of Claims 1-4, 6-8, and 12-17 of the '224, it is my opinion that any such limitations would have been rendered obvious by Takashi. It is also my opinion that Claim 5 is rendered obvious by Takashi.

10. It is my opinion that Claims 9-11 of the '224 Patent are anticipated by Onishi. To the extent it is argued that Onishi does not expressly or inherently disclose one or more limitations of Claims 9-11 of the '224, it is my opinion that any such limitations would have been rendered obvious by Onishi.

11. It is my opinion that Claims 9-11 of the '224 Patent are anticipated by Kim. To the extent it is argued that Kim does not expressly or inherently disclose one or more limitations of Claims 9-11 of the '224, it is my opinion that any such limitations would have been rendered obvious by Kim.

### **III. BACKGROUND AND QUALIFICATIONS**

12. My background and qualifications are stated more fully in my *curriculum vitae*, a copy of which can be found in Appendix A to my Declaration. As reflected in my curriculum vitae (and as explained below), I have extensive professional experience with electronic circuits, battery cells and battery packs, battery management systems, power converters, control systems, and motors and motor drivers, including application to electric vehicles and battery storage systems,, including the design, development, implementation, and operation of such technologies.

13. I received my Bachelor of Science degree in Electrical Engineering (BSEE) from the University of Colorado at Boulder in 1996. In 1998, I received a Master of Science degree in Electrical Engineering (MSEE) from the University of Colorado at Boulder. In 1999, I received a Doctor of Philosophy (Ph.D.) degree in electrical engineering from the University of Colorado at Boulder. My Ph.D. dissertation research focused on the design of low-cost, high performance custom integrated circuit (IC) controllers and gate drives for isolated AC/DC power converters.

14. In 1999, I joined the Corporate Research and Development Center at General Electric (GE) as a Senior Research Scientist. At GE, I developed and commercialized electronic ballasts and drivers using custom integrated circuits (IC) for a wide range of applications, including multiple generations of controllers

for compact fluorescent lamps (e.g., residential lighting), high intensity discharge lamps (e.g., commercial lighting), and light emitting diodes (LEDs). In my experience at GE I had custom power ICs fabricated at the Taiwan Semiconductor Manufacturing Corporation (TSCM), led laboratory system testing and evaluation, and transitioned the circuits to GE Lighting for pre-production testing. The success of this work led to my Six Sigma Green Belt certification at GE.

15. In 2001, I joined the Department of Electrical, Computer, and Energy Engineering at the University of Colorado at Boulder (CU Boulder) as an Assistant Professor, and I received tenure and was promoted to Associate Professor in 2008. While at CU Boulder, I was one of three faculty members at the Colorado Power Electronics Center (CoPEC), where we developed power solutions in close partnership with industry sponsors. I led numerous research and development (R&D) projects with industry partners on topics including IC design, analog and digital control of power converters, magnetics design, solar power systems, LED drivers, voltage regulation modules for processors, and power distribution in data centers.

16. In 2004 I received the NSF CAREER award for my R&D and commercialization work on electronic circuits and drivers for LED lighting, and in 2006 I received the Inventor of the Year and Provost Faculty achievement awards for continued advancements to state-of-the-art in the power electronics area. At

CU Boulder I also taught courses and provided industry seminars and training on electronic circuit design, the fundamentals of power electronics, and advanced courses in modeling and control of power converters, where I received the Holland Teaching Award and the John and Mercedes Peebles Innovation in Teaching Award.

17. In 2012, I became a Full Professor with a USTAR endowment in the Department of Electrical and Computer Engineering at Utah State University (USU). There, I founded and continue to direct the Electric Vehicle & Roadway (EVR) Research Facility and Test Track, the USU Power Electronics Lab (UPEL), and the Battery Limits and Survivability Test (BLAST) lab. In 2016, I formed and launched the multi-university industry sponsored Center for Sustainable Electrified Transportation (SELECT) focused on advanced technologies for electric drive and battery systems for EVs. In 2018, I received and continue to hold the David G. and Diann L. Sant Endowed Professorship at Utah State University.

18. In 2020, I led SELECT the team to receive the National Science Foundation's (NSF's) highest award for international center level research and became the founding Director of the NSF Engineering Research Center for Advancing Sustainability through Powered Infrastructure for Roadway Electrification (ASPIRE ERC). The ASPIRE ERC includes 10 universities, more than 65 faculty and 250 students, and over 60 industry and innovation sponsors

including automotive original equipment manufacturers (OEMs), Tier 1 component suppliers, utilities, battery manufacturers, national laboratories, and a wide range state, government, and non-profit agencies.

19. While at USU I have led numerous large-scale R&D and commercialization programs on technologies for battery systems, electric vehicles (EVs), and battery charging infrastructure. As one example, I was the lead principle investigator (PI) for a multi-million dollar, multi-year project in partnership with key industry and national lab partners where we developed new concepts for advanced active battery management systems that were conceived, modeled, and simulated, then developed into hardware prototypes, integrated into commercial battery packs for a leading automotive OEM plug-in hybrid electric vehicle, evaluated for over one year of testing, and finally transitioned for commercialization at a leading automotive OEM.

20. Multiple additional projects on advanced battery management systems for a wide range of applications have stemmed from this early work and continue in my research laboratory today. These include development, testing and delivery of plug-and-play portable lithium ion battery packs for vehicles and DC microgrids in military applications, robust battery solutions for electric aircraft, high power fast charging battery packs for electric vehicles, and battery management systems for second life application of batteries that provide support to the electric utility

grid. This work has received numerous awards, including the Utah Innovation Award in Clean Technology and Energy for “Robust and Efficient Battery Management Systems” and the USU Campus Research of the Year Award.

21. Since 2006, I have served as an Associate Editor with IEEE Transactions on Power Electronics. In addition, since 2013 I have served as an Associate Editor for the IEEE Journal of Emerging and Selected Topics in Power Electronics. I have served as conference chairman, co-chair, session chair, and committee member for numerous professional conferences in power electronics over the past 20 years and maintained active participation as a journal article reviewer and elected professional society leader.

22. I am a named inventor on 34 issued United States patents with many pending in the field of power electronics, including multiple in the areas of battery management systems, battery charging systems, and power control technologies. .

23. I have authored or co-authored over 200 peer-reviewed journal and top-rated conference papers and articles, and have received 3 best journal paper awards, am co-author of the book titled “Digital control of high-frequency switched-mode power converters,” and have provided more than 60 invited seminars and talks. In my more than 20 years as a faculty member, I have trained, advised, and supervised hundreds of students in laboratory work and I have led multi-million-dollar projects in partnership with industry that include hardware

prototype development and evaluation, systems demonstration, and pilot deployment in commercial settings. In all, I have been a lead or co-lead on competitive R&D and commercialization projects in partnership with industry totaling over \$85 million leading to well over 100 hardware systems that have been developed and tested in my labs.

24. I am being compensated for my work associated with this case plus reimbursement of reasonable expenses. My compensation is not contingent on my opinions or the outcome of the case, and I have no other interest in this case or the parties thereto.

#### **IV. MATERIALS CONSIDERED**

25. I have considered information from various sources in forming my opinions. Besides drawing from my extensive background and experience in power electronics, batteries and battery management systems, and electric vehicles, I also have reviewed the documents and references as cited herein, including those identified in the following table:

| <b>Exhibit Number</b> | <b>Document<sup>1</sup></b>                                                                                                                     |
|-----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Petition</b>       | Petition for <i>Inter Partes</i> Review of U.S. Patent No. 10,640,224, IPR2023-01198                                                            |
| <b>1001</b>           | U.S. Patent No. 10,640,224 (“the ’224 Patent”)                                                                                                  |
| <b>1002</b>           | Declaration of Dr. Regan Zane                                                                                                                   |
| <b>1003</b>           | File History for the ’224 Patent                                                                                                                |
| <b>1004</b>           | Certified English Translation of Japanese Patent Application No. H05-39875 (“Takashi”)                                                          |
| <b>1005</b>           | Japanese Patent Application No. H05-39875 (“Takashi”)                                                                                           |
| <b>1006</b>           | Certified English Translation of Japanese Patent Application No. 2011-193653 (“Onishi”)                                                         |
| <b>1007</b>           | Japanese Patent Application No. 2011-193653 (“Onishi”)                                                                                          |
| <b>1008</b>           | U.S. Patent No. 8,330,419 (“Kim”)                                                                                                               |
| <b>1009</b>           | Complaint, <i>SZ DJI Technology Co. Ltd. v. Textron Specialized Vehicles Inc.</i> , Case No. 1:23-cv-00055 (DE), Dkt. 1, filed January 17, 2023 |

---

<sup>1</sup> In this Declaration, references to Exhibits 1001 and 1008 correspond to the column and line number found within the document itself, rather than the page indicated by the exhibit label. References to Exhibits 1003 and 1009-1013 correspond to the page indicated by the exhibit label. References to Exhibits 1004-1007 correspond to the paragraph number found within the document itself, rather than the page indicated by the exhibit label.

|             |                                                                                                                                                                                                                                |
|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>1010</b> | Defendants' Opening Brief in Support of its Motion to Dismiss for Failure to State a Claim, <i>SZ DJI Technology Co. Ltd. v. Textron Specialized Vehicles Inc.</i> , Case No. 1:23-cv-00055 (DE), Dkt. 18, filed April 3, 2023 |
| <b>1011</b> | Amended Complaint, <i>SZ DJI Technology Co. Ltd. v. Textron Specialized Vehicles Inc.</i> , Case No. 1:23-cv-00055 (DE), Dkt. 21, filed May 17, 2023                                                                           |
| <b>1012</b> | AUSTIN HUGHES, ELECTRIC MOTORS AND DRIVES: FUNDAMENTALS, TYPES AND APPLICATIONS (3 <sup>rd</sup> ed. 2006)                                                                                                                     |
| <b>1013</b> | DAVIDE ANDREA, BATTERY MANAGEMENT SYSTEMS FOR LARGE LITHIUM-ION BATTERY PACKS (2010)                                                                                                                                           |

26. I have reviewed the Petition in detail and agree with both its analysis and conclusions.

## **V. LEGAL UNDERSTANDING**

27. I have relied on instructions from counsel for Petitioner as to the applicable legal standards to use in arriving at my opinions in this Declaration. My opinions are informed by my understanding of the relevant law.

28. I understand that, in this proceeding, claims are to be given their broadest reasonable interpretation consistent with the patent specification.

29. I understand that a patentability analysis is conducted on a claim-by-claim basis and that there are several possible reasons that a patent claim may be found to be unpatentable. I understand that earlier publications and patents may act to render a patent claim unpatentable for one of two reasons: (1) anticipation and (2) obviousness.

**A. Anticipation**

30. I understand that a single piece of prior art anticipates a claim if that prior art discloses each and every claim element as arranged in the claim. I further understand that, where a claim element is not explicitly disclosed in a prior art reference, the reference may anticipate a claim if the missing claim element is necessarily present in the apparatus or is a natural result of the method disclosed, *i.e.*, the missing claim element is “inherent.”

**B. Obviousness**

31. Second, I understand that the prior art may render a patent claim obvious. I understand that a claim may be invalid as obvious if the subject matter described by the claim as a whole would have been obvious to a person of ordinary skill in the art (“POSITA”) in view of a prior art reference, or in view of a combination of references at the time the claimed invention was made. Therefore, I understand that obviousness is determined from the perspective of a POSITA, and that the challenged claims of the patent should be read from the point of view of such a person at the time the claimed invention was made. I further understand that a POSITA is assumed to know and to have all relevant prior art in the field of endeavor covered by the patent in suit and all analogous prior art. I understand that obviousness in an *inter partes* review proceeding is evaluated using a

preponderance of the evidence standard, which means that the claims must be more likely obvious than nonobvious.

32. I also understand that an analysis of whether a claimed invention would have been obvious should be considered in light of the scope and content of the prior art, the differences (if any) between the prior art and the claimed invention, and the level of ordinary skill in the pertinent art involved. I understand as well that a prior art reference should be viewed as a whole. I further understand that in considering whether an invention for a claimed combination would have been obvious, I may assess whether there are apparent reasons to combine known elements in the prior art in the manner claimed in view of interrelated teachings of multiple prior art references, the effects of demands known to the design community or present in the marketplace, and/or the background knowledge possessed by a POSITA.

33. In addition, I understand that other principles may be relied on in evaluating whether a claimed invention would have been obvious, and that these principles include the following:

- A combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results;
- When a device or technology is available in one field of endeavor,

design incentives and other market forces can prompt variations of it, either in the same field or in a different one, so that if a POSITA can implement a predictable variation, the variation is likely obvious;

- If a technique has been used to improve one device, and a POSITA would have recognized that it would improve similar devices in the same way, using the technique is obvious unless its actual application is beyond his or her skill;
- An explicit or implicit teaching, suggestion, or motivation to combine two prior art references to form the claimed combination may demonstrate obviousness, but proof of obviousness does not depend on or require showing a teaching, suggestion, or motivation to combine;
- Market demand, rather than scientific literature, can drive design trends and may show obviousness;
- One of the ways in which a patent's subject can be proved obvious is by noting that there existed at the time of invention a known problem for which there was an obvious solution encompassed by the patent's claims;
- Any need or problem known in the field of endeavor at the time of

invention and addressed by the patent can provide a reason for combining the elements in the manner claimed;

- “Common sense” teaches that familiar items may have obvious uses beyond their primary purposes, and in many cases a POSITA will be able to fit the teachings of multiple patents together like pieces of a puzzle;
- A POSITA is also a person of ordinary creativity, not an automaton;
- A patent claim can be proved obvious by showing that the claimed combination of elements was “obvious to try,” particularly when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions such that a POSITA would have had good reason to pursue the known options within his or her technical grasp; and
- One should be cautious of using hindsight in evaluating whether a claimed invention would have been obvious.

### **C. Claim Construction**

34. I understand that, in an *inter partes* review, claim terms are given their ordinary and customary meaning in view of the specification, as would be understood by one of ordinary skill in the art at the time of invention. Moreover, I

understand that a construction must be consistent with the one that those skilled in the art would reach and that a construction that is unreasonably broad and which does not reasonably reflect the plain language of the disclosure does not fall under the broadest reasonable construction. I also understand that it is important not to import claim limitations that are not part of the claim when construing a claim term.

35. I also understand that the claims should be construed consistent with the patent's intrinsic record, which includes the patent itself as well as the patent's prosecution history. I further understand that a patentee can act as his or her own "lexicographer" by explicitly defining claim terms in the body of the patent.

36. Moreover, I understand that extrinsic evidence (including, for example, technical dictionaries and treatises) may shed light on the meaning claim terms would have to one of ordinary skill in the art. I also understand that, where extrinsic evidence conflicts with the intrinsic record, the intrinsic record governs the meaning of claim terms.

## **VI. LEVEL OF ORDINARY SKILL IN THE ART**

37. I have been informed by counsel for Petitioner that the claims of a patent are judged from the perspective of a hypothetical construct involving "a person of ordinary skill in the art" at the time the claimed invention of the patent was made. The "art" is the field of technology to which the patent is related. I

understand that the purpose of using the view point of a person of ordinary skill in the art is for objectivity.

38. In my opinion, a person of ordinary skill must generally have the capability of understanding the general principles that are applicable to the pertinent art. I understand that the factors to be considered in determining the level of ordinary skill in the art to be: (1) the educational level of active workers in the field, including the named inventors of the patent; (2) the type of problems encountered in the art; (3) prior art solutions to those problems; (4) the rapidity with which innovations are made; and (5) the sophistication of the technology in the art.

39. I understand that the '224 Patent is a continuation of International Application No. PCT/CN2016/075097 ("097 PCT") filed on March 1, 2016. For purposes of my analysis in this Declaration, I have used March 1, 2016 as the "relevant time."

40. In my opinion, as of the earliest claimed priority date, a person of ordinary skill in the art pertaining to the '224 Patent would be a person with a B.S. degree in electrical engineering, mechanical engineering, computer engineering, or equivalent training or job experience, along with 1-2 years of experience in any of the fields of power electronics, motor control systems, and battery systems for electric motor applications. Additional education could compensate for less

practical experience and vice versa.

41. Based on my education and experience set forth above and in my curriculum vitae, I meet the definition of one of ordinary skill in the art, and I believe I am qualified to provide opinions about how one of ordinary skill in the art at the relevant time would have interpreted and understood the '224 Patent and the prior art cited in the Petition.

## **VII. BRIEF OVERVIEW OF THE '224 PATENT**

### **A. Summary of the '224 Patent**

42. The '224 Patent relates to “a method, a device, and a system for controlling a motor” that include calculating a “compensation amount” that may be used “to prevent the rotation speed of the motor from being changed by the fluctuation of the battery voltage.” EX1001, 1:15-16, 5:66-6:3. The '224 Patent explains that “[i]n conventional technologies, a battery supplies power to an electronic speed controller (ESC), such that the ESC outputs a voltage to a motor and thus control a speed of the motor.” *Id.*, 1:20-23. “However, a voltage of the battery continuously decreases during the discharging process. Compared with an original full voltage of the battery, the voltage outputted from the ESC to the motor decreases as the battery voltage decreases, when the ESC receives a same throttle signal. Thus, the rotation speed of the motor decreases.” *Id.*, 1:28-33.

43. Claim 1 includes “obtaining a present electrical parameter of a battery

[S101], calculating a compensation amount of a control signal of the motor according to the present electrical parameter [S102], and modifying the control signal according to the compensation amount [S103].” *Id.*, 1:41-45, FIG. 1. Corresponding method claim 12 includes “one or more processors” configured to perform the steps of claim 1. *Id.*, Cl. 1. Calculating the compensation amount of the control signal may include “calculating in real time a compensation amount of a voltage outputted to the motor according to the present voltage of the battery” where “the compensation amount of the voltage is determined according to a difference between a full voltage of the battery and the present voltage of the battery.” *Id.*, Cls. 7-8. The compensation amount may then be added to the motor control signal outputted by the ESC to the motor to ensure that the motor rotation speed does not change with the variation of the battery voltage. *See id.*, 7:13-18.

44. Claim 9 includes calculation of “a voltage compensation amount of [a] battery according to [a] present electrical parameter” and “compensating an output voltage of the battery according to the voltage compensation amount to maintain the output voltage of the battery stable.” *Id.*, Cl. 9. One example of this method claim includes a diagram including “a voltage sensor 24 coupled to a power supply, i.e., a battery, in parallel. Through the voltage sensor 24, the output voltage of the battery may be detected in real time or periodically.” *Id.*, 7:42-46.

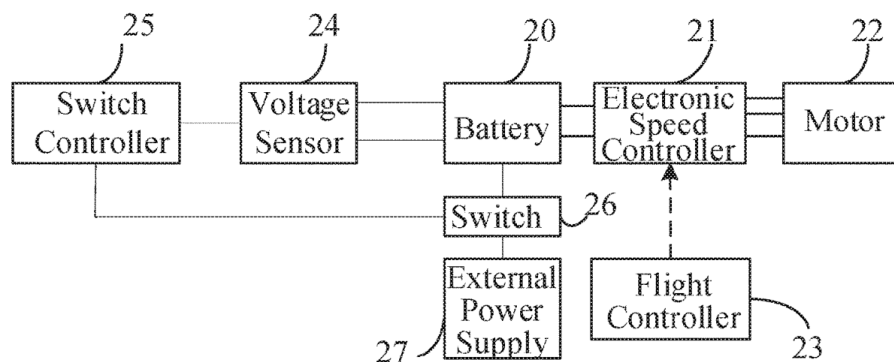


FIG. 7

EX1001, FIG. 7.

45. “When the voltage sensor 24 detects the present battery voltage, a magnitude of the present battery voltage may be transmitted to a switch controller 25, and the switch controller 25 may calculate an amplitude drop of the battery voltage. For example, the full battery voltage may be approximately 5V, the present battery voltage may be approximately 4.5V, and thus the voltage compensation amount of the battery may be approximately 0.5V.” *Id.*, 7:54-61. “As shown in FIG. 7, the battery 20 is coupled to an external power supply 27 through a switch 26. As the battery voltage drops, the switch controller 25 turns on the switch 26 to electrically couple the battery 20 to the external power supply 27. The external power supply 27 compensates the battery 20 by a voltage of approximately 0.5 V, to ensure that the output voltage of the battery is held at approximately 5V.” *Id.*, 7:65-8:4.

## **B. '224 Patent Prosecution History**

46. It is my understanding that there are no office actions associated with U.S. Patent Application No. 16/116,279 that led to the '224 Patent—i.e., the USPTO Examiner never rejected any claims of the application. On October 17, 2019, the Patent Office issued a Notice of Allowance (“NOA”) of Applicant’s originally submitted claims 1-17. EX1003 at 138-143. The prosecution history cites seven U.S. patent documents and eleven foreign patent documents. EX1001 at (56). Nine of the foreign documents are in a foreign language (Chinese or Japanese). *Id.* The file history does not include English translations of these documents other than the abstracts. *See generally* EX1003. In the NOA, the Examiner commented that “no prior art has taught an identical or a similar method or apparatus of controlling a motor that includes a compensation circuit. The compensation circuit has a compensation control signal to compensate the voltage, or the current, or the charge, or the internal resistance of the battery.” EX1003 at 143. However, it is my opinion that the prior art discussed below, which to the best of my knowledge was not considered by the Examiner, does in fact teach an identical method and apparatus of controlling a motor as claimed in the '224 Patent.

## **C. Challenged Claims of the '224 Patent**

47. Petitioner requested instituting *inter partes* review on Claims 1-17 of

the '224 Patent. The Challenged Claims are set forth below.

1. A method for controlling a motor comprising:  
obtaining a present electrical parameter of a battery;  
calculating a compensation amount of a control signal of the motor according to the present electrical parameter; and  
modifying the control signal according to the compensation amount.

2. The method according to claim 1, wherein the present electrical parameter includes at least one of a present charge quantity of the battery, a present voltage of the battery, a present output electrical current of the battery, or a present internal resistance of the battery.

3. The method according to claim 2, wherein the control signal includes at least one of a control signal configured to control a rotation speed of the motor or a control signal configured to control an output power of the motor.

4. The method according to claim 3, wherein:  
the present electrical parameter of the battery includes the present voltage of the battery; and  
calculating the compensation amount includes:

calculating the compensation amount of the control signal of the motor corresponding to a subsequent time point according to the present voltage of the battery and a preset voltage model including one-to-one correspondences between

voltages of the battery and preset compensation amounts.

5. The method according to claim 4, wherein modifying the control signal includes:

modifying, at a present time point, the control signal according to the compensation amount.

6. The method according to claim 3, wherein:

the present electrical parameter of the battery includes the present voltage of the battery; and

calculating the compensation amount of the control signal of the motor includes:

calculating in real time the compensation amount of the control signal of the motor according to the present voltage of the battery.

7. The method according to claim 6, wherein:

calculating in real time the compensation amount of the control signal includes:

calculating in real time a compensation amount of a voltage outputted to the motor according to the present voltage of the battery; and

modifying the control signal includes:

modifying an original voltage outputted to the motor according to the compensation amount of the voltage.

8. The method according to claim 7, wherein the compensation amount of the voltage is determined according to a difference between

a full voltage of the battery and the present voltage of the battery.

9. A method for controlling a motor comprising:

obtaining a present electrical parameter of a battery;

calculating a voltage compensation amount of the battery according to the present electrical parameter; and

compensating an output voltage of the battery according to the voltage compensation amount to maintain the output voltage of the battery stable.

10. The method according to claim 9, wherein the present electrical parameter of the battery includes at least one of a present charge quantity of the battery, a present voltage of the battery, a present output electrical current of the battery, or a present internal resistance of the battery.

11. The method according to claim 10, wherein:

the present electrical parameter of the battery includes the present voltage of the battery; and

calculating the voltage compensation amount of the battery includes:

calculating the voltage compensation amount of the battery according to the present voltage of the battery and a full voltage of the battery, the voltage compensation amount being equal to a difference between the full voltage and the present voltage.

12. An apparatus for controlling a motor comprising:

one or more processors configured to:

obtain a present electrical parameter of a battery;

calculate a compensation amount of a control signal of the motor according to the present electrical parameter; and

modify the control signal according to the compensation amount.

13. The apparatus according to claim 12, further comprising:

an electrical parameter detection circuit electrically coupled to the one or more processors and configured to detect the present electrical parameter.

14. The apparatus according to claim 13, wherein the electrical parameter detection circuit includes at least one of a coulometer, a voltage detection circuit, an electrical current detection circuit, or a resistance detection circuit.

15. The apparatus according to claim 14, wherein the one or more processors are further configured to:

calculate the compensation amount of the control signal of the motor corresponding to a subsequent time point according to the present voltage of the battery and a preset voltage model including one-to-one correspondences between voltages of the battery and preset compensation amounts; and

modify, at a present time point, the control signal according to the compensation amount.

16. The apparatus according to claim 14, wherein the one or

more processors are further configured to:

calculate in real time the compensation amount of the control signal of the motor according to the present voltage of the battery.

17. The apparatus according to claim 16, wherein the one or more processors are further configured to:

calculate in real time a compensation amount of a voltage outputted to the motor according to the present voltage of the battery;  
and

modify an original voltage outputted to the motor according to the compensation amount of the voltage outputted to the motor.

## **VIII. OVERVIEW OF THE PRIOR ART REFERENCES**

48. In this section, I provide a summary of the three prior art references that, in my opinion, collectively anticipate and/or render obvious all Challenged Claims. These three references are set forth in the table below.

| <b>Exhibit No.</b> | <b>Prior Art Reference</b> |
|--------------------|----------------------------|
| 1004-1005          | Takashi                    |
| 1006-1007          | Onishi                     |
| 1008               | Kim                        |

### **A. Takashi**

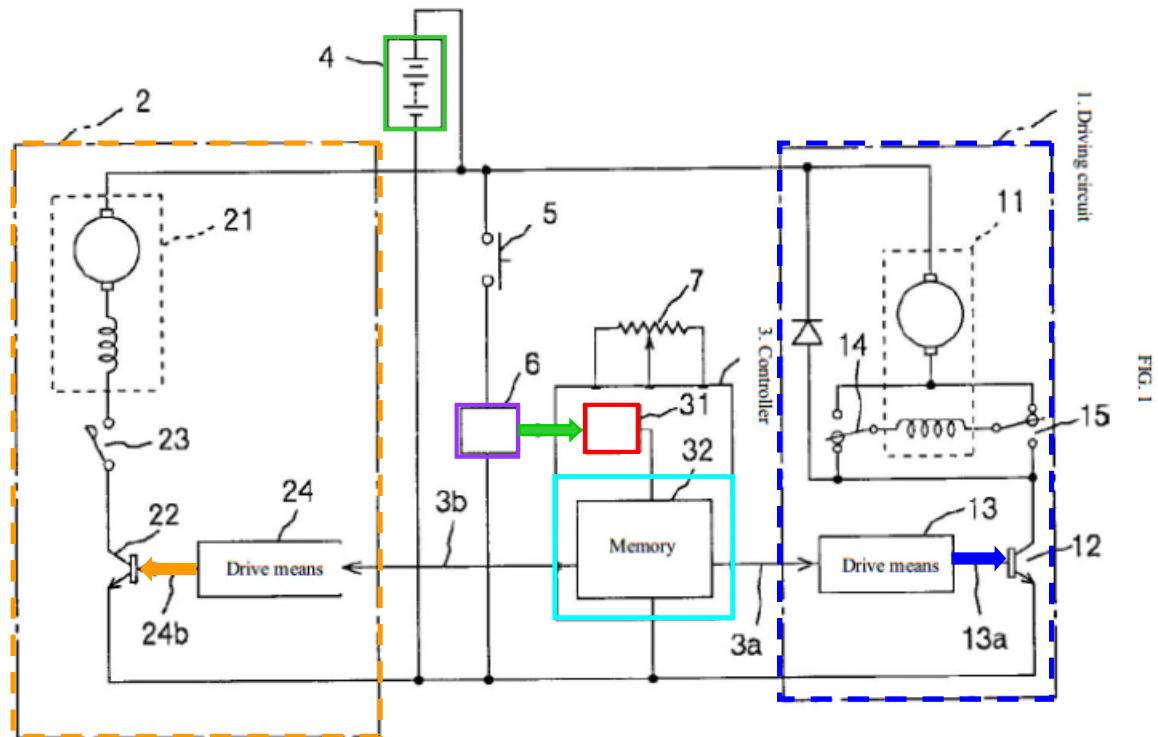
49. Takashi recognizes the same problems as those identified in the '224 Patent. In particular, Takashi explains that battery vehicles use motors that are “rotation driven by a chopper circuit intermittently operated by a pulse signal,” and “the rotation speed thereof is controlled using the duty of the pulse signal.”

EX1004, [0002]. The “maximum rotational speed of the motor is defined depending on battery voltage and for this chopper control method, the motor maximum rotational speed for a constant duty changes based on voltage” of the battery. EX1004, [0004]. However, as the battery charge decreases, the voltage decreases as well. *Id.* As a consequence, “in the case of a cargo handling circuit of a conventional battery vehicle, actuator operation delay gradually progresses and operating efficiency degrades and in the case of the driving circuit, acceleration performance is impaired due to a decrease in driving speed.” EX1004, [0005]. Takashi resolves these issues in the same way as the ’224 Patent, by providing for “motor control technology for continually maintaining operability with no abnormal feel while battery voltage is within the operating range.” EX1004, [0006].

50. Like the motor control method and apparatus of claims 1 and 12, Takashi discloses “a motor control device of a battery vehicle and in particular to a device that enables obtaining a constant sense of operation regardless of battery charge state.” EX1004, [0001]. More specifically, Takashi’s “controller 3 has detecting means 31 for detecting the output of the constant voltage power supply circuit 6 as the voltage of the battery 4.” EX1004, [0012] (annotations added). “Each of the detection values of the detecting means 31 is process[ed] using duty setting means for commanding each of the duties of the pulse signal[] 13a and

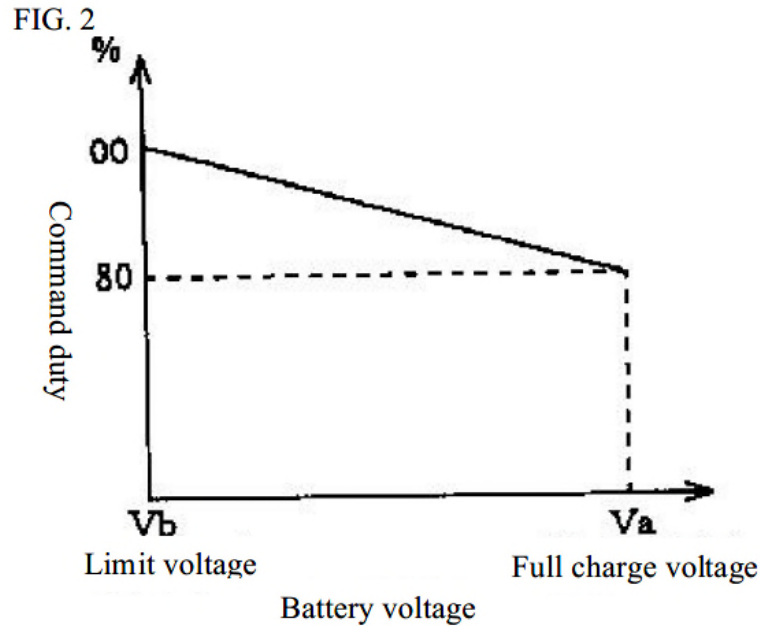
[pulse signal] 24b in the driving circuit 1 and the cargo handling circuit 2.”

EX1004, [0012].



EX1004, FIG. 1 (annotated). “This duty setting means reads and controls from the memory 32, control characteristics (FIG. 2) in which command duty<sup>2</sup> is increased inversely proportional to voltage characteristics where the voltage of the battery 4 drops from fully charged voltage characteristic to the limit voltage at 80% discharge.” EX1004, [0012].

<sup>2</sup> Takashi uses the terms “command duty” and “duty command” interchangeably. See, e.g., EX1004 [0009] (using a “duty command” from a controller 3), [0012] (setting a “command duty” by a controller).

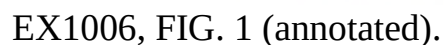


EX1004, FIG. 2.

## B. Onishi

51. Like the method for controlling a battery output voltage disclosed in claim 9, Onishi discloses “a **storage battery system** that maintains a constant terminal voltage until the remaining capacity is exhausted, even if the terminal voltage of the storage battery drops due to advancement of discharge of the storage battery.” EX1006, [0007]. The **storage battery system** “maintains a constant direct current **output voltage** applied to a load 40 by controlling the capacitor voltage by controlling a switching power converting device 30 that performs charging and discharging between the storage battery and the capacitor based on a switching signal from a control block 50 that has protected the output voltage as an overall storage battery system that connects in series a capacitor 20 a storage battery 10

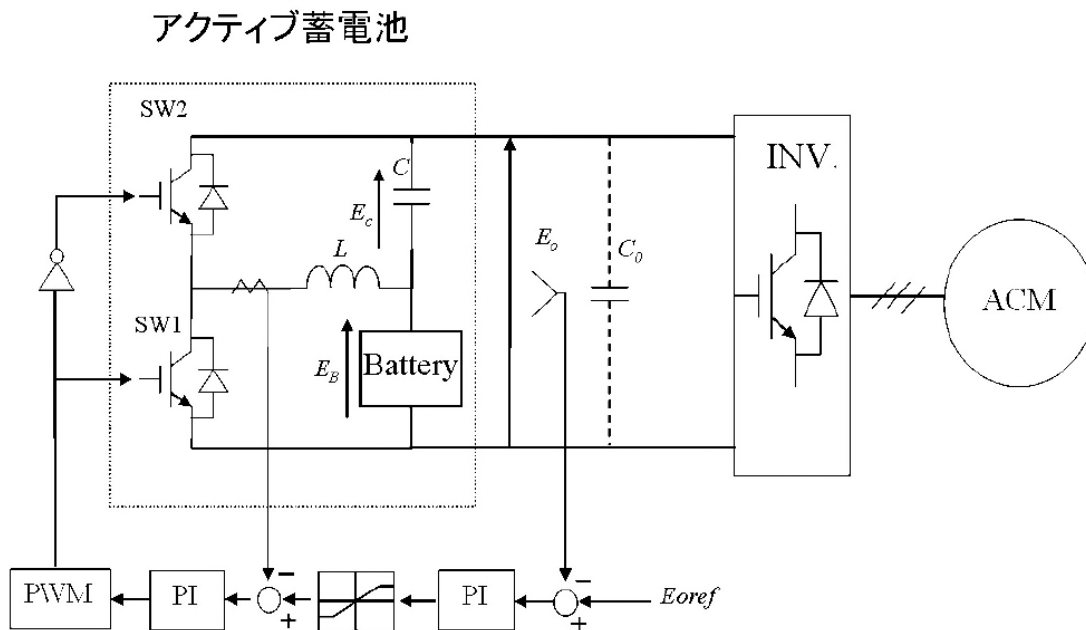
EX1006, [0010].



35  
Textron Specialized Vehicles Inc., Exh. 1002, p. 35

the drop is compensated by the charging voltage of the capacitor 20 that is connected in series.” EX1006, [0011]. “On the other hand, when the series voltage of the storage battery 10 and the capacitor 20 rises above the reference voltage due to regenerative current from the load, or the like, the load terminal voltage can be kept constant by transferring the energy of the capacitor 20 to the storage battery 10 by the switching power converting device 30, and performing discharge voltage control of the capacitor 20.” EX1006, [0014]. The storage battery may be used as a power source for driving an electric vehicle motor (ACM). EX1006, [0024], FIG. 7.

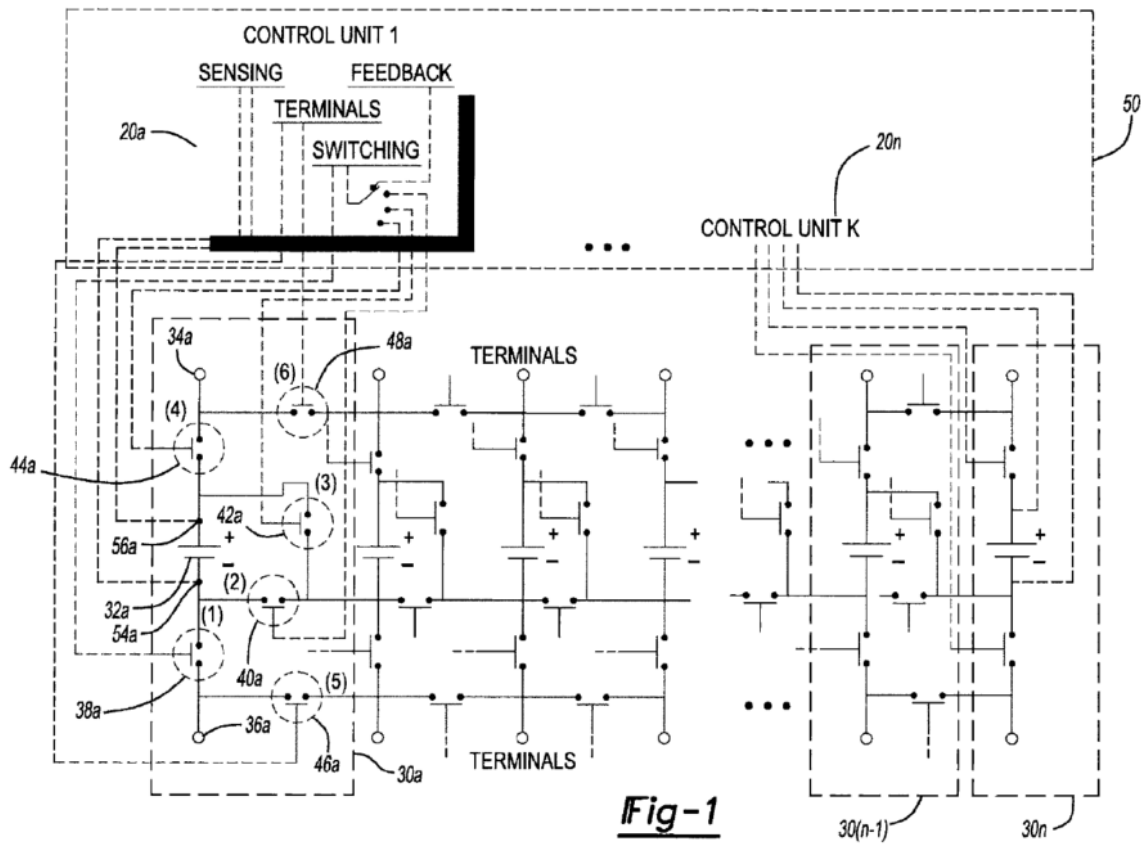
## 【 図 7 】



### C. Kim

53. Kim describes a “reconfigurable battery system” that can be used to

control a motor, for example, of an electric vehicle. EX1008, 11:34-44, 12:32-36; *see also id.* at 1:21-2:5. Kim's reconfigurable battery system includes a "battery pack" with "battery circuits 30a-30n" each having "an associated control module 20a-20n" and a "battery cell 32a." *Id.*, 4:22-27, 4:42-67. "Control units 20a-20n configure the switches in the plurality of battery circuits to form different circuit arrangements. For example, battery cells [of battery circuits] may be configured in a series arrangement by setting the switches in a given battery circuit" to a certain configuration. *Id.*, 5:1-16. The battery cells also may be configured "in parallel with each other" by setting certain switches. *Id.*, 5:17-25. Different configurations of the switches further provide for bypassing respective battery cells arranged in series and/or in parallel. *Id.*, 5:8-16, 5:21-25.



EX1008, Fig-1.

54. During operation, a respective control module “monitors changes in the state of charge (SOC) and voltage of its battery cells via sensing devices 54a-54n and 56a-56n” and “controls switches in the battery circuit in accordance with the operational state.” *Id.*, 5:60-6:16. For example, if the supply voltage of a battery pack is less than a demand voltage, Kim’s reconfigurable battery system may trigger a “reconfiguration event” that “causes a controller to change the topology of the battery circuits” according to “one of two policies.” *Id.*, 6:40-7:10, 8:11-19. If the “constant-voltage keeping policy” is applied (which keeps the

supply voltage above or equal to the demand voltage), the battery connectivity is reconfigured to compensate for the voltage drop below the demand voltage or above an upper bounds and keep the supply voltage constant. *Id.*, 6:65-7:42, 8:11-19, 15:45-16:7.

## **IX. CLAIM CONSTRUCTION**

55. For purposes of this IPR, I understand that Petitioner has construed the terms and phrases of the challenged claims of the '224 Patent to have their plain and ordinary meaning.

## **X. A REASONABLE LIKELIHOOD EXISTS THAT THE CHALLENGED CLAIMS ARE UNPATENTABLE**

56. In my opinion, all Challenged Claims of the '224 Patent are unpatentable for the reasons I set forth below with respect to each of the three grounds.

### **A. Grounds 1A and 1B: Claims 1-8 and 12-17 are (1A) Anticipated by or (1B) Obvious in View of Takashi**

57. For the reasons set forth below, it is my opinion that Claims 1-8 and 12-17 are anticipated by Takashi. Should the Board or Patent Owner take the position that some of these claim limitations are not disclosed in Takashi, it is my opinion that a POSITA would have nevertheless understood those limitations to be rendered obvious by Takashi.

**1. Claim 1**

**a) 1[pre] A method for controlling a motor comprising:**

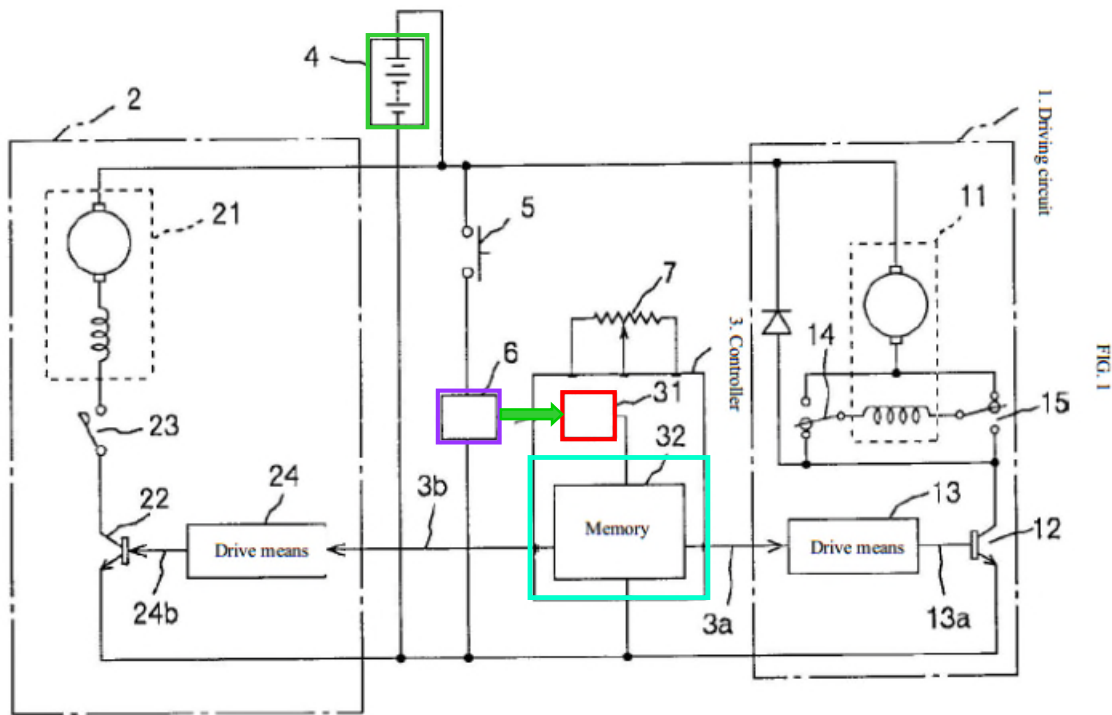
58. In my opinion, Takashi discloses the preamble to the extent that it is limiting. Takashi describes “a motor control device of a battery vehicle and in particular [] a device that enables obtaining a constant sense of operation regardless of battery charge state.” EX1004, [Abstract]. The motor control device of Takashi includes “detecting means for detecting battery voltage and duty setting means for commanding that the duty of the pulse signal be increased inversely proportional to a voltage drop characteristic from the voltage when the battery is fully charged to the limit voltage, based on the detection values from the detecting means.” *Id.*, [0007]. To control a motor, “duty commanded is increased with characteristics inverse to battery voltage characteristics within operation limits so maximum rotational speed of the motor dependent on battery voltage is practically constant relative to battery voltage within operation limits, enabling obtaining stable operability regardless of battery state of charge.” *Id.*, [0018]. It is my opinion that Takashi’s maintenance (i.e., control) of the rotational speed of a motor relative to battery voltage discloses a method of controlling a motor.

**b) 1[a] obtaining a present electrical parameter of a battery;**

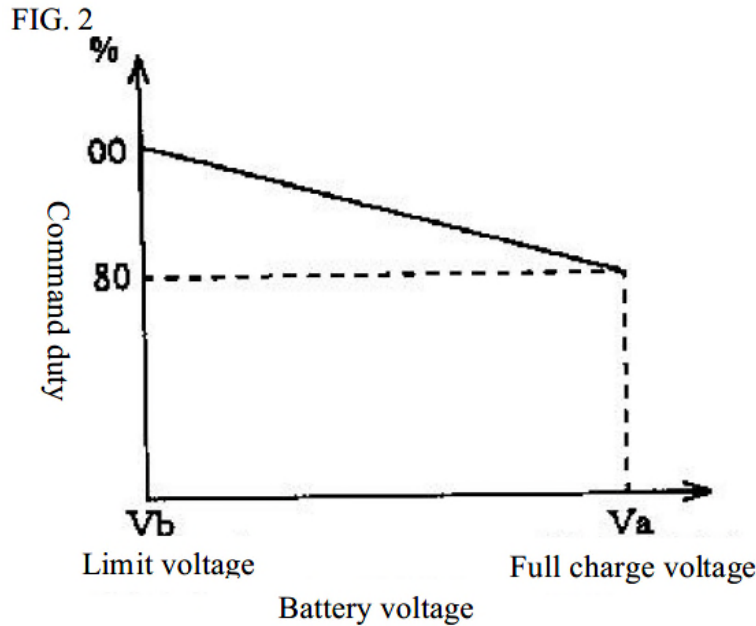
59. Takashi’s use of a detecting means 31 to detect the current battery voltage is a method of obtaining a present electrical parameter (i.e., voltage) of a

battery. According to the '224 Patent, an “electrical parameter detection circuit may be used for the electrical parameter of the battery” and the present electrical parameter may include “a present voltage of the battery.” EX1001, 3:48-54. The '224 Patent discusses multiple components responsible for obtaining the present electrical parameter including battery voltage. For example, a “control apparatus may obtain a present electrical parameter of [a] battery from [an] electrical parameter sensor.” EX1001, 3:44-46. In another example, the '224 Patent explains that a voltage sensor (i.e., an electrical parameter sensor) “may obtain the present battery voltage.” EX1001, 4:54-57.

60. Like the '224 Patent, Takashi discloses obtaining the electrical parameter of a battery through use of a control apparatus (i.e., the duty setting means of a controller 3) as well as an electrical parameter sensor (i.e., a detecting means 31). Annotated FIG. 1 of Takashi discloses a motor control device for an electric forklift including a controller 3 and a battery 4:



61. As shown above in annotated FIG. 1 of Takashi, “[t]he controller 3 is connected to a constant voltage power supply circuit 6 that supplies voltage from the battery 4....” EX1004, [0012]. The controller 3 further includes a “detecting means 31 for detecting the output of the constant voltage power supply circuit 6 as the voltage of the battery 4.” *Id.* The controller 3 detects a detection voltage  $V_a$  when the battery 4 is fully charged and a detection voltage  $V_b$  when the battery 4 reaches the limit voltage. EX1004, [0014]-[0015]. The controller 3 additionally “detects the voltage between the detected value  $V_a$  to  $V_b$  at the resolution defined by the detection capability of the detecting means 31.” *Id.*, [0015], FIG. 2.



62. Thus, it is my opinion that Takashi's use of a detecting means 31 to detect the current battery voltage, is a method of obtaining a present electrical parameter (i.e., voltage) of a battery.

63. Takashi further discloses that “[e]ach of the detection values of the detecting means 31 is process[ed] using **duty setting means** for commanding each of the duties of the pulse signals 13a and 24b in the driving circuit 1 and the cargo handling circuit 2. This duty setting means reads and controls from the memory 32, control characteristics (FIG. 2) in which command duty is increased inversely proportional to voltage characteristics where the voltage of the battery 4 drops from fully charged voltage characteristic to the limit voltage at 80% discharge....” EX1004, [0013]. In my opinion, Takashi's use of a duty setting means to read the detected battery voltage (i.e., “voltage characteristic”) also discloses a method of

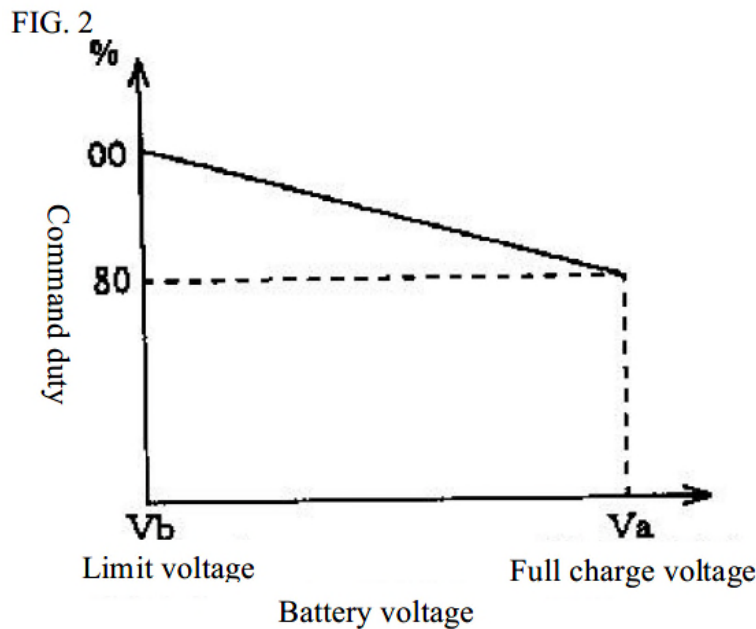
obtaining a present electrical parameter (i.e., voltage) of a battery.

**c) 1[b] calculating a compensation amount of a control signal of the motor according to the present electrical parameter;**

64. Takashi's use of the duty setting means to read pre-calculated command duties stored in memory and/or calculate a percent command duty according to the detected battery voltage discloses "calculating a compensation amount." Takashi explains that in battery-driven vehicles "a DC motor is rotation driven by a chopper circuit intermittently operated by a pulse signal, and the rotation speed thereof is controlled using the duty of the pulse signal. Furthermore, the duty of the pulse signal is commanded by a controller having a central processing function." EX1004, [0002]. However, Takashi recognizes that "maximum rotational speed of the motor is defined depending on battery voltage and for this chopper control method, the motor maximum rotational speed for a constant duty changes based on voltage within the operating range." EX1004, [0005]. Thus, Takashi proposes a "detecting means for detecting battery voltage and duty setting means for commanding that the duty of the pulse signal be increased inversely proportional to a voltage drop" of the battery. EX1004, [0007].

65. Specifically, FIG. 2 of Takashi reproduced below illustrates a method by which a command duty is increased inversely proportional to battery 4 voltage drop starting with a fully charged voltage  $V_a$  to the limit voltage  $V_b$  (in this

example, 80% discharge). EX1004, [0013].



For example, when Takashi's detecting means 31 detects the battery 4 in a fully charged state  $V_a$ , "the [duty setting means of] the controller 3 reads data such as 80% as the command duty" and supplies this data "to the drive means 24 as the control signal 3b. Thus, the drive means 24 outputs a pulse signal 24b with a duty of 80% and the transistor 22 supplies current to the DC motor 21 with intermittent operation of 80% ON time." EX1004, [0014]. Similarly, when the battery 4 reaches the limit voltage  $V_b$ , "the [duty setting means of the] controller 3 reads data setting command duty to 100% and the control signal 3b based on this data is supplied to the drive means 24 and the DC motor 21 drives the hydraulic pump at a maximum rotational speed corresponding to a duty of 100%." EX1004, [0015]. Takashi discloses that the duty setting means similarly uses the data read from

memory 32 to supply control signal 3a to the drive means 13 of the driving circuit 1. *Id.*, [0013].

66. Takashi notes that for some embodiments the “control characteristics of the duty command to the driving circuit 1 are written to the memory 32 in advance” (i.e., the characteristics are calculated in advance) and in other embodiments, “the same control characteristics may be calculated through computation.” *Id.* [0017]. An example of calculating control characteristics includes “calculating each command duty and accelerator depression angle data for the offset setting point O as well as command duty relative to each accelerator depression angle based on the detection value of battery voltage corresponding to duty gradient.” *Id.*

67. Thus, Takashi’s use of the duty setting means to read pre-calculated command duties stored in memory and/or calculate a percent command duty according to the detected battery voltage discloses “calculating a compensation amount.” As shown in FIG. 2 and described throughout the disclosure, Takashi’s duty setting means calculates a command duty as a percentage amount from 80-100% to compensate for battery discharge according to the detected battery voltage.

68. Takashi’s command duty is a compensation amount “of a control signal of a motor” because the command duty is used by the duty setting means of

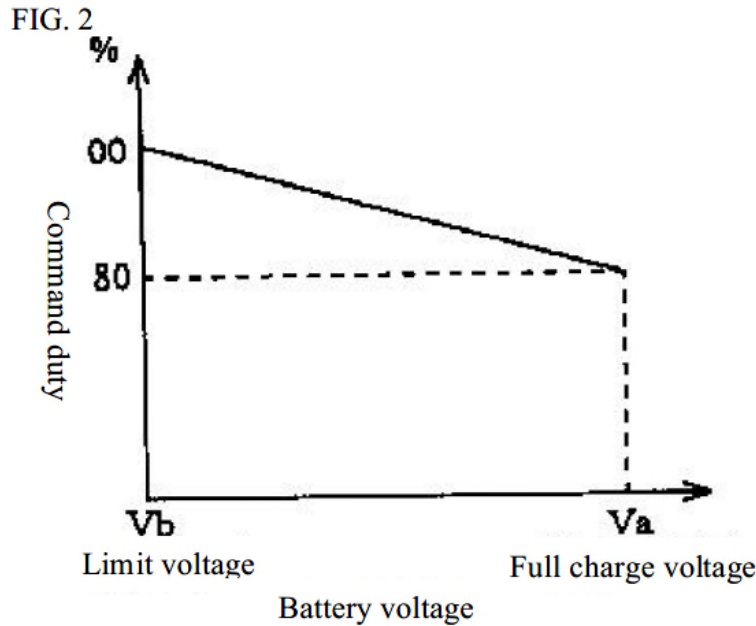
the controller 3 to determine control signals 3a and 3b, which are used to drive motors 11 and 21 (with control signals 3a and 3b each being the claimed “control signal,” as explained further below for element 1[c]). Finally, the command duty is calculated “according to the present electrical parameter” because, as shown in FIG. 2, the duty setting means calculates the command duty based on the detected battery voltage (i.e., a voltage between  $V_a$  to  $V_b$ ).

69. In addition, and as an alternative, pulse signals 13a and 24b output from the duty setting means each also disclose the claimed “control signal,” as discussed further below for element 1[c]. Takashi explains that the controller 3 reads the percent command duty data and then supplies the percent command duty data to the drive means 24 as the control signal 3b (and similarly provides control signal 3a to the drive means 13). EX1004, [0014]. And as explained above, Takashi further elaborates that the control signals 3a and 3b are “based” on the percent command duty data. *Id.*, [0015]. In this alternative mapping, Takashi’s calculated command duty and the control signals 3a and 3b that result from this calculated command duty serve as a compensation amount of pulse signals 13a and 24b (“a control signal of the motor”) because the control signals 3a and 3b, and the command duty represented in those control signals 3a and 3b, are used to determine the pulse signals 13a and 24b that control motors 11 and 21 (with pulse signals 13a and 24b each being the claimed “control signal” in this alternative

mapping, as explained further with respect to element 1[c]). Finally, the control signals 3a and 3b are calculated “according to the present electrical parameter” because the control signals 3a and 3b are calculated by the duty setting means based on the command duty, which in turn is calculated based on the detected battery voltage (i.e., a voltage between  $V_a$  to  $V_b$ ). For example, according to FIG. 2 of Takashi, when the battery voltage is at voltage  $V_a$ , the signal 3b will be a signal that represents a compensation amount of 80% (e.g., a voltage or digital value that represents 80%, or in other words, 20% less than 100%), and the drive means 24 will generate a control signal 24b to drive transistor 22 with a periodic time-domain waveform that has an 80% duty cycle (meaning it is turned on for 80% of the time) according to the compensation amount from signal 3b.

**d) 1[c] modifying the control signal according to the compensation amount.**

70. As discussed under element 1[b], Takashi discloses the claimed control signal in two different ways: either as one or both of the control signals 3a and 3b or as one or both of the pulse signals 13a and 24b. With respect to the mapping where control signals 3a and 3b are the claimed control signals, Takashi discloses that the duty setting means of the controller calculates a command duty between 80-100%, in a relationship that is inversely proportional to the detected voltage, which the duty setting means then supplies as control signals 3a and 3b to the drive means 13 and 24. See EX1004, FIG. 2; *id.*, [0014]-[0015].



For example, based on a detected value  $V_a$ , the duty setting means of the controller 3 determines an 80% command duty, which it supplies to the drive means 24 as control signal 3b. EX1004, [0014]. In addition, when “the [duty setting means of the] controller 3 reads data setting command duty to 100%,” “the control signal 3b based on this data is supplied to the drive means 24 and the DC motor 21 drives the hydraulic pump at a maximum rotational speed corresponding to a duty of 100%.” EX1004, [0015]. Because Takashi’s duty setting means modifies the control signals 3a and 3b according to the command duty between 80-100%, Takashi discloses this limitation.

71. With respect to the mapping where pulse signals 13a and 24b are the claimed control signals, the drive means’ modification of the pulse signals according to control signals 3a and 3b (which are themselves determined by the

calculated command duty) discloses this limitation. Takashi discloses that “[d]ata read from the memory 32 is supplied as control signals 3a and 3b that command duties of the drive means 13 of the driving circuit 1 and drive means 24 of the cargo handling circuit.” EX1004, [0013]. For example, “based on the detected value  $V_a$ , the controller 3 reads data such as 80% as the command duty,” which “is supplied to the drive means 24 as the control signal 3b,” which causes “the drive means 24 to output a pulse signal 24b with a duty of 80% and the transistor 22 supplies current to the DC motor 21 with intermittent operation of 80% ON time.” *Id.* Because the pulse signals are signals that control the transistors’ electrical supply to the motors, a POSITA would also understand the pulse signals to be “control signals.” Thus, it my opinion that the drive means’ modification of the pulse signals according to the control signals from the duty setting means also discloses this limitation.

2. **Claim 2: The method according to claim 1, wherein the present electrical parameter includes at least one of a present charge quantity of the battery, a present voltage of the battery, a present output electrical current of the battery, or a present internal resistance of the battery.**

72. I understand that when a claim, such as this one, recites a list of multiple alternatives (i.e., a “Markush” group), the entire element is disclosed by the prior art if one alternative is disclosed. As discussed under element 1[a], the controller 3’s detecting means and duty setting means obtain the present voltage of

the battery 4. EX1004, [0015]; FIG. 2 *see also id.*, [0012]. Takashi thus discloses a present electrical parameter that includes a present voltage of the battery.

3. **Claim 3: The method according to claim 2, wherein the control signal includes at least one of a control signal configured to control a rotation speed of the motor or a control signal configured to control an output power of the motor.**

73. As discussed under elements 1[b]-1[c], Takashi discloses the claimed “control signals” in two different ways: as control signals 3a and 3b and as pulse signals 13a and 24b. Each of these signals are configured to control the rotation speed of the motor, one of the two alternatives in the claimed Markush group.

74. Takashi discloses that “[d]ata read from the memory 32 is supplied as control signals 3a and 3b that command duties of the drive means 13 of the driving circuit 1 and drive means 24 of the cargo handling circuit 2.” EX1004, [0018]. Takashi further discloses that “duty commanded is increased with characteristics inverse to battery voltage characteristics within operation limits so maximum rotational speed of the motor dependent on battery voltage is practically constant relative to battery voltage within operation limits, enabling obtaining stable operability regardless of battery state of charge.” EX1004, [0018]; *see also* EX1004, [0008] (“[T]he maximum rotational speed of the motor dependent on battery voltage can be controlled to nearly a constant level regardless of battery voltage.”). Takashi further discloses that “[t]ypically, battery vehicles such as an

electric forklift use a motor for cargo and for driving, and for example, a DC motor is rotation driven by a chopper circuit intermittently operated by a pulse signal, and the rotation speed thereof is controlled using the duty of the pulse signal. Furthermore, the duty of the pulse signal is commanded by a controller having a central processing function. In this case, duty that imparts the rotational speed corresponding to the set operating speed of the actuator is set in the motor for cargo handling and duty imparting rotational speed corresponding to the depression angle of an accelerator pedal ... is set for the driving motor.” EX1004, [0002]. In short, the calculated command duty is used to generate command signals 3a and 3b, which reflect the command duty, and these command signals are then used by the drive means 13 and 24 to generate the pulse signals 13a and 24b that control the rotation speed of the motors. Thus, each of Takashi’s control signals 3a and 3b and its pulse signals 13a and 24b are “at least one of a control signal configured to control a rotation speed of the motor.”

**4. Claim 4**

- a) **4[pre] The method according to claim 3, wherein:  
4[a] the present electrical parameter of the battery  
includes the present voltage of the battery; and:**

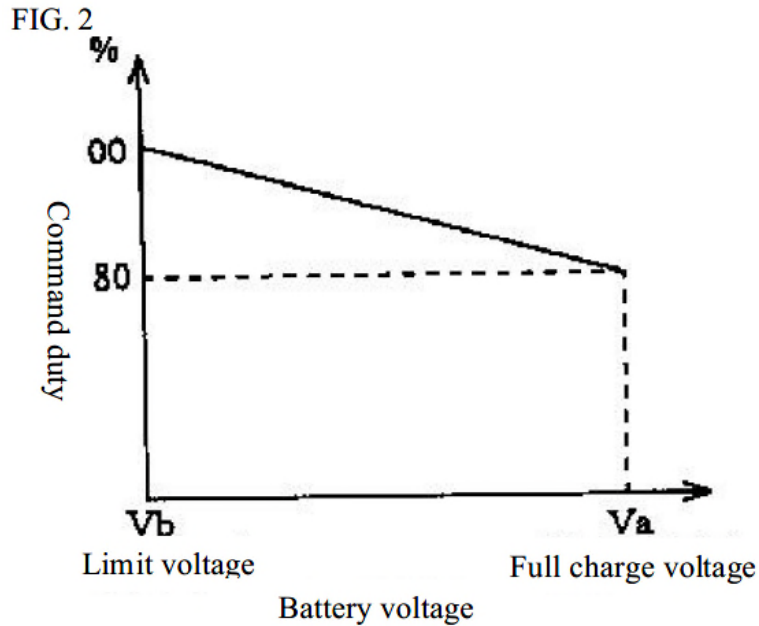
75. As discussed under claim 2, Takashi discloses a present electrical parameter of a battery that includes the present voltage of the battery.

- b) **4[b] calculating the compensation amount includes:  
calculating the compensation amount of the control**

**signal of the motor corresponding to a subsequent time point according to the present voltage of the battery and a preset voltage model including one-to-one correspondences between voltages of the battery and preset compensation amounts.**

76. The '224 Patent explains, “[a] compensation amount of the control signal of the motor corresponding to the subsequent time point may be calculated according to a present battery voltage and the preset voltage model. The control signal of the motor may be modified at the present time point to prevent a drop of the motor rotation speed caused by a drop of the battery voltage at the subsequent time point, thereby improving timeliness of modifying the control signal of the motor.” EX1001, 5:27-35.

77. As discussed under element 1[b], Takashi discloses “calculating a compensation amount of a control signal of the motor,” where the command duty percentage is a compensation amount and control signals 3a and 3b reflect the compensation amount. *See supra* Section X.A.1.c. Takashi further discloses that duty setting means calculates the command duty “according to the present voltage of the battery and a preset voltage model including one-to-one correspondences between voltages of the battery and preset compensation amounts,” as recited in element 4[b]. More specifically, FIG. 2 of Takashi is a diagram of the command duties (y-axis) calculated by the duty setting means according to the present voltage of the battery (x-axis):



This diagram is a “voltage model” because it models the inversely proportional relationship between the present voltage of the battery and the command duty (“compensation amounts”). Because the “control characteristics of the duty command to the driving circuit 1 are written to the memory 32 *in advance*,” the voltage model, including the compensation amounts along the y-axis are “preset” according to the present voltage of the battery along the x-axis. EX1004, [0017] (emphasis added). Because the command duty is a unique value between the voltages of the battery along the x-axis and the preset command duties along the y-axis, the voltage model includes “one-to-one correspondences” between the voltages of the battery and preset compensation amounts. EX1004, [0013]. Moreover, because the percent command duty data is supplied to the drive means 24 as control signals 3a and 3b (i.e., the control signals are “based on” the

command duty), the control signals 3a and 3b are also “preset” and include “one-to-one correspondences” between the voltages of the battery. EX1004, [0014]-[0015].

78. Finally, because the “duty setting means reads and controls from memory 32,” and “[d]ata read from the memory 32 is supplied as control signals 3a and 3b that command duties of the drive means 13” and “drive means 24,” and the controller 3 sets “the command duty of the pulse signal 13a” and “24b,” a skilled person would recognize that in Takashi the compensation amount of the control signal applied to the motor corresponds to “a subsequent time point” relative to the measured (present) value of the battery voltage. EX1004, [0012]-[0013]. This is true because there is an inherent time delay in Takashi from the time of measuring the battery voltage to the time of applying the compensation amount through the drive signal to the motor for at least the following reasons. (1) Reading data from a memory circuit and applying it to an output requires at least one time step of the controller when using a digital memory element or an analog delay when using an analog memory circuit. In this way, the controller in Takashi operates by measuring a present voltage of the battery, then reading a compensation value from the preset voltage map that will be applied to the control signals 3a and 3b at a subsequent time point. (2) The drive means 24 creates an inherent delay as it converts the control signals 3a and 3b that represent 80% to 100% to the pulse

signals that have periodic time-domain waveforms with 80% to 100% duty cycles. The combination of the above time delays may vary from a fraction of a second to more than a second depending on the speed of the controller and the frequency of the pulse signals.

79. To the extent that Takashi does not disclose calculating the command duty “corresponding to a subsequent time point according to the present voltage of the battery,” it is my opinion that this limitation would have been obvious to a POSITA in view of Takashi alone. For example, Takashi discloses that the purpose of the invention is to maintain maximum rotational speed of the motor and stable operability regardless of battery state of charge. *See, e.g.*, EX1004, [0018]. Because of signaling and processing delays as described above, a POSITA would have understood that by the time the motor control device calculates a command duty and/or control signals based on a measured battery voltage, the voltage of the battery will have decreased further to a voltage at a subsequent time point and the command duty and/or control signals would be “out of date,” resulting in a drop in rotational speed of the motor and unstable operability. Thus, it would be obvious to shift the duty curve of Figure 2 so that the calculated command duty and/or control signals are increased to compensate for the additional decreased voltage of the battery at the subsequent time point by the time the calculation is performed. Such a shift would permit the motor control device to calculate the corresponding

command duty and/or control signals in time to prevent a drop in motor rotational speed despite signaling and processing delays.

80. A POSITA would have found such a modification to the duty curve straightforward and achievable with a reasonable expectation of success. Takashi's voltage model is preset and the command duties corresponding to the battery voltage at all time points is known in advance. *See supra* element 4[c]; EX1004, [0017], FIGS 2-3. A POSITA would simply shift the command duty curve, such that the command duty calculated according to the present voltage of the battery obtained would be increased to the required command duty at the subsequent time point to account for the voltage drop during the signaling and processing delay and prevent a drop in motor rotational speed.

81. Accordingly, it is my opinion that element 4[b] is disclosed or at least rendered obvious by Takashi.

**5. Claim 5: The method according to claim 4, wherein modifying the control signal includes: modifying, at a present time point, the control signal according to the compensation amount.**

82. As discussed under element 1[c], Takashi discloses that the duty setting means and/or drive means performs the step of "modifying the control signal according to the compensation amount." *See supra* element 1[c] (explaining that the duty setting means modification of control signals 3a and 3b according to the command duty discloses element 1[c] and also that "the drive means'

modification of the pulse signals according to the control signals from the duty setting means” discloses 1[c]).

83. Claim 5 depends on claim 4, and as discussed under claim element 4[c], Takashi renders obvious calculating the compensation amount “corresponding to a subsequent time point according to the present voltage of the battery.” Takashi further renders obvious this step of modifying, at a present time point, the control signal according to the compensation amount calculated under element 4[c]. For the same reasons as discussed under claim element 4[c], a POSITA would have found it obvious to shift the duty curve to compensate for any additional decrease in battery voltage at the subsequent time point by the time the calculation is performed. This modification allows for calculation of a duty curve that “calculat[es] the compensation amount of the control signal of the motor corresponding to a subsequent time point according to the present voltage of the battery” by *a present time point*.

84. Upon calculation of the compensation amount described under element 4[c], a POSITA would have further found it obvious to use the duty setting means and/or drive means modify the control signals at that point in time according to the compensation amount. As previously noted, Takashi discloses that the purpose of the invention is to maintain maximum rotational speed of the motor and stable operability regardless of battery state of charge. *See, e.g.,*

EX1004, [0018]. Furthermore, the particular point in time at which the control signals are actually modified is necessarily the “present time point” when the modification occurs.<sup>3</sup> Thus, a POSITA would have understood that modification of the control signal *at a present time point* according to the compensation amount of the control signal *corresponding to the subsequent time point* would be beneficial to maintain maximum rotational speed of the motor and stable operability by accounting for additional voltage drop during that time it takes for the controller to implement the calculating and modifying steps.

85. A POSITA would have found such a modification straightforward and achievable with a reasonable expectation of success. A POSITA would need only use the duty setting means and/or drive means to implement the shifted duty curve described under element 4[c] to account for the voltage drop during signaling and processing delays and prevent a drop in motor rotational speed.

86. For at least these reasons, it is my opinion that Claim 5 is rendered obvious by Takashi.

---

<sup>3</sup> Claim 5 only makes technical sense if the “present electrical parameter of the battery” in claims 1 and 4 is obtained at first time  $t_1$ , the “subsequent time point” in claim 4 is some later time  $t_2$ , and the “present time point” in claim 5 is whatever time the control signal is modified, which is in the “present” whenever the modification is actually made. As an example, the “present time point” could be time  $t_2$ .

**6. Claim 6**

- a) 6[pre] The method according to claim 3, wherein:  
6[a] the present electrical parameter of the battery  
includes the present voltage of the battery; and:**

87. As discussed under claim 2, Takashi discloses a present electrical parameter of a battery that includes the present voltage of the battery.

- b) 6[b] calculating the compensation amount of the  
control signal of the motor includes: calculating in  
real time the compensation amount of the control  
signal of the motor according to the present voltage of  
the battery.**

88. As discussed under element 1[b] and claim 2, Takashi discloses that the duty setting means performs the step of “calculating a compensation amount of a control signal of the motor according to the present electrical parameter [(i.e., the present voltage of the battery)].” Element 6[b] includes the additional limitation that the calculation of the compensation amount occurs in real time, which Takashi also discloses.

89. Takashi explains that control characteristics may be calculated “in advance” but may also be “calculated through computation.” EX1004, [0017]. For example, “[t]his would be calculating each command duty and accelerator depression angle data for the offset setting point O as well as command duty relative to each accelerator depression angle based on the detection value of battery voltage corresponding to duty gradient.” *Id.* Takashi’s control characteristics “calculated through computation” disclose calculation of the compensation amount

in “real time,” because the control characteristics are calculated at the time the battery voltage is measured (i.e., “on the fly”). This may be contrasted with Takashi’s alternative embodiment of calculation of control characteristics “in advance,” where the control characteristics are pre-calculated for every battery voltage ahead of time. Because Takashi’s control signals 3a and 3b are “based” on the command duty (e.g., the command duty is supplied to the drive means as control signals), the controller’s real-time calculation of the command duty also results in a calculation of control signals in real time. EX1004, [0014]-[0015].

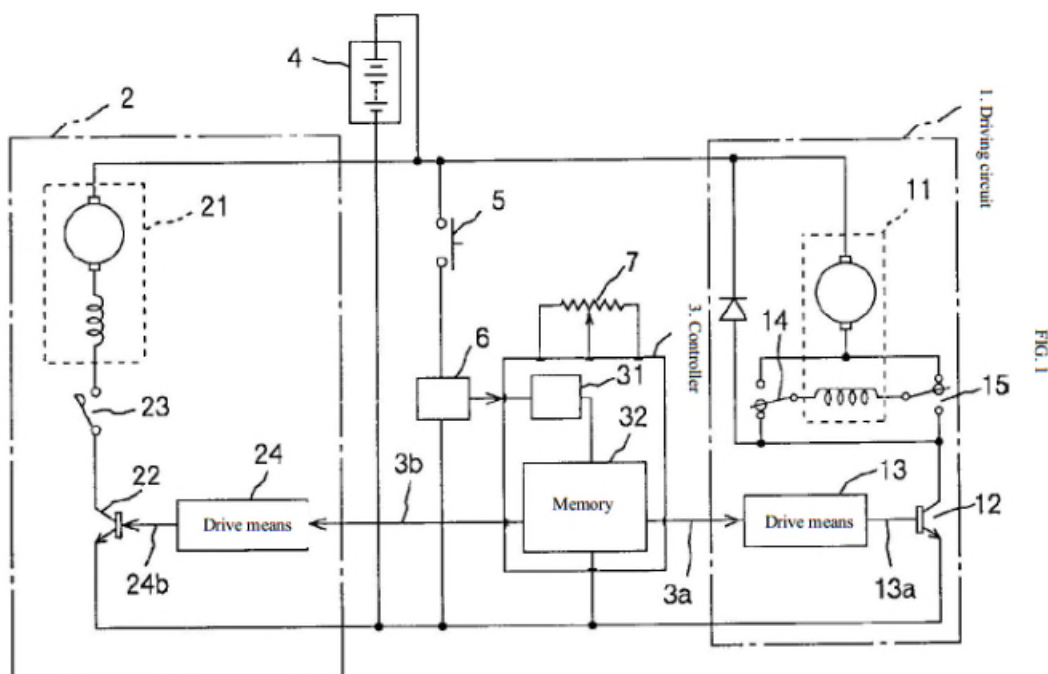
## 7. Claim 7

- a) **7[pre] The method according to claim 6, wherein:  
7[a]: calculating in real time the compensation amount of the control signal includes:  
calculating in real time a compensation amount of a voltage outputted to the motor according to the present voltage of the battery; and**

90. As discussed under element 1[b] and claim 2, Takashi’s calculation of a command duty and/or control signals by the duty setting means discloses “calculating a compensation amount *of a control signal of the motor* according to the present electrical parameter [i.e., the present voltage of the battery].”

91. Takashi’s calculation of a command duty and/or control signals further includes “calculating in real time a compensation amount of a voltage outputted to the motor.” Takashi explains that prior art battery vehicles typically implement a motor that is “rotation driven by a chopper circuit intermittently

operated by a pulse signal.” EX1004, [0002]. “[M]aximum rotational speed of the motor is defined depending on battery voltage” and “maximum rotational speed for a constant duty changes based on the voltage within the operating range.” EX1004, [0004]. Takashi’s motor control device includes “a motor driven by power supplied from a battery” and “a chopper circuit [(e.g., transistor 12)] that intermittently supplies battery power to the motor.” EX1004, [Claim 1], [0009], FIG. 1. The sequence of operation of the motor control device begins when the duty setting means of the controller 3 reads a command duty based on detected battery voltage and supplies control signals 3a and 3b to drive means 13 and 24 based on the detected value. *See, e.g.*, EX1004, FIGS. 1-2. From there, drive means 13 and 24 outputs pulse signals 13a and 24b to the transistors 12 and 22 to intermittently supply battery power to the motor. EX1004, [0010], [0013]-[0015], FIG. 1.



EX1004, FIG. 1. For example, in response to a fully charged battery  $V_a$ , “the [duty setting means of the] controller 3 reads data such as 80% as the command duty” which “is supplied to the drive means 24 as the control signal 3b,” at which point “the drive means 24 outputs a pulse signal 24b with a duty of 80% and the transistor 22 supplies current to the DC motor 21 with intermittent operation of 80% ON time.” EX1004, FIG.2, [0014]. Because Takashi’s calculation of the command duty and/or control signals includes a calculation of the amount of battery voltage that the chopper circuit outputs to the DC motor in order to maintain maximum rotational speed, Takashi’s calculation of a command duty and/or control signals includes “calculating in real time a compensation amount of a voltage outputted to the motor.”

92. As explicitly noted in Takashi, it was well known to a POSITA at the time of the invention that a chopper circuit controls the rotation of a motor based on the battery voltage outputted to the motor. EX1004, [0002], [0004]. For example, Hughes, a textbook on Electric Motors and Drives, explains that “[t]he speed of the motor is determined by the average armature voltage, ( $V_{dc}$ ), which in turn depends on the proportion of the total cycle time ( $T$ ) for which the transistor is ‘on’. If the on and off times are defined as  $T_{on} = kT$  and  $T_{off} = (1 - k) T$ , where  $0 < k < 1$ , then the average voltage is simply given by  $V_{dc} = kV$  from which we see that speed control is effected via the on time ratio,  $k$ .” This is illustrated in Figure 4.13 of Hughes as copied below for reference. The square-wave voltage waveform shown in part (c) has an on time and an off time with an average value shown as  $V_{dc}$ . This operation of a chopper is indicative of what is achieved by transistors 12 and 22 in Takashi to provide an average voltage to the motor. The chopped voltage is filtered by the inductance of the motor, shown as an inductor in series with the motor, and provides a relatively continuous current as shown in the waveforms. EX1012, 177-178.

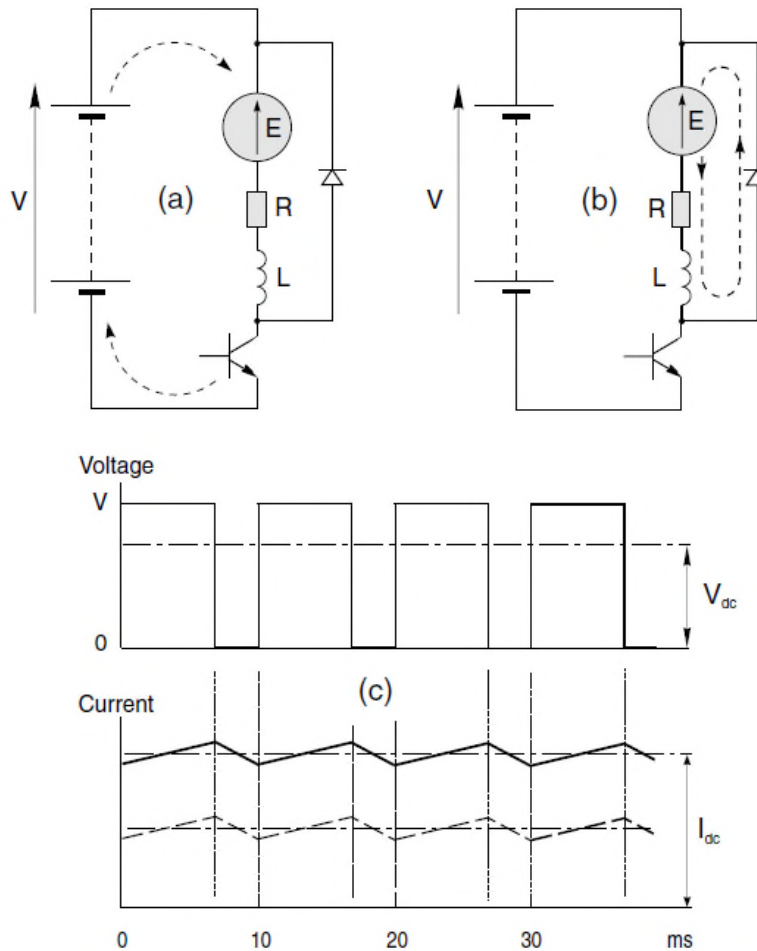


Figure 4.13 Chopper-fed d.c. motor. In (a) the transistor is 'on' and armature current is flowing through the voltage source; in (b) the transistor is 'off' and the armature current freewheels through the diode. Typical armature voltage and current waveforms are shown at (c), with the dotted line representing the current waveform when the load torque is reduced by half

93. In other words, the voltage outputted to the motor by the circuit in Takashi is equal to the battery voltage times the duty cycle. A POSITA would therefore understand that Takashi's chopper circuit is merely an on/off switch that controls the amount voltage outputted from the battery to the motor according to the voltage of the battery such that the maximum rotational speed remains constant despite variations in the battery voltage. Thus, a POSITA would recognize the

average voltage output from the chopper circuit of Takashi as the “voltage outputted to the motor” in claim element 7[a].

94. For example, in Takashi, if the full charge voltage were 10 V, then a POSITA would recognize from FIG. 3 of Takashi that the controller would calculate a compensation amount of 80% command duty (or 2 V below max voltage) and output 8 V to the motor. When the battery voltage discharges to the limit voltage  $V_b$  of 8 V, the controller would calculate a compensation amount of 100% command duty (or 0 V below max) and output 8 V to the motor.

95. Finally, as discussed under element 6[b], Takashi’s duty setting means calculates the compensation amount of the control signal of the motor (i.e., the command duty and/or control signals) in real time. Because the duty setting means’ real-time calculation of the command duty and/or control signals conveys to the chopper circuit the amount of battery voltage outputted to the motor, Takashi’s real time calculation of the control signal to the motor includes a real time calculation of the compensation amount of the voltage outputted to the motor. EX1004, [0014]-[0015].

**b) 7[b] modifying the control signal includes:  
modifying an original voltage outputted to the motor  
according to the compensation amount of the voltage.**

96. As discussed under element 1[c], Takashi’s modification of control signals 3a and 3b by the duty setting means according to the command duty

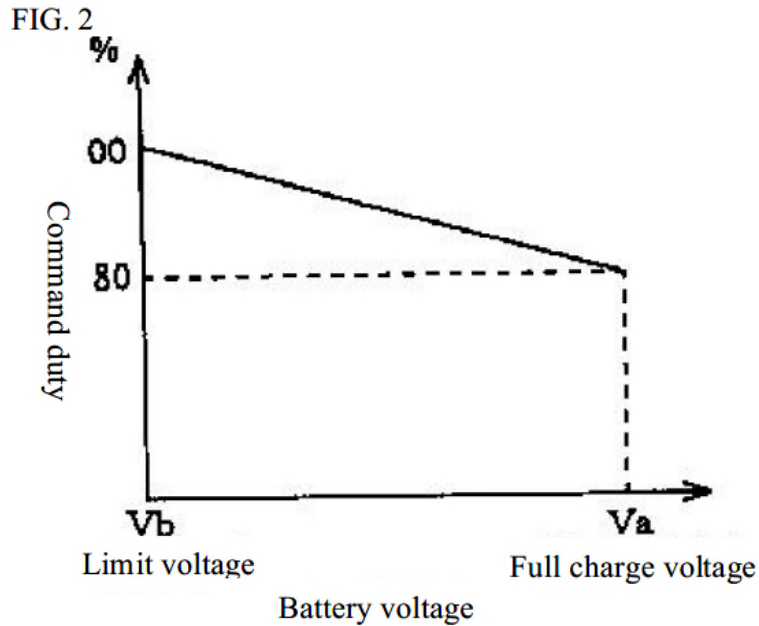
discloses “modifying the control signal.” In addition, Takashi’s modification of pulse signals 13a and 24b by the drive means according to the control signals 3a and 3b discloses “modifying the control signal.” *Supra* 1[c]. As discussed under element 7[a], Takashi’s calculation of the command duty and/or control signals includes a calculation of “a compensation amount of a voltage outputted to the motor according to the present voltage of the battery.” Takashi’s modification of the control signal further includes “modifying an original voltage outputted to the motor according to the compensation amount of voltage.”

97. As more fully explained under element 7[a], a POSITA at the time of the invention would have understood that Takashi’s chopper circuit (i.e., transistor) acts as a switch to control the voltage outputted from the battery to the motor. *See, e.g.,* EX1004, [0002], [0009]-[0011], [0013]; *see supra* 7[a]. More specifically, the chopper circuit modifies the voltage that would otherwise be outputted from the battery to the motor by intermittently switching on/off according to an amount communicated by control signals 3a and 3b and pulse signals 13a and 24b. *See supra* 7[a]. For example, in response to a fully charged battery  $V_a$ , “the [duty setting means of the] controller 3 reads data such as 80% as the command duty” which “is supplied to the drive means 24 as the control signal 3b,” at which point “the drive means 24 outputs a pulse signal 24b with a duty of 80% and the transistor 22 supplies current [(i.e., power/current/voltage)] to the DC motor 21

with intermittent operation of 80% ON time.” EX1004, FIG.2, [0014]. Thus, the chopper circuit’s modification of the voltage that would otherwise be outputted from the battery to the motor according to the control signals 3a and 3b and pulse signals 13a and 24b discloses “modifying an original voltage outputted to the motor according to the compensation amount of voltage.” And because the chopper circuit’s modification of the voltage outputted to the battery results from control signals 3a and 3b and pulse signals 13a and 24b, Takashi’s “modif[ication] of the control signal includes[] modifying an original voltage outputted to the motor according to the compensation amount of voltage.”

**8. Claim 8: The method according to claim 7, wherein the compensation amount of the voltage is determined according to a difference between a full voltage of the battery and the present voltage of the battery.**

98. As discussed under claim 7, Takashi’s calculation of the command duty and/or control signals includes a calculation of a compensation amount of the voltage. Takashi further discloses that the voltage outputted by the chopper circuit is determined according to the difference between a full voltage of the battery and the present voltage of the battery.



99. As shown in FIG. 2 and described throughout Takashi, the command duty and corresponding voltage outputted from the battery to the motor via the chopper circuit is determined according to a relationship that is “inversely proportional to battery voltage drop.” EX1004, (57), FIG. 2, [0007]-[0008], [0013], [0016]. Here, “voltage drop” literally means a voltage difference, or in this case, the difference between the full voltage of the battery and the present voltage of the battery. Takashi thus further discloses that the calculation of the compensation amount of the voltage is determined according to a difference between a full voltage of the battery and the present voltage of the battery.

9. **Claim 12: An apparatus for controlling a motor comprising: one or more processors configured to: obtain a present electrical parameter of a battery; calculate a compensation amount of a control signal of the motor according to the present electrical parameter; and modify the control signal according to the compensation amount.**

100. Claim 12 recites essentially identical limitations to method claim 1 in the form of an apparatus claim. The only difference between claims 12 and 1 is that claim 12 further requires “one or more processors” that are “configured to” perform the steps of claim 1.

101. Takashi discloses this additional limitation. As discussed under element 1[a], Takashi’s use of a detecting means 31 of the controller 3 to detect the current battery voltage is a method of obtaining a present electrical parameter (i.e., voltage) of a battery. In addition, Takashi’s use of a duty setting means of the controller 3 to read the detected battery voltage (i.e., “voltage characteristic”) also discloses a method of obtaining a present electrical parameter (i.e., voltage) of a battery. As discussed under element 1[b], Takashi’s use of the duty setting means of the controller 3 to read a pre-calculated command duty and/or calculate a command duty according to the detected battery voltage is a method of “calculating a compensation amount of a control signal of the motor according to the present electrical parameter,” as is Takashi’s use of the duty setting means to calculate control signals 3a and 3b according to the detected battery voltage. As discussed under element 1[b], Takashi’s use of a duty setting means of the

controller 3 to modify the control signals 3a and 3b that are sent to the drive means 24 is a method of “modifying the control signal according to the compensation amount,” as is the drive means’ modification of the pulse signals that are sent to the transistors.

102. Takashi further discloses that the motor control device is “*configured* to set the current flowing in each of the DC motors 11 and 21 in a driving circuit 1 and a cargo handling circuit 2 using a duty command from a controller 3 as a *central processing unit*.” EX1004, [0010] (emphasis added). The controller includes a detecting means 31 and a duty setting means 32. “Each of the detection values of the detecting means 31 is *process[ed]* using duty setting means....” EX1004, [0013] (emphasis added). “This duty setting means reads and controls from the memory 32, control characteristics (FIG. 2) in which command duty is increased inversely proportional to voltage characteristics where the voltage of the battery 4 drops from fully charged voltage characteristic to the limit voltage at 80% discharge....” EX1004, [0013].

103. A POSITA would have understood from this disclosure, and at the very least found it obvious, that “controller 3 as a central processing unit” with its detecting means 31, duty setting means<sup>4</sup>, and drive means 24 are “processors.”

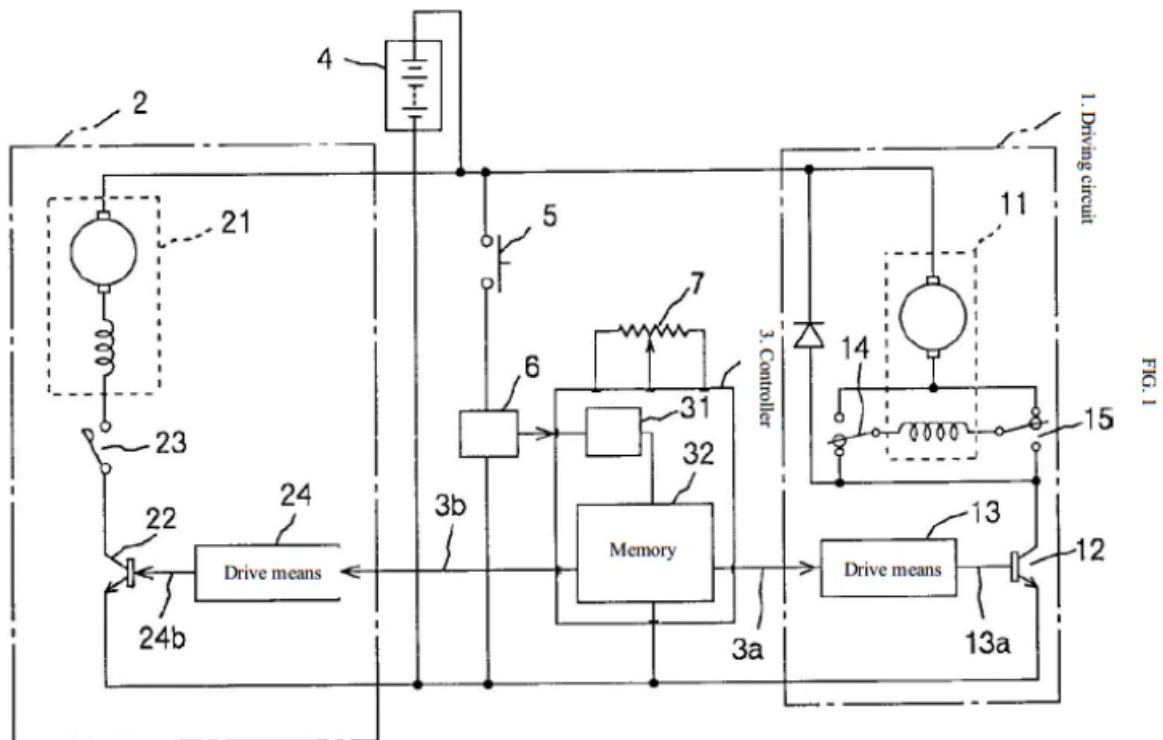
---

<sup>4</sup> Takashi at times refers to the controller’s duty setting means as 32 as a memory 32. EX1004, (57), [0013]. However, a POSITA would understand that in order to access memory, a processor would be used. See, e.g., EX1004, [0013] (The “duty

EX1004, [0009]. For example, the detecting means obtains the battery voltage signal and sends it as a signal to the duty setting means. The duty setting means obtains the battery voltage signal from the detecting means and calculates a command duty signal. The duty setting means modifies control signals according to the command duty signal. The drive means calculates pulse signals from control signals and then modifies the pulse signals according to the control signals. Each of these instances of obtaining, calculating, and modifying is an example of signal processing that is performed by a “processor.” The use of microcontrollers, digital signal processors (DSPs), and field programmable gate arrays (FPGAs) were all well-known options for implementing such processing and realizing Takashi’s “controller 3 as a central processing unit.”

---

setting means reads and controls from the memory 32, control characteristics ....”). Thus, Takashi’s duty setting means at least includes a processor in addition to a memory.

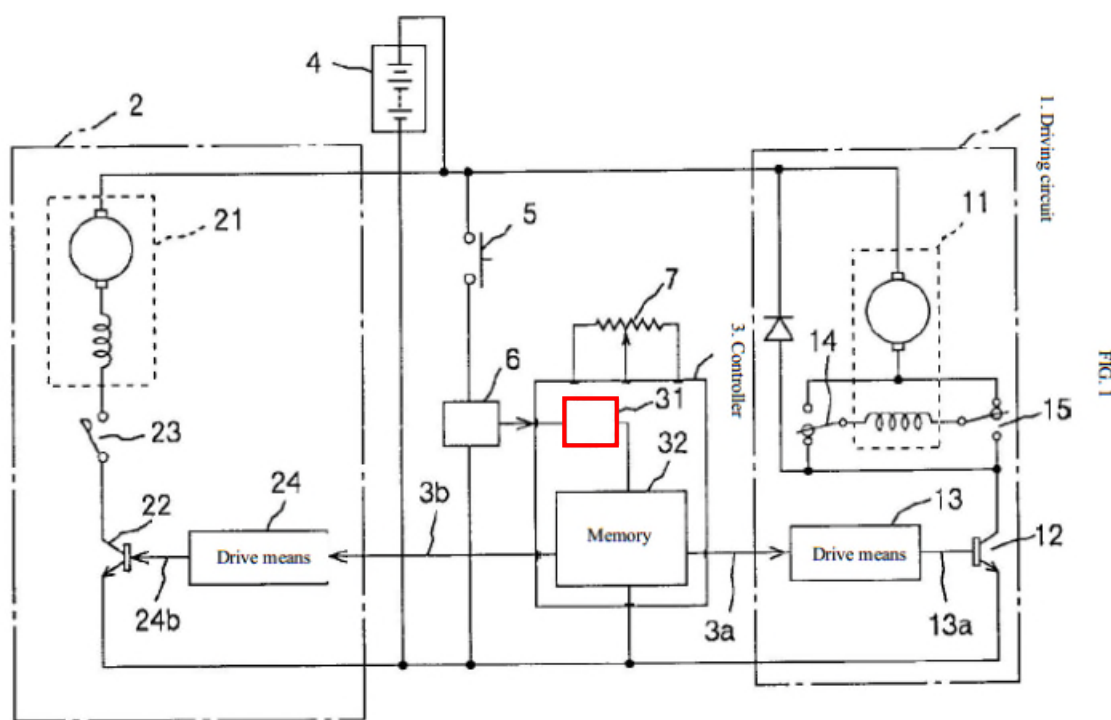


104. Because the controller 3 and/or drive means 13 and 24 performs each of the claimed steps, Takashi discloses one or more processors that are configured to perform the claimed steps.

**10. Claim 13: The apparatus according to claim 12, further comprising: an electrical parameter detection circuit electrically coupled to the one or more processors and configured to detect the present electrical parameter.**

105. As shown in FIG. 1, the detecting means 31 in combination with the power supply circuit 6 is a component of the motor control device circuit. A POSITA would have understood, and at the very least found it obvious, that the “detecting means 31 for detecting the output of the constant voltage power supply circuit 6 as the voltage of the battery 4” would have been implemented as a circuit electrically coupled to both the battery and the processor within controller 3.

EX1004, [0013]. At the time of the invention, several types of circuit components for detecting battery voltage were well known to a POSITA, including a resistor divider, an operational amplifier (op-amp), a voltage buffer or filter, and an analog-to-digital (A/D) converter. EX1013, 8-11. Each of these detecting means is a voltage detection circuit and voltage is a type of electrical parameter. Takashi's **detecting means 31** is therefore “an electrical parameter detection circuit.”



EX1004, FIG. 1 (annotated).

106. As discussed under claim elements 1[a]/12[b], Takashi's detecting means 31 obtains a present electrical parameter (i.e., voltage) of a battery. The detecting means 31 obtains the present electrical parameter by “detecting the output of the constant voltage power supply circuit as the voltage of the battery.”

EX1004, [0012]. The detecting means 31 is therefore also “configured to detect the present electrical parameter.”

107. Finally, Takashi’s detecting means 31 is “electrically coupled to the one or more processors.” Takashi explains that “[e]ach of the detection values of the detecting means 31 is process[ed] using duty setting means for commanding each of the duties of the pulse signals 13a and 24b in the driving circuit 1 and the cargo handling circuit 2.” EX1004, [0013]. As discussed under claim 12, Takashi’s duty setting means is a processor. For the duty setting means to process detection values from the detecting means 31, the two components must be electrically coupled. Thus, the detecting means 31 is “electrically coupled” to the duty setting means.

**11. Claim 14: The apparatus according to claim 13, wherein the electrical parameter detection circuit includes at least one of a coulometer, a voltage detection circuit, an electrical current detection circuit, or a resistance detection circuit.**

108. As discussed under Claims 2 and 13, Takashi’s detecting means 31 includes a voltage detection circuit and therefore Takashi discloses that alternative of the recited Markush group. See Claim 2,13 analysis, above.

**12. Claim 15**

**a) 15[pre] The apparatus according to claim 14, wherein the one or more processors are further configured to:**  
**15[a] calculate the compensation amount of the control signal of the motor corresponding to a subsequent time point according to the present**

**voltage of the battery and a preset voltage model including one-to-one correspondences between voltages of the battery and preset compensation amounts; and  
15[b] modify, at a present time point, the control signal according to the compensation amount.**

109. Claim 15 recites essentially identical limitations to method claims 4 and 5 in the form of an apparatus claim. The only difference between claim 15 and claims 4 and 5 is that claim 15 further requires “one or more processors” that are “configured to” perform the “calculating” and “modifying” steps of claims 4 and 5.

110. To the extent that claim 15 is not indefinite for lack of antecedent basis, Takashi discloses this additional limitation.<sup>5</sup> As discussed in claims 4 and 5, Takashi’s duty setting means (i.e., processor) performs the “calculating” and “modifying” steps. *See also supra* cl. 12 (explaining that the duty setting means is a processor). Takashi’s drive means (i.e., a processor) also performs the “modifying step.” *Id.* (explaining that the drive means is a processor). Because the duty setting means and/or drive means performs the claimed steps, Takashi discloses one or more processors that are configured to perform the claimed steps.

**13. Claim 16: The apparatus according to claim 14, wherein the one or more processors are further configured to: calculate**

---

<sup>5</sup> I understand that Claim 15’s “present voltage of the battery” lacks proper antecedent basis. For the purposes of this proceeding, I have been asked to assume that claim 15’s “present voltage of the battery” refers to claim 12’s “present electrical parameter.”

**in real time the compensation amount of the control signal of the motor according to the present voltage of the battery.**

111. Claim 16 recites essentially identical limitations to method claim element 6[c] in the form of an apparatus claim. The only difference between claim 16 and element 6[c] is that claim 15 further requires “one or more processors” that are “configured to” perform the “calculating” step of element 6[c].

112. To the extent that claim 16 is not indefinite for lack of antecedent basis, Takashi discloses this additional limitation.<sup>6</sup> As discussed in claim 6, Takashi’s duty setting means (i.e., processor) performs the “calculating” step. See *also supra* cl. 12 (explaining that the duty setting means is a processor). Because the duty setting means performs this step, Takashi discloses one or more processors that are configured to perform the step.

**14. Claim 17: The apparatus according to claim 16, wherein the one or more processors are further configured to: calculate in real time a compensation amount of a voltage outputted to the motor according to the present voltage of the battery; and modify an original voltage outputted to the motor according to the compensation amount of the voltage outputted to the motor.**

113. Claim 17 recites essentially identical limitations to method claim elements 6[b], 7[a], and 7[b] in the form of an apparatus claim. The only

---

<sup>6</sup> I understand that Claim 16’s “present voltage of the battery” lacks proper antecedent basis. For the purposes of this proceeding, I have been asked to assume that claim 16’s “present voltage of the battery” refers to claim 12’s “present electrical parameter.”

difference between claim 17 and elements 6[b], 7[a], and 7[b] is that claim 17 further requires “one or more processors” that are “configured to” perform the “calculating” and “modifying” steps of these elements.

114. To the extent that claim 17 is not indefinite for lack of antecedent basis, Takashi discloses this additional limitation.<sup>7</sup> As discussed in claims 6 and 7, Takashi’s duty setting means (i.e., processor) performs the “calculating” and “modifying” steps. *See also supra* cl. 12 (explaining that the duty setting means and drive means are processors). Takashi’s drive means (i.e., a processor) also performs the “modifying step.” *Id.* (explaining that the drive means is a processor). Because the duty setting means and/or drive means perform these steps, Takashi discloses one or more processors that are configured to perform these steps.

**B. Grounds 2A and 2B: Claims 9-11 are (2A) Anticipated by or (2B) Obvious in View of Onishi**

115. For the reasons set forth below, it is my opinion that Claims 9-11 are anticipated by Onishi. Should the Board or Patent Owner take the position that some of these claim limitations are not disclosed in Onishi, it is my opinion that a POSITA would have nevertheless understood those limitations to be rendered

---

<sup>7</sup> I understand that Claim 17’s “present voltage of the battery” lacks proper antecedent basis. For the purposes of this proceeding, I have been asked to assume that claim 17’s “present voltage of the battery” refers to claim 12’s “present electrical parameter.”

obvious by Onishi.

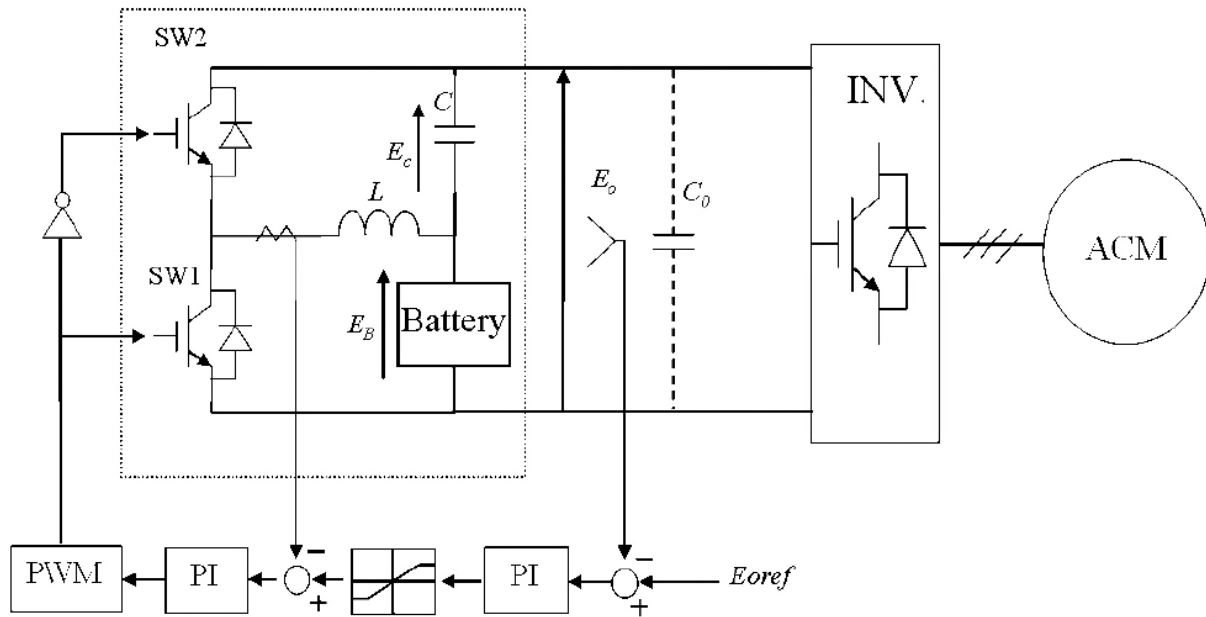
**1. Claim 9**

**a) 9[pre] A method for controlling a motor comprising:**

116. To the extent the preamble is argued to be limiting, it is nonetheless disclosed by Onishi. Onishi discloses a storage battery system for electric vehicles that includes a storage battery. EX1006, [0024], FIG. 7. The storage battery “is used as a power source to drive an alternating current motor via an inverter” (e.g., control a motor of an electric vehicle). EX1006, [0024]; FIG. 7. When “the discharge of the storage battery progresses and the terminal voltage drops, the terminal voltage can be kept constant until the remaining capacity is exhausted, and the battery can be used to the final discharge voltage.” *Id.*

# 【 図 7 】

## アクティブ蓄電池

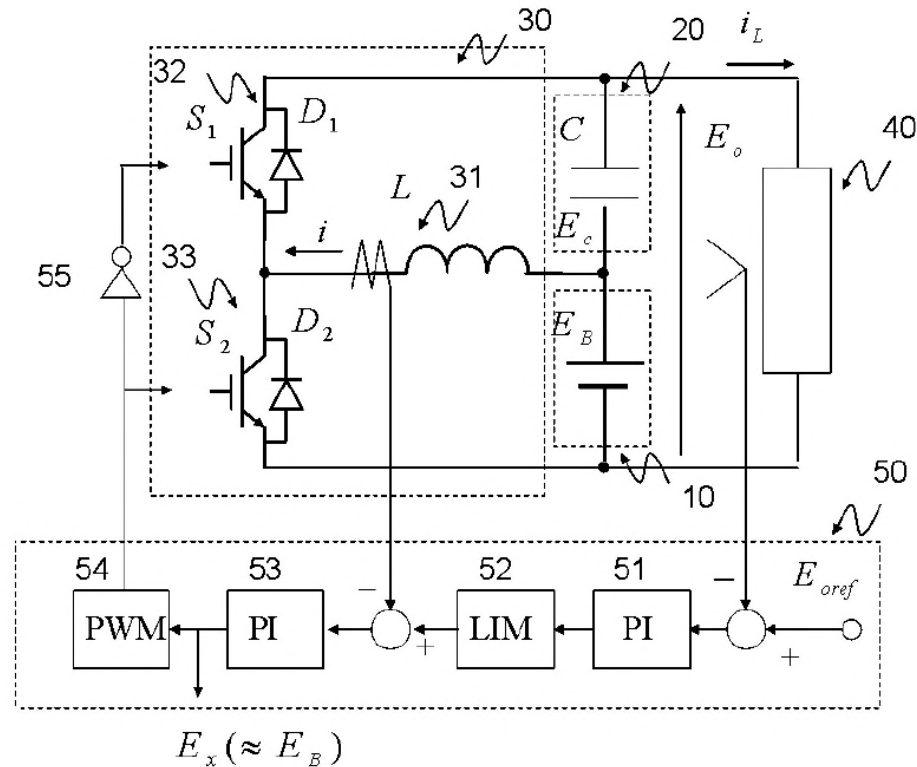


*Id.*, FIG. 7.

117. Onishi notes that the storage battery can be used “without affecting the performance of the device used, even if the voltage of the battery drops.” EX1006, [0026]. The storage battery control system compensates for the voltage fluctuations caused by charging and discharging of the battery by actively charging and discharging a capacitor. *Id.* More specifically, the storage battery control system “maintains a constant direct current output voltage to a load 40 (e.g., a motor) by controlling a capacitor 20 voltage by controlling a switching power converting device 30 that performs charging and discharging between the storage battery 10 and the capacitor 20 based on a switching signal from a control block

50.” EX1006, [0010], FIG. 1.

【 図 1 】



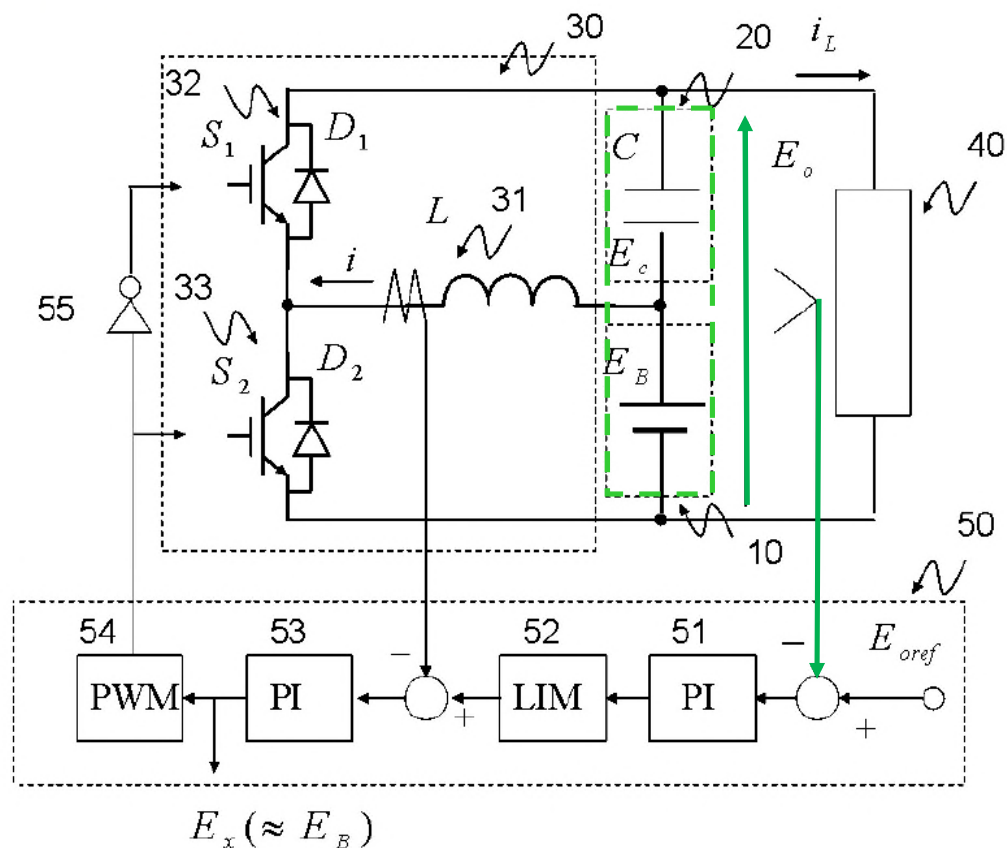
118. Onishi’s use of a storage battery control system to control a capacitor in series with a storage battery and a switching power converting device in order to maintain a constant direct current output voltage (e.g.,  $E_o$ ) from the storage battery system to a load (including an electric vehicle motor) discloses a method of controlling a motor.

**b) 9[a] obtaining a present electrical parameter of a battery;**

119. The storage battery system of Onishi obtains a present electrical parameter of a battery. For example, as shown in annotated Figure 1 below, the

control block 50 of Onishi measures the current value of voltage  $E_o$  (which is the output voltage of the battery system formed by the series voltage of the storage battery 10 and capacitor 20 (voltage  $E_b$  + voltage  $E_c$ )).

【 図 1 】



EX1006, FIG. 1 (annotated); *see also id.* at [0010], [0016], [0026]. The current output voltage  $E_o$  of the battery system is the claimed “present electrical parameter.” EX1001, 3:50-54.

120. A POSITA would understand that the overall battery system of Onishi (i.e., storage battery 10, capacitor 20, switching power converter 30, and control

block 50)—and not just the storage battery cells 10—is the claimed “battery” of Claim 9. Onishi explicitly defines the “**storage battery system**” as comprising “a storage battery and a capacitor connected in series” and states that the voltage of the “entire storage battery system integrating the storage battery and the capacitor is kept constant.” EX1006, Cl. 1, [0009]. Onishi further states that since the output voltage is “actively kept constant ... the storage battery system of the present invention is called an “**active control storage battery**.” *Id.*, ¶ [0016]. Thus, it is clear that the battery voltage in Onishi that is measured and kept constant is that of the storage battery system at  $E_o$ , which is the battery voltage applied to the load such as an “alternating current motor via an inverter.” *Id.*, ¶ [0024].

121. Onishi also states that “[a]s an example of application to secondary batteries, the present invention is highly useful as an **active storage battery** for electric vehicles.” EX1006, ¶ [0026]. This is consistent with the use of the terms in Claim 9, where the term “output voltage of the battery” refers to the output voltage that is maintained to be “stable.” EX1001, 14:56-62; *see also id.* at 8:19-33. This is clear since it is recognized in the ’224 Patent and throughout the industry that the voltage of a battery cell alone is not stable (it necessarily decreases as it is discharged and increases as it is charged (*see, e.g.*, EX1001, 1:28-29, 3:28-29), where a POSITA would easily recognize that the statement “the

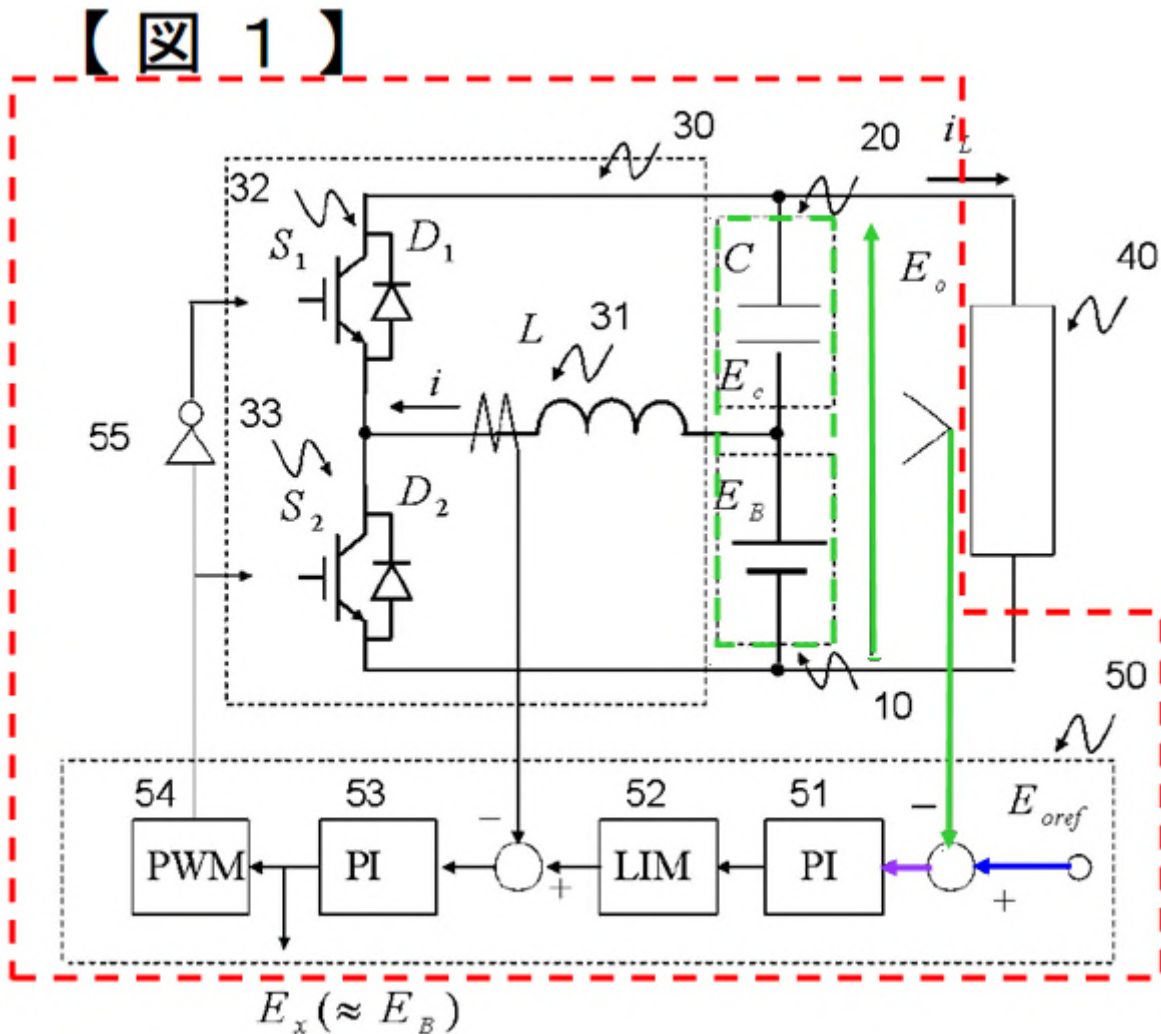
battery voltage continuously decreases during the discharging process” refers to the natural decrease in a battery cell voltage as it is discharged). Thus, the claimed “output voltage of the battery” of the ’224 Patent that is maintained stable and does not continuously decrease during discharge clearly refers to the output of the battery system. A POSITA would recognize that such a battery system will be made up of a combination of battery cell(s) and additional components since a battery cell alone has no ability to be maintained stable.

122. For at least these reasons, Onishi’s measuring of  $E_o$  of the storage battery system satisfies the “obtaining a present electrical parameter of a battery.”

**c) 9[b] calculating a voltage compensation amount of the battery according to the present electrical parameter; and**

123. Onishi discloses calculating a voltage compensation amount of the battery according to the present electrical parameter (e.g., value of voltage  $E_o$ ). As explained above, Onishi’s storage battery system measures the current value of battery system output voltage  $E_o$ . See *supra* Section X.B.1.b. As would be understood by a POSITA, the control block 50 of Onishi’s storage battery system then compares the obtained value of **voltage  $E_o$**  (green) to the **full/reference voltage  $E_{oref}$**  (blue) to calculate a **voltage compensation amount** (purple) of the **battery** (e.g., the difference between voltage  $E_o$  and voltage  $E_{oref}$ , which is input into the voltage controlled PI controller block 51 of control block 50). EX1006, [0001], [0010]-

[0011], [0014], [0018], [0021].



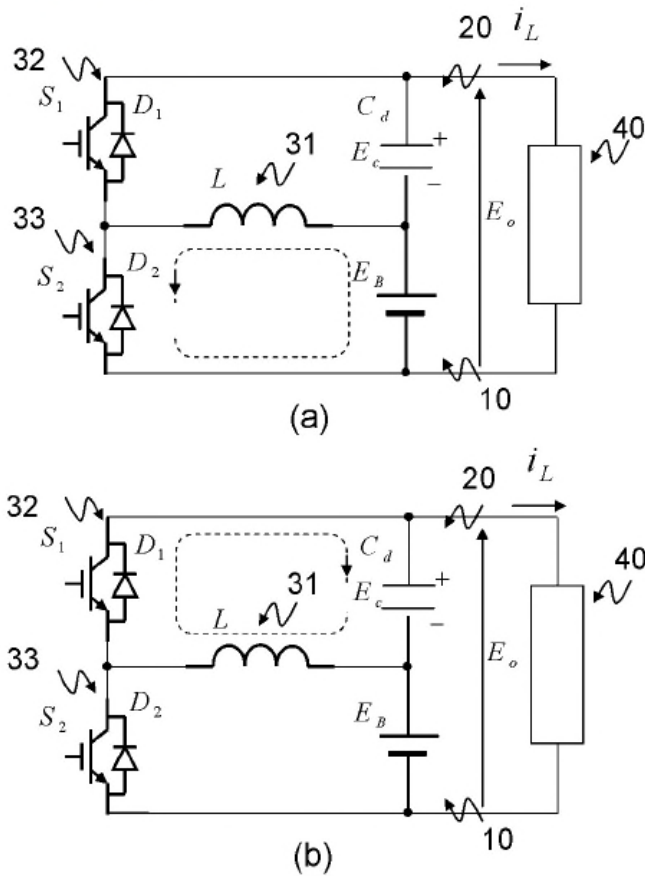
EX1006, FIG. 1 (annotated). The voltage compensation amount will be negative if voltage  $E_o$  is above voltage  $E_{oref}$  and positive if voltage  $E_o$  is below voltage  $E_{oref}$ . The voltage compensation amount is therefore calculated according to the present electrical parameter (e.g.,  $E_o$ ).

**d) 9[c] compensating an output voltage of the battery according to the voltage compensation amount to maintain the output voltage of the battery stable.**

124. Onishi discloses compensating an output voltage of the battery according to the voltage compensation amount to maintain the output voltage of the battery stable. In particular, the voltage compensation amount (e.g., the difference between voltage  $E_o$  and voltage  $E_{oref}$ ) is used by control block 50 (including the voltage and current controlled PI controllers 51 and 53, saturation function block 52, and PWM switch signal generating circuit 54) to generate the PWM control signal that controls the timing of the switching between switches 32 and 33 of the switching power converting device 30, which in turn controls the charging and discharging between the storage battery 10 and capacitor 20 to compensate  $E_o$  back to the reference voltage level. EX1006, [0009], [0013] (“The control input amount [to the control block 50] that generates the PWM control signal (i.e., switching control signal) for the switches 33 and 32 has a value that is proportional to the voltage of the storage battery 10”), [0015] (“The control block 50 similarly generates a PWM control signal for the switches 33 and 32 of the switching power converting device 30 and can monitor the voltage of the storage battery from the signal of the control circuit because the control input level that generates the PWM control signal to the switches 33 and 32 is a value proportional to the voltage of the storage battery 10”).

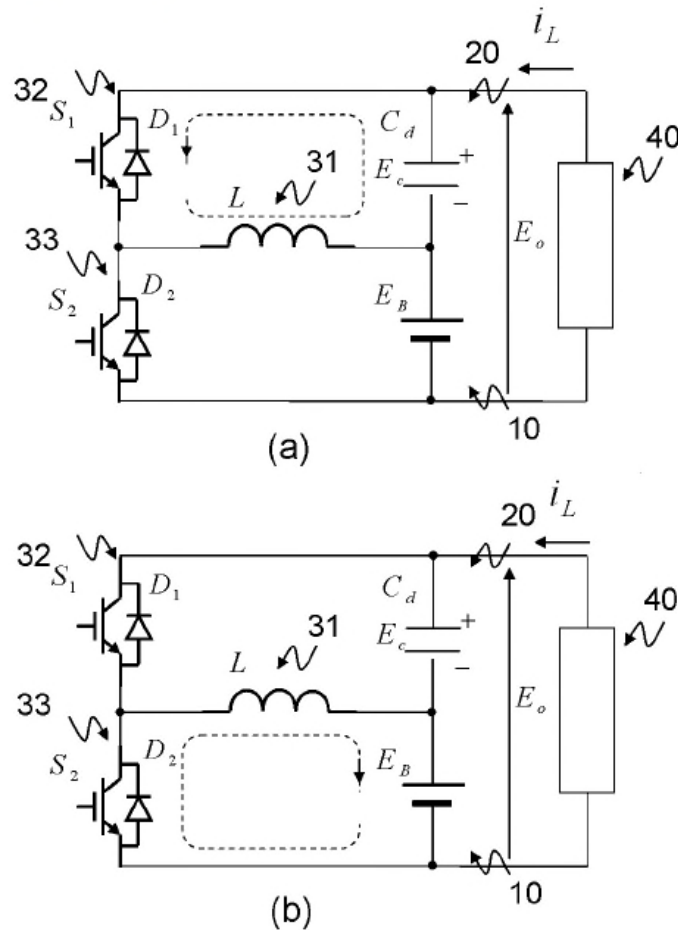
125. For example, as shown in FIG. 2, when the output voltage  $E_o$  of the battery storage system drops below the reference voltage  $E_{oref}$  due to discharge to the load, “the energy of the storage battery 10 is transferred to the capacitor 20 by the switching power converting device 30, and the drop is compensated by the charging voltage of the capacitor 20 that is connected in series.” EX1006, [0011]. FIG. 2 shows the “compensation circuit operation when the output voltage of the battery storage system drops below a reference value.” *Id.*, [0019]. From the controller block 50 in FIG. 1, the compensation amount calculated when  $E_o$  drops below  $E_{oref}$  is negative. This will cause the PI controller 51 to request current to be drawn from the storage battery  $E_B$ , which transfers energy from  $E_B$  to the inductor  $L$  of the DC-DC converter as shown in FIG. 2(a). EX1006, FIG. 2(a)-2(b), ¶¶ [0011]-[0013]. The energy in the inductor is then transferred to the capacitor  $C_d$  as shown in FIG. 2(b). *Id.* This sequence is repeated by operating at least switch  $S_2$  on and off from the pulse-width-modulator (PWM) 54 until the control block 50 calculates that the compensation amount has been returned to zero and the battery system output voltage  $E_o$  is at the target voltage level  $E_{oref}$ . *Id.*

【 図 2 】



126. On the other hand, when the output voltage  $E_o$  of the battery storage system (*e.g.*, the series voltage of the storage battery 10 and the capacitor 20) rises above the reference voltage due to, for example, regenerative current from the load, “the load terminal voltage can be kept constant by transferring the energy of the capacitor 20 to the storage battery 10 by the switching power converting device 30, and performing discharge voltage control of the capacitor 20.” EX1006, [0014]-[0015]. FIG. 3(a)-3(b) shows the “compensation circuit operation when the output voltage of the battery storage system is above a reference value.” *Id.*, [0019].

【 3 】

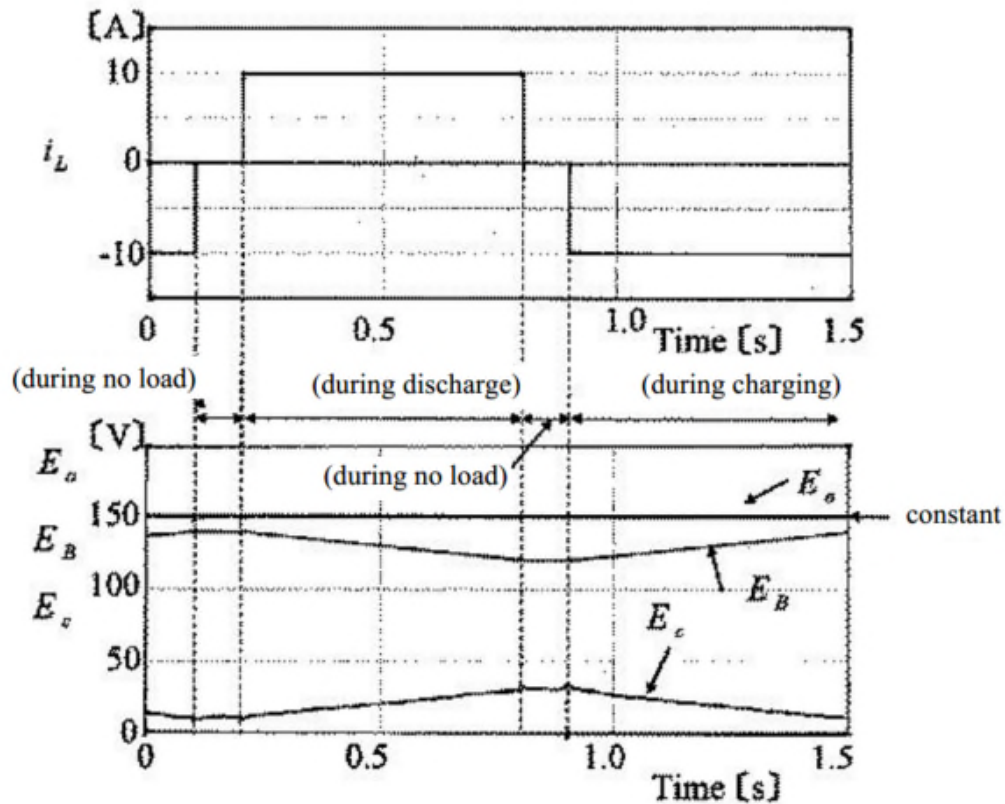


127. In sum, the voltage compensation amount of the battery (e.g., the difference between the voltage  $E_o$  and voltage  $E_{oref}$ ) is used to compensate for battery system output voltage fluctuations due to the charging and discharging of the storage battery 10 by: (1) operating switch circuit 33 and transferring energy from the storage battery 10 to the capacitor 20 during discharge (e.g., when  $E_o$  is below  $E_{oref}$ ) to increase the value of voltage  $E_c$  and compensate for the amount of voltage drop in  $E_o$ ; and (2) operating switch circuit 32 and transferring energy from the capacitor 20 to the storage battery 10 during charging (e.g., when  $E_o$  is above

$E_{\text{oref}}$ ) to decrease the value of voltage  $E_c$  and compensate for the amount of voltage above the reference voltage. *Supra* Section VIII.B; EX1006, [0009]-[0016], [0021]. Through this process of charging and discharging capacitor 20 based on the calculated compensation amount, Onishi's storage battery system maintains the output voltage  $E_o$  of the battery system stable. *Id.* FIG. 5 of Onishi illustrates how the compensating of the output voltage  $E_o$  according to the difference between voltage  $E_o$  and voltage  $E_{\text{oref}}$  maintains the output voltage of the battery stable. As shown in the figure below, the battery system output voltage  $E_o$  is maintained stable over time despite variations in  $E_B$  during charging and discharging by controlling an equal and opposite voltage variation  $E_c$  in the capacitor. *Id.*, FIG. 5. Onishi states that "[a]s a result, the voltage fluctuation caused by charging and discharging of the battery can be compensated actively by charging and discharging the capacitor." EX1006, [0026].

128. Onishi thus discloses compensating an output voltage of the battery according to the voltage compensation amount to maintain the output voltage of the battery stable.

[FIG. 5]



EX1006, FIG. 5.

2. **Claim 10:** The method according to claim 9, wherein the present electrical parameter of the battery includes at least one of a present charge quantity of the battery, a present voltage of the battery, a present output electrical current of the battery, or a present internal resistance of the battery.

129. As discussed under element 9[a], Onishi's control block 50 obtains the present voltage of the storage battery. EX1006, FIG. 1, [0010], [0016], [0026]. Onishi thus discloses a present electrical parameter that includes a present voltage of the battery.

### 3. Claim 11

- a) **11[pre] The method according to claim 10, wherein:  
11[a] the present electrical parameter of the battery  
includes the present voltage of the battery; and:**

130. As discussed under claim 10 in Ground 2, it is my opinion that Onishi discloses a present electrical parameter of a battery that includes the present voltage of the battery.

- b) **11[b] calculating the voltage compensation amount of  
the battery includes:**
- c) **11[c] calculating the voltage compensation amount of  
the battery according to the present voltage of the  
battery and a full voltage of the battery, the voltage  
compensation amount being equal to a difference  
between the full voltage and the present voltage**

131. As discussed under claim 9[b] and 10, Onishi discloses calculating the voltage compensation amount of the battery according to the present electrical parameter of the battery (e.g., present voltage of the battery). *See supra* Sections X.B.1.c, X.B.2. More specifically, the control block 50 calculates the difference between voltage  $E_o$  and a reference voltage  $E_{oref}$ . EX1006, FIG. 1, [0010]-[0011], [0014]. Furthermore, Onishi discloses calculating this voltage compensation amount according to a full voltage of the battery because a POSITA would have understood that  $E_{oref}$  corresponds to the full voltage of the battery system. Onishi “provide[s] a storage battery system that maintains a constant terminal voltage until the remaining capacity is exhausted, even if the terminal voltage of the

storage battery drops due to advancement of discharge of the storage battery, and which can be used until the final discharge voltage.” EX1006, [0007]. Because Onishi’s storage battery system maintains a constant terminal/output voltage and this is performed through a control loop that keeps that terminal voltage at or near  $E_{\text{oref}}$ , it would have been understood by a POSITA that the reference voltage  $E_{\text{oref}}$  is the full voltage of the battery system because that is where the output voltage of the system is when operation begins.

132. To the extent that it is argued that  $E_{\text{oref}}$  could be set to some other voltage than the full battery system voltage, it would have at least been obvious to a POSITA to set  $E_{\text{oref}}$  as the full voltage of the battery system—i.e., the battery system output voltage when the storage battery 10 is fully charged—because any other reference value would cause unnecessary voltage  $E_c$  to be built up on the capacitor (for a larger reference value) or underutilization of the storage battery (for a lower reference value). Higher voltages on the capacitor would mean more voltage stress on components leading to higher cost and lower efficiency. An underutilized storage battery would lead to a larger, heavier, and more expensive battery system. Thus, a POSITA would expect to maintain only the necessary capacitor voltage to compensate for the drop in the storage battery voltage as it is discharged. This is consistent with the operation as described in Onishi and

depicted in FIG. 5, showing the capacitor voltage dropping close to zero as the storage battery voltage  $E_B$  approaches the target reference voltage  $E_{\text{oref}}$ .

**C. Grounds 3A and 3B: Claims 9-11 are (3A) Anticipated by or (3B) Obvious in View of Kim**

133. For the reasons set forth below, it is my opinion that Claims 9-11 are anticipated by Kim. Should the Board or Patent Owner take the position that some of these claim limitations are not disclosed in Onishi, it is my opinion that a POSITA would have nevertheless understood those limitations to be rendered obvious by Onishi.

**1. Claim 9**

**a) 9[pre] A method for controlling a motor comprising:**

134. To the extent the preamble is argued to be limiting, it is nonetheless disclosed by Kim. Kim discloses a “dynamically reconfigurable battery framework for management of a large-scale battery system” for, *e.g.*, powering the motor of electric vehicles (“EVs”). EX1008, Abs., 1:21-2:20, 2:15-16, 11:34-44, 12:32-36. “The framework monitors, reconfigures, and controls large-scale battery systems” and “is built upon a topology-based bypassing mechanism that provides a set of rules for changing the battery-pack configuration, and a semantic bypassing mechanism by which the battery-cell connectivity is reconfigured to recover from a battery-cell failure.” *Id.*, Abs. The “semantic bypassing mechanism implements a constant-voltage-keeping policy” that “is effective in preventing unavoidable

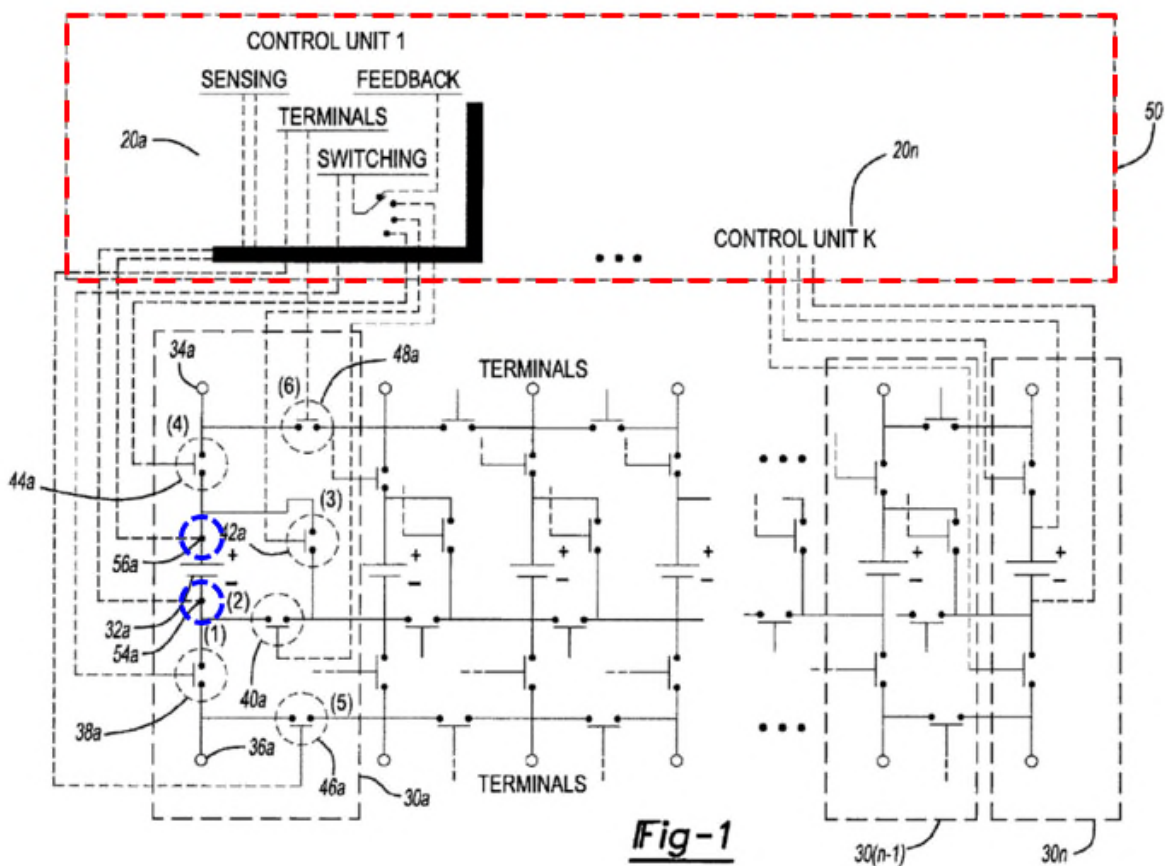
voltage drops during the battery lifetime.” *Id.*; *see also id.*, 6:65-7:19, 8:11-19, 15:29-35. More specifically, the “constant-voltage-keeping policy is applied to keep the supply voltage above or equal to the demand voltage while the supply voltage is being monitored.” *Id.*, 15:45-66. For example, “when the [monitored] supply voltage drops below  $V_d$ ” (e.g., demand voltage requirement), the battery pack connectivity is reconfigured (e.g., by reconfiguring/rotating battery cells in a series chain via switches) to compensate for the voltage drop and keep the output supply voltage constant. *Id.*, 2:37-43, 7:10-42, 8:11-9, 11:34-44, 15:45-66; *see also supra* Section VIII.C (identifying various battery arrangements).

135. Kim’s technique of reconfiguring, for example, the connection of battery cells in a given series chain to maintain a constant output supply voltage satisfies the claimed “method of controlling a motor.” In particular, as would be understood by a POSITA, the output voltage of the battery is used to “power” the motor of an electric vehicle and thus affects the operation of the motor. EX1008, 11:34-44. A POSITA would therefore understand the Kim’s controlling of the output voltage is a method of controlling the motor powered by and connected to the battery output voltage.

**b) 9[a] obtaining a present electrical parameter of a battery;**

136. Kim’s reconfigurable battery system obtains a present electrical parameter of a battery. For example, each “battery pack” (e.g., a battery) of the

reconfigurable battery system includes “battery circuits 30a-30n” each having “an associated control module 20a-20n” and a “battery cell 32a.” EX1008, 4:22-27, 4:42-67. “During operation, the control unit for a given battery circuit monitors an operational state of the battery cell in the battery circuit and controls switches in the battery circuit in accordance with the operational state.” *Id.*, 5:60-63. “For example, control unit 20a-20n monitors changes in the state of charge (SOC) and voltage of its battery cells via sensing devices 54a-54n and 56a-56n.” *Id.*, 5:66-6:1.



*Id.*, Fig-1 (annotated). Then, at periodic monitoring intervals, the controller 50 of

the battery system measures the supply voltage (e.g., the average voltage  $V_a$  multiplied by the number of battery cells connected in series  $n_s$ ) of the battery pack (e.g., obtains a present electrical parameter of a battery). *Id.*, 5:48-50, 6:40-46, 15:45-66. A POSITA would therefore understand Kim to disclose claim element 9[a].

**c) 9[b] calculating a voltage compensation amount of the battery according to the present electrical parameter; and**

137. Kim's battery system calculates a voltage compensation amount of the battery according to the present electrical parameter. As explained above, the controller 50 of Kim's battery system obtains the supply voltage of the battery pack (e.g., the present electrical parameter of the battery). EX1008, 5:48-50, 6:40-46, 15:45-66. As illustrated by the below equation in Kim, the controller 50 then compares the measured supply voltage (e.g.,  $V_a * n_s$ ) of the battery pack to a demand voltage  $V_d$  and calculates the difference between the supply voltage and demand voltage. EX1008, 6:40-47, 15:45-66.

$$V_d \leq V_a * n_s < V_d + \alpha$$

EX1008, (4). This equation can be rewritten as " $0 \leq V_a * n_s - V_d < \alpha$ " by subtracting  $V_d$  from all three terms. A POSITA would understand that the calculated difference between  $V_a * n_s - V_d$  is "a voltage compensation amount of the battery according to the present electrical parameter."

138. If the supply voltage is less than the demand voltage  $V_d$  (e.g.,  $V_a * n_s - V_d < 0$ ) or greater than the sum of the demand voltage and alpha ( $V_a * n_s - V_d > \alpha$ )—“where  $\alpha$  specifies an upper bounds of voltage unbalancing”—the battery pack connectivity is reconfigured (e.g., by bypassing faulty cells and connecting healthy battery cells in a series chain) to compensate for the difference (e.g.,  $V_a * n_s - V_d$ ) below zero or above  $\alpha$  (e.g., a voltage compensation amount of the battery) and thereby keep the supply output voltage constant. EX1008 at 6:40-54, 6:65-7:42, 8:12-19, 15:45-16:7, Figs. 8A-8D. A POSITA would therefore understand that Kim discloses calculating a voltage compensation amount of its battery pack according to the present electrical parameter.

139. Accordingly, it is my opinion that Kim discloses element 9[b].

**d) 9[c] compensating an output voltage of the battery according to the voltage compensation amount to maintain the output voltage of the battery stable.**

140. Kim’s battery system compensates an output voltage of the battery according to the voltage compensation amount to maintain the output voltage of the battery stable. For example, as would be understood by a POSITA, the battery system of Kim compensates the supply voltage (e.g., the output voltage of the battery pack) based on the difference between the supply voltage— $V_a * n_s$ —and the demand voltage  $V_d$  (i.e.,  $V_a * n_s - V_d$  is the voltage compensation amount). EX1008, 6:40-48, 15:45-16:7. Specifically, if the supply voltage is less than the

demand voltage  $V_d$  (e.g.,  $V_a * n_s - V_d < 0$ ) or greater than the sum of the demand voltage and alpha ( $V_a * n_s - V_d > \alpha$ ), the battery pack connectivity is reconfigured to compensate for the difference (e.g.,  $V_a * n_s - V_d$ ) below zero or above  $\alpha$  (e.g., a voltage compensation amount of the battery) and thereby keep the supply voltage constant (e.g., maintain the output voltage of the battery stable). EX1008 at 6:40-54, 6:65-7:42, 8:12-19, 15:45-16:7, Figs. 8A-8D.

141. The output voltage is compensated according to the voltage compensation amount (e.g.,  $V_a * n_s - V_d$ ) by reconfiguring the battery cells in a series chain (e.g., by removing or adding battery cells) such that the output supply voltage is “above or equal to the demand voltage” and below the sum of the demand voltage and alpha (e.g.,  $0 \leq V_a * n_s - V_d < \alpha$ ). EX1008, (4), 6:40-54, 6:65-7:42, 8:11-19, 15:45-66; *see also id.* at 2:37-43. In this constant-voltage keeping scenario, Kim reconfigures the battery pack connectivity by calculating the new number of battery cells to be connected in series needed to maintain the output voltage stable (e.g., after calculating that the difference  $V_a * n_s - V_d$  is below zero or above alpha,  $V_d$  is divided by  $V_a$  and rounded up to the nearest integer to determine the new  $n_s$  that is needed to compensate the new voltage  $V_a * n_s - V_d$  to be greater than zero and below alpha). EX1008, 7:20-29, 15:59-66. The switches within Kim’s reconfigurable battery system are then controlled to implement the new battery cell configuration according to a configuration algorithm. EX1008, 8:45-

9:32.

142. The results of Kim's voltage compensation process are illustrated in, for example, Fig-8B, where at each reconfiguration, seen as a vertical step in voltage, the battery configuration is indicated in parenthesis as (# of cells in series "." # of cells in parallel, e.g., (142.4) means 142 in series and 4 in parallel). EX1008, Fig-8B, 15:55-66. In this figure, the "[d]emand voltage ( $V_d$ ) for an application is assumed to be 600 volts" as indicated as "600" on the y-axis and shown with a dashed horizontal line. *Id.* As the supply voltage in each time step indicated by an "x" decreases as the battery is discharged, it is compared with the demand voltage  $V_d$ , e.g., by calculating the difference  $V_a * n_s - V_d$ . *Id.* Soon after the supply voltage drops below the demand voltage ( $V_a * n_s - V_d$  is less than zero), the battery pack is reconfigured by adding one additional battery cell in series to increase the voltage back up, e.g., from (142.4) to (143.4). *Id.* A POSITA would understand that this process clearly represents compensation of the output voltage of the battery according to the compensation amount to maintain the output voltage of the battery stable (e.g., near 600 volts despite decreasing cell voltages as the battery is discharged).

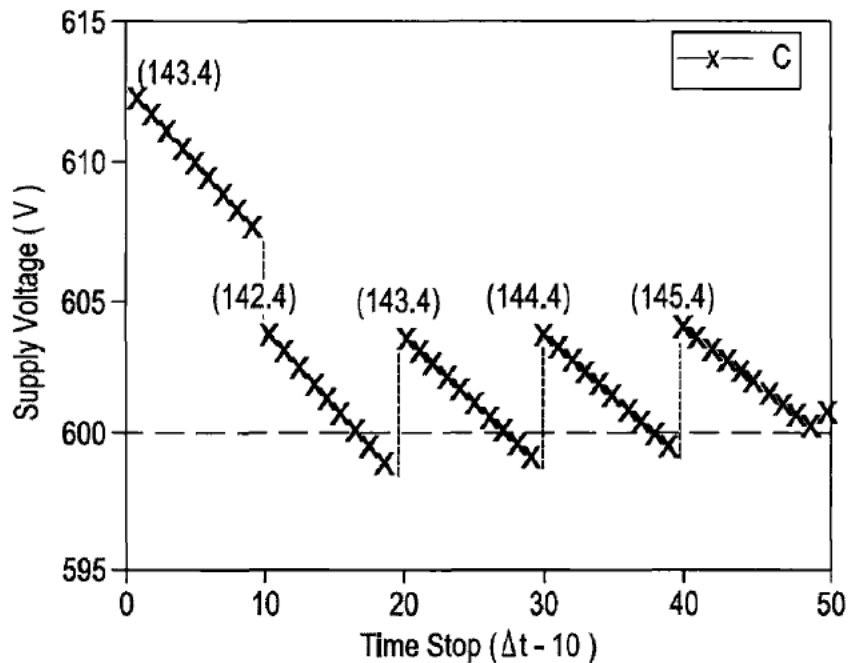


**Fig-8B**

143. Accordingly, it is my opinion that Kim discloses element 9[c].

2. **Claim 10: The method according to claim 9, wherein the present electrical parameter of the battery includes at least one of a present charge quantity of the battery, a present voltage of the battery, a present output electrical current of the battery, or a present internal resistance of the battery.**

144. As discussed with respect to element 9[a], Kim's battery system obtains the present voltage of the battery cells in a battery pack. EX1008, 5:48-50, 6:40-46, 15:45-66. Kim therefore discloses a present electrical parameter that includes a present voltage of the battery.

### 3. Claim 11

- a) **11[pre] The method according to claim 10, wherein:  
11[a] the present electrical parameter of the battery  
includes the present voltage of the battery; and:**

145. As discussed with respect to claims 9 and 10 above, the present electrical parameter of Kim's battery system that is obtained includes the present voltage of the battery. It is therefore my opinion that Kim discloses elements 11[pre] and 11[a].

- a) **11[b] calculating the voltage compensation amount of  
the battery includes:**
- b) **11[c] calculating the voltage compensation amount of  
the battery according to the present voltage of the  
battery and a full voltage of the battery, the voltage  
compensation amount being equal to a difference  
between the full voltage and the present voltage**

146. As discussed above with respect to claim element 9[b] and claim 10, Kim's battery system calculates the voltage compensation amount of the battery according to the present electrical parameter of the battery (*e.g.*, present voltage of the battery). *See supra* Sections X.C.1.c, X.C.2. In particular, the controller 50 compares the output supply voltage (*e.g.*,  $V_a * n_s$ ) to the output demand voltage  $V_d$  and calculates the difference between the supply voltage and demand voltage (*e.g.*,  $V_a * n_s - V_d$ ). EX1008, 6:40-47, 15:46-16:7. Kim emphasizes that "[i]n particular, the more steeply does the supply voltage drop, the larger the difference between the supply and demand voltages." EX1008, 16:1-3. The difference between the

supply and demand voltages (i.e.,  $V_a * n_s - V_d$ ) corresponds to the voltage compensation amount. Kim states that the compensation can be improved by “reducing the monitoring interval.” *Id.* at 16:3-4. This is the processing interval between voltage compensation events. EX1008, 6:40-47, 15:45-66, 16:1-6.

147. Furthermore, Kim discloses calculating this voltage compensation amount according to a target demand voltage  $V_d$  of the battery pack. A POSITA would understand the target demand voltage  $V_d$  to correspond to a “full voltage” of the battery pack. A POSITA would recognize that the “full voltage” of a cell within a battery pack is a target voltage indicative of when a battery cell is considered fully charged. A POSITA would further recognize that the full voltage of a battery cell would rarely if ever be set as the absolute maximum voltage that the battery cell can achieve, which occurs at the maximum possible charge that the battery cell can store. A POSITA would know that if a battery cell is brought to the absolute maximum voltage it can achieve, it is likely to be damaged and will at least irreversibly lose capacity if kept at the maximum voltage for an extended period of time. For this reason, it was and is common practice to designate the full voltage of a battery cell within a pack as the voltage of the cell when it is brought to a voltage that is a safe margin below the maximum voltage, and thus to a charge level that is a safe margin below the absolute maximum. Thus, a POSITA would recognize the demand voltage  $V_d$  as shown in Fig-8D and described in Kim to

represent at least as an exemplary embodiment a safe target voltage that the battery pack can reasonably maintain constant over the full life of the pack when the battery cells are fully charged. As shown in Fig-8D and described in Kim, the battery voltage is maintained constant (meaning stable) at the target full voltage within a small margin above and/or below that target (as determined by the parameter alpha).

148. To the extent that it is argued that  $V_d$  could be set to some other voltage than the full battery system voltage, it would have at least been obvious to a POSITA to set  $V_d$  as the full voltage of the battery system—*i.e.*, the output supply voltage when the battery pack is considered fully charged. This is because any lower voltage as a target value would cause underutilization of the battery pack due to the cells within the pack never being brought to what is considered a full charge. An underutilized storage battery would lead to a larger, heavier, and more expensive battery system because the physical size and cost of a battery is related to its capabilities when fully charged. There may be scenarios where what is considered a full voltage for an application is purposely set lower than the manufacture listed value, for example to further improve the battery life with additional margin below the absolute maximum voltage. In such a case, a POSITA would consider the new value as the “full voltage” for use of the battery cells in a battery pack for that application. Additionally, Kim considers applications such as

EVs where multiple voltages may be required to support different components. EX1008, 2:14-20, 11:34-40, 12:32-36. In these cases, the reconfigurable battery pack of Kim is configured into multiple packs with multiple output voltages, and each output would have a target “full voltage” that is maintained within a small margin above and/or below that target.

149. Moreover, to the extent it is argued that Kim does not expressly disclose calculating a voltage compensation amount that is equal to a difference between the full voltage and the present voltage, it would have nevertheless been obvious over Kim. For example, given Kim’s disclosure of reconfiguring battery connectivity such that the supply voltage satisfies the below equation, a POSITA would have found it obvious to calculate the difference between  $V_a * n_s$  and  $V_d$  to determine whether the equation is satisfied.

$$V_d \leq V_a * n_s < V_d + \alpha$$

EX1008, (4).

150. First, Kim specifically states that “the more steeply does the supply voltage drop, the larger the difference between the supply and demand voltages” when teaching methods to improve the constant-voltage keeping policy. EX1008, 16:1-3. This would cause a POSITA to consider solutions that calculate “the difference between the supply and demand voltages” when evaluating the equation. To simplify visualizing the calculation, a POSITA could easily rearrange equation

(4) to show the difference as  $0 \leq V_a * n_s - V_d < \alpha$  by subtracting  $V_d$  from both sides of the inequality.

151. Further, Kim describes that “since the voltage drop is unavoidable, the constant-voltage-keeping policy is applied to keep the supply voltage above or equal to the demand voltage while the supply voltage is being monitored” and uses Fig-8B to explain the process, indicating the demand voltage as a dotted line and the supply voltage plotted against it. EX1008 15:45-65, Fig-8B. This language and graphical depiction would clearly indicate to a POSITA that these two quantities, the demand and supply voltages, are being evaluated relative to the difference between them. A POSITA would immediately recognize in reviewing Fig-8B common solutions to evaluate the relative difference between the two values, such as using a difference calculation in a digital processor or using the positive and negative inputs in an operational amplifier in an analog circuit. This difference can be used as directly disclosed in Kim to determine when to reconfigure the battery pack in order to keep the difference within a small margin around zero.

152. Accordingly, it my opinion that Kim discloses or at least renders obvious elements 11[b] and 11[c].

## **XI. CONCLUSION**

153. For the reasons set forth above, it is my opinion that all Challenged

Claims of the '224 Patent are unpatentable.

154. If asked to do so, I may testify about any of the preceding topics. I may also provide a general tutorial on the relevant subject matters, including battery cells and battery packs, battery management systems, power converters, control systems, motors and motor drivers, and electric drive systems for electric vehicles. I may use demonstrative exhibits or refer to publicly-available information to aid my testimony at any proceeding.

155. I reserve the right to respond to any declarations that are submitted by Petitioner's expert witness(es), to any testimony by Petitioner's fact or expert witnesses or to any further decisions, including amendments, from the USPTO.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Executed in Hyde Park, Utah on July 16, 2023.

  
\_\_\_\_\_  
Regan Zane, Ph.D.



## Dr. Regan A. Zane

### Director ASPIRE NSF Engineering Research Center

**David G. and Diann L. Sant Endowed Professor**  
*Department of Electrical and Computer Engineering*

Utah State University, 4120 Old Main Hill, Logan, UT, 84322-4120  
435-797-9118 | regan.zane@usu.edu

#### SHORT BIO

---

Dr. Regan Zane is the Director of the Center for Advancing Sustainability through Powered Infrastructure for Roadway Electrification (ASPIRE), an NSF sponsored engineering research center involving 9 universities, more than 65 faculty, 200 students and a dozen full-time staff, 4 national lab partners, and more than 50 industry and innovation partners. He holds the David G. and Diann L. Sant Endowed Professor position at Utah State University in the Department of Electrical and Computer Engineering, where he founded the USU Power Electronics Lab (UPEL), the Electric Vehicle and Roadway (EVR) research facility and test track, and the Battery Limits and Survivability Test (BLAST) lab.

Dr. Zane has published more than 200 peer-reviewed articles, served as co-inventor on more than 30 issued patents, has received international and institutional recognition in research, teaching and innovation, and has raised more than \$85 million in research funding to date. His research programs cover key aspects of electrified transportation charging systems and infrastructure, from battery, vehicle, and charging systems to grid integration, smart charge management, demand response and distributed energy resources. His programs maintain a strong emphasis on collaboration with academic, government and industry partners to develop and transition innovative technologies into the marketplace.

Additional research topics include wireless power transfer, control of series/parallel input/output converters, high efficiency, high frequency, high power density, and high performance dc-dc, ac-dc, dc-ac power converters, ac and dc microgrids, battery management systems, drivers for LEDs and discharge lamps in energy efficient lighting systems, active stability control and adaptive tuning in multi-input, multi-output converter systems, active converter and system health monitoring, power integrated circuit design, and low-power energy harvesting.

#### EMPLOYMENT

---

- 2020 – present **Director**, NSF Advancing Sustainability through Powered Infrastructure for Roadway Electrification (ASPIRE) Engineering Research Center, College of Engineering, Utah State University.
- 2012 – present **Full Professor**, *Department of Electrical and Computer Engineering*, Utah State University. **David G. and Diann L. Sant Endowed Professor** (since 2018) and **USTAR Professor** (2012 – 2018). Founding Director of the Center for Sustainable Electrified Transportation (SELECT), Electric Vehicle & Roadway (EVR) Research Facility and Test Track and USU Power Electronics Lab (UPEL).
- 2008 – 2016 **Associate Professor**, *Department of Electrical, Computer, and Energy Engineering*, University of Colorado at Boulder.
- 2001 – 2008 **Assistant Professor**, *Department of Electrical and Computer Engineering*, University of Colorado at Boulder.
- 1999 – 2001 **Senior Research Scientist**, *Electronic Power Conversion*, Corporate Research & Development Center, General Electric, Niskayuna, NY. Principle researcher in area of custom integrated circuits for power management applications within GE businesses with an emphasis on miniature controllers for energy efficient lighting systems.

**EDUCATION**

| <b>Institution</b>                                                                                                                                                                    | <b>Degree</b>    | <b>Year</b> | <b>Field of Study</b>  |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|-------------|------------------------|
| University of Colorado at Boulder<br><b>Dissertation title</b> , “ <i>Development, analysis, and implementation of an ASIC controller for single-phase power factor correction.</i> ” | Ph.D. (GPA: 4.0) | 1999        | Electrical Engineering |
| University of Colorado Boulder                                                                                                                                                        | M.S. (GPA: 4.0)  | 1998        | Electrical Engineering |
| University of Colorado Boulder                                                                                                                                                        | B.S. (GPA: 4.0)  | 1996        | Electrical Engineering |

**HONORS AND AWARDS**

|             |                                                                                                                                                                        |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2021        | Campus Researcher of the Year Award, Utah State University                                                                                                             |
| 2020        | Utah Clean Cities Sustainability Partner of the Year (for SELECT & ASPIRE Centers)                                                                                     |
| 2019        | Utah Innovation Award in Clean Technology and Energy for “Robust and Efficient Battery Management System,” sponsored by Utah Governor’s Office of Economic Development |
| 2018        | David G. and Diann L. Sant Endowed Professor, Utah State University                                                                                                    |
| 2017        | Department Researcher of the Year Award, ECE Department, Utah State University                                                                                         |
| 2015        | Inaugural Director of the USU Electric Vehicle and Roadway (EVR) Research Facility and Test Track                                                                      |
| 2011        | Selected member of the 2012-2013 Defense Sciences Study Group (DSSG), Institute for Defense Analyses (IDA), US Defense Advanced Research Projects Agency (DARPA)       |
| 2011        | Holland Teaching Award, University of Colorado                                                                                                                         |
| 2009        | IEEE Power Electronics Society Transaction Prize Letter Award                                                                                                          |
| 2008        | IEEE Power Electronics Society Richard M. Bass Outstanding Young Power Electronics Engineer Award                                                                      |
| 2008        | Coleman Institute Faculty Sabbatical Fellowship                                                                                                                        |
| 2008        | John and Mercedes Peebles Innovation in Teaching Award, University of Colorado                                                                                         |
| 2007        | IEEE Power Electronics Society Transaction Prize Letter Award                                                                                                          |
| 2007        | Senior Member, IEEE                                                                                                                                                    |
| 2006        | Provost Faculty Achievement Award, University of Colorado                                                                                                              |
| 2006        | Inventor of the Year Award, Technology Transfer Office, University of Colorado                                                                                         |
| 2006        | IEEE MTT Microwave Prize for best journal paper                                                                                                                        |
| 2004        | NSF Faculty Early Career Development (CAREER) Program Award Recipient                                                                                                  |
| 2001        | Six-Sigma Green Belt Certificate, GE Corporate Research and Development                                                                                                |
| 2001        | Manager’s Award, General Electric Corporate Research and Development                                                                                                   |
| 1993 – 1998 | Member Dean’s list, University of Colorado                                                                                                                             |
| 1995 – 1996 | Marcellus and Geraldine Merrill Scholarship, University of Colorado                                                                                                    |
| 1992        | National DECA competition, 2 <sup>nd</sup> place in marketing and business                                                                                             |

**PUBLICATION RECORD**

**Books** (published or in press)

- [1] L. Corradini, D. Maksimovic, P. Mattavelli, R. Zane, *Digital control of high-frequency switched-mode power converters*, Hoboken, NJ: Wiley, 2015.

#### Journals (published or in press)

---

- [1] R. Hassan, H. Wang and R. Zane, "A New Online Continuous Stability Monitoring Method for DC Microgrids," in *IEEE Transactions on Power Electronics*, doi: 10.1109/TPEL.2023.3284512.
- [2] T. Newbolt, P. Mandal, H. Wang and R. Zane, "Sustainability of Dynamic Wireless Power Transfer Roadway for In-motion Electric Vehicle Charging," in *IEEE Transactions on Transportation Electrification*, doi: 10.1109/TTE.2023.3262202.
- [3] H. Wang, M. Rasheed, R. Hassan, M. Kamel, S. Tong and R. Zane, "Life-extended Active Battery Control for Energy Storage Using Electric Vehicle Retired Batteries," in *IEEE Transactions on Power Electronics*, vol. 38, no. 6, pp. 6801-6805, June 2023, doi: 10.1109/TPEL.2023.3252362.
- [4] S. Inoue, D. Goodrich, S. Saha, R. Nimri, A. Kamineni, N. Flann, R. Zane, "Fast Design Optimization Method Utilizing a Combination of Artificial Neural Networks and Genetic Algorithms for Dynamic Inductive Power Transfer Systems," in *IEEE Open Journal of Power Electronics*, vol. 3, pp. 915-929, 2022, doi: 10.1109/OJPEL.2022.3224422.
- [5] T. Saha, A. C. Bagchi, H. Wang and R. Zane, "Bidirectional LCL–T Resonant DC–DC Converter for Priority Loads in Undersea Distribution Networks," in *IEEE Transactions on Power Electronics*, Jun. 2022, doi: 10.1109/TPEL.2022.3187133.
- [6] M. Kamel, M. M. U. Rehman, F. Zhang, R. A. Zane and D. Maksimović, "Differential Input Current Regulation in Parallel Output Connected Battery Power Modules," in *IEEE Transactions on Power Electronics*, vol. 37, no. 4, pp. 3854-3864, April 2022, doi: 10.1109/TPEL.2021.3120365.
- [7] D. Trinkoa, N. Horesh, R. Zane, Z. Song, A. Kamineni, T. Konstantinou, K. Gkritza, C. Quinn, T. H. Bradley, J. C. Quinn, "Economic feasibility of in-motion wireless power transfer in a high-density traffic corridor," *eTransportation*, Volume 11, Feb. 2022, doi: 10.1016/j.etrans.2021.100154.
- [8] H. Alan Mantooth, R. Zane and M. Manjrekar, "Guest Editorial Special Section on Cybersecurity of Power Electronics Through Hardware Hardening," in *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 10, no. 1, pp. 1255-1257, Feb. 2022, doi: 10.1109/JESTPE.2021.3133857.
- [9] M. Kamel, V. Sankaranarayanan, R. Zane, D. Maksimovic, "State-of-Charge Balancing with Parallel and Series Output Connected Battery Power Modules," *IEEE Transactions on Power Electronics*, vol. 37, no. 6, pp. 6669 – 6677, Jan. 2022, doi: 10.1109/TPEL.2022.3143835.
- [10] M. Kamel, R. Zane, D. Maksimovic, "Voltage sharing with series output connected battery modules in a plug-and-play dc microgrid," *IEEE Transactions on Power Electronics*, vol. 3, no. 11, pp. 13118 – 13127, Nov. 2021, doi: 10.1109/TPEL.2021.3076475.
- [11] C. Teeneti, U. Pratik, G. Philips, A. Azad, M. Greig, R. Zane, C. Bodine, C. Coopmans, Z. Pantic, "System-level approach to designing a smart wireless charging system for power wheelchairs," *IEEE Transactions on Industry Applications*, vol. 57, no. 5, pp. 5128 – 5144, Sep. 2021, doi: 10.1109/TIA.2021.3093843.
- [12] N. Horesh, C. Quinn, H. Wang, R. Zane, M. Ferry, S. Tong, J. C. Quinn, "Driving to the future of energy storage: Techno-economic analysis of a novel method to recondition second life electric vehicle batteries," *Applied Energy*, Volume 295, Aug. 2021, doi: 10.1016/j.apenergy.2021.117007.
- [13] A. Bagchi, A. Kamineni, R. Zane, R. Carlson, "Review and comparative analysis of topologies and control methods in dynamic wireless charging of electric vehicles," *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 9, no. 4, pp. 4947 – 4962, Aug 2021, doi: 10.1109/JESTPE.2021.3058968.
- [14] T. Saha, A. Bagchi, R. Zane, "Analysis and Design of an LCL-T Resonant DC-DC Converter for Underwater Power Supply," *IEEE Transactions on Power Electronics*, Early Access, pp. 1 – 13, Oct. 2020.

- [15] P. Thummala, D. Yelaverthi, R. Zane, Z. Ouyang, M. Anderson, “A 10-MHz GaNFET-Based-Isolated High Step-Down DC-DC Converter: Design and Magnetics Investigation,” *IEEE Transactions on Industry Applications*, vol. 55, no. 4, pp. 3889 – 3900, Mar. 2019.
- [16] B. Limb, Z. Asher, T. Bradley, E. Sproul, D. Trinko, B. Crabb, R. Zane, J. Quinn, “Economic viability and environmental impact of in-motion wireless power transfer,” *IEEE Transactions on Transportation Electrification*, vol. 5, no. 1, pp. 135 – 146, Mar. 2019.
- [17] A. Azad, A. Echols, V. Kulyukin, R. Zane, Z. Pantic, “Analysis, Optimization, and Demonstration of a Vehicular Detection System Intended for Dynamic Wireless Charging Applications,” *IEEE Transactions on Transportation Electrification*, vol. 5, no. 1, pp. 147 – 161, Mar. 2019.
- [18] H. Wang, T. Saha, B. Riar, R. Zane, “Design considerations for current-regulated series-resonant converters with a constant input current,” *IEEE Transactions on Power Electronics*, vol. 34, no. 1, pp. 141-150, Jan. 2019.
- [19] T. Yilmaz, N. Hasan, R. Zane, Z. Pantic, “Multi-Objective Optimization of Circular Magnetic Couplers for Wireless Power Transfer Applications,” *IEEE Transactions on Magnetics*, vol. 53, no. 8, pp. 1 – 12, Aug. 2017.
- [20] W. Chen, R. Zane, L. Corradini, “Isolated bidirectional grid-tied three-phase ac-dc power conversion using series resonant converter modules and a three-phase unfold,” *IEEE Trans. Power Electron.*, vol. 32, no. 12, pp. 9001– 9012, Jan. 2017.
- [21] M. Evzelman, M. Rehman, K. Hathaway, R. Zane, D. Costinett, D. Maksimovic, “Active balancing system for electric vehicles with incorporated low voltage bus,” *IEEE Trans. Power Electron.*, vol. 31, no. 11, pp. 7887 – 7895, Nov. 2016.
- [22] H. Nguyen, R. Zane, D. Maksimovic, “On/off control of a modular DC-DC converter based on active-clamp LLC modules,” *IEEE Trans. Power Electron.*, vol. 30, no. 7, pp. 3748 – 3760, Jul. 2015.
- [23] D. Costinett, D. Maksimovic, R. Zane, “Circuit-oriented treatment of nonlinear capacitances in switched-mode power supplies,” *IEEE Trans. Power Electron.*, vol. 30, no. 2, pp. 985 – 995, Feb. 2015.
- [24] V. Lopez, F. Azcondo, R. Zane, “Universal digital controller for boost CCM power factor correction stages based on current rebuilding concept,” *IEEE Trans. Power Electron.*, vol. 29, no. 7, pp. 3818 – 3829, Jul. 2014.
- [25] L. Corradini, D. Seltzer, D. Bloomquist, R. Zane, D. Maksimovic, B. Jacobson, “Zero voltage switching technique for bidirectional DC/DC converters,” *IEEE Trans. Power Electron.*, vol. 29, no. 4, pp. 1585 – 1594, Apr. 2014.
- [26] Z. Popovic, S. Korhummel, S. Dunbar, R. Scheeler, A. Dolgov, R. Zane, E. Falkenstein, J. Hagarty, “Scalable RF Energy Harvesting,” *IEEE Trans. Microw. Theory Tech.*, vol. 62, no. 4, pp. 1046 – 1056, Apr. 2014.
- [27] Z. Popovic, E. Falkenstein, D. Costinett, R. Zane, “Low-power far-field wireless powering for wireless sensors,” *Proceedings of the IEEE*, invited paper, Vol. 101, No. 6, pp. 1397 – 1409, Jun. 2013.
- [28] R. Schnell, R. Zane, F. Azcondo, “Size reduction in low-frequency square-wave ballasts for high-intensity discharge lamps using soft-saturation magnetic material and digital control techniques,” *IEEE Trans. Power Electron.*, vol. 28, no. 2, pp. 1036 – 1046, Feb. 2013.
- [29] D. Costinett, D. Maksimovic, R. Zane, “Design and Control for High Efficiency in High Step-Down Dual Active Bridge Converters Operating at High Switching Frequency,” *IEEE Trans. Power Electron.*, vol. 28, No. 8, pp. 3931 – 3940, Aug. 2013.
- [30] L. Corradini, D. Seltzer, D. Bloomquist, R. Zane, D. Maksimovic, B. Jacobson, “Minimum current operation of bi-directional dual-bridge series resonant DC/DC converters,” *IEEE Trans. Power Electron.*, Vol. 27, No. 7, pp. 3266 – 3276, Jul. 2012.
- [31] V. Lopez, A. Navarro, R. Schnell, C. Branas, F. Azcondo, R. Zane, “Current phase surveillance in resonant converters for electric discharge applications to assure operation in zero-voltage-switching mode,” *IEEE Trans. Power Electron.*, Vol. 27, No. 6, pp. 2925 – 2935, Jun. 2012.
- [32] C. Branas, F. Azcondo, R. Zane, “Power-mode control of multiphase resonant electronic ballast,” *IEEE Trans. Ind. Electron.*, vol. 59, no. 4, pp. 1770 – 1778, Apr. 2012.
- [33] E. Falkenstein, D. Costinett, R. Zane, Z. Popovic, “Far-field RF-powered variable duty-cycle wireless sensor platform,” *IEEE Trans. Circuits Syst. II*, vol. 58, no. 12, pp. 822 – 826, Dec. 2011.

- [34] Q. Hu, R. Zane, “Minimizing required energy storage in off-line LED drivers based on series-input converter modules,” *IEEE Trans. Power Electron.*, Vol. 26, No. 10, pp. 2887 – 2895, Oct. 2011.
  - [35] L. Corradini, A. Bjeletic, R. Zane, D. Maksimovic, “Fully digital hysteretic modulator for DC-DC switching converters,” *IEEE Trans. Power Electron.*, vol. 26, no. 10, pp. 2969 – 2979, Oct. 2011.
  - [36] T. Paing, E. Falkenstein, R. Zane, Z. Popovic, “Custom IC for ultra-low power RF energy scavenging,” *IEEE Trans. Power Electron.*, vol. 26, no. 6, pp. 1620 – 1626, Jun. 2011.
  - [37] D. Maksimovic, R. Zane, L. Corradini, “Advances in digital control for high-frequency switched-mode power converters,” *Power Electronics monthly*, sponsored by Xi'an Power Electronics Research Institute, China, vol. 44, no. 12, pp. 2-19, serial no. 217, Dec. 2010.
  - [38] F. Diaz, F. Azcondo, C. Branas, R. Casanueva, R. Zane, “Digitally controlled low-frequency square-wave electronic ballast with resonant ignition and power loop,” *IEEE Trans. Ind. Appl.*, vol. 46, no. 6, pp. 2222 – 2232, Nov. 2010.
  - [39] M. Doshi, R. Zane, “Control of solid state lamps using a multiphase pulse width modulation technique,” *IEEE Trans. Power Electron.*, vol. 25, no. 7, pp. 1894 – 1904, Jul. 2010.
  - [40] A. Dolgov, R. Zane, Z. Popovic, “Power management system for online low power RF energy harvesting optimization,” *IEEE Trans. Circuits Syst.*, vol. 57, no. 7, pp. 1802 – 1811, Jul. 2010.
  - [41] Q. Hu, R. Zane, “LED driver circuit with series-input-connected converter cells operating in continuous conduction mode,” *IEEE Trans. Power Electron.*, vol. 25, no. 3, pp. 574 – 582, Mar. 2010.
  - [42] J. Morroni, R. Zane, D. Maksimovic, “An Online Stability Margin Monitor for Digitally Controlled Switched-Mode Power Supplies,” *IEEE Trans. Power Electron.*, vol. 24, no. 11, pp. 2639 – 2648, Nov. 2009.
  - [43] J. Morroni, L. Corradini, R. Zane, D. Maksimovic, “Adaptive tuning of switched-mode power supplies operating in discontinuous and continuous conduction modes,” *IEEE Trans. Power Electron.*, vol. 24, no. 11, pp. 2603 – 2611, Nov. 2009.
  - [44] M. Shirazi, R. Zane, D. Maksimovic, “An Auto-tuning Digital Controller for DC-DC Power Converters Based on On-line Frequency Response Measurement,” *IEEE Trans. Power Electron.*, vol. 24, no. 11, pp. 2578 – 2588, Nov. 2009.
  - [45] M. Doshi, R. Zane, F. Azcondo, “Low frequency architecture for multi-lamp CCFL systems with capacitive ignition,” *IEEE J. Displ. Technol.*, vol. 5, no. 5, pp. 152 – 161, May 2009.
  - [46] J. Morroni, R. Zane, D. Maksimovic, “Design and implementation of an adaptive tuning system based on desired phase margin for digitally controlled DC-DC converters,” *IEEE Trans. Power Electron.*, vol. 24, no. 2, pp. 559 – 564, Feb. 2009.
- \*Received IEEE Power Electronic Society 2009 Prize Transactions Letter Award
- [47] M. Shirazi, J. Morroni, A. Dolgov, R. Zane, D. Maksimovic, “Integration of frequency response measurement capabilities in digital controllers for DC-DC converters,” *IEEE Trans. Power Electron.*, vol. 23, no. 5, pp. 2524 – 2535, Sep. 2008.
  - [48] F. Javier Diaz, F. J. Azcondo, Ch. Branas, R. Casanueva, R. Zane, “Digital control of a low-frequency square-wave electronic ballast with resonant ignition,” *IEEE Trans. Ind. Electron.*, vol. 55, no. 9, pp. 3180 – 3191, Sep. 2008.
  - [49] Y. Yin and R. Zane, “Dual low-voltage IC design for high-voltage floating gate drives,” *IEEE Trans. Circuits Syst. I, Reg. Papers*, vol. 55, no. 6, pp. 1751 – 1758, Sep. 2008.
  - [50] T. Carosa, R. Zane, D. Maksimović, “Scalable digital multiphase modulator,” *IEEE Trans. Power Electron., Lett.*, vol. 23, no. 4, pp. 2201-2205, Jul. 2008.
  - [51] T. Paing, J. Shin, R. Zane, Z. Popovic, “Resistor emulation approach to low-power RF energy harvesting,” *IEEE Trans. Power Electron.*, vol. 23, no. 3, pp. 1494 – 1501, May 2008.
  - [52] Y. Yin, M. Shirazi, R. Zane, “Electronic ballast control IC with digital phase control and lamp current regulation,” *IEEE Trans. Power Electron.*, vol. 23, no. 1, pp. 11 – 18, Jan. 2008.

- [53] D. Maksimović, R. Zane, “Small-signal discrete-time modeling of digitally controlled DC-DC converters,” *IEEE Trans. Power Electron., Lett.*, vol. 22, no. 6, pp. 2552 – 2556, Nov. 2007.  
\*Received the 2007 IEEE Power Electronics Society Transaction Prize Letter Award.
- [54] X. Zhao, T. Qian, G. Mei, C. Kwan, C. Walsh, T. Paing, R. Zane, Z. Popovic, “Active health monitoring of an aircraft wing with an embedded piezoelectric sensor/actuator network: II. Wireless approaches,” *Smart Mater. Struct.* 16 (2007) 1218 – 1225.
- [55] F.J. Azcondo, R. Zane, Ch. Brañas, “Design of resonant inverters for optimal efficiency over lamp life in electronic ballast with phase control,” *IEEE Trans. Power Electron., special issue on lighting*, vol. 22, no. 3, pp. 815 – 823, May 2007.
- [56] S. Johnson, R. Zane, “Custom spectral shaping for EMI reduction in high frequency inverters and ballasts,” *IEEE Trans. Power Electron.*, vol. 20, no. 6, pp. 1499 – 1505, Nov. 2005.
- [57] B. Miao, R. Zane, D. Maksimović, “System identification of power converters with digital control through cross-correlation methods,” *IEEE Trans. Power Electron.*, vol. 20, no. 5, pp. 1093 – 1099, Sep. 2005.
- [58] Y. Zhang, R. Zane, R. Erickson, D. Maksimović, A. Prodic “On-line calibration of MOSFET switch on-state resistance for precise current sensing,” *IEEE Trans. Power Electron., Lett.*, vol. 2, no. 3, pp. 100 – 103, Sep. 2004.
- [59] Y. Yin, R. Zane, R. Erickson, J. Glaser, “Direct modeling of envelope dynamics in resonant inverters,” *IEE Electron. Lett.*, vol. 40, no. 13, pp. 834 – 836, Jun. 2004.
- [60] Y. Yin, R. Zane, “Digital phase control for resonant inverters,” *IEEE Trans. Power Electron., Lett.*, vol. 2, no. 2, pp. 51 – 53, June 2004.
- [61] J. Hagerty, F. Helmbrecht, W. McCalpin, R. Zane, Z. Popovic, “Recycling ambient microwave energy with broadband rectenna arrays,” *IEEE Trans. Microw. Theory Tech.*, vol. 52, no. 3, pp. 1014 – 1024, Mar. 2004.  
\*Received the 2006 IEEE MTT Microwave Prize for best journal paper.
- [62] Y. Yin, R. Zane, J. Glaser, R. Erickson, “Small-signal analysis of frequency-controlled electronic ballasts,” *IEEE Trans. Circuits Syst. I: Fundam. Theory and Appl.*, vol. 50, No. 8, pp. 1103 – 1110, Aug. 2003.
- [63] R. Zane, D. Maksimović, “Nonlinear-carrier control for high-power-factor rectifiers based on up-down switching converters,” *IEEE Trans. Power Electron.*, vol. 13, no. 2, pp. 213 – 221, Mar. 1998.

#### **Full Conference Papers with Peer Review (published or in press)**

- 
- [1] A. Zade, C. R. Teeneti, S. Gurudiwan, S. Poddar, M. Mansour and R. Zane, "Analysis and Mitigation of Sector Transition Distortions for Unfolding-based Grid-tied AC-DC Converters," 2023 IEEE Applied Power Electronics Conference and Exposition (APEC), Orlando, FL, USA, 2023, pp. 1945-1952, doi: 10.1109/APEC43580.2023.10131393.
  - [2] S. Gurudiwan, R. Hatch, M. Mansour, H. Wang and R. Zane, "An 18 kW Battery Charger Module for Extreme Fast Charging Applications Using an Unfolding-Based AC-DC Topology," 2023 IEEE Applied Power Electronics Conference and Exposition (APEC), Orlando, FL, USA, 2023, pp. 1715-1722, doi: 10.1109/APEC43580.2023.10131542.
  - [3] T. M. Newbolt, P. Mandal, H. Wang and R. Zane, "Diverse Effects of Dynamic Wireless Power Transfer Roadway In-Motion Electric Vehicle Charging," 2023 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT), Washington, DC, USA, 2023, pp. 1-5, doi: 10.1109/ISGT51731.2023.10066429.
  - [4] M. Rasheed, C. Simpson, H. Wang and R. Zane, "Multi-Loop Control of Hybrid Li-ion Battery Packs Using the Auxiliary DC Bus for State-of-Charge Regulation," 2022 IEEE Energy Conversion Congress and Exposition (ECCE), Detroit, MI, USA, 2022, pp. 1-8, doi: 10.1109/ECCE50734.2022.9947462.
  - [5] M. Chawla, et al., "Modeling and Comparative Analysis of Power Distribution Architectures for Large-scale Electric Vehicle In-motion Wireless Charging Infrastructures," 2022 Wireless Power Week (WPW), Bordeaux, France, 2022, pp. 887-892, doi: 10.1109/WPW54272.2022.9901363.
  - [6] S. Inoue, C. R. Teeneti, D. Goodrich, J. Larsen, A. Kamineni and R. Zane, "High-Power Field-Focusing Circuit for Dynamic Wireless Power Transfer Systems," 2022 Wireless Power Week (WPW), Bordeaux, France, 2022, pp. 699-704, doi: 10.1109/WPW54272.2022.9901335.

- [7] M. Rasheed, H. Wang and R. Zane, "Analysis of a Five-Port Differential Power Processing Triple Active Bridge Converter for Active Cell Balancing in Lithium-ion Battery Packs," 2022 IEEE 23rd Workshop on Control and Modeling for Power Electronics (COMPEL), Jun. 2022, pp. 1-8, doi: 10.1109/COMPEL53829.2022.9829999.
- [8] B. Maughan, A. Mustafa, R. Zane and H. Wang, "Hot Swapping Analysis and System Operation of Series Connected Converters in Active Battery Reconditioning Systems for Second Life Battery Applications," 2022 IEEE 23rd Workshop on Control and Modeling for Power Electronics (COMPEL), Jun. 2022, pp. 1-6, doi: 10.1109/COMPEL53829.2022.9830014.
- [9] M. Mansour, D. B. Yelaverthi and R. Zane, "Voltage Balancing Control for Input-Series-Output-Parallel Three-Port Series Resonant Converter Modules," 2022 IEEE Applied Power Electronics Conference and Exposition (APEC), Mar. 2022, pp. 01-08, doi: 10.1109/APEC43599.2022.9773534.
- [10] K. Khatun, R. Zane, H. Wang and A. K. Rathore, "High Gain Non-isolated Interleaved Current-fed 3-Phase Partial Series Resonance Pulse Based ZCS Voltage Quadrupler," 2022 IEEE Applied Power Electronics Conference and Exposition (APEC), 2022, pp. 1048-1055, doi: 10.1109/APEC43599.2022.9773759.
- [11] S. Inoue, R. Nimri, A. Kamineni and R. Zane, "A New Design Optimization Method for Dynamic Inductive Power Transfer Systems utilizing a Neural Network," 2021 IEEE Energy Conversion Congress and Exposition (ECCE), Oct. 2021, pp. 1496-1501, doi: 10.1109/ECCE47101.2021.9595560.
- [12] M. Hansen, A. Kamineni and R. Zane, "Current Harmonics Dead Time Design Method to Achieve ZVS with Non-Linear Output Capacitance," 2021 IEEE Energy Conversion Congress and Exposition (ECCE), Oct. 2021, pp. 2189-2196, doi: 10.1109/ECCE47101.2021.9595311.
- [13] A. Palomino, M. Parvania and R. Zane, "Impact of COVID-19 on Mobility and Electric Vehicle Charging Load," 2021 IEEE Power & Energy Society General Meeting (PESGM), Jul. 2021, pp. 01-05, doi: 10.1109/PESGM46819.2021.9638077.
- [14] D. Yelaverthi, B. Hesterman, M. Mansour, R. Zane, "CLLLC Dual Active Bridge with Novel Insulation Approach for SST Applications," IEEE Applied Power Electronics Conference, APEC 2021, Jun. 2021, pp. 1651-1658, doi: 10.1109/APEC42165.2021.9487105.
- [15] S. Inoue, R. Nimri, A. Kamineni, R. Zane, "High-resolution design optimization for IPT including stray field and coupling coefficient," IEEE Applied Power Electronics Conference, APEC 2021, virtual conference and exposition, Jun. 2021, pp. 1573-1579, doi: 10.1109/APEC42165.2021.9487332.
- [16] M. Rasheed, H. Wang, R. Zane, D. Maksimovic, K. Afridi, G. Plett, M.S. Trimboli, "Composite hybrid energy storage system utilizing capacitive coupling for hybrid and electric vehicles," IEEE Applied Power Electronics Conference, APEC 2021, Jun. 2021, pp. 939-946, doi: 10.1109/APEC42165.2021.9487261.
- [17] R. Nimri, A. Kamineni, R. Zane, "A Modular Pad Design Compatible with SAE J2954 for Dynamic Inductive Power Transfer," IEEE PELS Workshop on Emerging Technologies: Wireless Power Transfer, WoW 2020, Seoul, Korea, Nov. 15 – Nov. 19, 2020, pp. 1-8.
- [18] B. Varghese, A. Kamineni, N. Roberts, M. Halling, D. Thrimawithana, R. Zane, "Design Considerations for 50 kW Dynamic Wireless Charging with Concrete-Embedded Coils," IEEE PELS Workshop on Emerging Technologies: Wireless Power Transfer, WoW 2020, Seoul, Korea, Nov. 15 – Nov. 19, 2020, pp. 1-8.
- [19] T. Saha, A. Bagchi, R. Zane, "Time-domain and ZVS Assistance Design for a DAB LCL-T Resonant Converter in Underwater DC Current Distribution Network," IEEE 21<sup>st</sup> Workshop on Control and Modeling for Power Electronics, COMPEL 2020, Aalborg, Denmark, Nov. 9 – Nov. 12, 2020, pp. 1 – 7.
- [20] M. Rasheed, M. Kamel, H. Wang, R. Zane, K. Smith, "Investigation of Active Life Balancing to Recondition Li-ion Battery Packs for 2nd Life," IEEE 21<sup>st</sup> Workshop on Control and Modeling for Power Electronics, COMPEL 2020, Aalborg, Denmark, Nov. 9 – Nov. 12, 2020, pp. 1 – 7.
- [21] A. Bagchi, A. Kamineni, R. Zane, R. Carlson, "Comparative Analysis of DWPT Topologies and Regulation Schemes for Improved Controllability," IEEE Energy Conversion Congress and Exposition, ECCE 2020, Detroit, MI, Oct. 11 – Oct. 15, 2020, pp. 1 - 8.
- [22] B. Varghese, R. Tavakoli, Z. Pantic, R. Zane, A. Kamineni, "Multi-Pad Receivers for High Power Dynamic Wireless Power Transfer," IEEE Energy Conversion Congress and Exposition, ECCE 2020, Detroit, MI, Oct. 11 – Oct. 15, 2020, pp. 1 - 8.

- [23] M. Hansen, A. Kamineni, R. Zane, “Zero-Crossing Current Detection for Modular and Robust Dynamic Wireless Power Transfer,” *IEEE Energy Conversion Congress and Exposition, ECCE 2020*, Detroit, MI, Oct. 11 – Oct. 15, 2020, pp. 1 - 8.
- [24] C. Teeneti, R. Hatch, D. Yelaverthi, A. Kamineni, H. Wang, R. Zane, “Unfolder-Based Single-Stage AC-AC Conversion System for Wireless Charging Applications,” *IEEE Energy Conversion Congress and Exposition, ECCE 2020*, Detroit, MI, Oct. 11 – Oct. 15, 2020, pp. 1 - 8.
- [25] G. Y. Dayanikli\*, R. R. Hatch\*, R. M. Gerdes, H. Wang and R. Zane, "Electromagnetic Sensor and Actuator Attacks on Power Converters for Electric Vehicles," *2020 IEEE Security and Privacy Workshops (SPW)*, San Francisco, CA, May 21, 2020, pp. 98-103, doi: 10.1109/SPW50608.2020.00032. \*Dayanikli and Hatch are co-first authors from separate institutions and disciplines.
- [26] M. Kamel, V. Sankaranarayanan, D. Maksimovic, R. Zane, “State-of-charge control with series output connected DC-DC modules in active battery management systems,” *IEEE Applied Power Electronics Conference, APEC 2020*, New Orleans, LA, Mar. 2020.
- [27] D. Yelaverthi, R. Hatch, M. Mansour, H. Wang, R. Zane, “3-Level asymmetrical full bridge soft-switched PWM converter for 3-phase unfolding based battery charger topologies,” *IEEE Energy Conversion Congress and Exposition, ECCE 2019*, Baltimore, MD, Sep. 29 – Oct. 3, 2019, pp. 2737 – 2743.
- [28] B. Varghese, A. Kamineni, R. Zane, “Empirical closed-form analysis for inductance and coupling coefficient calculation for ferrite-based matched inductive charging systems,” *IEEE Energy Conversion Congress and Exposition, ECCE 2019*, Baltimore, MD, Sep. 29 – Oct. 3, 2019, pp. 1210 – 1214.
- [29] D. Yelaverthi, M. Mansour, H. Wang, R. Zane, “Triple Active Bridge Series Resonant Converter for three-Phase Unfolding Based Isolated Converters,” *IEEE Industrial Electronics Society Annual Conference, IECON 2019*, Lisbon, Portugal, Oct. 2019, pp. 4924 – 4930.
- [30] B. Varghese, A. Kamineni, R. Zane, “Investigation of a DD2Q pad structure for high power inductive power transfer,” *IEEE Wireless Power Workshop, WPW2019*, London, England, Jun. 2019, pp. 129 – 133.
- [31] A. Azad, C.R. Teeneti, R. Zane, Z. Pantic, “DAB-based WPT Charger with Integrated Battery Management System for Fast Charging of Mobility Devices,” *IEEE Transportation Electrification Conference and Expo, ITEC 2019*, Detroit, MI, Jun. 2019, pp. 1 – 6.
- [32] D. Yelaverthi, M. Kamel, R. Hassan, R. Zane, “High Frequency Link Isolated Multi-Port Converter for Active Cell Balancing Applications,” *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2019*, Toronto, Canada, June 2019, pp. 1 – 7.
- [33] M. Rasheed, B. Riar, R. Zane, “Power Sharing Based Algorithm for Sizing Components in Fuel Cell Hybrid Electric Vehicles,” *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2019*, Toronto, Canada, June 2019, pp. 1 – 8.
- [34] M. Kamel, R. Zane, D. Maksimovic, “Voltage Sharing of Series Connected Battery Modules in a Plug-and-Play DC Microgrid,” *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2019*, Toronto, Canada, June 2019, pp. 1 – 7.
- [35] R. Hassan, H. Wang, R. Zane, “Continuous stability monitoring of DC microgrids using controlled injection,” *IEEE Applied Power Electronics Conference, APEC 2019*, Anaheim, CA, Mar. 2019, pp. 1357 – 1364.
- [36] M. Kamel, M. Rehman, F. Zhang, D. Maksimovic, R. Zane, “Control of independent-input, parallel-output DC/DC converters for modular battery building blocks,” *IEEE Applied Power Electronics Conference, APEC 2019*, Anaheim, CA, Mar. 2019, pp. 234 – 240.
- [37] A. Bagchi, H. Wang, T. Saha, R. Zane, “Small-signal phasor modeling of an underwater IPT system in constant current distribution,” *IEEE Applied Power Electronics Conference, APEC 2019*, Anaheim, CA, Mar. 2019, pp. 876 – 883.
- [38] D. Yelaverthi, M. Rehman, R. Zane, “Differential Power Processing Three-port Dual Active Bridge Converter for Active Balancing in Large Battery Packs,” *Proc. IEEE Energy Conversion Congress and Exposition, ECCE 2018*, Portland, OR, Sep. 2018, pp. 5591 – 5597.

- [39] A. Bagchi, A. Kamineni, R. Zane, “Analytical Optimization of a Litz Wire Spiral Coil Based Underwater IPT System,” *Proc. IEEE Energy Conversion Congress and Exposition, ECCE 2018*, Portland, OR, Sep. 2018, pp. 2456 – 2463.
- [40] W. Chen, B. Riar, R. Zane, “Battery Integrated Modular Multifunction Converter for Grid Energy Storage,” *Proc. IEEE Energy Conversion Congress and Exposition, ECCE 2018*, Portland, OR, Sep. 2018, pp. 2157 – 2163.
- [41] W. Wang, D. Thrimawithana, B. Riar, R. Zane, “A Novel Integrated Boost Modular Multilevel Converter for High Power Wireless EV Charging,” *Proc. IEEE Energy Conversion Congress and Exposition, ECCE 2018*, Portland, OR, Sep. 2018, pp. 81 – 88.
- [42] T. Saha, A. Bagchi, H. Wang, R. Zane, “Analysis and Design of Wide Range Output Voltage Regulated Power Supply for Underwater Constant Input Current DC Distribution System,” *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2018*, Padova, Italy, June 25-28 2018, pp. 1 – 7.
- [43] R. Hassan, H. Wang, M. Rehman, B. Riar, R. Zane, “Nodal Impedance-Based Stability Analysis of DC Nanogrids,” *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2018*, Padova, Italy, June 25-28 2018, pp. 1 – 7.
- [44] A. Bagchi, T. Saha, A. Kamineni, R. Zane, “Analysis and Design of a Wireless Charger for Underwater Vehicles fed from a Constant Current Distribution Cable,” *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2018*, Padova, Italy, June 25-28 2018, pp. 1 – 8.
- [45] H. Wang, T. Saha, R. Zane, “Small Signal Phasor Modeling of Phase-shift Modulated Series Resonant Converters with Constant Input Current,” *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2018*, Padova, Italy, June 25-28, 2018, pp. 1 – 8.
- [46] E. Sproul, D. Trinko, Z. Asher, B. Limb, T. Bradley, J. Quinn, R. Zane, “Electrification of Class 8 Trucking: Economic Analysis of In-Motion Wireless Power Transfer Compared to Long-Range Batteries,” *Proc. IEEE Transportation Electrification Conference and Expo, ITEC 2018*, Long Beach, CA, June 13-15, 2018, pp. 744 – 748.
- [47] P. Thummala, D. Yelaverthi, R. Zane, “A 10 MHz GaNFET based isolated high step-down DC-DC converter,” *Proc. IEEE Energy Conversion Congress Asia, IPEC-Niigata / ECCE-Asia 2018*, Niigata, Japan, Jun. 2018, pp. 4066 – 4073.
- [48] H. Wang, T. Saha, B. Riar, R. Zane, “Operational Study and Protection of a Series Resonant Converter with DC Current Input Applied in DC Current Distribution Systems,” *IEEE Energy Conversion Congress Asia, IPEC-Niigata / ECCE-Asia 2018*, Niigata, Japan, Jun. 2018, pp. 4145 – 4150.
- [49] T. Saha, H. Wang, B. Riar, R. Zane, “Analysis and design of a parallel resonant converter for constant current input to constant voltage output DC-DC converter over wide load range,” *IEEE Energy Conversion Congress Asia, IPEC-Niigata / ECCE-Asia 2018*, Niigata, Japan, Jun. 2018, pp. 4074 – 4079.
- [50] T. Saha, H. Wang, B. Riar, R. Zane, “An improved active zero voltage switching assisting circuit with lower dv/dt for DC-DC series resonant converter with constant input current,” *IEEE Applied Power Electronics Conference, APEC 2018*, San Antonio, TX, Mar. 2018, pp. 826 – 831.
- [51] G. Kalra, D. Thrimawithana, M. Neuburger, B. Riar, U. Madalawa, R. Zane, “A novel boost active bridge based wireless power interface for V2G/G2V applications,” *Proc. IEEE Southern Power Electronics Conference, SPEC 2017*, Puertos Varas, Chile, Dec. 2017, pp. 1-6.
- [52] F. Zhang, M. Rehman, R. Zane, D. Maksimovic, “Hybrid Balancing in a Modular Battery Management System for Electric-Drive Vehicles,” *Proc. IEEE Energy Conversion Congress and Exposition, ECCE 2017*, Cincinnati, OH, Oct. 2017, pp. 578 – 583.
- [53] B. Riar, T. Geyer, R. Zane, “Current THD Analysis in Direct Model Predictive Control,” *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2017*, Stanford, CA July 9-12, 2017, pp. 1 – 7.
- [54] T. Saha, H. Wang, R. Zane, “Zero Voltage Switching Assistance Design for DC-DC Series Resonant Converter with Constant Input Current for Wide Load Range,” *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2017*, Stanford, CA July 9-12, 2017, pp. 1 – 5.

- [55] W. Chen, B. Riar, R. Zane, “A three-port series resonant converter for three-phase unfolding inverters,” *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2017*, Stanford, CA July 9-12, 2017, pp. 1 – 7.
- [56] H. Wang, T. Saha, R. Zane, “Impedance-Based Stability Analysis and Design Considerations for DC Current Distribution with Long Transmission Cable,” *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2017*, Stanford, CA July 9-12, 2017, pp. 1 – 8.
- [57] Y. Shi, K. Smith, R. Zane, D. Anderson, “Life prediction of large lithium-ion battery packs with active and passive balancing,” *Proc. American Control Conference (ACC)*, Seattle, WA, May 2017, pp. 4704 – 4709.
- [58] R. D. Anderson, R. Zane, G. Plett, D. Maksimovic, K. Smith, M. S. Trimboli, “Life balancing – a better way of battery management for large battery packs,” *Society of Automotive Engineers (SAE) World Congress Experience*, Detroit, MI, Apr. 4-6, 2017.
- [59] M. Evzelman, H. Wang, R. Zane, X. Zhao, “Two-stage sinusoidal generator with calibration and pulse train amplitude feedback for ultrasonic applications,” *Proc. IEEE Applied Power Electronics Conference, APEC 2017*, Tampa, FL, Mar. 2017, pp. 2124 – 2130.
- [60] M. Rehman, F. Zhang, R. Zane, D. Maksimovic, “Control of bidirectional dc/dc converters in reconfigurable, modular battery systems,” *Proc. IEEE Applied Power Electronics Conference, APEC 2017*, Tampa, FL, Mar. 2017, pp. 1277 – 1283.
- [61] H. Wang, T. Saha, R. Zane, “Analysis and design of a series resonant converter with constant current input and regulated output current,” *Proc. IEEE Applied Power Electronics Conference, APEC 2017*, Tampa, FL, Mar. 2017, pp. 1741 – 1747.
- [62] T. Saha, H. Wang, B. Riar, R. Zane, “Analysis of zero voltage switching requirements and passive auxiliary circuit design for dc-dc series resonant converters with constant input current,” *Proc. IEEE Southern Power Electronics Conference, SPEC 2016*, Auckland, New Zealand, Dec. 2016, pp. 1-6.
- [63] B. Riar, D. Howey, D. Thrimawithana, D. Rogers, R. Zane, “Bidirectional current source converter: design, control and performance evaluation,” *Proc. IEEE Southern Power Electronics Conference, SPEC 2017*, Auckland, New Zealand, Dec. 2016, pp. 1-6.
- [64] W. Chen, R. Zane, “Active rectifier system using three-phase unfold and series resonant converters controlled in synchronous rotating frame,” *Proc. IEEE Telecommunications Energy Conference, INTELEC 2016*, Austin, TX, Oct 2016, pp. 1-7.
- [65] B. Limb, B. Crabb, R. Zane, T. Bradley, J. Quinn, “Economic feasibility and infrastructure optimization of in-motion charging of electric vehicles using wireless power transfer,” *Proc. IEEE PELS Workshop on Emerging Technologies: Wireless Power Transfer WoW 2016*, Knoxville, TN, Oct 2016, pp. 42 – 46.
- [66] M. Rehman, F. Zhang, R. Zane, D. Maksimovic, “Advanced cell-level control for extending electric vehicle battery pack lifetime,” *Proc. IEEE Energy Conversion Congress and Exposition, ECCE 2016*, Milwaukee, WI, Sept. 2016, pp. 1-8.
- [67] M. Rehman, F. Zhang, R. Zane, D. Maksimovic, “Design and control of an integrated BMS/DC-DC system for electric vehicles,” *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2016*, Trondheim, Norway, June 2016, pp. 1-7.
- [68] H. Wang, T. Saha, R. Zane, “Control of series connected resonant converter modules in constant current dc distribution power systems,” *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2016*, Trondheim, Norway, June 2016, pp. 1-7.
- [69] B. Limb, R. Zane, J. Quinn, T. Bradley, “Infrastructure optimization and economic feasibility of in-motion wireless power transfer,” *Proc. IEEE Transportation Electrification Conference and Expo, ITEC 2016*, Dearborn, MI, Jun 2016, pp. 1-4.
- [70] M. Evzelman, R. Zane, “Burst mode control and switched-capacitor converter losses,” *IEEE Applied Power Electronics Conference, APEC 2016*, Long Beach, CA, Mar 2016, pp. 1603 – 1607.

- [71] F. Zhang, M. Rehman, R. Zane, D. Maksimovic, "Improved steady-state model of the dual-active-bridge converter," *Proc. IEEE Energy Conversion Congress and Exposition, ECCE 2015*, Montreal, QC, Sept. 2015, pp. 630-636.
- [72] N. Hasan, I. Cocar, T. Amely, H. Wang, R. Zane, Z. Pantic, C. Bodine, "A practical implementation of wireless power transfer systems for socially interactive robots," *Proc. IEEE Energy Conversion Congress and Exposition, ECCE 2015*, Montreal, QC, Sept. 2015, pp. 4935-4942.
- [73] A. Azad, T. Saha, R. Zane, Z. Pantic, "Design of hybrid energy storage systems for wirelessly charged electric vehicles," *Proc. IEEE Vehicular Technology Conference, VTC 2015*, Boston, MA, Sept. 2015, pp. 1-5.
- [74] J. Quinn, B. Limb, Z. Pantic, P. Barr, R. Zane, T.H. Bradley, "Feasibility of wireless power transfer for electrification of transportation: Techno-economics and life cycle assessment," *Proc. IEEE Conference on Technologies for Sustainability, SusTech 2015*, Ogden, UT, July 2015, pp. 245-249.
- [75] W. Chen, R. Zane, "Application of three-phase unfold in electric vehicle drivetrain," *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2015*, Vancouver, BC, July 2015, pp. 1-8.
- [76] F. Zhang, M. Rehman, H. Wang, Y. Levron, G. Plett, R. Zane, D. Maksimovic, "State-of-charge estimation based on microcontroller-implemented sigma-point Kalman filter in a modular cell balancing system for Lithium-Ion battery packs," *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2015*, Vancouver, BC, July 2015, pp. 1-7.
- [77] H. Wang, M. Rehman, M. Evzelman, R. Zane, "SIMULINK based hardware-in-the-loop rapid prototyping of an electric vehicle battery balancing controller," *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2015*, Vancouver, BC, July 2015, pp. 1-6.
- [78] M. Rehman, F. Zhang, M. Evzelman, R. Zane, D. Maksimovic, "Control of a series-input, parallel-output, cell balancing system for electric vehicle battery packs," *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2015*, Vancouver, BC, July 2015, pp. 1-7.
- [79] N. Hasan, T. Yilmaz, R. Zane, Z. Pantic, "Multi-objective particle swarm optimization applied to the design of wireless power transfer systems," , *Proc. IEEE Wireless Power Transfer Conference, WPTC 2015*, Boulder, CO, May 2015, pp. 1-4.
- [80] J. Quinn, B. Limb, Z. Pantic, P. Barr, R. Zane, "Techno-economic feasibility and environmental impact of wireless power transfer roadway electrification," *Proc. IEEE Wireless Power Transfer Conference, WPTC 2015*, Boulder, CO, May 2015, pp. 1-3.
- [81] Md. M. U. Rehman, M. Evzelman, K. Hathaway, R. Zane, S. Trimboli, G. Plett, K. Smith, D. Maksimovic, "Modular approach for continuous cell-level balancing to improve performance of large battery packs," *Proc. IEEE Energy Conversion Congress and Exposition (ECCE 2014)*, Pittsburgh, PA, Sept. 14-18, 2014, pp. 4327 – 4334.
- [82] D. Seltzer, R. Zane, "Multi-Mode Control of Series and Parallel Converters for Bidirectional Power Systems," *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2014*, Santander, Spain, Jun. 2014, pp. 1-8.
- [83] M. Evzelman, R. Zane, X. Zhao, "A low-power, self-tuning resonant driver for generating sinusoidal pulse trains with piezoelectric element loads," *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2014*, Santander, Spain, Jun. 2014, pp. 1-5.
- [84] F. Azcondo, R. Zane, D. Maksimovic, D. Costinett, "A framework to share courses among universities: The case of a course on power electronics for electric vehicles," *Tecnologias Aplicadas a la Ensenanza de la Electronica (Technologies Applied to Electronics Teaching) (TAEE)*, Spain, 11-13 Jun. 2014, pp. 1 – 8.
- [85] W. Chen, K. Kennedy, D. Seltzer, R. Zane, L. Corradini, "Isolated bidirectional DC/AC and AC/DC three-phase power conversion using series resonant converter modules and a three-phase unfold," *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2014*, Santander, Spain, Jun. 2014, pp. 1-6.
- [86] D. Costinett, K. Hathaway, M. Rehman, M. Evzelman, R. Zane, Y. Levron, D. Maksimovic, "Active balancing system for electric vehicles with incorporated low voltage bus," *Proc. IEEE Appl. Power Electron. Conf. Expo*, Fort Worth, TX, Mar. 16-20, 2014, pp. 3230 – 3236.

- [87] D. Costinett, R. Zane, D. Maksimovic, “Discrete time modeling of output disturbances in the dual active bridge converter,” *IEEE Appl. Power Electron. Conf. Expo*, Fort Worth, TX, Mar. 16-20, 2014, pp. 1171 – 1177.
- [88] D. Costinett, D. Maksimovic, R. Zane, A. Rodriguez, A. Vazquez, “Comparison of reverse recovery behavior of silicon and wide bandgap diodes in high frequency power converters,” *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2013*, Salt Lake City, UT, Jun. 2013, pp. 1 – 8.
- [89] D. Seltzer, R. Zane, “Feedback control of phase shift modulated half bridge circuits for zero voltage switching assistance,” *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2013*, Salt Lake City, UT, Jun. 2013, pp. 1 – 7.
- [90] H. Nguyen, D. Maksimovic, R. Zane, “On/off control of a modular DC-DC converter based on active-clamp LLC modules,” *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2013*, Salt Lake City, UT, Jun. 2013, pp. 1 – 6.
- [91] B. Jacobson, E. Holmanský, R. Zane, D. Seltzer, M. Uva, “Bidirectional power converters perform DC/DC, AC/DC, and DC/AC functions in shipboard power systems,” in press, *American Society of Naval Engineers Annual Conference*, Washington, D.C., Feb. 20 – 22, 2013.
- [92] D. Costinett, D. Seltzer, R. Zane, D. Maksimovic, “Inherent volt-second balancing of magnetic devices in zero-voltage switched power converters,” in press, *IEEE Appl. Power Electron. Conf. Expo*, Long Beach, CA, Mar. 17-21, 2013.
- [93] Hien Nguyen, R. Zane, D. Maksimovic, “Active clamp LLC resonant converter for point-of-load (POL) applications,” in press, *IEEE Appl. Power Electron. Conf. Expo*, Long Beach, CA, Mar. 17-21, 2013.
- [94] Z. Popovic, E. Falkenstein, R. Zane, “Low-power density wireless powering for battery-less sensors,” in *Proc. IEEE Radio and Wireless Symposium (RWS)*, Austin, TX, Jan 20 – 23, 2013, pp. 31 – 33.
- [95] D. Seltzer, D. Bloomquist, R. Zane, D. Maksimovic, “Gain-scheduled control of multi-angle phase shift modulated dual active bridge series resonant DC/DC converters,” in *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2012*, Kyoto, Japan, Jun. 2012, pp. 1 – 7.
- [96] D. Costinett, R. Zane, D. Maksimovic, “Circuit-oriented modeling of nonlinear device capacitances in switched mode power converters,” in *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2012*, Kyoto, Japan, Jun. 2012, pp. 1 – 8.
- [97] D. Costinett, R. Zane, D. Maksimovic, “Discrete-time small-signal modeling of a 1 MHz efficiency-optimized dual active bridge converter with varying load,” in *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2012*, Kyoto, Japan, Jun. 2012, pp. 1 – 7.
- [98] D. Costinett, R. Zane, D. Maksimovic, “Automatic voltage and dead time control for efficiency optimization in a dual active bridge converter,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Orlando, FL, Feb. 5 – 9, 2012, pp. 1104 – 1111.
- [99] V. Lopez, A. Navarro-Crespin, C. Branas, F.J. Azcondo, R. Schnell, R. Zane, “Frequency control and phase surveillance in resonant electronic ballast,” in *Proc. IEEE Ind. Electron. Soc. Annual Conf. (IECON)*, Nov. 7 – 10, 2011, pp. 2929 – 2934.
- [100] Q. Hu, R. Zane, “Off-line LED driver with bidirectional second stage for reduced energy storage,” in *Proc. IEEE Energy Conversion Congress and Exposition (ECCE 2011)*, Phoenix, AZ, Sep. 17 – 22, 2011, pp. 2302 – 2309.
- [101] D. Seltzer, L. Corradini, D. Bloomquist, R. Zane, D. Maksimovic, “Small signal phasor modeling of dual active bridge series resonant DC/DC converters with multi-angle phase shift modulation,” in *Proc. IEEE Energy Conversion Congress and Exposition (ECCE 2011)*, Phoenix, AZ, Sep. 17 – 22, 2011, pp. 2757 – 2764.
- [102] L. Corradini, D. Seltzer, D. Bloomquist, R. Zane, D. Maksimovic, B. Jacobson, “Zero voltage switching technique for bi-directional DC/DC converters,” in *Proc. IEEE Energy Conversion Congress and Exposition (ECCE 2011)*, Phoenix, AZ, Sep. 17 – 22, 2011, pp. 2215 – 2222.
- [103] R. Schnell, R. Zane, F. J. Azcondo, “Improved performance of low frequency square wave ballasts using soft saturation magnetic cores and digital control techniques,” in *Proc. International Power Conversion and Drive Conference (IPCDC)*, St. Petersburg, Russia, June 8 – 9, 2011.

- [104] V. Lopez, A. Navarro-Crespin, R. Schnell, C. Branas, F. Azcondo, R. Zane, “Inductor size reduction and phase surveillance in resonant electronic ballast,” in *Proc. International Power Conversion and Drive Conference (IPCDC)*, St. Petersburg, Russia, June 8 – 9, 2011.
- [105] L. Corradini, A. Bjeletic, R. Zane, D. Maksimovic, “Specifications-driven design space boundaries for point-of-load converters,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Fort Worth, TX, Mar. 6 – 11, 2011, pp. 1166 – 1173.
- [106] D. Costinett, H. Nguyen, R. Zane, D. Maksimovic, “GaN-FET based dual active bridge DC-DC converter,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Fort Worth, TX, Mar. 6 – 11, 2011, pp. 1425 – 1432.
- [107] T. Paing, R. Zane, “Design and optimization of adaptive non-linear piezoelectric energy harvester,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Fort Worth, TX, Mar. 6 – 11, 2011, pp. 412 – 418.
- [108] D. Costinett, E. Falkenstein, R. Zane, Z. Popovic, “RF-powered variable duty cycle wireless sensor,” in *Proc. IEEE European Microwave Conference*, Paris, France, Sep. 28 – 30, 2010, pp. 41 – 44.
- [109] R. Schnell, R. Zane, “HID lamp driver with phase controlled resonant-mode ignition detection and fast transition to LFSW warm-up mode,” in *Proc. IEEE Workshop on Control and Modeling for Power Electronics, COMPEL 2010*, Boulder, CO, Jun. 2010, pp. 1 – 8.
- [110] Q. Hu, R. Zane, “A 0.9 PF LED driver with small LED current ripple based on series-input digitally-controlled converter modules,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Palm Springs, CA, Feb. 21 – 25, 2010, pp. 2314 – 2320.
- [111] L. Corradini, R. Zane, D. Maksimović, “Fully Digital Hysteretic Modulator for DC-DC Switching Converters,” in press *IEEE Energy Conversion Congress and Exposition*, San Jose, CA, Sep. 2009, pp. 3312 – 3319.
- [112] Q. Hu, R. Zane, “LED drive circuit with series input connected converter cells operating in continuous conduction mode,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Washington, DC, Feb. 2009, pp. 1511 – 1517.
- [113] J. Morroni, R. Zane, D. Maksimovic, “Robust adaptive tuning of digitally controlled switched-mode power supplies,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Washington, DC, Feb. 2009, pp. 240 – 246.
- [114] T. Paing, E. Falkenstein, R. Zane, Z. Popovic, “Custom IC for ultra-low power RF energy harvesting,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Washington, DC, Feb. 2009, pp. 1239 – 1245.
- [115] R. Schnell, J. Diaz, Ch. Branas, F. Azcondo, R. Zane, “Digital phase control of an integrated resonant ignitor using a soft saturation core for high intensity discharge lamps,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Washington, DC, Feb. 2009, pp. 1526 – 1531.
- [116] J. Patterson, R. Zane, “Series input modular architecture for driving multiple LEDs,” in *Proc. IEEE Power Electron. Specialists Conf*, Athens, Greece, June 2008, pp. 2650 – 2656.
- [117] J. Morroni, R. Zane, D. Maksimovic, “An online phase margin monitor for digitally controlled switched-mode power supplies,” in *Proc. IEEE Power Electron. Specialists Conf*, Athens, Greece, June 2008, pp. 859 – 865.
- [118] J. Morroni, R. Zane, D. Maksimovic, “Adaptive tuning of digitally controlled switched mode power supplies based on desired phase margin,” in *Proc. IEEE Power Electron. Specialists Conf*, Athens, Greece, June 2008, pp. 1250 – 1256.
- [119] M. Doshi, R. Zane, “Reconfigurable and fault tolerant phase shifted modulator for luminance control of LED light sources,” in *Proc. IEEE Power Electron. Specialists Conf*, Athens, Greece, June 2008, pp. 4185 – 4191.
- [120] T. Paing, J. Morroni, A. Dolgov, J. Shin, J. Brannan, R. Zane, Z. Popovic, “Wirelessly-powered wireless sensor platform,” in *Proc. IEEE European Microw. Conf.*, Munich, Germany, Oct. 2007, pp. 999 – 1002.
- [121] F. Javier Diaz, F. J. Azcondo, R. Zane, “Digitally controlled low frequency square wave electronic ballast with resonant ignition and power loop,” in *Proc. IEEE Ind. Appl. Soc. Ann. Meeting*, New Orleans, LA, Sept. 2007, pp. 826 – 832.
- [122] F. Javier Diaz, F. J. Azcondo, Ch. Branas, R. Casanueva, R. Zane, “Control of low frequency square-wave electronic ballast with resonant ignition using a dsPIC30F2010,” in *Proc. IEEE Int. Symp. Ind. Electron.*, Vigo, Spain, Jun., 2007, pp. 3019 – 3024.

- [123] J. Morroni, A. Dolgov, R. Zane, D. Maksimović, “Online health monitoring in digitally controlled power converters,” in *Proc. IEEE Power Electron. Specialists Conf.*, Orlando, FL, Jun. 2007, pp. 112 – 118.
- [124] M. Shirazi, L. Corradini, R. Zane, P. Mattavelli, D. Maksimović, “Autotuning techniques for digitally controlled point-of-load converters with wide range of capacitive loads,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Anaheim, CA, Feb. 2007, pp. 14 – 20.
- [125] M. Doshi, R. Zane, “Digital Architecture for Driving Large LED Arrays with Dynamic Bus Voltage Regulation and Phase Shifted PWM,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Anaheim, CA, Feb. 2007, pp. 287 – 293.
- [126] A. Dolgov, R. Zane, “Low-power wireless medical sensor platform,” in *Proc. IEEE Eng. in Medicine and Biology Soc. Ann. Conf.*, New York City, NY, Aug. 2006, pp. 2067 – 2070.
- [127] Y. Zhang, R. Zane, D. Maksimović, “Dynamic loop analysis for modular masterless multi-phase dc-dc converters,” in *Proc. IEEE Workshop Comput. Power Electron. (COMPEL)*, Troy, NY, Jul. 2006, pp. 22 – 28.
- [128] X. Zhang, Y. Zhang, R. Zane, D. Maksimović, “Design and implementation of a wide-bandwidth digitally controlled 16-phase converter,” in *Proc. IEEE Workshop Comput. Power Electron. (COMPEL)*, Troy, NY, Jul. 2006, pp. 106 – 111.
- [129] T. Carosa, R. Zane, D. Maksimović, “Implementation of a 16 phase digital modulator in a 0.35um process,” in *Proc. IEEE Workshop Comput. Power Electron. (COMPEL)*, Troy, NY, Jul. 2006, pp. 159-165.
- [130] D. Maksimović, R. Zane, “Small-signal discrete-time modeling of digitally controlled DC-DC converters,” in *Proc. IEEE Workshop Comput. Power Electron. (COMPEL)*, Troy, NY, Jul. 2006, pp. 231 – 235.
- [131] B. Miao, R. Zane, D. Maksimović, “FPGA-based digital network analyzer for digitally controlled SMPS,” in *Proc. IEEE Workshop Comput. Power Electron. (COMPEL)*, Troy, NY, Jul. 2006, pp. 240 – 245.
- [132] A. Dolgov, B. Miao, R. Zane, D. Maksimović, “GUI-based laboratory architecture for teaching and research in digital control of SMPS,” in *Proc. IEEE Workshop Comput. Power Electron. (COMPEL)*, Troy, NY, Jul. 2006, pp. 236 – 239.
- [133] T. Carosa, R. Zane, D. Maksimović, “Digital multiphase modulator – A power D/A perspective,” in *Proc. IEEE Power Electron. Specialists Conf.*, Jeju, South Korea, Jun. 2006, pp. 1 – 6.
- [134] T. Paing, R. Zane, “Resistor emulation approach to low-power energy harvesting,” in *Proc. IEEE Power Electron. Specialists Conf.*, Jeju, South Korea, Jun. 2006, pp. 1 – 7.
- [135] M. Weimer, T. Paing, R. Zane, “Remote area wind energy harvesting for low-power autonomous sensors,” in *Proc. IEEE Power Electron. Specialists Conf.*, Jeju, South Korea, Jun. 2006, pp. 1 – 5.
- [136] Y. Zhang, R. Zane, D. Maksimović, “System modeling and digital control in modular masterless multiphase dc-dc converters,” in *Proc. IEEE Power Electron. Specialists Conf.*, Jeju, Korea, Jun. 2006, pp. 1 – 7.
- [137] Y. Zhang, X. Zhang, R. Zane, D. Maksimović, “Wide-bandwidth control for multi-phase converters,” in *Proc. IEEE Power Electron. Specialists Conf.*, Jeju, Korea, Jun. 2006, pp. 1 – 7.
- [138] M. Doshi, R. Zane, F. Azcondo, “Low-frequency square-wave drive for large screen LCD-TV backlighting systems,” in *Proc. Soc. Inform. Display (SID) Int. Symp. Expo.*, Jun. 2006, San Francisco, CA, pp. 1238 – 1241.
- [139] F. Azcondo, F. J. Diaz, R. Casanueva, C. Branas, R. Zane, “Low-frequency square-wave electronic ballast with resonant ignition using digital mode and power control,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Dallas, TX, Mar. 2006, pp. 1044 – 1050.
- [140] B. Miao, R. Zane, D. Maksimović, “Automated digital controller design for switching converters,” in *Proc. IEEE Power Electron. Specialists Conf.*, Recife, Brazil, Jun. 2005, pp. 2729 – 2735.
- [141] Y. Zhang, R. Zane, D. Maksimović, “Current sharing in digitally controlled masterless multiphase DC-DC converters,” in *Proc. IEEE Power Electron. Specialists Conf.*, Recife, Brazil, Jun. 2005, pp. 2722 – 2728.
- [142] R. Zane, Z. Popovic, “Efficient broadband RF energy harvesting for wireless sensors,” in *Proc. Govern. Microcircuit Appl. Critical Tech. Conf. (GOMACTech)*, Las Vegas, NV, Apr. 2005, pp. 1 – 4.

- [143] M. Doshi, J. Bian, R. Zane, F.J. Azcondo, “Low Frequency Architecture for Multi-Lamp CCFL Systems with Capacitive Ignition,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Austin, TX, Mar. 2005, vol. 2, pp. 1072 – 1078.
- [144] Y. Yin, R. Zane, “Integrated Results for Dual Low Voltage IC Based High and Low Side Gate Drive,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Austin, TX, Mar. 2005, vol. 2, pp. 759 – 765.
- [145] Y. Yin, M. Shirazi, R. Zane, “Fully Integrated Ballast Controller with Digital Phase Control,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Austin, TX, Mar. 2005, vol. 2, pp. 1065 – 1071.
- [146] B. Miao, R. Zane, D. Maksimović, “Practical On-Line Identification of Power Converter Dynamic Responses,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Austin, TX, Mar. 2005, vol. 2, pp. 57 – 62.
- [147] B. Miao, R. Zane, D. Maksimović, “Detection of Instability and Adaptive Compensation of Digitally Controlled Switched Mode Power Supplies,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Austin, TX, Mar. 2005, vol. 2, pp. 63 – 69.
- [148] F.J. Azcondo, R. Zane, Ch. Brañas, “Design of Resonant Inverters for Optimal Efficiency over Lamp Life in Electronic Ballast with Phase Control,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Austin, TX, Mar. 2005, vol. 2, pp. 1053 – 1059.
- [149] R. Zane, B. Miao, D. Maksimović, “Active System Identification of a DC-DC Converter Using Digital Control,” in *Proc. Amer. Inst. Aeronaut. Astronaut. (AIAA) 2<sup>nd</sup> Int. Energy Convers. Eng. Conf. (IECEC)*, Providence, RI, Aug. 2004, pp. AIAA 2004 – 5731.
- [150] Y. Yin, R. Zane, “Digital Controller Design for Electronic Ballasts with Phase Control,” in *Proc. IEEE Power Electron. Specialists Conf.*, Aachen, Germany, Jun. 2004, pp. 1855 – 1860.
- [151] B. Miao, R. Zane, D. Maksimović, “A modified cross-correlation method for system identification of power converters with digital control,” in *Proc. IEEE Power Electron. Specialists Conf.*, Aachen, Germany, Jun. 2004, pp. 3728 – 3733.
- [152] D. Maksimović, R. Zane, R. Erickson, “Impact of digital control in power electronics,” in *Proc. IEEE Int. Symp. Power Semicond. Dev. ICs*, Kitakyushu, Japan, May 2004, pp. 13 – 22.
- [153] S. Johnson, Y. Yin, R. Zane, “Custom spectral shaping for EMI reduction in electronic ballasts,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Anaheim, CA, Feb. 2004, pp. 137 – 142.
- [154] Y. Yin, R. Zane, “Dual low voltage IC based high and low side gate drive,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Anaheim, CA, Feb. 2004, pp. 1033 – 1038.
- [155] Y. Zhang, A. Prodic, R. Zane, D. Maksimović, “On-line calibration of lossless current sensing,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, Anaheim, CA, Feb. 2004, pp. 1345 – 1350.
- [156] Y. Yin, R. Zane, J. Glaser, R. Erickson, “Direct modeling of envelope dynamics in resonant inverters,” in *Proc. IEEE Power Electron. Specialists Conf.*, Acapulco, Mexico, Jun. 2003, pp. 1313 – 1318.
- [157] Y. Yin, R. Zane, J. Glaser, R. Erickson, “Dynamic analysis of frequency-controlled electronic ballasts,” in *Proc. IEEE Ind. Appl. Soc. Ann. Meeting*, Pittsburgh, PA, Oct. 2002, vol. 1, pp. 685 – 691.
- [158] R. Zane, D. Maksimović, “A mixed-signal ASIC power-factor-correction (PFC) controller for high frequency switching rectifiers,” in *Proc. IEEE Power Electron. Specialists Conf.*, Charleston, SC, Jun. 1999, pp. 117 – 122.
- [159] R. Zane, D. Maksimović, “Frequency scalable non-linear waveform generator for mixed-signal power-factor-correction IC controller,” in *Proc. IEEE Custom Integrated Circuits Conf.*, San Diego, CA, May 1999, pp. 609 – 612.
- [160] R. Zane, D. Maksimović, “Modeling of high-power-factor rectifiers based on switching converters with nonlinear-carrier control,” in *Proc. IEEE Power Electron. Specialists Conf.*, Baveno, Italy, Jun. 1996, pp. 1105 – 1111.
- [161] R. Zane, D. Maksimović, “Nonlinear-carrier control for high-power-factor rectifiers based on flyback, Cuk or SEPIC converters,” in *Proc. IEEE Appl. Power Electron. Conf. Expo.*, San Jose, CA, Mar. 1996, pp. 814 – 820.

---

**Patents, Issued or allowed**

- [1] B. Varghese, A. Kamineni, R. Zane, “Wireless power transfer with active field cancellation using multiple magnetic flux sinks,” US Patent #11521792B2, Dec. 2022.
- [2] D. Thrimawithana, U. Madawala, G. Kalra, B. Riar, M. Neuburger, S. Ruddell, R. Zane, “AC-AC converter,” US patent #11451091B2, Sep 2022.
- [3] M. Hansen, R. Zane, A. Kamineni, “Zero-crossing current detection for modular and robust dynamic wireless power transfer,” US patent #11,218,026, Jan 2022.
- [4] H. Wang, R. Zane, “Dynamic inductive wireless power transmitter system with a power transmitter module,” US patent #11,059,380, Jul 2021.
- [5] B. Jacobson, D. Altman, C. Scheffler, R. Zane, “Energy-based adaptive stability control system,” US patent #11,063,435, Jul. 2021.
- [6] A. Bagchi, T. Saha, A. Kamineni, R. Zane, “Wireless charger for underwater vehicles fed from a constant current distribution cable,” US patent #11,018,529, May 2021.
- [7] T. Saha, H. Wang, A. Bagchi, R. Zane, “Constant DC Current Input to Constant DC Voltage Output Power Supply Covering a Wide Programmable Range,” US patent #10,938,313, Mar 2021.
- [8] D. Yelaverthi, R. Zane, “Quasi-single stage power converter topology,” US patent #10,917,019, Feb 2021.
- [9] D. Yelaverthi, R. Zane, “High Frequency Link Coupled Multi-Port Converter Topology,” US patent #10,804,809, Oct 2020.
- [10] T. Saha, H. Wang, R. Zane, “A low RMS current zero voltage switching assisting circuit with low power loss and EMI,” US patent #10,804,807, Oct. 2020.
- [11] H. Wang, R. Zane, T. Saha, “DC power supply from a constant current source,” US patent #10,770,978, Sep. 2020.
- [12] B. Riar, R. Zane, P. Thummala, W. Chen, M. Rehman, “Battery integrated modular multifunction converter for grid energy storage systems,” US patent #10,742,127, Aug 2020.
- [13] H. Wang, R. Zane, “Dynamic inductive wireless power transmitter system with a power transmitter module,” US patent #10,727,693, Jul 2020.
- [14] R. Bohm, T. Gardner, M. Halling, B. Riar, R. Zane, “Concrete embedded wireless power transfer coil,” US patent #10,622,142, Apr. 2020.
- [15] Y. Liang, M. Evzelman, M. Demers, J. Alvarado, A. Hosoi, K. Iagnemma, R. Zane, “Solid state pump using electro-rheological fluid,” US patent #10,309,386, Jun. 2019.
- [16] M. Trimboli, G. Plett, R. Zane, K. Smith, D. Maksimović, M. Evzelman, D. Costinett, R. Anderson, “Model predictive control and optimization for battery charging and discharging,” US patent #10,298,026, May 2019.
- [17] R. Zane, M. Evzelman, D. Costinett, D. Maksimovic, R. Anderson, K. Smith, M. Trimboli, G. Plett, “Autonomous Battery Control and Optimization,” US patent #10,277,041, Apr. 2019.
- [18] R. Zane, M. Evzelman, D. Costinett, D. Maksimovic, R. Anderson, K. Smith, M. Trimboli, G. Plett, “Battery Control,” US patent #10,063,066, Aug 2018.
- [19] R. Zane, D. Seltzer, D. Maksimovic, B. Jacobson, D. Desrosiers, “Assisted zero voltage switching for a dc-to-dc converter,” US patent #9,712,066, Jul. 2017.
- [20] R. Zane, D. Seltzer, D. Maksimovic, B. Jacobson, D. Desrosiers, “Zero voltage switching operation of a minimum current trajectory for a dc-to-dc converter,” US patent #9,595,873, Mar. 2017.
- [21] R. Zane, D. Seltzer, D. Maksimovic, B. Jacobson, D. Desrosiers, “Multi-mode control for a dc-to-dc converter,” US patent #9,584,029, Feb. 2017.
- [22] B. Jacobson, R. Zane, D. Seltzer, “High efficiency zero-voltage switching (ZVS) assistance circuit for power converter,” US patent #9,407,150, Aug. 2016.
- [23] D. Maksimovic, R. Zane, A. Carosa, “Multi-phase modulator,” US patent #8,384,365, Feb. 2013.
- [24] C. Hunt, R. Zane, R. Herring, “System and apparatus for cathodoluminescent lighting,” US patent #8,330,376, Dec. 2012.

- [25] C. Hunt, R. Zane, R. Herring, “System and apparatus for cathodoluminescent lighting,” US patent #8,102,122, Jan. 2012.
- [26] J. Morroni, D. Maksimovic, R. Zane, “Monitoring and control of power converters,” US patent #7,956,592, Jun. 2011.
- [27] R. Zane, Z. Popovic, “Systems and methods for receiving and managing power in wireless devices,” US patent #7,956,572, Jun. 2011.
- [28] R. Zane, M. Doshi, “Systems and methods for driving multiple solid-state light sources,” US patent #7,948,468, May 2011.
- [29] C. Hunt, R. Zane, R. Herring, “System and apparatus for cathodoluminescent lighting,” US patent #7,834,553, Nov. 2010.
- [30] R. Zane, “Capacitive coupling to aid ignition in discharge lamps,” US Patent #7,764,023.
- [31] R. Zane, D. Maksimović, Y. Zhang, “Active current sharing multiphase DC-DC converter,” US Patent #7,479,772, Jan. 2009.
- [32] L. Stevanovic, R. Zane, “System and method for regulating resonant inverters,” US patent #7,262,981, Aug. 2007.
- [33] J. Glaser, R. Zane, “Dimmable self-oscillating electronic ballast for fluorescent lamp,” US patent #6,815,908, Nov. 2004.
- [34] J. Glaser, R. Zane, “Non-synchronous control of self-oscillating resonant converters,” US Patent #6,407,514, Jun. 2002.

---

#### **Patents, Filed, Pending**

- [1] M. Kamel, R. Zane, D. Maksimovic, “State-of-charge balancing with parallel and series output connected battery power modules,” US patent application published Dec. 2022, filed Nov 2021, US20220393485A1.
- [2] M. Kamel, R. Zane, D. Maksimovic, “Voltage sharing of series connected battery modules in a plug-and-play dc microgrid,” US patent application filed Jan. 2021, published Jan 2023, US20210399352A1.
- [3] B. Sadeghi, M. Morley, R. Zane, R. Hatch, R. Bohm, “Battery-based system for powering refrigerated transport and other industrial applications,” US Patent Appl. No.: 17/018990, filed Sep 11, 2020, published Mar 2021 20210083335 A1.
- [4] N. Roberts, J. Mullen, R. Zane, A. Kamineni, B. Varghese, M. Halling, “Static heat exchanger for wireless power transfer pad,” US Patent Appl. No.: 17/023865, filed Sep 17, 2020, published Mar 2021 20210082613 A1.
- [5] B. Varghese, J. Mermigas, A. Kamineni, R. Zane, “Inductive wireless charging pad for electric vehicles reinforced with non-conductive elements,” US Patent Appl. No.: 17/023026, filed Sep 16, 2020, published Mar 2021 20210078425 A1.
- [6] R. Hassan, H. Wang, R. Zane, “A Power Electronic Instrument for Continuously Monitoring Stability and stabilizing a dc microgrid,” Disclosure submitted Dec. 2019, US patent application pending, US20210293893A1.
- [7] R. Hassan, H. Wang, R. Zane, “A Power Electronic Apparatus for Active Stability Regulation of Interconnected Converters Using Dynamic Virtual Impedance,” Disclosure submitted Dec. 2019, US patent application pending.
- [8] B. Riar, D. Thrimawithana, R. Zane, V. Wang, “A multi-level modular converter,” US Patent Appl. No.: 16/964948, filed Jan 2019, published Feb 2021, 20210044216 A1.
- [9] D. Maksimović, K. Afridi, R. Zane, G. Plett, M.S. Trimboli, “Heterogeneous Energy Storage System and Method of Controlling a Heterogeneous Energy Storage System,” US patent application filed Feb. 2017.

---

#### **Invited Presentations and Seminars**

- [1] R. Zane, invited speaker and panelist, “Status and Future of Wireless Charging,” IEEE International Transportation Electrification Conference, ITEC 2022, Anaheim, CA, Jun. 16, 2022.
- [2] R. Zane, invited plenary dinner presentation, “A Perspective on the Future of Electrified Transportation and its Demand for Copper,” Rio Tinto Customer Day, Salt Lake City, UT, Jun. 1, 2022.
- [3] R. Zane, invited public talk, “Electric Avenues – The Future of Electrified Transportation,” USU Science Unwrapped series, Logan, UT, Apr. 1, 2022. <https://www.youtube.com/watch?v=Kb7yXprPNhM>.

- [4] R. Zane, invited talk, “Launching your Engineering Career – Electrified Transportation,” USU Launch your Engineering Career series for engineering students, Logan, UT, Mar. 30, 2022.
- [5] R. Zane, invited webinar, “Impact of wireless charging on battery requirements for EVs,” Stanford StorageX International Symposium, August 27, 2021. <https://energy.stanford.edu/storagex-initiative/events/past-events>.
- [6] R. Zane, invited webinar, “An Electric Future for Transportation,” Center for Transportation, Environment, and Community Health (CTECH), Impacts of Transportation and Urban Systems on Health and the Environment Webinar Series, Apr. 6, 2021. [https://vod.video.cornell.edu/media/CTECH+Webinar+Series+-+An+Electric+Future+for+Transportation.CC1/1\\_rgf9l39m](https://vod.video.cornell.edu/media/CTECH+Webinar+Series+-+An+Electric+Future+for+Transportation.CC1/1_rgf9l39m)
- [7] R. Zane, invited speaker and panelist, “ASPIRE NSF Engineering Research Center and UTA Intermodal Hub Project,” Utah Institute of Transportation Engineers (ITE), UPA UT, WTS Panel Workshop, Feb. 16, 2021.
- [8] R. Zane, invited roundtable moderator, “An EV Future webinar: Designing the Infrastructure,” US DOE Office of Electricity An EV Future Initiative webinar, Dec. 9, 2020.
- [9] R. Zane, “Electric Road Studies: Utility Power Requirements and Upgrade Costs,” invited presentation, US Department of Energy (DOE) and International Energy Agency (IEA) Hybrid Electric Vehicle (HEV) Task 45 Electrified Roadways committee webinar, Nov. 18, 2020.
- [10] R. Zane, invited roundtable moderator, “An EV Future webinar: Managing Load,” US DOE Office of Electricity An EV Future Initiative webinar, Nov. 5, 2020.
- [11] R. Zane, C. Fawson, invited breakout speaker, Energy Technology and Innovation Outlook panel, Utah Economic & Energy Summit, Oct. 26, 2020.
- [12] R. Zane, “Advancing Sustainability through Powered Infrastructure for Roadway Electrification,” invited presentation, NSF POETS ERC Annual Meeting, Oct. 2020.
- [13] R. Zane, “Utah’s future in electrified transportation,” invited interview, Live Electric series podcast, hosted by Rocky Mountain Power, Oct. 2, 2020.
- [14] J. Campbell, R. Zane, A. Graul, Z. Song, T. Molloy, B. Grunkemeyer, “Western Smart Plug-in Electric Vehicle Community Partnership Lessons Learned,” invited panelists, webinar hosted by Rocky Mountain Power, Sep. 10, 2020.
- [15] R. Zane, “Electrified roadways,” invited radio interview, USU INSTEAD podcast series, Episode 36, Aug. 2020.
- [16] R. Zane, “Microgrid demonstration project, smart charge management, and electrified transportation,” invited presentation, UK delegation on electric utilities, hosted by Rocky Mountain Power, Salt Lake City, UT, Dec. 2019.
- [17] R. Zane, “Electric roadways – technology overview,” invited keynote presentation, Charging Ahead – SELECT Thought Leadership Series, West Lafayette, IN, Oct. 2018.
- [18] R. Zane, A. Kamineni, “Practical challenges in designing a dynamic wireless charging system,” invited presentation, IEA HEV-TCP Task 26 Workshop 9 on Wireless Charging, Detroit, MI, Nov. 6-7, 2018.
- [19] R. Zane, invited Future of Transportation Keynote Speaker, Utah Clean Cities 25<sup>th</sup> Anniversary celebration, Salt Lake City, UT, Nov. 2, 2018.
- [20] R. Zane, two-week invitation as a visiting professor at the University of Cantabria, Spain. Provided guest seminars on “Electric roads – a vision for the future of transportation,” “Electric bike design,” “Vehicle controller design,” and a tutorial on “Basics of inductive charging systems.” Santander, Spain, May 2018.
- [21] R. Zane, one-week invitation as a visiting professor at India Institute of Technology, Kharagpur. Provided an IEEE society Talk on “Challenges and opportunities in transportation electrification,” a seminar on “Electric vehicle charging infrastructure,” and guest lectures on “Vehicle controller design,” “Electric bike design,” and “Life balancing active battery management systems.” Kharagpur, India, March 2018.
- [22] R. Zane, Live Electric Week, invited guest panelist on RadioActive, KRCL 90.9fm Salt Lake City radio, Sep. 2017.
- [23] R. Zane, invited speaker and panelist, “Transportation Solutions for Improved Air Quality,” The Governor’s Utah Energy Development Summit, Salt Lake City, UT, May 2017.

- [24] R. Zane, “A sustainable (electrified) future for roadway transportation,” Clean Energy Institute invited seminar, University of Washington, Seattle, WA, Apr. 2017.
- [25] R. Zane, “Autonomy and electrification,” invited guest lunch speaker, Federal Highway Administration (FHWA) Western Administrators Annual Meeting, Salt Lake City, UT, Mar. 2017.
- [26] R. Zane, “Charging infrastructure for electric vehicles,” Rocky Mountain Power Electric Vehicle Technology Workshop, Salt Lake City, UT, Jan. 2017.
- [27] R. Zane, “Electric roadways,” invited guest interview, Cool Science Radio hosted by Lynn Ware Peek and Chris Cherniak, KPCW NPR radio, Dec. 2016.
- [28] R. Zane, “Modular battery systems,” IEEE ESARS / International Transportation Electrification Conference, Toulouse, France, Nov 2-4, 2016.
- [29] R. Zane, “Technologies to accelerate electric vehicle adoption,” SAGE Westin Roundtable Series, University of Wisconsin-Madison, WI, Nov. 2016.
- [30] R. Zane, “Wireless EV charging systems for electrified roadways,” Electric Vehicle Technology Conference (EVTC), Cocoa, FL, Oct. 2016.
- [31] R. Zane, “Center for Sustainable Electrified Transportation (SELECT),” invited presentation, Federal Highway Administration (FHWA), Salt Lake City, UT, Aug. 2016.
- [32] R. Zane, “Electrification: Sustainability for transportation systems,” invited presentation, Ben-Gurion University of the Negev, Ben-Gurion, Israel, Jul 2016.
- [33] R. Zane, “Electrification: Towards a sustainable future for our transportation system,” USU Sunrise Session, Salt Lake City, UT, Jan. 2016
- [34] R. Zane, “Sustainable electrified transportation,” Institute of Transportation Engineers (ITE) Annual Conference, Salt Lake City, UT, Jan. 2016.
- [35] R. Zane, “Center for Sustainable Electrified transportation Systems (SELECT),” USTAR confluence annual conference, Salt Lake City, UT, Sept. 2015.
- [36] R. Zane, “Rush Hour. Transportation solutions for a sustainable urban Salt Lake,” invited panelist, public event at The Leonardo, Salt Lake City, Aug. 2015.
- [37] R. Zane, “USTAR advanced transportation institute,” USTAR confluence annual conference, Salt Lake City, UT, Nov. 3-4, 2014.
- [38] R. Zane, “Vehicle power management: research advances for cost and weight reduction,” Battery Show and Electric & Hybrid Vehicle Technology Conference, Novi, MI, Sep. 15 – 17, 2014.
- [39] R. Zane, “Research directions at the USU Power Electronics Lab (UPEL),” invited presentation, University of Cantabria, Santander, Spain, Jun. 26, 2014.
- [40] R. Zane, “Advances in electrified transportation and power electronics at the USU Power Electronics Lab (UPEL),” USU Foundation Board Meeting, Park City, May 7, 2014.
- [41] R. Zane, “High efficiency energy conversion for next generation energy systems and electronic loads,” National Academy of Engineering (NAE), EU-US Frontiers of Engineering (FOE) Symposium, Beckman Center, Irvine, CA, Nov. 3 – 5, 2011.
- [42] R. Zane, Z. Popovic, “Low power RF energy harvesting,” invited presentation, MIT MTL/MITEI Workshop on Next Generation u-Energy Systems, Cambridge, MA, Dec. 2010.
- [43] Z. Popovic, R. Zane, “Integrated design of power management and RF powering,” invited presentation, *Energy challenges in RFIDs and wireless sensors, European microwave conference*, Paris, France, Sep. 2010.
- [44] R. Zane, D. Maksimovic, “Digital control of SMPS,” invited industry short course, Analog Devices, Inc., Shanghai, China and San Jose, CA, Aug. 2010.
- [45] R. Zane, “Energy harvesting & power electronics,” invited presentation and panel session on energy harvesting, *IEEE Appl. Power Electron. Conf. Expo.*, Palm Springs, CA, Feb. 2010.

- [46] R. Zane, Z. Popovic, “RF energy harvesting: what, where, why and how,” invited presentation, *IDTechEx Energy Harvesting & Storage USA*, Denver, CO, Nov. 2009.  
\*Hosted an invited laboratory tour for the conference at UCB.
- [47] R. Zane, “Efficient low power energy harvesting for miniature wireless devices,” invited presentation, *CMOS Emerging Technologies Workshop*, Vancouver, BC, Sep. 2009.
- [48] R. Zane, “Efficient power management for low power energy harvesting,” invited presentation, *Darnell nanoPower Forum*, San Jose, CA, May 2009.
- [49] R. Zane, D. Maksimovic, J. Morroni, “Digital control of SMPS,” invited industry short course, Lockheed Martin, Grand Prairie, TX, Mar. 2009.
- [50] R. Zane, “Low Power Energy Harvesting -- Making the Difference with Efficient Power Management,” invited presentation, Future of DC-DC Conversion, IEEE Applied Power Electronics Specialists Conference (APEC), Washington D.C., Feb. 2009.
- [51] R. Zane, “Towards externally powered telemetric chronic neural implants,” invited seminar as part of the NSF international collaboration travel grant, Towards a Dynamic Brain Clamp, Federal University of Ceara, Sobral, Brazil, Jan 2009.
- [52] R. Zane, “Low power energy harvesting for wireless sensors,” Grainger invited seminar series, University of Illinois, Champaign-Urbana, Dec. 2008.
- [53] R. Zane, “Digital control in SMPS,” invited industry short course, On-semiconductor, Toulouse, France, May 2008.
- [54] Z. Popovic, R. Zane, “RF energy harvesting,” invited presentation, *Darnell nanoPower Forum*, San Jose, CA, Jun. 2008.
- [55] R. Zane, “Digital auto-tuning and adaptive techniques for SMPS,” invited seminar, IEEE PELS-IES joint technical session, Santander, Spain, Apr. 2008.
- [56] J. Shin, R. Zane, Z. Popovic, “Batteryless microPower sensors for context aware technologies,” invited presentation, RESNA 2007, sponsored by NSF Emerging Technology – Tools for the Future, Phoenix, AZ, Jun. 2007.
- [57] R. Zane, Z. Popovic, “Efficient low power RF energy harvesting and power management,” invited presentation, *Darnell nanoPower Forum*, San Jose, CA, Jun. 2007.
- [58] R. Zane, “CAREER: Modeling, control and design of energy-efficient lighting systems,” invited presentation, NSF 2004 Grantees workshop, Reno, NV, Apr. 2007.
- [59] R. Zane, D. Maksimović, “Digital control of switch-mode power supplies,” on-site invited industry short course, Analog Devices Inc., San Jose, CA, Jul. 2006.
- [60] R. Zane, D. Maksimović, “Digital control of switched-mode power supplies,” professional educational seminar, *IEEE Applied Power Electronics Conference and Exposition*, Dallas, TX, Mar. 2006.
- [61] R. Zane, Z. Popovic, “Harvesting ambient energy for low power sensors,” invited presentation, *IEEE Presents Innovation and Technology in Colorado*, Colorado Technology Week, Denver, CO, Oct. 2005.
- [62] R. Zane, Z. Popovic, “Batteryless MicroPower Sensors for Context Aware Technologies,” invited presentation, *Annual Coleman Institute Meeting*, Oct. 2005.
- [63] R. Zane, D. Maksimović, B. Miao, “Active identification and automated digital controller design in DC-DC power converters,” invited presentation, *Annual AFRL Space Power Workshop*, Apr. 2005.
- [64] T. Zhao, J. Israel, R. Zane, Z. Popovic, “Electronics for wireless neural sensors,” poster presentation, *Coleman Institute Annual Conference*, Oct. 2004.
- [65] R. Zane, “Digital control in switch mode power supplies,” on-site invited industry tutorial, Artesyn Technologies, Framingham, MA, May 2004.
- [66] D. Maksimović, A. Prodic, R. Zane, “Digital control of high-frequency switching power converters,” professional educational seminar, *IEEE Applied Power Electronics Conference and Exposition*, Anaheim, CA, Feb. 2004.

- [67] D. Restrepo, D. Finch, R. Zane, A. Sharp, “CEMS-based chronic brain implants,” poster presentation, *Coleman Institute Annual Conference*, Oct. 2003.
- [68] R. Zane, D. Maksimović, “Custom IC blocks for enabling digital control in switching power converters,” invited lecture series, *IEEE Solid-State Circuits Society*, Denver chapter, Jul. 2003.
- [69] R. Zane, D. Maksimović, “Digital control in switching converters,” *Annual AFRL Space Power Workshop*, Apr. 2003.
- [70] D. Restrepo, D. Finch, R. Zane, M. Stowell, A. Sharp, “CEMS-based chronic brain implants,” poster presentation, *Coleman Institute Annual Conference*, October 2002.
- [71] D. Maksimović, R. Zane, “Scalable digital control for switching power converters,” invited presentation, *Intel Technology Symposium*, Seattle, Aug. 2002.
- [72] R. Zane, D. Maksimović “Intelligent control in power converters and systems” *DARPA workshop on integrated smart power*, Arlington, VA, Nov. 2002.

---

## RESEARCH GRANTS & CONTRACTS

---

### Research Grants and Contracts Awarded

---

- State of Utah, “Statewide Strategic Planning for Transportation Electrification Infrastructure,” \$2.1M per year ongoing state appropriation, USU total over first 5 years: \$10.5M. Role: PI. Jul 2023 – June 2028.
- State of Utah, “Freight Logistics Electrification Demonstration Project,” One-time State appropriation, USU total: \$15M. Role: PI. Jul 2022 – June 2025.
- Department of Energy, “Utility Managed Distributed Energy Resources Intelligent Community, UDERMS iCommunity,” total prime DOE share to Rocky Mountain Power: \$6.42M; USU subaward DOE share total: \$2.4M. Role: USU PI, program Co-PI. Jan 2021 – Dec 2024.
- National Science Foundation, “High School Creative Design Course Supplement: Engineering Research Center for Advancing Sustainability through Powered Infrastructure for Roadway Electrification (ASPIRE),” USU total: \$378k. Role: PI & Director. Sep 2021 – Aug 2023. Investigators: R. Zane (PI, USU), K. Gkritza (Purdue), Q. Lv (CU-Boulder), S. Nazarian (UTEP), G. Covic (Univ. of Auckland).
- National Science Foundation, “2021 NSF Internship Supplements: Engineering Research Center for Advancing Sustainability through Powered Infrastructure for Roadway Electrification (ASPIRE),” USU total: \$231k. Role: PI & Director. Sep 2021 – Aug 2023. Investigators: R. Zane (PI, USU), K. Gkritza (Purdue), Q. Lv (CU-Boulder), S. Nazarian (UTEP), G. Covic (Univ. of Auckland).
- State of Utah, “Freight Logistics Electrification Demonstration Pre-pilot,” One-time State appropriation, USU total: \$5M. Role: PI. June 2021.
- National Science Foundation, “Engineering Research Center for Advancing Sustainability through Powered Infrastructure for Roadway Electrification (ASPIRE),” USU total: \$26M. Role: PI & Director. Sep 2020 – Aug 2025 (renewable for 10 years, \$50.6M total). Investigators: R. Zane (PI, USU), K. Gkritza (Purdue), Q. Lv (CU-Boulder), S. Nazarian (UTEP), G. Covic (Univ. of Auckland).
- Department of Energy, “Western Smart Regional EV Adoption and Infrastructure at Scale (WSEV@Scale),” total prime DOE share to Rocky Mountain Power: \$6.6M; USU subcontract DOE share: \$3.3M. Role Co-PI, USU lead. Oct. 2020 – Sep. 2023.
- Department of Energy, “eMosaic: Electrification Mosaic Platform for Grid-Informed Smart Charging Management,” total prime DOE share to ABB, Inc.: \$4.9M; USU subcontract DOE share: \$1.5M. Role Co-PI, USU lead. Oct. 2020 – Dec. 2024.
- Department of Energy, “Increasing Affordability, Energy Efficiency, and Ridership of Transit Bus Systems through Large-Scale Electrification,” total prime DOE share to USU: \$1.75M. Role: Co-PI. Oct 2020 – Dec. 2023. USU Investigators: Z. Song (PI), R. Zane (Co-PI), A. Graul (Co-PI).

Department of Energy, “Resilient-Interoperable-Smart Charge Management Control Systems Architecture for EVs at scale,” total prime DOE share to Dream Team Co LLC: \$4.76M, USU subcontract DOE share \$1.1M. Role: Co-PI. Oct. 2020 – Dec. 2024. USU Investigators: A. Kamineni (PI, USU), R. Zane (USU).

State of Utah, “Electrified Transportation, Support for SELECT Center and ASPIRE ERC Growth,” One-time State appropriation, USU total: \$3M. Role: PI. June 2020.

Pacificorp, “Power Balance and Demand Response for a Charging Intermodal Hub,” USU total: \$1.9M. Role: PI. Dec 2019 – Dec 2021. Investigators: R. Zane (PI, USU), J. Gunther (USU).

CBMM North America, Inc., “Nanocrystalline cores in wireless chargers,” USU total: \$100k. Role: Co-PI. Dec 2019 – Dec 2010. Investigators: A. Kamineni (PI, USU), R. Zane (USU).

Tokef LLC, “Hybrid Energy Storage for UTVs – Milestone 2,” USU total: \$111k. Role: PI. Sep 2019 – Sep 2020. Investigators: R. Zane (USU, PI).

Toyota Motor North America, “Augmentation to Phase 2 and Phase 3: Design, Development and Testing of a Dynamic Wireless Power Transfer System for Electric Vehicles,” USU total: \$133k. Jan 2019 – Dec 2019. Investigators: R. Zane (USU, PI), A. Kamineni (USU).

Toyota Motor North America, Visiting Scientist PhD program agreement for Shuntaro Inoue, USU total: \$267k. Aug 2019 – Jul 2023. Investigators/co-advisors: R. Zane (USU, PI), A. Kamineni (USU).

Department of Energy, “Long-range battery electric vehicle with megawatt wireless charging,” total prime DOE share: \$5M; USU subcontract DOE share: \$960,000. Role: Project Co-PI, USU lead. Oct 2019 – Sep 2022. Investigators: B. Lindgren (Kenworth), R. Zane (USU), M. Masquelier (WAVE), M. Casteel (UPS), S. Kiliccote (eIQ), E. Smalley (Seattle City Light), L. Whittemore (PGE).

DOE ARPA-E, “Low-cost, easy-to-integrate, and reliable grid energy storage system with 2<sup>nd</sup> life lithium batteries,” total prime DOE ARPA-E share: \$2M; USU subcontract total DOE share: \$631,645. Role: Project Co-PI, USU lead. May 2019 – June 2021. Investigators: A. Tong (UCSD), R. Zane (USU), J. Quinn (CSU).

Idaho National Laboratory / Battelle, “WPT technical support for cyber security research,” USU total: \$31k. Role: PI. Feb 2019 – Jan 2020. Investigators: R. Zane (USU, PI), A. Kamineni (USU).

Toyota Motor North America, Inc., “Characterization of the Evatran PLUGLESS 7.2 kW System,” USU total: \$62k. Role: PI. Jan 2019 – Apr 2020. Investigators: R. Zane (USU, PI), A. Kamineni (USU).

AECOM Technical Services, Inc., “Illinois tollway pre-pilot feasibility study,” USU total: \$280k. Role: PI. Jan 2019 – Dec 2019. Investigators: R. Zane (PI, USU), A. Kamineni (USU), M. Halling (USU), N. Roberts (USU).

US DOT Federal Transit Administration (FTA), “Electric Bus Corridor Model,” USU total: \$50k. Role: Co-PI. Jan 2019 – Mar 2020. Investigators: Z. Song (PI, USU), R. Zane (USU).

USTAR Industry Partnership Program, “Development of an integrated thermal management and optimized concrete enclosure for stationary wireless charging systems,” USU total: \$363k, Jan. 2019 – Apr 2020. Investigators: N. Roberts (PI, USU), R. Zane (USU), M. Halling (USU).

Department of Energy, “Enabling secure and resilient XFC: A software/hardware security co-design approach,” Virginia Tech prime contractor, total DOE share \$2.5M; USU subcontract total DOE share: \$577,213. Role: Project Co-PI, USU lead. Oct. 2018 – Dec 2020. Investigators: R. Gerdes (VT), S. Rahman (VT), K. Heaslip (VT), R. Zane (USU), A. Paaso (ComEd), C. Rodine (ChargePoint), P. Jonathan (OnBoard Security), K. Vamvoudakis (Georgia Tech), M. Pipattanasomporn (VT), S. Bogosyan (Istanbul Tech).

Department of Energy, “High power wireless extreme fast charging development and deployment for electric trucks,” WAVE prime contractor, total DOE share: \$4.3M, USU total: \$636,364. Role: Project Co-PI, USU lead. Aug. 2018 – Jul. 2021. Investigators: M. Masquelier (WAVE), R. Zane (USU), K. Aron (Schneider Electric), J. Kreese (Cummins), T. Williamson (TTSI).

Raytheon Integrated Defense Systems, “Analysis and design of the series resonant converter and parallel resonant converter and wireless power transfer,” USU total: \$74,799. Role: PI. May 2018 – Dec 2018. Investigators: R. Zane (PI, USU).

TransChill, LLC, “Battery energy storage system for transport chillers,” USU total: \$99,949. Role: PI. Jan. 2018 – Aug. 2018. Investigators: R. Zane (PI, USU).

Tokef LLC, “Hybrid energy storage for electric trucks,” USU total: \$19,916. Role: PI. Apr. 2018 – Jul. 2018. Investigators: R. Zane (PI, USU).

Tokef LLC, “Feasibility study for electric roadway paint,” USU total: \$23,455. Role: Co-PI. Apr. 2018 – Sep. 2018. Investigators: R. Christensen (PI, USU), R. Zane (Co-PI, USU).

PacifiCorp, “Advancing smart inverter integration in Utah,” USU, total \$99,997. Role: PI. Jan. 2018 – Dec. 2018. Investigators: R. Zane (PI, USU).

PacifiCorp, “Development and demonstration of a microgrid system at the USU EVR,” USU, total \$189,999. Role: PI. Jan 2018 – Jun. 2020. Investigators: R. Zane (PI, USU).

DOE ARPA-E, “Feasibility analysis of electric roadways through localized traffic, cost, adoption, and environmental impact modeling,” USU, total \$498,170. Role: PI. Oct. 2017 – Sep. 2018. Investigators: R. Zane (PI, USU), Z. Song (Co-PI, USU), J. Quinn (Co-PI CSU), N. Gkritza (Co-PI Purdue).

USTAR, “Thermal management test lab for high reliability energy storage systems,” USU total: \$694,514. Role: PI. May 2017 – Feb 2017. Investigators: R. Zane, (PI, USU).

NASA, “Active battery management system with physics based life modeling,” EP Systems prime contractor, subcontract to USU. USU total: \$29,252. Role: PI. Jun 2017 – Nov 2017. Investigators: R. Zane (PI, USU).

Raytheon Integrated Defense Systems, “Power system control,” USU total: \$25,522. Role: PI. May 2017 – Sep 2017. Investigators: R. Zane (PI, USU).

Electric Power Systems LLC, “Development of a passive battery management system for a silicon nanowire battery,” USU total: \$15,078. Role: PI. Mar 2017 – Aug 2017. Investigators: R. Zane (PI, USU).

Department of Energy, “WestSmartEV: Western Smart Plug-in Electric Vehicle Community Partnership,” Rocky Mountain Power (RMP) prime contractor, total prime DOE share: \$4M; total DOE share subcontract to USU: \$1.2M. Role: Co-PI. Jan 2017 - Dec 2019. Investigators: Z. Song (PI, USU), R. Zane (Co-PI, USU).

Raytheon Integrated Defense Systems, “Analysis and design of series resonant converter (SRC) prototype with digital control,” USU total \$149,998. Role: PI, Jan 2017 – Dec 2017. Investigators: R. Zane (PI, USU).

Colorado DOT, “Phase 1: Planning study for electric roadway pilot project,” AECOM prime contractor, subcontract to USU. Role: PI. Jan 2017 – May 2017. USU Total: \$90k. R. Zane (PI, USU).

USTAR Engineering Research Triangle, “Automated monitoring and control of electric vehicle charging infrastructure,” USU total: \$40k. Role: Co-PI. Jan 2017 – Dec 2017. Investigators: M. Parvania (UofU), R. Zane (USU), J. Salmon (BYU).

NIDILRR, “Energy management system for battery powered mobility devices based on wireless power transfer concept to promote community living and participation,” USU total: \$599,077. Role: Co-PI. Sep 2016 – Sep 2019. Investigators: Z. Pantic (PI, USU), R. Zane (Co-PI, USU), C. Bodine (Co-PI, UC-Denver), C. Coopmans (Co-PI, USU).

Raytheon Integrated Defense Systems, “CHIPS: research, magnetics design, and breadboard,” USU total \$73,080. Role: PI, Oct 2016 – Mar 2017. Investigators: R. Zane (PI, USU).

ONR, “Robust plug-and-play expeditionary battery system,” Utah State University (USU). Total: \$737,217. Role: PI, Sep 2016 – Dec 2018. Investigators: R. Zane (PI, USU), K. Smith (Co-PI, NREL), S. Trimboli (Co-PI, UCCS), D. Maksimovic (Co-PI, CU-Boulder), J. Pinon (Co-PI, HDS).

FTA Lo-No, “Utah’s Public/Public/Private Partnership for the Deployment of Electric Bus Technology: Downtown to the University Connection,” Utah Transit Authority prime contract, subcontract to USU. USU total: \$78k.  
Investigators: R. Zane (PI, USU), Z. Song (Co-PI, USU), J. Quinn (Co-PI, CSU).

Raytheon Integrated Defense Systems, “Analysis and design of series resonant converter (SRC) prototype with digital control,” USU total \$149,044. Role: PI, Jun 2016 – Dec 2016. Investigators: R. Zane (PI, USU).

Department of Energy (DOE), ARPA-E AMPED, “Hybrid energy storage demonstration plus-up, advanced control of large battery packs,” Utah State University (USU). Total: \$500k.  
Role: PI, Jan. 2016 – Mar. 2017.  
Investigators: R. Zane (PI, USU), S. Trimboli (UCCS), D. Maksimovic (UCB), K. Smith (NREL).

USTAR, “Center for Sustainable Electrified Transportation Systems (SELECT),” Utah State University (USU). Total: \$750k. Role: PI, Jul. 2015 – Jun. 2016. Investigators: R. Zane (PI, USU), Z. Pantic (USU), J. Quinn (USU), R. Gerdes (USU), R. Sharma (USU), P. Barr, (USU).

Department of transportation, “Advance Radar based low ground clearance vehicle detection and warning system,” Intelligent Automation Inc (IAI) prime contractor, subcontract to USU. Role: PI, Sep. 2015 to Mar 2016. USU Total: \$10,350.

Peery Foundation, “Bidirectional three phase power inverter for dual purpose grid tied and grid forming applications,” USU total: \$150,000.  
Role: PI, Jan 2015 – Dec 2017. Investigators: R. Zane (PI, USU).

Utah State University, “Electric Vehicle and Roadway (EVR) Research Facility and Test Track,” R. Zane received \$2.4M award for EVR facility construction and selected as inaugural EVR Director. Construction Aug 2014 – Mar 2015.

Raytheon Integrated Defense Systems, “Analysis and design of series resonant converter (SRC) prototype with digital control,” USU total \$91,927. Role: PI, Jan 2015 – Dec 2015. Investigators: R. Zane (PI, USU).

Department of Energy (DOE), ARPA-E AMPED, “Tech-to-market plus-up, advanced control of large battery packs,” Utah State University (USU). Total: \$170k.  
Role: PI, Jan. 2015 – Dec. 2015.  
Investigators: R. Zane (PI, USU), S. Trimboli (UCCS), D. Maksimovic (UCB), K. Smith (NREL), D. Anderson (Ford).

Office of Naval Research, “Phase I: Hybrid Energy Storage Modules (HESM), Advanced Bi-Directional Power Conversion (BDPC) System,” subcontract to Raytheon, USU Total: \$110K.  
Role: PI, Aug 2014 – Jul 2015.  
Investigators: R. Zane (PI, USU).

Department of Transportation, “A Novel Multi-Sensor Wireless Network for Bridge Structural Health Monitoring,” subcontract to Intelligent Automation, Inc. (IAI), USU total: \$25K. Jan 2014 – May 2015.  
Investigators: R. Zane (PI, USU).

National Institute on Disability Rehabilitation Research, RERC-ACT, “Wireless power system for socially interactive robots,” subcontract to University of Colorado, USU total: \$106K. Nov. 2013 – Dec. 2014.  
Investigators: R. Zane (PI, USU), Z. Pantic (USU), R. Baktur (USU).

Raytheon Integrated Defense Systems, “High Power Series Resonant Converter (SRC) 32 kW prototype,” USU total \$99K. May 2013 – Dec. 2013.  
Investigators: R. Zane (PI, USU).

Raytheon Integrated Defense Systems, “High Power Series Resonant Converter (SRC) Proof of Concept,” USU total \$30K. May 2013 – Dec. 2013.  
Investigators: R. Zane (PI, USU).

DARPA, “Hydraulic actuation for micro-scale robots (HAMR),” subcontract to MIT, USU total: \$252K. Role: Co-PI, Mar 2013 – Aug 2015.

Investigators: A. Hosoi (PI, MIT), K. Iagnemma (MIT), R. Zane (USU).

Department of Energy (DOE), ARPA-E AMPED, “Robust cell-level modeling and control of large battery packs,” Utah State University (USU) lead, team members: National Renewable Energy Labs (NREL), University of Colorado Boulder and Colorado Springs, Ford. Total: \$3.4M.

Role: PI, Jan. 2013 – Dec. 2015.

Investigators: R. Zane (PI, USU), S. Trimboli (UCCS), D. Maksimovic (UCB), K. Smith (NREL), D. Anderson (Ford).

Office of Naval Research, “Support integration and test of power management controller (PMC) for Phase II compact power conversion technology (CPCT) program,” subcontract to Raytheon, USU Total: \$167K.

Role: PI, Aug 2012 – Apr 2013.

Investigators: R. Zane (PI, USU).

Department of Energy (DOE), ARPA-E Solar ADEPT, “Wafer-Level Sub-Module Integrated DC/DC Converter,” CU-Boulder (lead), team members Nuvotronics LLC, National Renewable Energy Labs (NREL), Total: \$1.3M.

Role: Co-PI, Nov. 2011 – Oct. 2014.

Investigators: D. Maksimovic (Program PI, UCB), Z. Popovic (Co-PI, UCB), R. Zane (Co-PI, UCB), Jean Marc Rollin (Co-PI, Nuvotronics), F. Patrick McCluskey (Co-PI, NREL).

Office of Naval Research, “Compact Power Conversion Technologies (CPCT) ONR Phase II: Bidirectional Power Converter,” subcontract to Raytheon, Total: \$542K. Program split between UCB and USU in 2012.

Role: PI, May 2011 – Dec 2012.

Investigators: R. Zane (PI, USU), D. Maksimovic (UCB).

Office of Naval Research, “Support on power converter controls: Compact Power Conversion Technologies (CPCT) ONR Phase I PROGRAM,” subcontract to Raytheon, Total: \$54K.

Role: PI, Jan 2010 – Jun 2010.

Investigators: R. Zane (PI, ECE, UCB), R. Erickson (ECE, UCB), D. Maksimovic (ECE, UCB).

Texas Instruments, “Power control and management for ultra high efficiency data servers,” \$264K:

Role: Co-PI, Colorado Power Electronics Center (CoPEC), Jun 2010 – May 2013.

Investigators: D. Maksimovic (PI, ECE, UCB), R. Zane (Co-PI, ECE, UCB).

Analog Devices, Inc., “Specifications-driven design space boundaries for point-of-load converters,” Total award: \$44K:

Role: PI, Colorado Power Electronics Center (CoPEC), Jan 2010 – Dec. 2010.

Investigators: R. Zane (PI, ECE, UCB), D. Maksimovic (ECE, UCB).

Raytheon Integrated Defense Systems, “Cascade operation of bi-directional power converter (BDPC) using digital control and power factor corrected (PFC) rectifier,” Total: \$18k.

Role: PI, Colorado Power Electronics Center (CoPEC), Jun 2010 – Dec 2010.

Investigators: R. Zane (PI, ECE, UCB), D. Maksimovic (ECE, UCB)

Raytheon Integrated Defense Systems, “Power converter controls for 3-phase DC-AC inverter,” Total: \$50k.

Role: PI, Colorado Power Electronics Center (CoPEC), Jan 2010 – Dec 2010.

Investigators: R. Zane (PI, ECE, UCB), R. Erickson (ECE, UCB), D. Maksimovic (ECE, UCB)

Department of Education, National Institute on Disability Rehabilitation Research, RERC-ACT, “Non-linear context-aware prompting system for adults with cognitive disabilities in the workplace,” Total: \$1.1M.

Role: co-PI, subcontract to UCD, RERC-ACT “Rehabilitation Engineering Research Center on the Advancement of Cognitive Technologies,” program period: Jan 2010 – Dec 2015.

Investigators: M. Melonis (PI, UCB), R. Zane (co-PI, ECE, UCB), Z. Popovic (co-PI, ECE, UCB), A. Mihailidis (co-PI, UCD), S. Van Vuuren (Co-PI, UCB). Prime contract: C. Bodine (PI, Assistive Technology Partners Director, Physical Medicine and Rehabilitation, UCHSC), M. Lightner (ECE, UCB).

Department of Transportation, “A novel multi-sensor wireless network for bridge structural health monitoring,” Total: \$35K, subcontract to Intelligent Automation, Inc.

- Role, PI, Jun. 2010 – Jul. 2011.  
Investigators: R. Zane (ECE, UCB).
- Northrop Grumman, “RF energy harvesting system miniaturization,” Total: \$22k.  
Role: PI, Colorado Power Electronics Center (CoPEC), Jan 2009 – Dec 2009.  
Investigators: R. Zane (PI, ECE, UCB), Z. Popovic (ECE, UCB).
- On-Semiconductor, “Digitally controlled Class-D audio amplifiers for portable applications,” Total: \$44k  
Role: PI, Colorado Power Electronics Center (CoPEC), Jan 2009 – Dec 2009.  
Investigators: R. Zane (PI, ECE, UCB), L. Corradini (ECE, UCB), R. Erickson (ECE, UCB).
- NSF, “Towards a Dynamic Brain Clamp,” International collaboration travel grant, Total: \$30K.  
Role: Co-PI; travel grant lead by PI D. Restrepo, UCHSC, UC-Denver; Travel to Federal University of Ceara, Sobral, Brazil, Jan 2009.
- Coleman Institute, “Low-power energy harvesting in cognitive disability applications,” Total: \$77K  
Sabbatical Faculty Fellowship, Fall 2008 – Spring 2009.  
Investigators: R. Zane (Co-PI, ECE, UCB), Z. Popovic (Co-PI, ECE, UCB).
- MSI/DARPA, “PPeC: Parasitically Powered embedded Communication,” Total: \$88K  
Role: Co-PI, subcontract to MicroSat Systems (MSI), Jan 2008 – Dec. 2008.  
Investigators: R. Zane (Co-PI, ECE, UCB), Z. Popovic (Co-PI, ECE, UCB).
- NASA, “Wireless Ultrasonic Transducer Network for Airframe Structure Health Management,” Total: \$100K, subcontract to Intelligent Automation, Inc.  
Role, PI, Jan. 2008 – Dec. 2010.  
Investigators: R. Zane (ECE, UCB).
- NSF, “IREE: Modeling, control and design of energy efficient lighting systems,” Total: \$44.5K  
Role: PI, International Research and Education in Engineering (IREE) supplement on NSF CAREER grant. Sep. 2007 – Jun. 2008.  
Investigators: R. Zane (PI, ECE, UCB).
- NSF CNS, “NOSS: An integrated power aware sensor-simulation network system for long-term performance assessment of concrete infrastructures,” Total: \$600K:  
Role, Co-PI, Sep. 2007 – Aug. 2010.  
Investigators: X.C. Cai (PI, CS, UCB), R. Zane (ECE, UCB), Y. Xi (Civil, UCB).
- DOE, “Miasolé Solar America Initiative, SAI,” Total: \$1,049,874 (Awarded by DOE, but later withdrawn by Miasole)  
Role: Co-PI, DOE SAI, subcontract to Miasolé, Aug. 2007 – Jul. 2010.  
Investigators: M. Brandemuehl (PI, CEAE, UCB), R.W. Erickson (ECE, UCB), R. Zane (ECE, UCB).
- On-Semiconductor, “LED drives for general lighting applications,” Total award: \$88K:  
Role: PI, Colorado Power Electronics Center (CoPEC), Jan. 2007 – Dec. 2008.  
Investigators: R. Zane (PI, ECE, UCB).
- National Semiconductor, “System IC controls for backlighting in LCD HDTV,” Total: \$326K:  
Role: PI, Colorado Power Electronics Center (CoPEC), Aug. 2003 – July. 2009.  
Investigators: R. Zane (PI, ECE, UCB).
- Powercast Corp., “Integrated design of rectenna and power management circuit,” Total: \$44K:  
Role: PI, Colorado Power Electronics Center (CoPEC), Aug. 2007 – July. 2008.  
Investigators: R. Zane (PI, ECE, UCB), Z. Popovic (ECE, UCB).
- Analog Devices, Inc., “Digital control loops in SMPS,” Total award: \$176K:  
Role: PI, Colorado Power Electronics Center (CoPEC), Oct. 2006 – Dec. 2009.  
Investigators: R. Zane (PI, ECE, UCB).
- NASA Glenn, “Spacecraft Power Converter Health Monitoring and Prognostics,” Total: \$137K:  
Role: PI, program period: Apr. 2006 – Mar. 2009.

- Investigators: R. Zane (PI, ECE, UCB), D. Maksimović (ECE, UCB).
- Astec / Artesyn Technologies, “Auto-tuning controller for POL converters” Total: \$88K  
Role: PI, Colorado Power Electronics Center (CoPEC), Jan. 2006 – Dec. 2007.  
Investigators: R. Zane (PI, ECE, UCB), D. Maksimović (ECE, UCB).
- Luna Innovations, “Phase II SBIR: RF Power Scavenging for Wireless Sensors,” Total: \$100K  
Role: Co-PI, subcontract to Luna Innovations on US Navy/Air Force SBIR Contract No. N00164-05-C-6088, program period: Nov. 2005 – Mar. 2007.  
Investigators: Z. Popovic (PI, ECE, UCB), R. Zane (ECE, UCB).
- CU TTO, “Energy harvesting for maintenance free operation of wireless devices,” Total: \$100K:  
Role: PI, Proof-of-Concept (POC) competition, program period: July 2006 – May 2007.  
Investigators: R. Zane (PI, ECE, UCB), Z. Popovic (ECE, UCB).
- DARPA, “Planer Integrated Power Processor (PIPP),” Total: \$320K:  
Role: PI, Phase I: Robust Integrated Power Electronics (RIPE), subcontract to General Electric, program period: Sep. 2005 – Aug. 2009.  
Investigators: R. Zane (PI, ECE, UCB), D. Maksimović (ECE, UCB).
- Intel, “High-frequency digital multi-phase controller and modulator,” Total: \$186K  
Role: Co-PI, Colorado Power Electronics Center, program period: Jan 2005 – Dec 2006.  
Investigators: D. Maksimović (PI, ECE, UCB), R. Zane (ECE, UCB).
- Department of Education, “Batteryless power supplies for sensor technologies,” Total: \$150K:  
Role: PI, subcontract to UCHSC, RERC-ACT “Rehabilitation Engineering Research Center on the Advancement of Cognitive Technologies,” program period: Jan 2005 – May 2007.  
Investigators: Subcontract: R. Zane (PI, ECE, UCB). Prime contract: C. Bodine (PI, Assistive Technology Partners Director, Physical Medicine and Rehabilitation, UCHSC), M. Lightner (ECE, UCB).
- NSF Faculty Early Career Development (CAREER) Program, “CAREER: Modeling, Control, and Design of Energy-Efficient Lighting Systems,” Total: \$400K + \$6K REU:  
Role: PI, program period: Feb. 2004 – Jan. 2010.  
Investigators: R. Zane (PI, ECE, UCB).
- NSF, “SENSORS: Collaborative Research: Self-Configuring In Situ Wireless Sensor Networks for Prescribed Fire Management,” Total: \$300K:  
Role: Co-PI, program period: Sept 2003 – May 2007.  
Investigators: R. Han (PI, CS, UCB), R. Zane (ECE, UCB), L. Queen (School of Forestry, University of Montana), C. Seielstad (School of Forestry, University of Montana).
- NASA Glenn Research Center, “Stability Control in PMAD Systems through Power Converter Modules with Direct Digital Control,” Total: \$74K,  
Role: PI, program period: Aug 2003 – Nov. 2005.  
Investigators: R. Zane (PI, ECE, UCB), D. Maksimović (ECE, UCB).
- Artesyn Technologies, “Digital control in multiphase converters” Total: \$74K  
Role: PI, Colorado Power Electronics Center (CoPEC), Jan. 2003 – Dec. 2005.  
Investigators: R. Zane (PI, ECE, UCB), D. Maksimović (ECE, UCB)
- Coleman Institute, “Feasibility study for CEMS-based chronic brain implants,” Total: \$370K:  
Role: Co-PI, program period: Jan 2001 – Dec 2004.  
Investigators: D. Restrepo (PI, Cell and Developmental Biology, Director Neuroscience, UCHSC), R. Zane (ECE, UCB), A. Sharp (Integrative Physiology, UCB), D. Finch (Mechanical Engineering, UCB).
- DOE, “Modeling and IC-Control of High Frequency Electronic Ballasts,” Total: \$154K:  
Role: PI, subcontract to General Electric, program period: Aug 2001 – Jul 2004.  
Investigators: R. Zane (PI, ECE, UCB).
- CoPEC associate memberships, various companies, Total: \$133K:  
Role: Co-PI, Zilker Labs, 2003 – 2007, Intersil, 2003 – 2004, Northrop Grumman, 2005 – 2007.

Investigators: R. Erickson, D. Maksimović, R. Zane (all Co-PIs, ECE, UCB).

Philips Research, “Development of Solid-State LED Power Supply,” Total: \$30K:

Role: Co-PI, Colorado Power Electronics Center, Aug 2001 – Jul 2002.

Investigators: R. Erickson (PI, ECE, UCB), R. Zane (ECE, UCB).

---

## TEACHING ACCOMPLISHMENTS

---

### Educational development and research grants

---

Department of Energy (DOE), “GATE Center of Excellence, in Innovative Drivetrains in Electric Automotive Technology Education (IDEATE),” joint program with University of Colorado Colorado Springs, Total: \$954K.

Role: PI (for CU-Boulder campus), Oct. 2011 – Sep. 2016.

Investigators: G. Plett (Program PI, UCCS), **R. Zane** (sub-contract PI, UCB/USU), D. Maksimovic (UCB).

---

### Teaching – Courses Taught at Utah State University

---

- Fundamentals of Electric Power Systems, ECE 5110, 3 credits.
  - Spring 2020: introduced new course materials on electric utility modeling and simulation
- Power Electronics for Electric Drive Vehicles, 3 credits.
  - Fall 2018: introduced as regular course, ECE 5150/6150.
  - Fall 2017, 2016, 2014, 2013, 2012: new course co-developed with CU-Boulder as part of the DOE IDEATE GATE Center. Course was offered via distance learning with lectures, assignments and materials shared between USU and CU-Boulder campuses. Offered as special topics, ECE 5930/6930.
- Electric Vehicles Design Lab, ECE 5930/6930, 3 credits (pre-requisite is Power Electronics for Electric Drive Vehicles theory course).
  - Spring 2018, 2017 and 2013: new laboratory course co-developed with visiting instructor, Daniel Costinett. Redesigning course in Spring 2017 for new lab designs in Spring 2018.
- Modeling and control of power electronics systems, ECE 7170
  - Spring 2020, ECE 7170.
  - Fall 2018, ECE 7170, introduced as regular course.
  - Summer 2017, Spring 2017, Spring 2015, independent study, ECE 7930
- Digital control of high frequency switched mode power supplies
  - Summer 2021, Fall 2019, Fall 2016, taught as independent study, ECE 7930
- Resonant and soft switching techniques in power electronics, ECE 7180
  - Spring 2019, Summer 2017, Spring 2016; introduced as new regular course.
- Power electronics for grid-connected systems
  - Fall 2014, Independent study, ECE 7930
- Undergraduate introduction to engineering, ENGR 1500
  - Spring 2019

---

### Teaching – Courses Taught at CU-Boulder

---

- Electronics Design Laboratory, ECEN 2830, 3 credits.
  - Spring 2011: co-developed and co-taught this new sophomore level laboratory as part of a new undergraduate curriculum development at CU-Boulder. 70 students.
  - Fall 2011: continued course development and taught course. 31 students.
- Renewable Sources and Efficient Electrical Energy Systems, ECEN 2060.
  - Spring 2008: co-developed and co-taught this new sophomore level course as a first step in developing a new curriculum in energy and energy efficiency.
- Circuits / Electronics III, Introduction to Microelectronic Circuits, ECEN 3250, 5 credits, combined lecture and laboratory required core undergraduate course.
  - Fall 2006: 20 undergraduate.
  - Fall 2007: 33 undergraduate enrolled.

- Received the 2008 John and Mercedes Peebles Innovation in Teaching Award, University of Colorado
- Fall 2011: 51 students. Developed and taught course as the first version within new undergraduate curriculum as a 3 credit theory course.
- Introduction to Power Electronics, dual-listed ECEN 4797/5797 + online CAETE remote delivery
  - Fall 2001: 19 undergraduate, 20 graduate
  - Fall 2009: 21 undergraduate, 54 graduate
- Power Electronics Laboratory, dual-listed ECEN 4517/5517
  - Spring 2004: 54 undergraduate (lecture included 10 graduate)
  - Spring 2005: 10 graduate
  - Spring 2006: 46 undergraduate (lecture included 16 graduate)
  - Spring 2007: 42 undergraduate and 10 graduate
  - Spring 2008: Co-developed and co-taught a major modification to the laboratory, with the new name: Power Electronics and Photovoltaic Power Systems Laboratory
    - Developed a mobile solar power system cart and re-designed the laboratory experiments to focus on power electronic components in the solar power system.
- Analog IC Design, dual-listed ECEN 4228/5228 – now ECEN 4827/5827 + online CAETE
  - Spring 2002: 12 undergraduate, 22 graduate
  - Spring 2003: 26 undergraduate, 37 graduate
  - Spring 2004: 22 undergraduate, 27 graduate
    - Developed detailed course notes, additional assignments, and adjusted course content to create a two-semester sequence, with Analog IC as a prerequisite for Mixed-Signal IC.
  - Fall 2004: 14 undergraduate, 9 graduate
    - Detailed course notes posted online in place of a formal textbook. Additional changes made to syllabus to coordinate with mixed-signal IC design. Submitted formal course proposals for the two-semester IC design sequence.
  - Fall 2010: 3 undergraduate, 27 graduates
- Mixed-Signal IC Design (new course developed in 2002), ECEN 5018 – Now ECEN 5837
  - Fall 2002: 15 graduate
    - Developed new course in Fall 2002, including detailed course notes (see website, [ece.colorado.edu/~ecen5007](http://ece.colorado.edu/~ecen5007)), assignments, on-line tutorials for Cadence tools, and final project designs. Course notes are used in place of a formal text book.
  - Fall 2003: 22 graduate
  - Spring 2005: 21 graduate
    - Developed new on-line tutorials and two-week design assignments integrating theory and extensive use of CAD tools for complete custom IC design.
  - Spring 2006: 16 graduate
  - Spring 2008: 16 graduate
  - Spring 2010: 5 graduate
- Digital Control in SMPS, Industry Short Course, University of Colorado, Boulder, CO, July 2005, August 2006, August 2007. Enrolled 28 industry participants in two sessions three days each. Instructors: R. Zane, D. Maksimović, B. Miao.
  - Materials on digital control of SMPS from this course have now been integrated into ECEN 5807: Modeling and control of power electronic systems, with detailed notes, tutorials and simulation models posted online: <http://ece-www.colorado.edu/~ecen5807>
- Student evaluations on Faculty Course Questionnaire (FCQ) results for Instructor to date
  - a. *Fall 2006 and on:* 6.0, 5.7, 5.5, 5.4, 5.2, 4.9, 4.3, 4.2 (out of 6)
  - b. *Spring 2006 and before:* 1 A+, 2 A, 1 A-, 4 B+, 3 B

---

### Graduate Final Thesis Examinations – Serving as Primary Advisor

1. Marium Rasheed, Ph.D., “Architectural Design of Hybrid Battery Energy Storage Systems with Integrated Active Balancing and Reconditioning Control,” May 2023. Currently at Ford Motor Company, Dearborn, MI.
2. Shuntaro Inoue, Ph.D., “Architectural Design of Hybrid Battery Energy Storage Systems with Integrated Active Balancing and Reconditioning Control,” Dec 2022. Currently at Toyota Central R&D Labs, Inc., Japan.
3. Chakridhar Reddy, Ph.D., “AC-AC Converter Topologies for Wireless Charging Applications,” May 2022. Currently at Lucid Motors, Newark, CA.
4. Mahmoud Mansour, M.S., “Power factor correction and multi-cell control for a medium-voltage three-phase unfolding input-series output-parallel AC-DC converter,” Dec 2021. Currently a Research Engineer III at USU-ASPIRE, Logan, UT.
5. Rees Hatch, M.S., “Analysis and design of 3-phase unfolding based AC-DC battery chargers,” June 2021. Currently a Research Engineer III at USU-ASPIRE, Logan, UT.
6. Joshua Wooten, M.S., “Control of series connected battery powered modules,” June 2021. Currently an engineer at Northrup Grumman, Ogden, UT.
7. Benny Varghese, Ph.D., “Roadway-embedded transmitters and multi-pad receivers for high power dynamic wireless power transfer,” May 2021. Currently Research Scientist at Idaho National Laboratory, Idaho Falls, ID.
8. Rohail Hassan, Ph.D., “Active stability monitoring and stability control of DC microgrids using incremental continuous injection,” April 2021. Currently Research Scientist at General Electric Global Research Center, Niskayuna, NY.
9. Mohamed Ahmed Kamel, Ph.D., “Analysis and control of parallel and series connected modular battery systems,” Nov 2020. Currently at General Motors.
10. Dorai Yelaverthi, Ph.D., “Three-phase unfolding based soft DC-link converter topologies for AC to DC applications,” Aug 2020. Currently Research Scientist at ABB US Corporate Research Center, Raleigh, NC.
11. Anindya Bagchi, Ph.D., Emerging works on wireless inductive power transfer: AUV charging from constant current distribution and analysis of controls in EV dynamic charging, Aug 2020. Currently at Advanced Energy.
12. Tarak Saha, Ph.D., “Soft-switched resonant DC-DC converter in underwater DC power distribution network,” Jul. 2020. Currently Research Scientist at General Electric Global Research Center, Niskayuna, NY.
13. Hongjie Wang, Ph.D., “Design and control of series resonant converters for DC current power distribution applications,” May 2018. Currently Assistant Professor at Utah State University in Logan, UT.
14. Muhammed Muneeb Ur Rehman, Ph.D., “Modular, scalable battery systems with integrated cell balancing and dc bus power processing,” March 2018. Currently at Amazon, Seattle, WA.
15. Weilun (Warren) Chen, Ph.D., “Bidirectional three-phase ac-dc power conversion using dc-dc converters and a three-phase unfold,” Nov 2017. Currently at United Technologies Research Center in Hartford, CT.
16. Hien Ngyuen, Ph.D., “Design and Control of a Modular Resonant DC-DC Converter for Point-of-Load Applications,” July 2014. Currently at a start-up solar company in CA.
17. Daniel Seltzer, Ph.D., “Modeling and Control of the Dual Active Bridge Series Resonant Converter,” May 2014. Currently employed at Space-X in Los Angeles, CA.
18. Daniel Costinett, Ph.D., “Analysis and Design of High Efficiency, High Conversion Ratio, DC-DC Power Converters,” June 2013. Currently an Assistant Professor of ECE at University of Tennessee, Knoxville.
19. Qingcong Hu, Ph.D., “Techniques to improve LED drivers by reducing voltage stress and required energy storage,” Sep. 2011. Current employed at CREE Semiconductor, Durham, NC.
20. Thurein Paing, Ph.D., “Power management techniques for micropower energy scavenging,” May, 2011. Currently employed at Maxim Integrated, Fremont, CA.
21. Ryan Schnell, Ph.D., “Digital control of LFSW HID lamp drivers with soft saturation magnetic materials and integrated resonant lamp ignition,” August, 2010. Currently employed at Analog Devices, Longmont, CO.
22. Jeffery Morroni, Ph.D., “Adaptive tuning and monitoring of digitally controlled switched mode power supplies,” October, 2009. Currently employed at Texas Instruments, Santa Clara, CA and Longmont, CO.

23. Mariko Shirazi, Ph.D., “Embedded frequency response measurement capability for monitoring and tuning of system dynamics in digitally-controlled DC-DC converters,” September, 2009. Currently employed at the National Renewable Energy Lab (NREL), Golden, CO.
24. Montu Doshi, Ph.D., “Power control architectures for CCFL and HBLED based light sources,” August, 2009. Currently employed at Texas Instruments, Longmont, CO.
25. Arseny Dolgov, M.S. Thesis, “Power management system for online low power RF energy harvesting optimization,” May 2009. Currently employed at Ball Aerospace, Boulder, CO.
26. Yang Zhang, Ph.D., “Digital control in modular masterless multiphase microprocessor power supplies,” August, 2006. Currently employed at Texas Instruments in Santa Clara, CA.
27. Yan Yin, Ph.D., “Modeling and IC control of electronic ballasts,” June 2004. Currently employed at Texas Instruments in Longmont, CO.
28. Preeti Bhandarkar, M.S. Thesis, “Design of a low-power sigma-delta A/D converter for chronic brain implants,” April 2004.

---

**Current Graduate Students – Serving as Primary Advisor (paid as RA or Fellowship)**

---

1. Moneeba Gulzar, Ph.D. candidate, entered Jan 2022.
2. Sanat Poddar, Ph.D. candidate, entered Aug. 2021.
3. Aditya Zade, Ph.D. candidate, entered Aug. 2021.
4. Shubhangi Gurudiwan, Ph.D. candidate, entered Aug. 2021.
5. Jackson Morgan, Ph.D. candidate, entered Jan 2021 (BS to PhD).

---

**Past Graduate Students, Non-Thesis MS – Serving as Primary Advisor**

---

1. Aaron Mattmiller, M.S. graduate, Aug. 2010.
2. Jieyeon Choi, M.S. graduate, May 2010.
3. Jim Patterson, M.S. graduate, May 2008.
4. Jeffrey Israel, M.S. graduate, May 2007.
5. Michael Weimer, M.S. graduate, May 2006.
6. Tony Carosa, M.S. graduate, Spring 2006.
7. Kevin Lybarger, M.S., expected graduation: May 2007.
8. Steve Scroggs, M.S. graduate, Fall 2005.
9. Sandra Johnson, M.S. graduate, Spring 2004.
10. Jonathan Gray, M.S. graduate, Fall 2002.

---

**Undergraduate Students Advised and Independent Study**

---

1. Jennifer Hinton, BS student, research on AC/DC power converters, Aug 2020 – Dec 2021.
2. Brooks Maughan, BS student, research on EV charging systems, May 2020 – May 2021.
3. Jackson Morgan, BS student, research on impacts of EV charging and renewable energy on electric grids, Aug. 2019 – Dec 2020.
4. Joshua Zaugg, BS student, research on DC-DC converter modeling and hardware design, Jan 2019 – May 2020.
5. Ian Colbert, BS student, research on battery systems and grid modeling for electric vehicle charging, Mar. 2018 – May 2019.
6. Mahmoud Mansour, BS student, research on microgrid and energy management systems and high power electric vehicle charging, Mar. 2018 – May 2019.
7. Rees Hatch, BS student, research on battery systems, transport chillers, and wireless power transfer systems, Mar. 2018 – May 2019.
8. Daniel Bosco, BS student, research on solar inverters, microgrid, and grid modeling. Jan. 2018 – May 2020.

9. Shaun Bartschi, BS student, research on electric transportation and RFID tags for autonomous vehicle alignment, Sep 2017 – Jan 2019.
10. Matthew Hansen, BS student, research on electric vehicle dynamic modeling, charging infrastructure, and electric roadways, Jan 2017 – Aug 2020.
11. Jacob Alder, BS student, research on solar power installation and support of SELECT research center, Oct 2016 – May 2019.
12. Justin Jones, BS student, research on bidirectional power supplies, Jan 2014 – 2015.
13. William Balling, BS student, research on high voltage, low power, pulse generation circuit for piezoelectric structural health monitoring systems, Jan 2014 – 2015.
14. Justin Cox, BS student, research on high voltage, low power pulse power supply design for solid-state pumps and valves, May 2013 – present.
15. Kelly Hathaway, MS/BS student, research on bidirectional DC-DC converter modules for battery management systems in electric vehicles. May 2013 – 2015.
16. Kevin Kennedy, BS student, research on digital control of bidirectional resonant power converters, Aug 2012 – 2105.
17. Douglas Bloomquist, BS student, research on low power wireless sensor networks and energy harvesting, DLC apprentice, Aug. 2009 – Aug. 2010. Continued on as a graduate research assistant.
18. Daniel Costinett, BS student, research on low power energy harvesting for wireless sensors, DLC apprentice, Aug. 2008 – 2009. Continued as a Ph.D. student.
19. Daniel Seltzer, MS/BS student, research on low power piezo-electric element drive circuit for aircraft wing integrity monitoring, Mar. 2008 – 2009. Continued as a Ph.D. student.
20. Adam Bierman, MS/BS student, research on energy efficient lighting systems, Sep 2007 – present. Sponsored by NSF REU and IREE supplements, including international exchange in Spain.
21. Ryan Dolan, MS/BS student, research on lighting electronics, Jun 2007 – Dec. 2007.
22. Carey Davis, BS student, research on energy efficient lighting systems, DLC apprentice, Jan 2007 – May 2008.
23. Michael Weimer, MS/BS student, independent study in 2005 on harvesting power and electronics design for NSF Sensors project: Fire sensors.
24. Arseny Dolgov, B.S. candidate, research work on an NSF REU project in lighting electronics and on a Coleman Foundation project on wireless sensors, graduation: May 2007.
  - a. Received the **Dean's Outstanding Graduate for Research** award, May 2007.
25. Eric Hicks, independent study project, "A/D converter design and Cadence software tutorial development," Fall 2002.
26. Deirdre Lynch, independent study project, "Electronics 4 laboratory," Fall 2002.
27. Andrew Kowles, independent study project, "Analysis of resonant LCC circuits," Spring 2002.

### Postdoctoral Researchers Advised

---

1. Dr. Yingying Zhang, Mar 2020 – Aug 2020.
2. Dr. Hongjie Wang, Jun 2018 – Jul 2019.
3. Dr. Abhilash Kamineni, Aug 2017 – Jul 2019.
4. Dr. Prasanth Thummala, Nov 2016 – Jun 2017.
5. Dr. Baljit Riar, Sep 2016 – Dec 2019.
6. Dr. Shijie Zhou, Jun 2015 – May 2016.
7. Dr. Mehmed Celebi, Sep 2015 – Aug 2016.

8. Dr. Michael Evzelman, Sep 2013 – Sep 2016.
9. Dr. Tuba Yilmaz, Nov 2013 – Dec 2014.
10. Dr. Sara Dadras, Nov 2012 – Jun 2013.
11. Dr. Victor Manuel Lopez Martin, Jun 2012 – Dec 2012.
12. Dr. Luca Corradini, Jun 2009 – Dec 2011.
13. Dr. Botao Miao, Jun 2004 – Dec 2006.

---

## SERVICE ACTIVITIES

---

### Service – Editorial staff, conference, society and standards committees

---

1. Conference Co-Chair, Wireless Power Technologies Conference and Exhibit, WPTCE 2023, Jun. 2023.
2. Society for Automotive Engineers (SAE) standards committee member, SAE J2954/2, Wireless power transfer of heavy duty plug-in electric vehicles and positioning communication, Dynamic Wireless Power Transfer sub-team chair, Jun. 2017 – present.
3. IEEE PELS Cyber-Physical Security Initiative Steering Committee member, Jan. 2018 – Dec. 2021.
4. IEEE Workshop on Cybersecurity of Power Electronic Systems (CyberPELS), organizing committee member, Treasurer, 2019.
5. Guest Editor, IEEE Journal of Emerging and Selected Topics in Power Electronics, Special Section on Cybersecurity of Power Electronics through Hardware Hardening, 2018 – 2019.
6. Associate Editor, IEEE Transactions on Power Electronics, Jan. 2006 – present.
7. Associate Editor, IEEE Journal of Emerging and Selected Topics in Power Electronics, 2013 – present.
8. General Co-Chair, Conference on Electric Roads and Vehicles, 2015, 2016, 2018, 2020, 2023.
9. IEEE Power Electronics Society (PELS), Administrative Committee (AdCom), 2008 – 2014.
10. IEEE Applied Power Electronics Conference and Exposition (APEC) conference committee member (2001 – 2012) and Topic Chair (2005-2006)
11. IEEE Power Electronics Specialists Conference (PESC) committee member (2001 – 2010)
12. IEEE Power Electronics Society (PELS) Simulation, Modeling, and Control Committee vice-chair 2006
13. IEEE Workshop on Control and Modeling for Power Electronics (COMPEL), Program Chair & Treasure, COMPEL 2014, University of Oviedo, Spain; Program Chair, COMPEL 2010, hosted at the University of Colorado, Boulder, CO
14. IEEE Energy Conversion Congress & Exposition (ECCE), Topic Chair, 2016 – present.
15. IEEE Standards Committee, PAR 1789, “Recommending practices for modulating current in High Brightness LEDs for mitigating health risks to viewers,” Dec. 2008 – 2012.

---

### Service – Major Internal, Utah State University

---

- Faculty search committee chair, power / power electronics, 2018 – 2019.
- College of Engineering undergraduate research committee, 2013 – 2016.
- ECE department graduate studies committee, 2013 – present.
- Faculty search committee member, computer engineering, 2016-2017.
- Workshop organizer, Engineering State, Summer 2017, 2018, 2019.
- Director, USU Power Electronics Lab (2012-2020), Electric Vehicle and Roadway (EVR) Test Track and Research Facility (2015 – present), and Battery Limits and Survivability (BLAST) Lab, 2018 – present.
- Director, Center for Sustainable Electrified transportation (SELECT), 2015 – 2020.
- Faculty search committee chair, power / power electronics, 2012 – 2013.

---

### Service – Major Internal, University of Colorado Boulder

---

- Faculty search committee chair, 2011 – 2012
  - a. Led faculty search for energy engineering area faculty in the ECEE department.
- Undergraduate curriculum committee, 2010 – 2012

- a. Participate in weekly department committee meetings and provide materials and updates on curriculum for circuits, electronics and power courses.
- Curriculum development
  - a. Participated in new curriculum development teams for analog courses (3 core circuits courses, new sophomore Electronics Design Lab, and sophomore elective on renewable energy)
- Course assessment teams, 2004 – 2008
  - a. Team member, ECEN 3250, Circuits III
  - b. Team member, ECEN 3100 Digital Logic
- Internal review committee, 2003
  - a. Participated in department review meetings, reviewed final committee report, participated in discussions with external review board
- Graduate studies committee, 2001-2010
  - a. Participate annually in graduate student admissions, departmental teaching assistant (TA) offers and fellowships; periodic meetings on graduate studies and curriculum
- Chairman, power area Ph.D. preliminary examination committee
  - a. Committee chairman in 2002, 2005, 2007; committee member in 2003, 2004, 2006.
- Colorado power electronics center (CoPEC) faculty member
  - a. Assist in hosting annual CoPEC industry sponsor meeting and laboratory exposition and coordinate weekly group meetings with student presentations
  - b. Participate in student recruiting, curriculum development, and lab management

#### **Service – Journal and Conference Paper Reviews**

---

- IEEE Journal of Emerging and Selected Topics in Power Electronics (~2 papers per year)
- IEEE Transactions on Power Electronics (full papers and letters) (~ 6 papers per year)
- IEEE Journal of Solid-State Circuits (~ 2 papers per year)
- IEEE Transactions on Circuits and Systems, Parts I & II (~ 2 papers per year)
- IEEE Industrial Applications Society Transactions (~ 1 paper per year)
- IEEE Transactions on Industrial Electronics (~1 paper per year)
- IEEE Transactions on Microwave Theory and Techniques (~1 paper per year)
- IEEE Energy Conversion Congress & Exposition (ECCE) (~ 10 papers per year)
- IEEE Applied Power Electronics Conference (APEC) (~ 10 papers per year)
- IEEE Transportation Electrification Conference & Expo, ITEC (~10 papers per year)
- IEEE Workshop on Control and Modeling for Power Electronics (COMPEL) (~10 papers per year)
- IEEE International Symposium on Circuit and Systems (ISCAS) (~ 10 papers per year)
- IEEE International Symposium on Industrial Electronics (ISIE) (~ 2 papers per year)

#### **Service – Consulting Positions**

---

- Feb 2022 – Dec 2022. Bond Shoeneck & King. Patent consultant and expert witness.
- May 2021 – Jun 2022. Holland & Knight LLP. Patent consultant and expert witness.
- Apr 2021 – Jan 2022. Paul Hastings LLP. Patent consultant and expert witness.
- Sep 2020 – Dec 2020. Akin Gump Strauss Hauer & Feld LLP. Patent consultant and expert witness.
- Nov 2019 – present. Alston & Bird LLP. Patent consultant and expert witness.
- July 2019 – May 2021. Radulescu LLP. Patent consultant and expert witness.
- Sep 2018 – Oct 2019, Dec 2021 – present. Baker Botts LLP. Patent consultant and expert witness.
- May 2018 – Aug 2018. Bookoff McAndrews, PLLC. Patent consultant and expert witness.
- Aug 2016 – Dec 2017. Bristows LLP. Patent consultant and expert witness.
- Jul 2016 – Aug 2022. Friedman, Suder & Cooke. Patent consultant and expert witness.

- Feb 2016 – Nov 16. Jenner & Block, LLP. Patent consultant and expert witness.
- Jan 2015 – present. Finnegan, Henderson, Farabow, Garrett & Dunner, L.L.P. Patent consultant and expert witness.
- Jan 2012 – Dec 2013. Institute for Defense Analysis (IDA). Selected as member of the 2012-2013 Defense Sciences Study Group (DSSG), US Defense Advanced Research Projects Agency (DARPA).
- Feb 2010 – Aug. 2011. Friedman, Suder & Cooke, patent consultant. Served as an expert witness on electronic ballast case, including expert report, deposition, and testimony at trial.
- May 2008 – Dec 2014: Intelligent Automation Inc., low power piezo-electric driver design consultant.
- Nov 2008 – Nov 2009: Cymbet Corporation, low power energy harvesting design consultant.
- Jun. 2006 – Nov 2009: Telegen / Vu1, electronic ballast design consultant.
- Oct. 2005 – Mar. 2007: Luna Innovations, low power management design consultant.
- Aug. 2005 – Dec. 2005: Intertainment, low power management design consultant.
- June 2005 – Dec. 2006: Intelligent Automation Inc., power converter design consultant.
- Dec. 2004 – May 2005: Cooley Godward LLP, patent consultant.
- Nov. 2004 – Jan 2005: ITU Ventures, technology consultant.
- Nov. 2004 – Dec. 2006: Winstead Sechrest & Minick P.C., patent consultant.
- May 2004: Zilker Labs, consultant on digital control and custom IC design in power converters.
- May 2004: Artesyn Technologies, 3-day short course on digital control in switching power converters.
- 2002 – 2005: Jet Propulsion Labs, University of Washington, Neptune Project Power Group Review Committee
- 2001 – 2005: General Electric Global Research, consulting on application of digital and custom mixed-signal IC controls in lighting electronics and related applications

**Expert testimony – Summary list of cases with expert testimony at deposition or trial (past 6 years)**

---

- IPR Case No. IPR2022-00147. Volkswagen Group of America, Inc. v. Arigna Technology Ltd. US Patent No 7,049,850.
- District Case No: 2:20-CV-00269-JRG (Eastern District of Texas). Garrity Power Services LLC v. Samsung Electronics\*. US Patent 9,906,067.
- District Case No. 1:19-cv-02240-UNA (D. Del, Dec. 2019). Volterra Semiconductor, LLC., v. Monolithic Power Systems, Inc. (MPS)\*. US Patent Nos. 7,772,955, 7,525,408, and 6,362,986.
- IPR Case No. 2020-00836. Satco Products, Inc. v. Seoul Semiconductor Co., Ltd\*. US Patent No 7,081,722.
- District Case No. 6:20-cv-00018 (Western District of Texas, WACO Division). Jiaxing Super Lighting Electric Appliance Co., Ltd., and Obert, Inc. v. CH Lighting Technology Co., Ltd.\*, Elliott Electric Supply Inc. and Shaoxing Ruising Lighting Co., Ltd.
- District Case No. 2:19-cv-04047 (Central District of California). Jiaxing Super Lighting Electric Appliance Co., Ltd., and Obert, Inc. v. MaxLite, Inc\*.
- District Case No. 1:19-cv-5516-DLC (Southern District of New York). Signify North America Corporation et al.\* v Axis Lighting Inc.
- District Case No. 2:19-cv-06125-JMA-SIL (Eastern District of New York). Signify North America Corporation and Signify Holding B.V.\* v. Satco Products, Inc. Oct 2019.
- IPR Case No (unassigned). Maxlite, Inc.\* v. Jiaxing Super Lighting Electric Appliance Co., Ltd. US Patent No 9,879,265.
- IPR Case No (unassigned). Maxlite, Inc.\* v. Jiaxing Super Lighting Electric Appliance Co., Ltd. US Patent No 9,723,662.
- IPR Case No (unassigned). Maxlite, Inc.\* v. Jiaxing Super Lighting Electric Appliance Co., Ltd. US Patent No 9,807,826.

- Ex Parte Reexam, Control No. 90/014,297, Patent 6,958,623, Mail date May 2019.
- District Case No. 1:17-cv-00247-LPS-CJB (D. Del, Oct 2018). ON Semiconductor\* v. Power Integrations, Inc.
- IPR Case No. IPR2018-00921. Feit Electric Company, Inc., v. Philips Lighting Holding\*. US Patent No 6,586,890.
- ITC Investigation No. 337-TA-1081. Complainant: Philips Lighting\*. Respondents: Feit Electric, Satco, and Lowe's. In the Matter of: Regarding Certain LED Lighting Devices. Patents: 7,038,399 and 7,256,554.
- District Case No. 17-cv-03597-WHO (Northern District of California). Opticurrent, LLC\* v. Power Integrations, Inc. US Patent No. 6,958,623.
- IPR case IPR2018-01524. MPOWERD INC. v. LUMINAID LAB, LLC. US Patent No. 9,347,629.
- UK Court Case Claim No HP-2016-00046. Philips Lighting\* v. Megaman Limited, Neonlite International Limited, and Neonlite Electronic & Lighting Limited. Intellectual property list patents court London UK. EP 1 502 483 and EP 1 887 836 B1 patents.
- IPR Case No. IPR2016-01133. Acuity Brands Lighting, Inc. v. Lynk Labs, Inc. US Patent No. 8,841,855.
- IPR Case No. IPR2016-01116. Acuity Brands Lighting, Inc. v. Lynk Labs, Inc. US Patent No. 8,531,118.
- IPR Case No. IPR2015-01293. WAC Lighting Co. v. Philips Lighting\*. 7,352,138 patent.
- IPR Case No. IPR2015-01294. WAC Lighting Co. v. Philips Lighting\*. 7,038,399 patent.
- IPR Case No. IPR2015-01287. WAC Lighting Co. v. Philips Lighting\*.
- IPR Case No. IPR2015-01292. WAC Lighting Co. v. Philips Lighting\*.

*Additional cases as expert or consultant with no testimony to date (past 4 years)*

- District Case No. 6:22-cv-812-ADA (Western District of Texas). Signify North America Corporation and Signify Holding B.V.\* v. Eglo Leuchten GMBH and Eglo Hong Kong Lighting LTD. Patents 8,963,449, 7,852,017, and 7,256,554.
- District Case No. 6:21-cv-398-ADA (Western District of Texas). MyPAQ Holdings Ltd. v. Dell Technologies Inc. and Dell Inc. US Patent Nos. 7,675,759 and 8,477,514.
- District Case No. 2:22-cv-10730 (Eastern District of Michigan). Scramage, Ltd. v. Volkswagen\*. US Patent Nos. 10,243,400 and 7,825,537.
- District Case No. 0:20-cv-62302-KMM (Southern District of Florida). Signify North America Corporation and Signify Holding B.V.\* v. Robe Lighting Inc. and Robe Lighting S.R.O. Patents 7,557,521 and 7,802,902.
- District Case Nos. 2:21-cv-00173 and 2:21-cv-00175 (Eastern District of Texas). Arigna Technology, Ltd. v. Volkswagen\*, Lamborghini, Audi, and Bentley. US Patent No. 7,049,850.
- District Case No. 3:19-cv-3563-EMC. Opticurrent, LLC\* v. Power Integrations, Inc. US Patent No. 6,958,623.

\*indicates party represented.