

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SHENZHEN XINZEXING E-COMMERCE CO., LTD.,

Petitioner,

v.

SHENZHEN CAR KU TECHNOLOGY CO., LTD.,

Patent Owner.

PTAB Case No. IPR2024-00222

Patent No. 9,643,506 B2

**DECLARATION OF DAVID RICKETTS, PH.D. IN SUPPORT OF
PATENT OWNER'S RESPONSE TO PETITION FOR
INTER PARTES REVIEW OF U.S. PATENT NO. 9,643,506 B2**

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Appendix C	Datasheet, Monolithic Power Systems (MPS) MP4462 3.5A Step-Down Converter, Rev. 1.01, Dated 6/9/2011

I. INTRODUCTION

1. I, David Ricketts, have been retained by Patent Owner Shenzhen Carku Technology Co., Ltd. (“Patent Owner”) to investigate and opine on certain issues relating to United States Patent No. 9,643,506 B2 (“the ’506 patent”) in connection with Patent Owner’s Response to Petition for *Inter Partes* Review. The Petition, filed by Shenzhen Xinzexing E-commerce Co., Ltd. (“Petitioner” or “SXE”) requests that the Patent Trial and Appeal Board (“PTAB” or “Board”) review and cancel claims 1–3, 6–23, and 25–33 of the ’506 patent.

2. The opinions set forth in this declaration are based on my personal knowledge, my professional judgment, and my analysis of the materials and information referenced in this declaration and its exhibits.

3. I am being compensated for consulting services including time spent testifying at any hearing that may be held. I am also reimbursed for reasonable and customary expenses associated with my work in this case. I receive no other forms of compensation related to this case. My compensation does not depend on the outcome of this post-grant review or the co-pending district court litigation, and I have no other financial interest in this post-grant review.

4. I understand that the ’506 patent has been assigned to Shenzhen Carku Technology Co., Ltd.

5. This declaration is based on the information currently available to me. To the extent that additional information becomes available, I reserve the right to continue my investigation and study, which may include a review of documents and information that may be produced, as well as testimony from depositions that have not yet been taken.

6. In forming my opinions, I have relied on information and evidence identified in this declaration, including the '506 Patent, the prosecution history of the '506 Patent, and prior art references including the listed Exhibits to the Petitioner's IPR Petition on the '506 Patent (Paper 2 of IPR2024-0222, hereafter "IPR Petition" or "Petition"). I have also considered the IPR Petition and the Declaration of Gary Woods (Ex. 1003 of IPR2024-0222). I have also relied on my own experience and expertise in the relevant technologies and systems. I have provided and cited to additional evidence in this declaration beyond the evidence in the Petitioner's IPR Petition on the '506 Patent.

II. SUMMARY OF OPINIONS

7. Based on my review and analysis, it is my opinion that challenged claims 1–3, 6–8, 11–23, and 25, 27–33 of the '506 Patent are entitled to the December 9, 2011 priority date of China patent application number 201110409190.9 cited on the face of the '506 Patent.

8. Based on my review and analysis, it is my opinion that challenged claims 9, 10, and 26 of the '506 Patent are entitled to the April 29, 2016 priority date of U.S. patent application number 15/141,841 cited on the face of the '506 Patent.

9. Based on my review and analysis, it is my opinion that claims 1–3, 6–23, and 25–33 of the '506 Patent are valid over the grounds and teachings thereof cited in the IPR Petition. The grounds are summarized below.

Ground Label from IPR Petition	Challenged Claims	Prior Art Relied Upon in Ground
1A	1, 9, 11-14, 16-19, 21, 26-28, 30-33	§102 –Chen (CN102005796A)
1B	1-2, 6-9, 11-14, 16-22, 25-28, 30-33	§103 –Chen in view of White (US7,279,640)
1C	10	§103 –Chen in view of Richardson (US2009/0218988)
1D	15, 29	§103 –Chen in view of Gozdz (US7,348,101)
2A	1, 3, 6-14, 16-17, 20-21, 23, 25-28, 30-31	§103 –Inskeep (US2010/0301800) in view of Johnson (US4,969,834)
2B	19, 33	§103 –Inskeep in view of Johnson and Durando (US2012/0068662)
3A	1, 2, 6, 8-16, 19-22, 26-30, 33	§102 –Nook (WO2016/003471)

3B	1, 2, 6-16, 19-22, 25-30, 33	§103 – Nook in view of White
3C	3, 23	§103 – Nook in view of Miller (US2016/0072329)
3D	10	§103 – Nook in view of Richardson (US2009/0218988)
3E	17-18, 31-32	§103 –Nook in view of Shoji (US6,404,168)

10. First, because it is my opinion that claims 1–3, 6–8, 11-23, and 25, 27–33 of the '506 Patent are entitled to the December 9, 2011 priority date, Durando, Nook, and White references are not prior art to these claims, and thus, Grounds 2B, 3A, 3B, 3C, 3D, and 3E, which rely on one or more of these references, fail to invalidate any of the challenged claims 1–3, 6–8, 11-23, and 25, 27–33.

11. Moreover, even if it is found that the priority date of every claim of the '506 patent is April 29, 2016 as alleged by the Petitioner, each of the prior art grounds fail because the evidence presented by Petitioner either fails to literally disclose or render obvious one or more claim limitations, as explained in further detail.

12. The subsequent sections of this declaration will first provide my qualifications and experience and then describe details of my analysis and observations.

III. QUALIFICATIONS AND EXPERIENCE

A. Education and Work Experience

13. My curriculum vitae, including complete my education and work experience, is attached to this declaration as Appendix A. In this section I will summarize some aspects of my education, employment, teaching, and research experience.

14. I am currently a Professor of Electrical and Computer Engineering at the North Carolina State University (“NCSU”). In my position I conduct research and teach undergraduate and graduate students in the area of electrical and computer engineering. The courses I teach include Advanced Analog Integrated Circuit (“IC”) Design, Radio System Design, Analog Circuit Laboratory and Power Management IC Design. I also lead a research group that conducts research and design of electrical and electronic circuits, including millimeter wave and microwave circuits and systems, radio frequency identification circuits, wireless power transfer circuits, analog circuits, and radio frequency circuits. I also lead research in power electronics and power conversion integrated circuit as well as research in mixed signal RF/digital systems, including microcontroller-based Bluetooth systems. I have served in my current position since 2012.

15. At NCSU my group designs microcontroller-based Bluetooth systems as well as power management systems, including integrated circuits as well as discrete power converters. I have supervised PhD and Master's students in power electronics and power management. I teach a graduate course ECE734 Power Management IC Design, which covers many aspects of power management, including use of FETs as switches, battery chargers and analog and digital electronics.

16. Prior to my current position, I served as an Assistant Professor of Electrical and Computer Engineering and Assistant Professor (courtesy) of Materials Science and Engineering at Carnegie Mellon University from 2006 to 2012.

17. I received my B.S. and M.S. in Electrical Engineering in 1995 and 1997, respectively, from Worcester Polytechnic Institute in Worcester, Massachusetts. I received my Ph.D. in Electrical Engineering from Harvard University in Cambridge, Massachusetts in 2006. I was employed full time while pursuing my master's degree.

18. Prior to entering academia, I worked as an engineer in private industry holding several engineering and managerial positions where I developed and oversaw the development of electrical and electronic circuits, including those

related to power transfer, power conversion, and semiconductor design in wired and wireless circuits and systems.

19. From 1995 to 1999, I held a position as an engineer and senior engineer at American Power Conversion, where I designed AC-DC and DC-DC converters. I headed the battery technology group.

20. As a design engineer at American Power Conversion, I designed and tested uninterruptible power supplies, which contained a microcontroller, AC-DC converters, and DC-AC converters. These systems connect to the mains and charge their internal battery from the mains, providing mains voltage output power either directly from the mains or from the internal battery if the mains fails. As part of my work, I headed the battery technology group and developed models for battery health that could be adapted into microcontroller based systems.

21. As part of my work at APC I was tasked with conducting the evaluation of competitors' products, by particular reference to their product features. This would include a literature search using printed and online materials to compare features, performance, and other relevant aspects of competitor products. I traveled numerous times in the US and internationally to trade conferences where I would evaluate competitor products being displayed. This included documenting features and performance as well as other commercially

relevant aspect, such as size, ease of use, etc. My findings would be provided to and discussed with Product Marketing Directors with a view to specifying the features for future APC products.

22. In my experience as an industry engineer, this sort of assessment typically forms part of a new product design process. My activity was typical for an engineer with 1-3 years' experience working in a consumer product company producing power management devices. When I moved on to a more senior role, another engineer would have assumed this responsibility.

23. I also lead the battery technology group, which investigated how to properly charge and maintain batteries, causes of battery failure and general health of batteries. The primary battery was the lead acid battery, which is the same as used in automobiles for starting and operating electronics.

24. From 1999 to 2001, I held a position as a Principal Consultant at Renaissance Design, Inc., where I designed power management ICs.

25. From 2000 to 2002, I held a position as a Manager of New Product Development at ON Semiconductor Corp., where I was responsible for six product development teams. In that role I oversaw the development of over twenty power management ICs in bipolar, CMOS, and BiCMOS technologies. At ON

Semiconductor my group designed power management controllers and built application boards for battery chargers and buck converters.

26. From 2002 to 2003, I held the position of Advanced System Engineering Manager at ON Semiconductor Corp., where I directed a team of system engineers to develop multi-phase power management ICs for Intel and AMD microprocessors.

27. I have published at least 51 academic journal papers, as shown in my curriculum vitae, relating to various topics related to millimeter wave and microwave circuits and systems, RFID circuits, wireless power transfer circuits, analog circuits, and RF circuits.

28. I have been the author of at least 79 conference articles, as shown in my curriculum vitae, relating to various topics related to millimeter wave and microwave circuits and systems, RFID circuits, wireless power transfer circuits, analog circuits, and RF circuits.

B. Curriculum Vitae

29. A copy of my curriculum vitae is attached as Appendix A to this declaration.

C. Compensation

30. I am being compensated at my standard consulting rate for the services I am providing in this case. The compensation is not contingent upon my performance, the outcome of this inter partes review or any other proceeding, or any issues involved in or related to this inter partes review.

D. Materials Reviewed

31. The documents on which I rely for the opinions expressed in this declaration are documents and materials identified in this declaration, including the '506 Patent, patents in the same family as the '506 Patent, the prosecution history for the '506 Patent and the prosecution history for patents in the priority chain of the '506 Patent, the prior art references and information discussed in this declaration, and any other references specifically identified in this declaration, in their entirety, even if only portions of these documents are discussed here in an exemplary fashion.

32. I have also relied on my own experience and expertise in electrical engineering, and specifically, in microcontroller-controller power management systems with internal batteries.

IV. STATEMENT OF LEGAL PRINCIPLES

33. I am not an attorney. For the purposes of this declaration, I have been informed about certain aspects of the law that are relevant to my analysis and opinions.

A. Claim Construction

34. I understand that words of a claim are generally given their ordinary and customary meaning, as understood by a person of ordinary skill in the art (“POSITA”) at the time of the invention, while construing to preserve validity in case of ambiguity.

35. With respect to means-plus-function claim terms, I am informed that use of the word “means” in a claim element creates a rebuttable presumption that the term is a means-plus-function claim term. The presumption is rebutted if the claim term as properly construed recites sufficiently definite structure.

36. I understand that the presence of a dependent claim that adds a particular limitation gives rise to a presumption that the limitation in question is not present in the independent claim. Under claim differentiation, there is an especially strong presumption that an independent claim does not require a limitation that is the only meaningful difference between that claim and its dependent claim; otherwise the dependent claim would be superfluous.

B. Written Description

37. I have been informed by counsel that the application for the '506 patent must satisfy the written description requirement of 35 USC § 112. I have been informed that, to satisfy the written description as to a given claim, the disclosure must convey with reasonable clarity to those skilled in the art that, as of the filing date of the patent, the inventor was in possession of the invention as claimed. The written description requirement is satisfied if the later-claimed subject matter is exactly described in the original disclosure, but it does not have to be described exactly if one skilled in the art, reading the original disclosure, would discern the limitation at issue in the claims. A satisfactory description may be found in originally filed claims or any other portion of the originally-filed specification. The subject matter of a claim need not be described literally (i.e., using the same terms) in order for the disclosure to satisfy the description requirement. However, the claim must be supported in the specification through express, implicit, or inherent disclosure. The adequacy of the written description is analyzed from the standpoint of one of ordinary skill in the art. Information which is well known in the art need not be described in detail in the specification. However, sufficient information must be provided to show that the inventor had

possession of the invention as claimed. My opinion regarding the written description requirement of 35 U.S.C. §112 is based upon this understanding.

C. Enablement

38. I have been informed that a claimed invention is enabled under 35 U.S.C. §112 if the specification teaches those of ordinary skill in the art how to make and use the invention as broadly as it is claimed, without undue experimentation. I have been advised that the assessment of undue experimentation is based on the level of skill in the art as of the effective filing date of the application on which the patents-in-suit claim priority. My opinion regarding 35 U.S.C. §112 enablement is based upon this understanding.

39. I understand that whether one reasonably skilled in the art could make or use the invention from disclosures in the patent must consider the information known in the art. I understand that a patent need not teach what is already well known. My opinion regarding 35 U.S.C. §112 enablement is based upon this understanding.

D. Indefiniteness

40. I have been informed that patent claim is invalid for indefiniteness if its claim, read in light of the specification delineating the patent, and the

prosecution history, fail to inform, with reasonable certainty, those skilled in the art about the scope of the invention.

E. Anticipation

41. I have been informed that in order to anticipate a patent claim, a single prior art reference must explicitly or inherently disclose every feature of the claim. I understand that a prior art reference merely capable of being modified so as to operate in the same manner as the patented device does not anticipate. I understand that, to establish inherency, the missing characteristic must be necessarily present in the single reference, and that it would be so recognized by persons of ordinary skill in the art. I also understand that the missing descriptive material cannot merely be probably or possibly present. I further understand that obviousness is not inherent anticipation, and that it is insufficient that a missing limitation is so similar to a limitation actually disclosed in the reference that one of ordinary skill in the art would see the substitution as obvious. I also understand that, if it is necessary to reach beyond the boundaries of a single reference to provide missing disclosure of the claimed invention, the proper ground for asserting invalidity is not anticipation, but obviousness.

F. Obviousness

42. I have been informed that an Asserted Claim may be found invalid, although not identically disclosed or described, if the claimed invention is obvious. I understand that an Asserted Claimed invention is obvious when the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which the subject matter pertains.

43. I have been informed that a patent claim is invalid because it is “obvious” under 35 U.S.C. § 103 if the claimed subject matter would have been obvious to a POSITA at the time the application for patent was filed, based upon one or more prior art references. I understand that an obviousness analysis should take into account (1) the scope and content of the prior art; (2) the differences between the claims and the prior art; and (3) the level of ordinary skill in the pertinent art.

44. I further understand that, in some circumstances, objective evidence or secondary considerations of non-obviousness (such as unexpected results, commercial success, long-felt but unsolved needs, failure of others, copy by others, licensing, and skepticism of experts) can rebut a prima facie showing of

obviousness, but if prima facie obviousness showing is strong enough, the evidence on secondary considerations may be inadequate. I understand that this objective evidence or secondary considerations of non-obviousness is relevant to the issue of obviousness and must be considered.

45. I have been informed that a conclusion of obviousness may be based upon a combination of prior art references. However, I understand that a patent composed of several elements may not be proved obvious merely by demonstrating that each of its elements was independently known in the art. I further understand that there must be an appropriate articulation of a reason to combine the elements from the prior art in the manner claimed, and obviousness cannot be based on a hindsight combination of components selected from the prior art using the patent claims as a roadmap.

46. I have been informed that the following exemplary rationales may lead to a conclusion of obviousness: the combination of prior art elements according to known methods to yield predictable results; the substitution of one known element for another to obtain predictable results; the use of known techniques to improve similar devices in the same way; and some teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill to modify the prior art reference teachings to arrive at the claimed invention.

However, a claim is not obvious if the improvement is more than the predictable use of prior art elements according to their established functions. Similarly, a claim is not obvious if the application of a known technique is beyond the level of ordinary skill in the art. Furthermore, when the prior art teaches away from combining certain known elements, discovery of a successful means of combining them is not obvious.

47. I have been informed that a prior art reference must be considered in its entirety, i.e. as a whole, including portions that would lead away from the claimed invention.

48. I have been informed that if the proposed modification or combination of the prior art would change the principle of operation of the prior art invention being modified, then the teachings of the references are not sufficient to render the Asserted Claims *prima facie* obvious.

49. I have been informed that when considering a disclosure or reference, it is proper to take into account not only specific teachings of the reference but also the inferences which one skilled in the art would reasonable be expected to draw therefrom.

G. Priority Date of the Claims

50. I have been informed that a U.S. patent application may claim the benefit of the filing date of an earlier patent application if the earlier patent application disclosed each limitation of the invention claimed in the later-filed U.S. patent application. I have also been informed that priority is determined on a claim-by-claim basis so that certain claims of a patent may be entitled to the priority date of an earlier-filed patent application even if other claims of the same patent are not entitled to that priority date.

51. I have also been informed that a patented claim is invalid if the claimed invention was patented, described in a printed publication, or in public use, on sale, or otherwise available to the public before the effective filing date of the claimed invention, or the claimed invention was described in an issued patent or a published patent application that was effectively filed before the effective filing date of the claimed invention.

V. LEVEL OF ORDINARY SKILL IN THE ART

52. I am not an attorney and offer no legal opinions. I have been informed about certain aspects of the law for purposes of my analyses and opinions.

53. I understand that in analyzing questions of invalidity and infringement, the perspective of a person having ordinary skill in the art (“POSA”) is often implicated, and the Court may need assistance in determining that level of skill.

54. I understand that the claims and written description of a patent must be understood from the perspective of a POSA. I have been informed that the following factors may affect the level of skill of a POSA: (1) the educational level of the inventor; (2) the type of problems encountered in the art; (3) the prior-art solutions to those problems; (4) the rapidity with which innovations are made; (5) the sophistication of the technology; and (6) the educational level of active workers in the field. A person of ordinary skill in the art is also a person of ordinary creativity in the art.

55. As provided in the ’506 Patent summary section (Section VI.A), I consider the ’506 Patent to be in the general technological field of power management supply, particularly an automobile battery charger. The “Abstract” describes “[a] portable backup charger” with certain technical features. The “Technical Field” of the ’506 Patent is “a portable backup power supply capable of providing DC power to various devices.” Col. 1:17-18. The ’506 Patent summary section (Section VI.A) describes “provid[ing] a portable backup charger which is

able to provide DC-current outputs in various-level voltages, and is able to output a large current source as the start-up source of the automobile.” Col. 1:28-31.

56. A person having ordinary skill in the art (“POSA” or “POSITA”) with respect to the ’506 Patent by the time of its earliest effective filing date (December 9, 2011) would have at least a Bachelor’s Degree in Electrical Engineering and at least two years of experience in the field of electrical engineering and specifically power supply management such as battery charging system design. Further education could also suffice in lieu of experience in the field or significant experience in the field could substitute for formal education.

57. While I consider my personal skills at the relevant time (whether December 9, 2011 for challenged claims 1–3, 6–8, 11-23, and 25, 27–33 and April 29, 2016 for challenged claims 9, 10, and 26, as I explain further below, or April 29, 2016 as alleged by the Petitioner for all challenged claims) to have been above the level of ordinary skill, in arriving at my conclusions for this report, I have considered the issues from the perspective of this person of ordinary skill. Thus, when I am discussing what a prior art reference discloses or suggests in this report, I am describing what I believe a POSITA would have understood as being disclosed or suggested by the prior art reference during the relevant time frame.

58. I have also considered the POSITA definition offered by Dr. Gary Woods on behalf of the Petitioner:

“Based on my knowledge and experience in the field and my review of the ’506 patent and its file history, I believe that a POSITA would have had at least a Bachelor’s of Science in electrical engineering or physics and at least two years of experience in circuit design for portable electronics. Such experience could be obtained through research and study in a graduate program or through employment in industry. I base this opinion on my experience collaborating with, consulting, and managing teams of engineers and technicians working on circuit design for portable electronics, including designs for power supply devices.”

Ex. 1003 (“Woods Decl.”) ¶ 17.

59. While there are some differences between Dr. Woods definition and mine, they are generally consistent, and my opinions remain the same even if Dr. Woods’ definition is applied when considering validity issues presented in this IPR proceeding. Moreover, I would qualify as a POSITA as of December 9, 2011 or April 29, 2016 under Dr. Woods’ definition.

VI. OVERVIEW OF THE TECHNOLOGY

A. The ’506 Patent

60. The ’506 Patent discloses a portable backup charger with an internal battery pack with lithium-based batteries, and DC-DC conversion circuitry to output

a first DC current controlled by the user via MCU (such as 5V, 12V, or 19V output ports) or a second large current output at output terminals (e.g., for jumpstarting a vehicle). Ex. 1001, Fig. 3, 3:36-4:7, 4:39-47; 5:30-45, *see generally* 3:48-7:41.

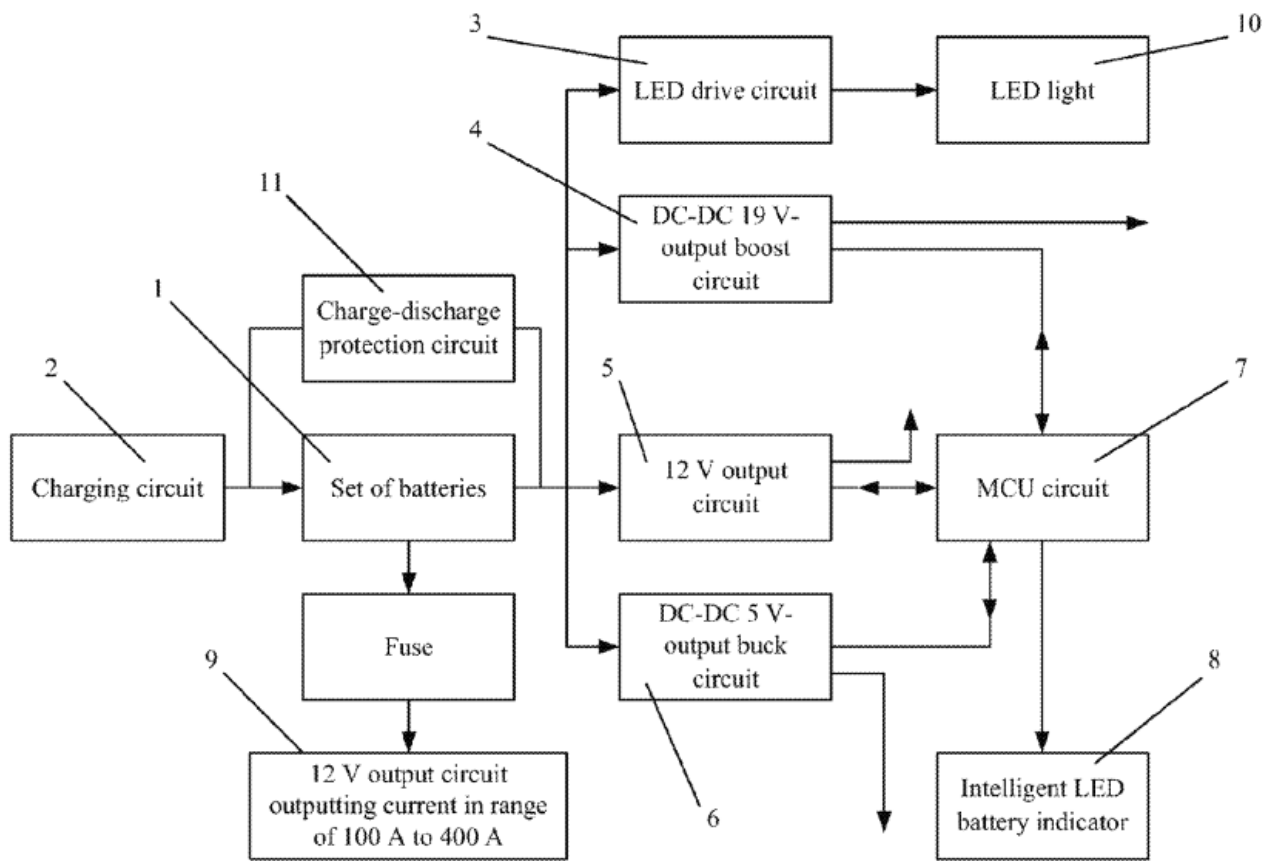


Figure 3

61. Fig. 3 and the corresponding description of the circuit appears in the priority application. Another embodiment of portable charger is in Fig. 1, and the specification of the '506 Patent explains the correspondence between the elements of Fig. 3 and the elements of Fig. 1. Ex. 1001 3:48-7:41.

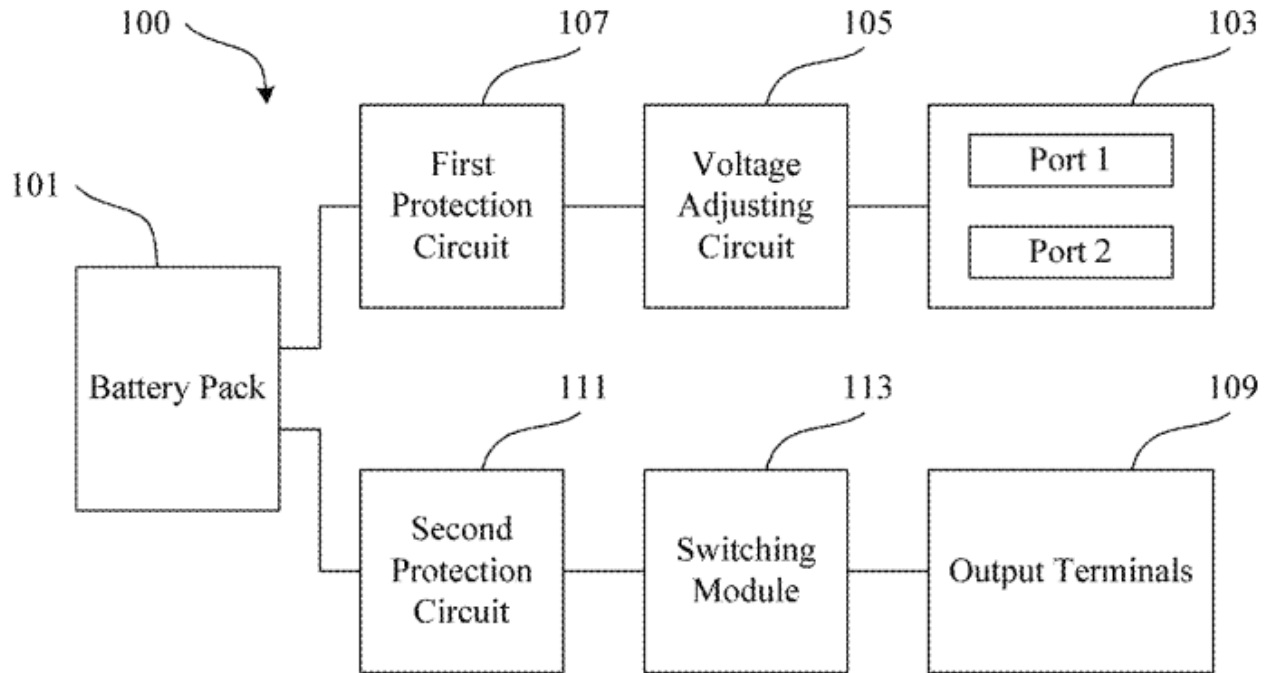


Figure 1

62. The charger uses first and second “protection circuits” 107 and 111 shown in Fig. 1, or shown as reference 11 and the fuse (not labeled with a reference number) in Fig. 3. Ex. 1001 at Fig. 1; 1:52-57, Fig. 3; 5:1-3, 6:7-21, 6:38-52.

63. The ’506 Patent discloses that the first protection circuit that “may also be used to protect overcurrent condition of the current outputting through the output ports 103.” Ex. 1001, Fig. 1, Fig. 3, Col. 5:1-20-29.

64. The ’506 Patent discloses that the second protection circuit “is used to protect against an overcurrent condition” when outputting a second current to the output terminals, and may comprise a fuse that would “cut off the current path from

the battery pack [] to the pair of output terminals []” in the event of an overcurrent condition caused a short-circuit of the output terminals or other reasons.” Ex. 1001, Col. 6:7-21, 6:38-52.

65. The ’506 Patent discloses that at direction of the user, the microcontroller can selectively enable the 19V, 12V, or 5V output to supply a first current for a particular instrument connected to the charger. Ex. 1001, Col. 7:30-39 (“By controlling the MCU circuit 7, the user can flexibly choose a particular output voltage for the charger (19 V. 12 V. or 5 V) to supply current source for a particular instrument (a cellphone, a computer, a digital camera, and etc.”).

66. A POSITA would understand that through these disclosures of the output circuits, the following output configurations or operating modes are possible (using one of the DC outputs – the 5V output – as an example):

Configuration / Operating Mode	5V Output (Fig. 3 Ref. 6)	12V 100-400A Output (Fig. 3 Ref. 9)
1	Enabled by user	Disabled because fuse is blown
2	Disabled by user	Enabled because fuse is not blown
3	Enabled by user	Enabled because fuse is not blown
4	Disabled by user	Disabled because fuse is blown

67. The specification of the '506 Patent has an express, additional text description of these modes shown in the table above.

- In a first operating mode, the charger is capable of outputting a first current to one or more of the output ports (e.g. 5V, 12V, 19V ports) for charging an accessory like a cell phone: “when the portable battery charger 100 is working in the first operating mode, it can output one or more output currents to one or more external electronic devices, respectively.” Col. 4:30-33; *see generally* Col. 4:30-5:29.
- In a second operating mode, the charger is capable of outputting a second current for starting a vehicle engine: “Moreover, when the portable battery charger 100 is working in the second operating mode, it can output a high current capable of starting the vehicle engine.” Col. 5:30-33; *see generally* Col. 5:30-57.
- In a third operating mode, the charger is capable of outputting a first current and second current at the same time: “In another embodiment, the charger can work in a third operating mode. In the third operating mode, the charger can output current through the at least one output ports 103 and through the pair of output terminals 109 simultaneously. In such a

case, the charger will have both current path outputting two currents at the same time.” Col. 5:58-62; *see generally* Col. 5:58-67.

68. There are multiple advantages of a mode where the output port’s first current and the output terminals’ second current are enabled one at a time in the first and second modes, respectively. For example, when second current output to the second terminals is enabled for a demanding jumpstart operation, it may be important to not have any battery power or current being provided to other connected accessories at the same time, such as a cell phone connected to the 5V output. This would allow the battery’s power to be maximally used for jumpstart operations. In another example, when using the 5V output to charge a cell phone over a period of hours, it may be advantageous to disable the second current to the output terminals (the 12V high-current output for jumpstarting) because the device may be left unattended, and thus, the output is preferably disabled to improve safety.

B. The ’506 Challenged Claims

69. I understand that the Petitioners are challenging 1–3, 6–23, and 25–33 claims in the ’506 Patent. These challenged claims are reproduced below, with labeling applied to the limitations that will be used in my declaration.

i. Claim 1

[1.P]	1. A portable backup charger, comprising:
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[1.1]	a battery pack having at least one battery cell;
[1.2]	at least one output port coupled to the battery pack, wherein the battery pack is configured to output a first current through one or more output ports of the at least one output port in a first operating mode;
[1.3]	a pair of output terminals coupled to the battery pack and having a current path to the battery pack different from that of the at least one output port to the battery pack, wherein the battery pack is configured to output a second current capable of starting a vehicle engine through the pair of output terminals in a second operating mode, wherein the second current is higher than the first current;
[1.4]	a first protection circuit coupled to the battery pack and configured to protect the battery pack when the battery pack is working in the first operating mode; and
[1.5]	a second protection circuit coupled to the battery pack and configured to prevent overcurrent condition of the second current when the battery pack is working in the second operating mode.

ii. Claim 2

[2]	2. The portable backup charger of claim 1, wherein when the first protection circuit is configured to prevent overcurrent condition of the first current, and overcharge and overdischarge condition of the battery pack.
-----	---

iii. Claim 3

[3]	3. The portable backup charger of claim 1, wherein the battery pack is further configured to work in a third operating mode for outputting the first current and the second current simultaneously, and in the third operating mode both the first protection circuit and the second protection circuit are active.
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iv. Claim 6

[6]	6. The portable backup charger of claim 1, further comprising a pair of connecting wires for detachably coupling the pair of output terminals
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	with the battery pack, each connecting wire having a clamp for clamping an electrode of an external vehicle battery.
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v. Claim 7

[7]	7. The portable backup charger of claim 6, wherein the second protection circuit is built into at least one of the pair of connecting wires.
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vi. Claim 8

[8]	8. The portable backup charger of claim 6, wherein the pair of connecting wires comprises a reverse connection-proof plug.
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vii. Claim 9

[9]	9. The portable backup charger of claim 1, further comprising a switching module operable to switch on or off the second current from the battery pack.
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viii. Claim 10

[10]	10. The portable backup charger of claim 9, wherein the switching module is further configured to prohibit the outputting of the second current after a predetermined time
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ix. Claim 11

[11]	11. The portable backup charger of claim 1, further comprising at least one voltage adjusting circuit, each voltage adjusting circuit being coupled between the battery pack and one of the at least one output port and configured to elevate or reduce an output voltage of the battery pack to a predetermined voltage at the respective output port.
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x. Claim 12

[12]	12. The portable back up charger of claim 1, wherein the first current is of 0.5 to 10 A.
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xi. Claim 13

[13]	13. The portable backup charger of claim 1, wherein the second current is of 100 to 400 A.
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xii. Claim 14

[14]	14. The portable backup charger of claim 1, further comprising a controller configured to control the operating mode of the battery pack.
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xiii. Claim 15

[15]	15. The portable backup charger of claim 1, wherein the discharge rate of the battery pack is in a range of 20 c to 70 c.
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xiv. Claim 16

[16]	16. The portable backup charger of claim 1, wherein the at least one output port comprises a universal serial bus (USB) port.
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xv. Claim 17

[17]	17. The portable backup charger of claim 1, wherein the at least one output port comprises an output port of a rating voltage of 12V.
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xvi. Claim 18

[18]	18. The portable backup charger of claim 1, wherein the at least one output port comprises an output port of a rating voltage of 19V.
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xvii. Claim 19

[19]	19. The portable backup charger of claim 1, wherein the at least one battery cell is lithium based battery cell.
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xviii. Claim 20

[20]	20. The portable backup charger of claim 1, wherein the pair of output terminals is detachably coupled to the battery pack.
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xix. Claim 21

[21.P]	21. A portable backup charger, comprising:
[21.1]	a battery pack having at least one battery cell;
[21.2]	a first current path through which a first current is output by the battery pack when it is working in a first operating mode;
[21.3]	a second current path through which a second current capable of starting a vehicle engine is output by the battery pack when it is working in a second operating mode, wherein the second current is higher than the first current;
[21.4]	a first protection circuit coupled to the battery pack and configured to protect the battery pack when it is working in the first operating mode; and
[21.5]	a second protection circuit coupled in the second current path and configured to prevent overcurrent condition of the second current when it is working in the second operating mode.

xx. Claim 22

[22]	22. The portable backup charger of claim 21, wherein the first protection circuit is configured to prevent overcurrent condition of the first current, and overcharge and overdischarge condition of the battery pack.
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xxi. Claim 23

[23]	23. The portable backup charger of claim 21, wherein the battery pack is further configured to work in a third operating mode for outputting the first current and the second current simultaneously, and in the third operating mode both the first protection circuit and the second protection circuit are active.
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xxii. Claim 25

	25. The portable backup charger of claim 21, further comprising: a pair
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[25.1]	of connecting wires for detachably coupling the battery pack with the vehicle engine to allow the second current flow through the second current path;
[25.2]	wherein the second protection circuit is built into at least one of the pair of connecting wires.

xxiii. Claim 26

[26]	26. The portable backup charger of claim 21, further comprising a switching module operable to switch on or off the second current path.
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xxiv. Claim 27

[27]	27. The portable backup charger of claim 21, wherein the second current is of 100 to 400 A.
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xxv. Claim 28

[28]	28. The portable backup charger of claim 21, further comprising a controller configured to control the operating mode of the battery pack.
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xxvi. Claim 29

[29]	29. The portable backup charger of claim 21, wherein the discharge rate of the battery pack is in a range of 20 c to 70 c.
------	--

xxvii. Claim 30

[30]	30. The portable backup charger of claim 21, wherein the at least one output port comprises a universal serial bus (USB)
------	--

xxviii. Claim 31

[31]	31. The portable backup charger of claim 21, wherein the at least one output port comprises an output port of a rating voltage of 12V.
------	--

xxix. Claim 32

	32. The portable backup charger of claim 21, wherein the at least one
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[32]	output port comprises an output port of a rating voltage of 19V.
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xxx. Claim 33

[33]	33. The portable backup charger of claim 21, wherein the at least one battery cell is lithium based battery cell.
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VII. CLAIM CONSTRUCTION

70. I understand that claim terms generally are construed in accordance with the ordinary and customary meaning they would have to a POSA at the time of the invention in light of the claim language, the specification, and the prosecution history. I understand that dictionaries and other extrinsic evidence may be considered as well, though such evidence is typically regarded as less significant than the intrinsic record in determining the meaning of the claim language

71. For all terms of the challenged claims of the '506 patent, I have interpreted them as they would have been understood by a POSA at the time of the invention, *i.e.*, December 9, 2011 for challenged claims 1–3, 6–8, 11–23, and 25, 27–33 and April 29, 2016 for challenged claims 9, 10, and 26, as explained further in Section VIII. Even if Petitioner is found to be correct that April 29, 2016 is the correct priority date for all claims, my analysis and conclusions about the proper construction of the claims remains the same.

72. It is my opinion that the following terms require construction to address this Petition; I do not address terms that may require construction in the district court.

1. “first operating mode”

73. This term appears in independent claims 1 and 21.

74. In my opinion, the proper construction for “first operating mode” is “an operating mode of the portable backup charger wherein the battery pack is configured to output a first current through one or more output ports of the at least one output port, and outputting a second current capable of starting a vehicle engine through the pair of output terminals is inhibited.”

75. The claims of the ’506 patent claim three operating modes, each of which are defined by the current output by the device during that mode.

76. Claim 1 recites “wherein the battery pack is configured to output a first current through one or more output ports of the at least one output port in a first operating mode.” Claim 1 further recites “wherein the battery pack is configured to output a second current capable of starting a vehicle engine through the pair of output terminals in a second operating mode.” Claim 1 further recites that a first protection circuit operable when the first current is being output, and a second protection circuit operable when the second current is being output.

77. Claim 3 depends on Claim 1, further reciting “wherein the battery pack is further configured to work in a third operating mode for outputting the first current and the second current simultaneously.” Col: 8:47-52.

78. If the battery pack could output the first current and the second current simultaneously in the first operating mode, then there would be no difference between the claimed first operating mode and the claimed third operating mode. In other words, by claiming a third operating mode for outputting the first current and the second current simultaneously, in the first operating mode, the first current can be output and outputting of a second current is inhibited.

79. The construction is also supported by the specification. As explained in the overview of the '506 Patent in Section VI.A, the specification of the '506 Patent describes three operating modes:

- In a first operating mode, the charger is capable of outputting a first current to one or more of the output ports (e.g. 5V, 12V, 19V ports) for charging an accessory like a cell phone: “when the portable battery charger 100 is working in the first operating mode, it can output one or more output currents to one or more external electronic devices, respectively.” Col. 4:30-33; *see generally* Col. 4:30-5:29.
- In a second operating mode, the charger is capable of outputting a second current for starting a vehicle engine: “Moreover, when the portable battery charger 100 is working in the second operating mode, it can

output a high current capable of starting the vehicle engine.” Col. 5:30-33; *see generally* Col. 5:30-57.

- In a third operating mode, the charger is capable of outputting a first current and second current at the same time: “In another embodiment, the charger can work in a third operating mode. In the third operating mode, the charger can output current through the at least one output ports 103 and through the pair of output terminals 109 simultaneously. In such a case, the charger will have both current path outputting two currents at the same time.” Col. 5:58-62; *see generally* Col. 5:58-67.

80. Taken together, these disclosures indicate that in the first operating mode, the device cannot output a second current to the output terminals. This is further supported by the '506 Patent specification disclosure that that operation in the first operating mode and second operating mode are alternatives to one another: “the portable battery charger 100 can work in a first operating mode or in a second operating mode.” Col. 4:18-20. In other words, the first operating mode and second operating mode are alternatives for outputting the first current or second current, respectively, but not both simultaneously.

81. As further explained in the overview of the '506 Patent in Section VI.A, the December 9, 2011 priority application discloses these three modes to a POSITA, albeit without the express use of the term operating mode.

2. “second operating mode”

82. This term appears in independent claims 1 and 21.

83. In my opinion, the proper construction for “second operating mode” is “an operating mode of the portable backup charger wherein the battery pack is configured to output a second current capable of starting a vehicle engine through the pair of output terminals, and outputting a first current through one or more output ports of the at least one output port is inhibited.”

84. The analysis and reasoning for this term is similar to the “first operating mode” term, and is provided below for completeness.

85. The claims of the '506 patent claim three operating modes, each of which are defined by the current output by the device during that mode.

86. Claim 1 recites “wherein the battery pack is configured to output a second current capable of starting a vehicle engine through the pair of output terminals in a second operating mode.” Claim 1 further recites “wherein the battery pack is configured to output a first current through one or more output ports of the at least one output port in a first operating mode.” Claim 1 further recites that a first

protection circuit operable when the first current is being output, and a second protection circuit operable when the second current is being output.

87. Claim 3 depends on Claim 1, further reciting “wherein the battery pack is further configured to work in a third operating mode for outputting the first current and the second current simultaneously.” Col: 8:47-52.

88. If the battery pack could output the first current and the second current simultaneously in the second operating mode, then there would be no difference between the claimed second operating mode and the claimed third operating mode. In other words, by claiming a third operating mode for outputting the first current and the second current simultaneously, in the first operating mode, the first current can be output and outputting of a first current is inhibited.

89. The construction is also supported by the specification. As explained in the overview of the '506 Patent in Section VI.A, the specification of the '506 Patent describes three operating modes:

- In a first operating mode, the charger is capable of outputting a first current to one or more of the output ports (e.g. 5V, 12V, 19V ports) for charging an accessory like a cell phone: “when the portable battery charger 100 is working in the first operating mode, it can output one or

more output currents to one or more external electronic devices,
respectively.” Col. 4:30-33; *see generally* Col. 4:30-5:29.

- In a second operating mode, the charger is capable of outputting a second current for starting a vehicle engine: “Moreover, when the portable battery charger 100 is working in the second operating mode, it can output a high current capable of starting the vehicle engine.” Col. 5:30-33; *see generally* Col. 5:30-57.
- In a third operating mode, the charger is capable of outputting a first current and second current at the same time: “In another embodiment, the charger can work in a third operating mode. In the third operating mode, the charger can output current through the at least one output ports 103 and through the pair of output terminals 109 simultaneously. In such a case, the charger will have both current path outputting two currents at the same time.” Col. 5:58-62; *see generally* Col. 5:58-67.

90. Taken together, these disclosures indicate that in the second operating mode, the device cannot output a first current to the first output. This is further supported by the '506 Patent specification disclosure that that operation in the first operating mode and second operating mode are alternatives to one another: “the portable battery charger 100 can work in a first operating mode or in a second

operating mode.” Col. 4:18-20. In other words, the first operating mode and second operating mode are alternatives for outputting the first current or second current, respectively, but not both simultaneously.

91. As further explained in the overview of the ’506 Patent in Section VI.A, the December 9, 2011 priority application discloses these three modes to a POSITA, albeit without the express use of the term operating mode.

3. “a current path to the battery pack different from that of the at least one output port to the battery pack”

92. This term appears in independent claim 1.

93. In my opinion, the proper construction for “a current path to the battery pack different from that of the at least one output port to the battery pack” is “a current path between the output terminals and the battery pack that does not overlap with a current path between the at least one output port and the battery pack.”

94. First, this interpretation is supported to the claim language itself. Claim 1 recites a “*pair of output terminals* coupled to the battery pack and *having a current path to the battery pack different from that of the at least one output port to the battery pack.*” Col. 8:28-30. In other words, the path the current takes from the output terminals to the battery pack is different than the path the current takes from the output port to the battery pack. If the paths were partially or completely the same, the paths would not be different paths as the claim requires.

95. Figure 1 of the '506 Patent, shown below) shows separate, non-overlapping current paths between 1) the battery pack 101 and output terminals 109 (highlighted in green) and 2) the battery pack 101 and ports 103 (highlighted in red). These paths originate at the battery and do not overlap with one another.

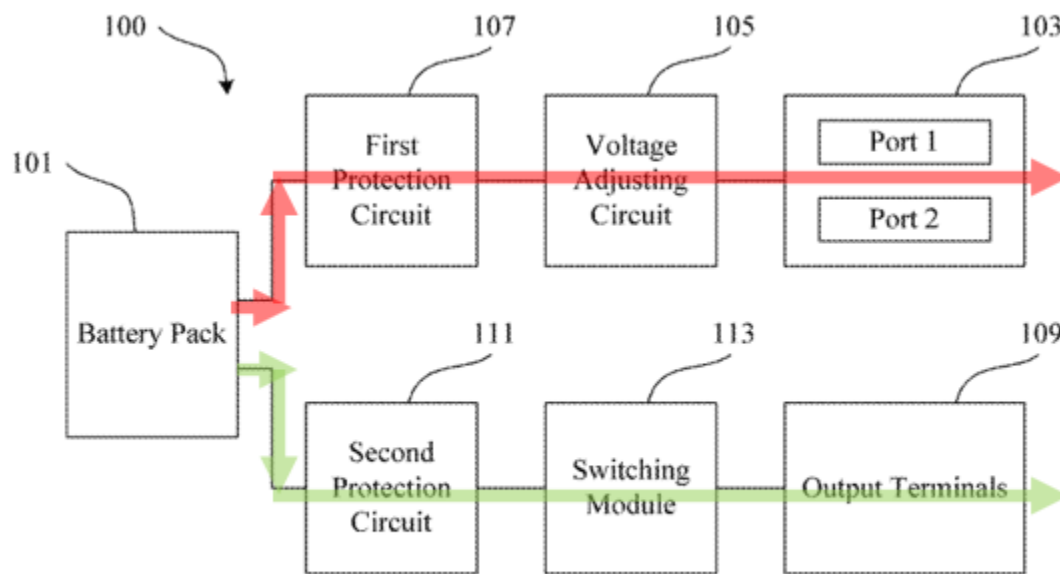
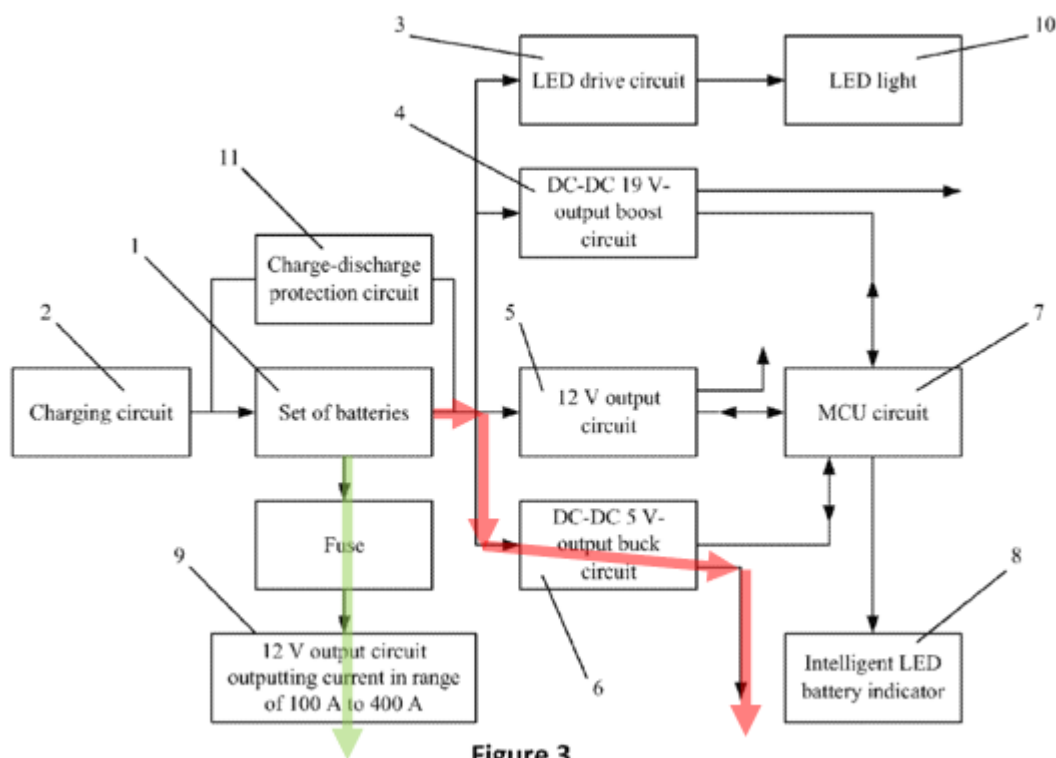


Figure 1

96. Figure 3 of the '506 Patent, shown below) shows separate, non-overlapping current paths between 1) the battery pack 1 and output terminals 9 (highlighted in green) and 2) the battery pack 1 and 5V output port 6 (highlighted in red). These paths originate at the battery and do not overlap with one another.



97. The specification of the '506 Patent states that: “The pair of output terminals 109 provides a current path different and separate from the current path from the battery pack 101 to the output ports 103.” Ex. 1001 Col. 5:46-48. This further supports the construction that the paths are non-overlapping.

98. Moreover, a construction that allowed for partials overlap of the current paths is inconsistent with the language of the claim. Since the termination point of the first current path is an output port, and the termination of the second current path is the output terminals, it follows that the current paths are already at least partially different from each other. If that was all this claim limitation required, all possible

first and second current paths would be different, and the additional claim language would be meaningless. Rather, the specification and claim language make it clear that no portion of the current path between the output terminals and battery pack should be shared or overlap with the current path between the output port and battery pack.

99. Additionally, Claim 1 recites a “a second protection circuit coupled to the battery pack and configured to prevent overcurrent condition of the second current.” Ex. 1001 at Col. 8:39-42. Such a circuit could detect the magnitude of the second current, or take an action if the magnitude of the second exceeded a value such as a fuse that will interrupt flow of current if the second current exceeds a value, as described in Col. 6:7-21. The second protection circuit requires a separate and independent current path between the battery and the output terminals, so that what the second protection circuit measures is the second current (i.e., the current between the battery and output terminals), and not a mixture of the second current and other current to other loads connected to the battery.

VIII. PRIORITY OF THE '506 PATENT CLAIMS

100. I was asked to analyze the disclosure of the priority applications for the '506 Patent, to find exemplary support for the challenged claims in China Patent Application Number 201110409190.9 (original document in Ex. 2002, certified

translation in Ex. 2003, issued as CN102496985B, original document is Ex. 2004, certified translation of CN102496985B in Ex. 2005), or PCT/CN2012/083793, published as WO 2013/082982 A1 (original document in Ex. 2006, certified translation in Ex. 2006).

1. Claim 1

101. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[1.P]	1. A portable backup charger, comprising:	“The present invention relates to the field of DC power supplies, specifically to a portable backup power supply capable of providing DC power to various devices.”
[1.1]	a battery pack having at least one battery cell;	“A portable backup power supply that includes a battery pack comprises lithium iron phosphate or lithium cobalt oxide batteries ...” “This portable backup power supply uses lithium iron phosphate or lithium cobalt oxide batteries as the battery pack ...”
[1.2]	at least one output port coupled to the	“The lithium iron phosphate or

	battery pack, wherein the battery pack is configured to output a first current through one or more output ports of the at least one output port in a first operating mode;	lithium cobalt oxide battery pack 1 is connected to multiple DC-DC voltage regulation circuits, namely the DC-DC 19 V boost output circuit 4, the 12V output circuit 5, and the DC-DC 5 V buck output circuit 6. Each of these DC- DC regulation circuits is connected to the MCU microcomputer control circuit 7.” “...4. DC-DC 19 V boost output circuit; 5. 12 V output circuit; 6. DC-DC 5 V buck output circuit; 7. MCU microcomputer control circuit;...” Fig. 1, refs. 4, 5, 6. “As shown in FIG. 1, the schematic structure of the portable backup power supply described in this invention is provided. The lithium iron phosphate or lithium cobalt oxide battery pack 1 is connected to multiple DC-DC voltage regulation circuits, namely the DC-DC 19 V boost output circuit 4, the 12V output circuit 5, and the DC-DC 5 V buck output circuit 6. Each of these DC-DC regulation circuits is connected to the MCU microcomputer control circuit 7. Through the MCU
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		microcomputer control circuit 7, users can flexibly select the desired voltage output to meet the outdoor power supply requirements for devices such as mobile phones, computers, and digital cameras.”
[1.3]	a pair of output terminals coupled to the battery pack and having a current path to the battery pack different from that of the at least one output port to the battery pack, wherein the battery pack is configured to output a second current capable of starting a vehicle engine through the pair of output terminals in a second operating mode, wherein the second current is higher than the first current;	“Since this power supply uses the lithium iron phosphate or lithium cobalt oxide battery pack 1 as an energy storage device, it has the advantages of being lightweight, compact, durable, having a high instantaneous discharge current, and being able to be recharged repeatedly.. ... It is also connected to a 12V high-current output circuit 9 that can provide a current output of 100 A 400 A at 12 V, which can be used as an emergency power supply to start a car.” Fig. 1, refs. 9. “...this invention provides a portable backup power supply that not only has charging capabilities and offers multiple voltage-level DC outputs, but also features high-current output capability, making it suitable as a car starter power supply”
[1.4]	a first protection circuit coupled to the battery pack and configured to protect	“11. protection circuit”

	the battery pack when the battery pack is working in the first operating mode; and	Fig. 1, ref. 11. “To ensure safe charging and discharging of the battery pack, the lithium iron phosphate or lithium cobalt oxide battery pack 1 is connected to a protection circuit 11 that provides overcurrent and overload protection.” “...said battery pack is connected to a charging and discharging protection circuit ...” “The high-current output for starting cars is connected directly across the battery pack without passing through the discharge protection circuit.”
[1.5]	a second protection circuit coupled to the battery pack and configured to prevent overcurrent condition of the second current when the battery pack is working in the second operating mode.	“It is also connected to a 12V high-current output circuit 9 that can provide a current output of 100 A 400 A at 12 V, which can be used as an emergency power supply to start a car. The high-current output for starting cars is connected directly across the battery pack without passing through the discharge protection circuit. To prevent the battery from overheating due to short-circuiting or reverse connection of the positive and negative

		clips during emergency car starting, a 150 A to 250 A fuse is included in the circuit. To reduce the probability of short-circuiting due to collisions between the two battery clips during emergency starting, a 150A 250A fuse is also included in the high-current output circuit for car starting. The output end uses an anti-reverse connection plug, and the positive and negative external connection wires are made of silicone wires of different lengths.” “In particular, in order to reduce the probability of short-circuiting due to collision of two battery clips during emergency starting, the high-current output circuit for car starting is connected in series with a 150 A to 250 A fuse.”
--	--	--

102. A POSITA would understand that through these disclosures of the output circuits for the DC-DC outputs (Fig. 1 Refs. 4, 5, 6) and 12V high current output (Fig. 1 Ref. 9), the following output configurations or operating modes are possible (using one of the DC outputs – the 5V output – as an example):

Configuration / Operating Mode	5V Output (Fig. 1 Ref. 6)	12V 100-400A Output (Fig. 2 Ref. 9)
-----------------------------------	------------------------------	--

1	Enabled by user	Disabled because fuse is blown
2	Disabled by user	Enabled because fuse is not blown
3	Enabled by user	Enabled because fuse is not blown
4	Disabled by user	Disabled because fuse is blown

103. In these modes, when an output is active (e.g. 5V output is enabled by the user or 12V output active because the fuse is not blown), the protection circuit 11 is active and the fuse is active to protect against overcurrent.

104. Fig. 1 shows that the current path from the output terminals of large current output circuit (Ref. 9) to the battery pack (Ref. 1) is different from the current path from the DC-DC output ports (such as 5V output circuit Ref. 6) to the battery pack (Ref. 1) as shown below.

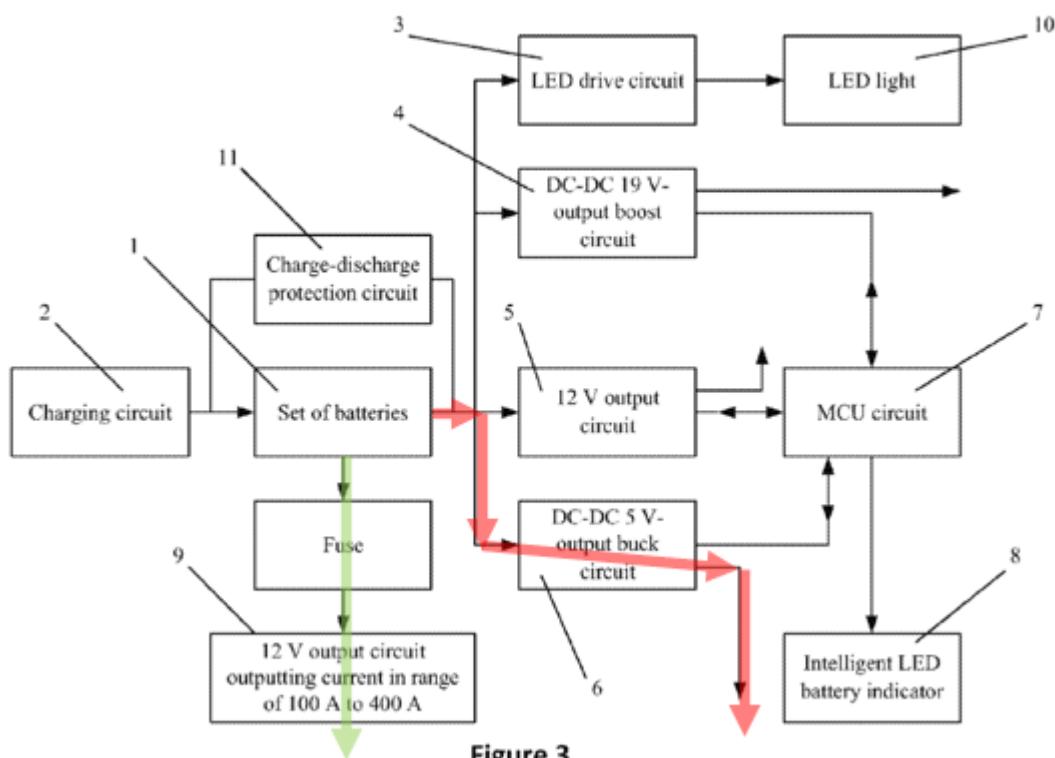


Figure 3

105. A POSITA would understand that the 19V, 12V, 5V DC-DC outputs (Fig. 1, refs. 4, 5, 6) with the specification states provide power (voltage and current) to “meet the outdoor power supply requirements for devices such as mobile phones, computers, and digital cameras,” and a POSITA would also understand that the current provided to these devices would be less than that provided to the terminals for the 100A-400A output (Fig. 1, ref. 9) for vehicle starting operations. For example, the image below is a brochure page for the E-Power Elite jumpstarter released in 2011, illustrative of typical battery chargers in this timeframe with similar outputs, showing 12V/10A, 5V/2A, and 19V/3.5A outputs, showing that the

typical current supplied to these outputs is far less than the 100A-400A supplied to the high current output for jumpstarting operations.



106. Moreover, the Fig. 1, reference 9 is described as the “large current” or “high current” output circuit with reference to the other DC-DC outputs, which

indicates that the current output to the output terminals is higher than the current to the DC-DC outputs.

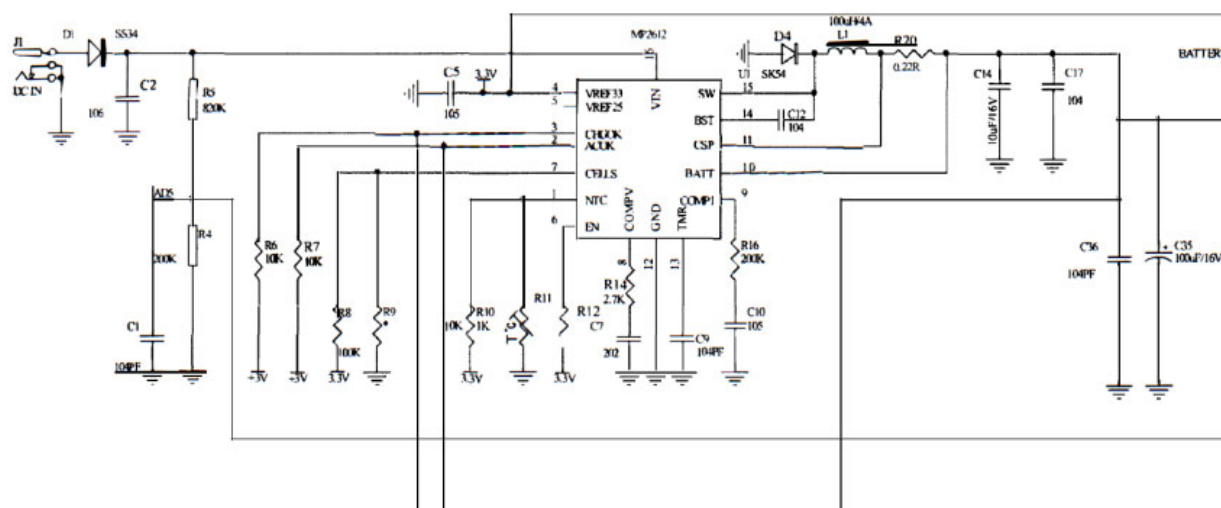
2. Claim 2

107. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

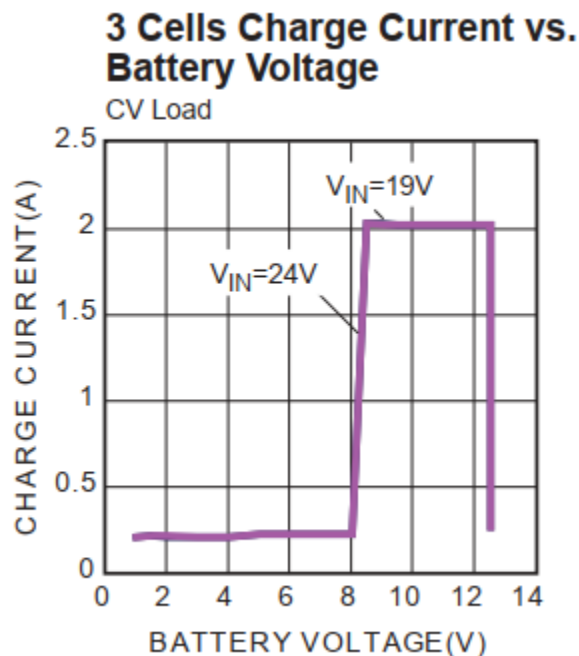
No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[2]	2. The portable backup charger of claim 1, wherein when the first protection circuit is configured to prevent overcurrent condition of the first current, and overcharge and overdischarge condition of the battery pack.	“...battery pack is equipped with a charge and discharge protection circuit.” Fig. 1, Ref. 11. “To ensure safe charging and discharging of the battery pack, the lithium iron phosphate or lithium cobalt oxide battery pack 1 is connected to a protection circuit 11 that provides overcurrent and overload protection..” Fig. 1 (showing a MP2612 connected between charging input J1 and the internal battery) Fig. 5 (showing a MP4462 connected between the internal battery and the USB connector

		J4)
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108. Fig. 1 of CN 201110409190.9 shows a charging input J1 that connects through an integrated circuit, marked on the schematic as the MP2612, to the internal battery being charged. A clearer copy of the Fig. 1 is included in the PCT publication (Ex. 2007) to which CN201110409190.9 claims priority, shown below.



109. Appendix B attached to this declaration is a publicly dated datasheet for the MP2612 marked with a publication date before the December 2011 priority date, and shows that charging stops to prevent the battery voltage from exceeding a maximum, avoiding overcharging of the battery, for example in the figure excerpted below from page 6 of the datasheet.



110. Figs. 5-6 of CN 201110409190.9 shows MPS integrated circuit step down converted MP4462 connected between the switched internal battery voltage and the USB output connector J4. A clearer copy of the Figs. 5-6 is included in the PCT publication (Ex. 2007) to which CN201110409190.9 claims priority, shown below, with the MP4462 annotated in blue, USB output J4 in orange.

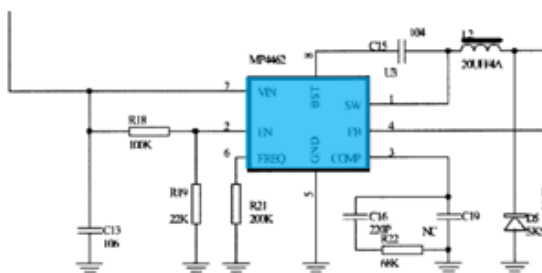


FIG 5

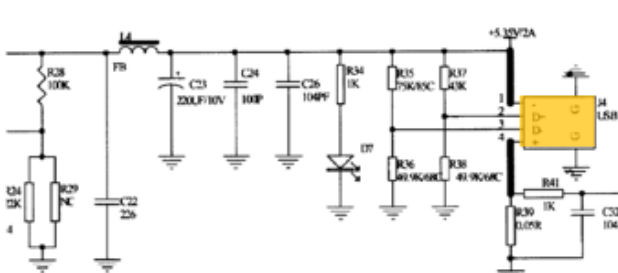


FIG 6

111. Appendix C attached to this declaration is a publicly dated datasheet for the MP4462 marked with a publication date before the December 2011 priority date.

112. The MP4462 prevents overdischarging by using an enable input at pin 2 that is a voltage divided version of the battery voltage, using resistors R18 and R19. If the battery voltage input is too low, the enable voltage will fall below the minimum voltage required to enable the circuit, defined on page 3 of the datasheet in Appendix B as 1.5 volts. Additionally, MP4462 has an overcurrent protection, described as “Internally Set Current Limit without a Current Sensing Resistor” on pages 1 and 9, and defined as 4.7A on page 3 of the datasheet.

3. Claim 3

113. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[3]	3. The portable backup charger of claim 1, wherein the battery pack is further configured to work in a third operating mode for outputting the first current and the second current simultaneously, and in the third operating mode both the first protection circuit and the second	See disclosure of Claim 1.

	protection circuit are active.	
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114. The analysis of Claim 1 explains that the disclosure of CN 201110409190.9 contemplates a mode where both a DC-DC output is enabled by the user via the microcontroller, and the 12V high-current output is active, where the protection circuit 11 and fuse shown in Fig. 1 protected each of these outputs, respectively.

4. Claim 6

115. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[6]	6. The portable backup charger of claim 1, further comprising a pair of connecting wires for detachably coupling the pair of output terminals with the battery pack, each connecting wire having a clamp for clamping an electrode of an external vehicle battery.	“To prevent the battery from overheating due to short-circuiting or reverse connection of the positive and negative clips during emergency car starting, a 150 A to 250 A fuse is included in the circuit.” “The output end uses a reverse connection-proof plug...” “The output end uses an anti-reverse connection plug, and the positive and negative external connection wires are made of

		silicone wires of different lengths.” “The output end uses an anti-reverse connection plug, ...”
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116. The disclosure contemplates a cable assembly with clips (the word used in the patent to refer to clamps) to connect to a vehicle battery, and a plug for connecting the cables to the battery pack without causing a reverse connection of the cable assembly to the battery pack. The plug disclosure indicates to a POSITA that the cables can be connected and disconnected from the battery pack.

5. Claim 7

117. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[7]	7. The portable backup charger of claim 6, wherein the second protection circuit is built into at least one of the pair of connecting wires.	See disclosure for claim 6. “To prevent the battery from overheating due to short-circuiting or reverse connection of the positive and negative clips during emergency car starting, a 150 A to 250 A fuse is included in the circuit. To reduce the

		probability of short-circuiting due to collisions between the two battery clips during emergency starting, a 150A 250A fuse is also included in the high-current output circuit for car starting.” “In particular, in order to reduce the probability of short-circuiting due to collision of two battery clips during emergency starting, the high-current output circuit for car starting is connected in series with a 150 A to 250 A fuse.” “The fuse is connected in series with either the positive or negative wire of the external connection cable.”
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118. A POSITA would understand that a fuse connected in series with a wire is integrated with one of the wires of the cable assembly.

6. Claim 8

119. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9

[8]	8. The portable backup charger of claim 6, wherein the pair of connecting wires comprises a reverse connection-proof plug.	“The output end uses an anti-reverse connection plug, and the positive and negative external connection wires are made of silicone wires of different lengths..” “The output end uses a reverse connection-proof plug, and the external connection cables use silicone wires of different lengths for the positive and negative wires..”
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120. The disclosure indicates that the battery pack and corresponding cable assembly with clips have reverse connection proof plugs to connect each other.

7. Claim 9

121. The limitations of this claim are supported at least in the application resulting in the '506 Patent, U.S. Application Ser. No. 15/141,841 (Ex. 1001) filed on April 29, 2016, as shown in the table below.

No.	Limitation Text	Support in U.S. Application Ser. No. 15/141,841
[9]	9. The portable backup charger of claim 1, further comprising a switching module operable to switch on or off the second current from the battery pack.	Ex. 1001, Fig. 1, Ref. 113. “The switching module 113 is operable to switch on or off the current from the battery pack 101 through the pair of output terminals 109,” Ex. 1001, Col. 6:55-58. <i>See generally</i> Ex. 1001, Col.

		6:53-7:22.
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8. Claim 10

122. The limitations of this claim are supported at least in the application resulting in the '506 Patent, U.S. Application Ser. No. 15/141,841 (Ex. 1001) filed on April 29, 2016, as shown in the table below.

No.	Limitation Text	Support in U.S. Application Ser. No. 15/141,841
[10]	10. The portable backup charger of claim 9, wherein the switching module is further configured to prohibit the outputting of the second current after a predetermined time	"For example, the switching module 113 may prohibit the outputting of the starting current after a predetermined time period from the outputting of the current, because the starting current is of a big amplitude Such as 100 A or even higher. Timely switching off the switching module 113 helps to reduce the power consumption of the engine starting as well as increase the lifetime of the battery pack 101." Ex. 1001, Col. 6:60-66.

9. Claim 11

123. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent
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		Application Number 201110409190.9
[11]	11. The portable backup charger of claim 1, further comprising at least one voltage adjusting circuit, each voltage adjusting circuit being coupled between the battery pack and one of the at least one output port and configured to elevate or reduce an output voltage of the battery pack to a predetermined voltage at the respective output port.	Fig. 1, reference 6 (showing (6) DC-DC 5V buck output circuit) “(6) DC-DC 5V buck output circuit;” Fig. 5 (showing a MP4462 connected between the internal battery and the USB connector J4) “...battery pack 1 is connected to multiple DC-DC voltage regulation circuits, namely the DC-DC 19 V boost output circuit 4, the 12V output circuit 5, and the DC-DC 5 V buck output circuit 6. Each of these DC-DC regulation circuits is connected to the MCU microcomputer control circuit 7....” “As shown in FIG. 1, the schematic structure of the portable backup power supply described in this invention is provided. The lithium iron phosphate or lithium cobalt oxide battery pack 1 is connected to multiple DC-DC voltage regulation circuits, namely the DC-DC 19 V boost output circuit 4, the 12V output

		circuit 5, and the DC-DC 5 V buck output circuit 6. Each of these DC-DC regulation circuits is connected to the MCU microcomputer control circuit 7. Through the MCU microcomputer control circuit 7, users can flexibly select the desired voltage output to meet the outdoor power supply requirements for devices such as mobile phones, computers, and digital cameras.” “The battery pack connects to various voltage regulation circuits and, through the MCU microcomputer control circuit, can provide outdoor power supply for devices such as mobile phones, computers, and digital cameras”
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124. The datasheet for the MP4462 shows that it is a DC-DC step down converter that accepts a voltage input up to 36V input and generates a regulated output, such as 5 volts. See Appendix C, page 1.

10. Claim 12

125. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[12]	12. The portable back up charger of claim 1, wherein the first current is of 0.5 to 10 A.	Fig. 5 (showing a MP4462 connected between the internal battery and the USB connector J4) “...battery pack 1 is connected to multiple DC-DC voltage regulation circuits, namely the DC-DC 19 V boost output circuit 4, the 12V output circuit 5, and the DC-DC 5 V buck output circuit 6. Each of these DC-DC regulation circuits is connected to the MCU microcomputer control circuit 7....” “As shown in FIG. 1, the schematic structure of the portable backup power supply described in this invention is provided. The lithium iron phosphate or lithium cobalt oxide battery pack 1 is connected to multiple DC-DC voltage regulation circuits, namely the DC-DC 19 V boost output circuit 4, the 12V output circuit 5, and the DC-DC 5 V buck output circuit 6. Each of these DC-DC regulation circuits is connected to the MCU microcomputer control circuit 7. Through the MCU microcomputer control circuit 7, users can flexibly select the desired voltage output to meet

		the outdoor power supply requirements for devices such as mobile phones, computers, and digital cameras.” “The battery pack connects to various voltage regulation circuits and, through the MCU microcomputer control circuit, can provide outdoor power supply for devices such as mobile phones, computers, and digital cameras.”
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126. The datasheet for the MP4462 shows that it is a DC-DC step down converter that accepts a voltage input up to 36V input and generates a regulated output, such as 5 volts, with a maximum current of 4.7A. See Appendix C, pages 1 and 3.

127. Moreover, a POSITA would understand that a conventional USB 1.0 output port at the priority date can supply 0.5A, 1.0A, or 2.0A of current.

11. Claim 13

128. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
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[13]	13. The portable backup charger of claim 1, wherein the second current is of 100 to 400 A.	“Preferably, the output voltage of said high-current output circuit for vehicle starting is 12 V DC, and the instantaneous current is 100 A to 400 A.” “It is also connected to a 12V high-current output circuit 9 that can provide a current output of 100 A 400 A at 12 V, which can be used as an emergency power supply to start a car.” See Fig. 1 reference 9 (“12V LARGE CURRENT OUTPUT CIRCUIT (100A-400A)”)
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12. Claim 14

129. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[14]	14. The portable backup charger of claim 1, further comprising a controller configured to control the operating mode of the battery pack.	“Through the MCU microcomputer control circuit 7, users can flexibly select the desired voltage output to meet the outdoor power supply requirements for devices such as mobile phones, computers, and digital cameras.”

		“The lithium iron phosphate or lithium cobalt oxide battery pack 1 is connected to multiple DC-DC voltage regulation circuits, namely the DC-DC 19 V boost output circuit 4, the 12V output circuit 5, and the DC-DC 5 V buck output circuit 6. Each of these DC-DC regulation circuits is connected to the MCU microcomputer control circuit 7.” Fig 1 (showing connection between the MCU (Ref. 7) and 19V, 12V, 5V output circuits (Refs. 4, 5, 6)).
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130. CN 201110409190.9 discloses that the user can configure the operating mode in part by interacting with an MCU, which in turn selectively enables one of 19V/12V/5V outputs (“Through the MCU microcomputer control circuit 7, users can flexibly select a desired voltage output....”). See the analysis of Claim 1 for disclosure of the operating modes disclosed in CN 201110409190.9.

13. Claim 15

131. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
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[15]	15. The portable backup charger of claim 1, wherein the discharge rate of the battery pack is in a range of 20 c to 70 c.	“The lithium iron phosphate or lithium cobalt oxide batteries are designed for high power, with a discharge rate reaching 20 c to 70 c.”
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14. Claim 16

132. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[16]	16. The portable backup charger of claim 1, wherein the at least one output port comprises a universal serial bus (USB) port.	See Fig. 6, J4 (showing USB connector) Fig. 1, reference 6 (showing (6) DC-DC 5V buck output circuit) “(6) DC-DC 5V buck output circuit;” Fig. 5 (showing a MP4462 connected between the internal battery and the USB connector J4) “The lithium iron phosphate or lithium cobalt oxide battery pack 1 is connected to multiple DC-DC voltage regulation circuits, namely the DC-DC 19 V boost output circuit 4, the 12V output circuit 5, and the DC-DC 5 V

	buck output circuit 6. Each of these DC-DC regulation circuits is connected to the MCU microcomputer control circuit 7” “As shown in FIG. 1, the schematic structure of the portable backup power supply described in this invention is provided. The lithium iron phosphate or lithium cobalt oxide battery pack 1 is connected to multiple DC-DC voltage regulation circuits, namely the DC-DC 19 V boost output circuit 4, the 12V output circuit 5, and the DC-DC 5 V buck output circuit 6. Each of these DC-DC regulation circuits is connected to the MCU microcomputer control circuit 7. Through the MCU microcomputer control circuit 7, users can flexibly select the desired voltage output to meet the outdoor power supply requirements for devices such as mobile phones, computers, and digital cameras.” “The battery pack connects to various voltage regulation circuits and, through the MCU microcomputer control circuit, can provide outdoor power supply for devices such as mobile phones, computers, and
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		digital cameras.”
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15. Claim 17

133. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[17]	17. The portable backup charger of claim 1, wherein the at least one output port comprises an output port of a rating voltage of 12V.	Fig. 1, ref. 5 (showing 12V output circuit). “The lithium iron phosphate or lithium cobalt oxide battery pack 1 is connected to multiple DC-DC voltage regulation circuits, namely the DC-DC 19 V boost output circuit 4, the 12V output circuit 5, and the DC-DC 5 V buck output circuit 6. Each of these DC-DC regulation circuits is connected to the MCU microcomputer control circuit 7” “As shown in FIG. 1, the schematic structure of the portable backup power supply described in this invention is provided. The lithium iron phosphate or lithium cobalt oxide battery pack 1 is

		connected to multiple DC-DC voltage regulation circuits, namely the DC-DC 19 V boost output circuit 4, the 12V output circuit 5, and the DC-DC 5 V buck output circuit 6. Each of these DC-DC regulation circuits is connected to the MCU microcomputer control circuit 7. Through the MCU microcomputer control circuit 7, users can flexibly select the desired voltage output to meet the outdoor power supply requirements for devices such as mobile phones, computers, and digital cameras.” “The battery pack connects to various voltage regulation circuits and, through the MCU microcomputer control circuit, can provide outdoor power supply for devices such as mobile phones, computers, and digital cameras.”
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134. A POSITA looking at the disclosure of CN 201110409190.9 would understand that the Fig. 1, ref. 5 includes a port for connecting the circuit to the devices to be powered/charged with the 12V output of the circuit.

16. Claim 18

135. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[18]	18. The portable backup charger of claim 1, wherein the at least one output port comprises an output port of a rating voltage of 19V.	Fig. 1, ref. 4 (showing 19V output circuit). “The lithium iron phosphate or lithium cobalt oxide battery pack 1 is connected to multiple DC-DC voltage regulation circuits, namely the DC-DC 19 V boost output circuit 4, the 12V output circuit 5, and the DC-DC 5 V buck output circuit 6. Each of these DC-DC regulation circuits is connected to the MCU microcomputer control circuit 7” “As shown in FIG. 1, the schematic structure of the portable backup power supply described in this invention is provided. The lithium iron phosphate or lithium cobalt oxide battery pack 1 is connected to multiple DC-DC voltage regulation circuits, namely the DC-DC 19 V boost output circuit 4, the 12V output circuit 5, and the DC-DC 5 V

		buck output circuit 6. Each of these DC-DC regulation circuits is connected to the MCU microcomputer control circuit 7. Through the MCU microcomputer control circuit 7, users can flexibly select the desired voltage output to meet the outdoor power supply requirements for devices such as mobile phones, computers, and digital cameras.” “The battery pack connects to various voltage regulation circuits and, through the MCU microcomputer control circuit, can provide outdoor power supply for devices such as mobile phones, computers, and digital cameras.”
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136. A POSITA looking at the disclosure of CN 201110409190.9 would understand that the Fig. 1, ref. 4 includes a port for connecting the circuit to the devices to be powered/charged with the 19V output of the circuit.

17. Claim 19

137. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent
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		Application Number 201110409190.9
[19]	19. The portable backup charger of claim 1, wherein the at least one battery cell is lithium based battery cell.	“A portable backup power supply that includes a battery pack comprises lithium iron phosphate or lithium cobalt oxide batteries”

18. Claim 20

138. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[20]	20. The portable backup charger of claim 1, wherein the pair of output terminals is detachably coupled to the battery pack.	See the analysis for claim 6.

19. Claim 21

139. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[21.P]	21. A portable backup charger, comprising:	See analysis of limitation [1.P].
[21.1]	a battery pack having at least one	See analysis of limitation [1.1].

	battery cell;	
[21.2]	a first current path through which a first current is output by the battery pack when it is working in a first operating mode;	See analysis of limitation [1.2].
[21.3]	a second current path through which a second current capable of starting a vehicle engine is output by the battery pack when it is working in a second operating mode, wherein the second current is higher than the first current;	See analysis of limitation [1.3].
[21.4]	a first protection circuit coupled to the battery pack and configured to protect the battery pack when it is working in the first operating mode; and	See analysis of limitation [1.4].
[21.5]	a second protection circuit coupled in the second current path and configured to prevent overcurrent condition of the second current when it is working in the second operating mode.	See analysis of limitation [1.5].

20. Claim 22

140. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[22]	22. The portable backup charger of claim 21, wherein the first protection circuit is configured to prevent overcurrent condition of the first	See analysis of Claim 2.

	current, and overcharge and overdischarge condition of the battery pack.	
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21. Claim 23

141. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[23]	23. The portable backup charger of claim 21, wherein the battery pack is further configured to work in a third operating mode for outputting the first current and the second current simultaneously, and in the third operating mode both the first protection circuit and the second protection circuit are active.	See analysis of Claim 3.

22. Claim 25

142. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[25.1]	25. The portable backup charger of claim 21, further comprising: a pair of	See analysis of Claim 6.

	connecting wires for detachably coupling the battery pack with the vehicle engine to allow the second current flow through the second current path;	
[25.2]	wherein the second protection circuit is built into at least one of the pair of connecting wires.	See analysis of Claim 7.

23. Claim 26

143. The limitations of this claim are supported at least in the application resulting in the '506 Patent, U.S. Application Ser. No. 15/141,841 (Ex. 1001) filed on April 29, 2016, as shown in the table below.

No.	Limitation Text	Support in U.S. Application Ser. No. 15/141,841
[26]	26. The portable backup charger of claim 21, further comprising a switching module operable to switch on or off the second current path.	See analysis of Claim 9.

24. Claim 27

144. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[27]	27. The portable backup charger of claim 21, wherein the second current is of 100 to 400 A.	See analysis of Claim 13.

25. Claim 28

145. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[28]	28. The portable backup charger of claim 21, further comprising a controller configured to control the operating mode of the battery pack.	See analysis of Claim 14.

26. Claim 29

146. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[29]	29. The portable backup charger of claim 21, wherein the discharge rate of the battery pack is in a range of 20 c to 70 c.	See analysis of Claim 15.

27. Claim 30

147. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[30]	30. The portable backup charger of claim 21, wherein the at least one output port comprises a universal serial bus (USB) port.	See analysis of Claim 16.

28. Claim 31

148. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[31]	31. The portable backup charger of claim 21, wherein the at least one output port comprises an output port of a rating voltage of 12V.	See analysis of Claim 17.

29. Claim 32

149. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[32]	32. The portable backup charger of claim 21, wherein the at least one output port comprises an output port of a rating voltage of 19V.	See analysis of Claim 18.

30. Claim 33

150. The limitations of this claim are supported in the priority application of the '506 Patent, China Patent Application Number 201110409190.9 (Ex. 2002 and Ex. 2003) filed on December 9, 2011, as shown in the table below.

No.	Limitation Text	Support in China Patent Application Number 201110409190.9
[33]	33. The portable backup charger of claim 21, wherein the at least one battery cell is lithium based battery cell.	See analysis of Claim 19.

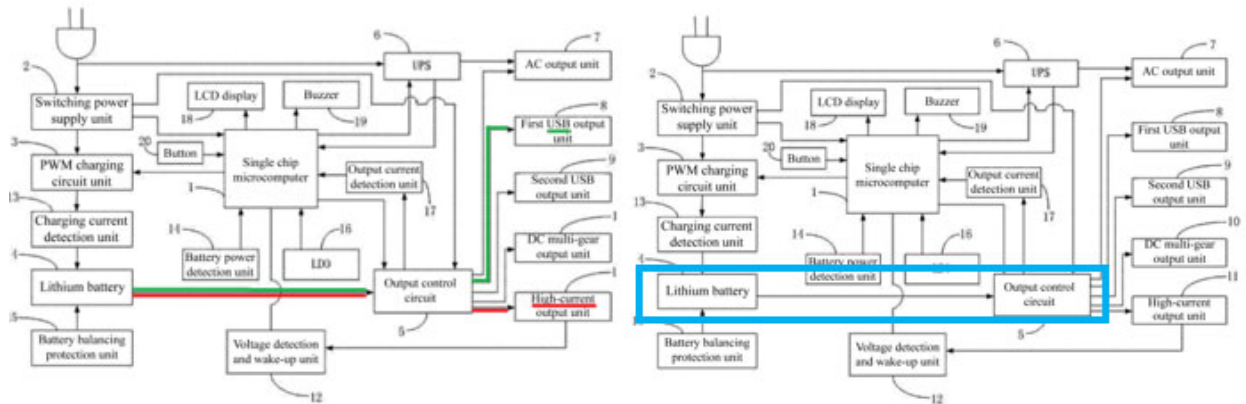
IX. PATENTABILITY OF THE CHALLENGED '506 PATENT CLAIMS

A. Ground 1A: §102 – Chen (CN102005796A)

1. Chen does not disclose a different current path from the output terminals to the battery pack that is different from the current path from the output port to the battery pack (Limitation [1.3] / [21.3]/[21.4])

151. Limitation [1.3] recites in part “a pair of output terminals coupled to the battery pack and having a current path to the battery pack different from that of the at least one output port to the battery pack.” Limitations [21.3]/[21.4] impose a similar requirement by separately reciting “a first current path” and “a second current path” in separate limitations: “a first current path through which a first current is output by the battery pack when it is working in a first operating mode;” “a second current path through which a second current capable of starting a vehicle engine is output by the battery pack when it is working in a second operating mode.”

152. The IPR petition on page 19 relies current paths in Chen which overlap between the lithium battery 4 and output control circuit 5. Without the highlighting added by Petitioner in the IPR Petition to the line connecting lithium battery 4 and output control circuit 5 in Chen Fig. 1, it is clearer that this is a single current path shared by the high current output unit 11, = DC multi-gear output 10, and USB outputs 8 and 9.



153. In fact, the paths only diverge when making connecting the output control circuit to these respective outputs, which I explained above in connection with claim construction of this term in Section VII.3, is insufficient to meet the claim requirement of different paths.

154. Therefore, because the current paths relied upon in the Petition are not “different” current paths to the battery pack as required by the plain language of this limitation and proper construction of this limitation, and in fact share the same current path to the battery pack, this limitation [1.3] is not met.

155. Limitations [21.3] and [21.4] recite separate structures in different claim elements for the first current path and second current path. Despite this, the IPR petition relies in part on the same structure (the current path between lithium battery 4 and output control circuit 5 in Chen Fig. 1) to meet the requirements of both limitations [21.3] and [21.4], each of which recite current paths output from the

battery pack. My understanding is that is not permitted, and thus, these limitations are not met.

2. The Petition Does Not Identify the Claimed First Protection Circuit (Limitation [1.4] / [21.4])

156. Limitation [1.4] recites “a first protection circuit coupled to the battery pack and configured to protect the battery pack when the battery pack is working in the first operating mode.” Limitation [21.4] similarly recites “a first protection circuit coupled to the battery pack and configured to protect the battery pack when it is working in the first operating mode.”

157. These limitations that the first protection circuit protects the battery pack when the device is working in the first operating mode, e.g. when “the battery pack is configured to output a first current through one or more output ports of the at least one output port in a first operating mode” as recited in limitation [1.2] and similarly, when “a first current is output by the battery pack when it is working in a first operating mode” through “a first current path” as recited in limitation [21.2].

158. In the IPR petition, the petitioner pointed to Chen paragraph 26 and the electronics “‘U3B and D12’ to form ‘an output power limit control’,” stating that “this circuit is configured to protect Chen’s internal battery 4 from an overcurrent condition through the USB outputs 8, 9 (or the multi-gear output 10) that might otherwise cause “damage” to Chen’s battery and other electronics.” IPR Petition at

20. This is incorrect. Chen Figs. 6 and 7 show that U3B and D12 (highlighted in blue below) are not connected to the USB outputs (highlighted in orange below) and have no role in providing a “power limit control” or other protection of those USB outputs.

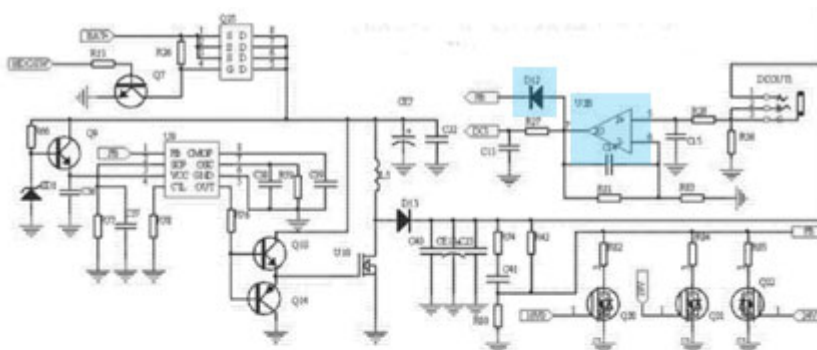
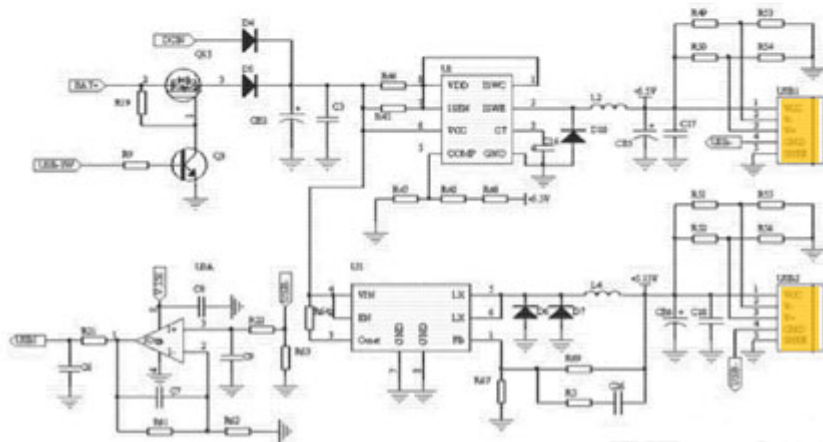


FIG. 6



159. The IPR Petition apparently relies only on the USB output ports for limitations [1.2] and [1.3], as those ports are the only ports analyzed in limitation [1.3] for the requirement that the second current is higher than the first current.

160. Stated another way, the IPR petition does not analyze whether the multi-gear output 10 has a current less than the first current as required by limitation [1.3], and the IPR petition does not identify a first protection circuit for the USB outputs 8, 9 as required by limitation [1.4].

161. For limitation [21.4], the IPR petition on page 28 simply refers to the analysis and evidence cited in limitation [1.4], and thus fails to address the requirements of this limitation for the same reason.

3. Chen does not disclose a second protection circuit that prevents an overcurrent condition (Limitation [1.5] / [21.5])

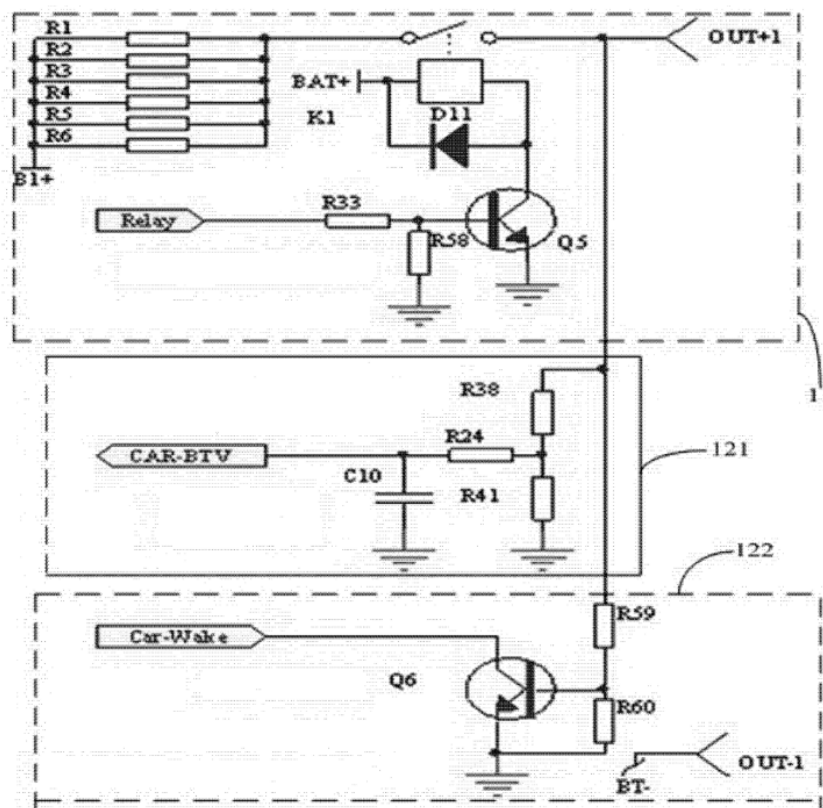
162. Limitation [1.5] recites “a second protection circuit coupled to the battery pack and configured to prevent overcurrent condition of the second current when the battery pack is working in the second operating mode.” Limitation [21.5] similarly recites “a second protection circuit coupled in the second current path and configured to prevent overcurrent condition of the second current when it is working in the second operating mode.” Thus, both limitations require the second protection circuit to prevent an overcurrent condition in the second operating mode.

163. The IPR Petition at page 21 identifies the “high-current output unit 11” as providing this protection. However, the operation of this circuit measures voltages to determine when to output a high current for ignition, and uses a detection of a voltage returning to normal to determine that the high current for ignition should

be turned off, as explained below in Paragraph 25 of Chen relied upon by the Petitioner, with reference to Fig. 4:

“When the car battery is connected to the high-current output unit 11, the wake-up unit 122 notifies the single-chip microcomputer 1 that the car battery has been connected, the single-chip microcomputer 1 controls the high-current output unit 11 to instantly output a high current for ignition, and then a battery voltage is detected by means of the electrical device voltage detection unit 121. If the battery voltage returns to normal, the high-current instantaneous output module is turned off. That is, when the mobile power supply is connected to the car battery, sampling is performed by means of the voltage dividing resistors R59 and R60 of the wake-up unit 122, and the transistor Q6 is controlled to turn on, and the single-chip microcomputer 1 is notified that the car battery has been connected. When the car ignites, high-current control components R1 to R6 instantly output a large current to complete the ignition. When the car starts, the voltage of the car battery is divided and detected by means of the detection resistors R38 and R41. When the battery voltage returns to normal, the relay K1 is automatically turned off to prevent long-term high-current output from damaging the lithium battery 4.”

Ex. 1006 at Paragraph 26.



Ex. 1006 at Fig. 4.

164. Paragraph 35 of Chen, also cited in the IPR petition, does not provide any additional technical disclosure.

165. A POSITA would understand from the description of the circuits, and from the circuits themselves (i.e. the circuit including the voltage dividing resistors R59 and R60 of the wake-up unit 122, and the voltage detecting circuit including detection resistors R38 and R41) that these circuits are voltage detection circuits, and not current detection circuits. Stated another way, these circuits do not detect a current or protect against an overcurrent condition -- the second current being

provided in the second path exceeding a maximum current value -- as required by the claims. Rather, the circuit detects voltages to determine when a jumpstarting operation is completed.

166. For limitation [21.5], the IPR petition on page 28 simply refers to the analysis and evidence cited in limitation [1.5], and thus fails to disclose the limitation for the same reason.

4. Dependent Claims 9, 11-14, 16-19, 26-28, 30-33

167. Claims 9, 11-14, 16-19, 26-28, 30-33 depend on either independent claim 1 or claim 21, and thus, are not invalid for the same reasons above explaining why claims 1 and 21 are valid in view of Chen.

B. Ground 1B: §103 –Chen in view of White (US7,279,640)

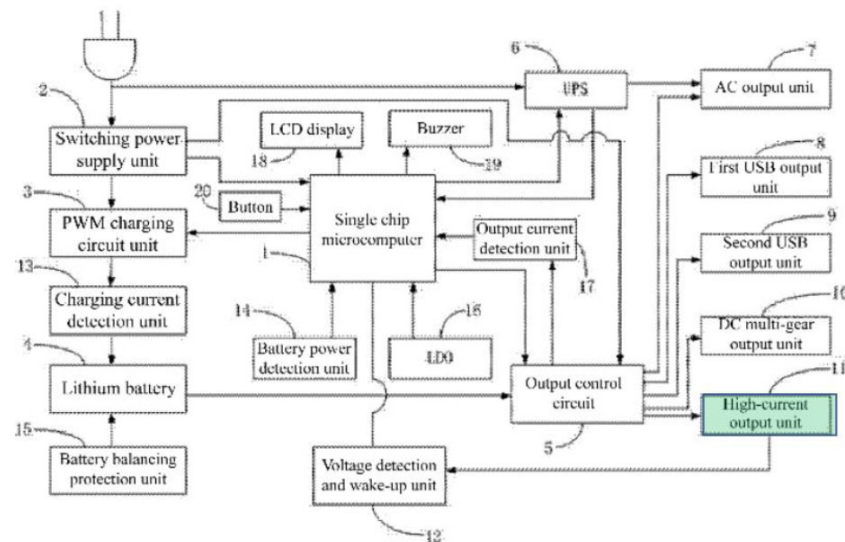
1. Claims 1-2, 6-9, 11-14,16-22, 25-28, 30-33

168. Petitioner's Ground 1B contends a combination of Chen and White under 35 USC §103.

169. This combination fails to invalidate Claims 1-2, 6-9, 11-14,16-22, 25-28, 30-33 at least for the reason that Chen fails to disclose all of the requirements of independent claims 1 and 21, as explained in Section IX.A, and this ground does not rely on any additional teachings of White to address all of these deficiencies.

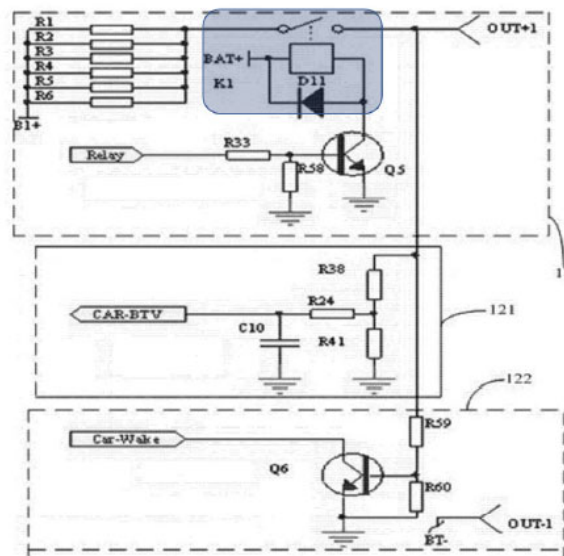
170. Moreover, this contended combination of Chen and White is improper because the teachings in Chen and White refute such combination.

171. Chen discloses a mobile power supply with a high-current output unit 11 as a high-current instantaneous output module (car ignition module). Petitioner's annotated FIG. 1 of Chen is reproduced below.



EX1006, FIG. 1 (annotated)

172. Petitioner acknowledges that the high-current output unit 11 in Chen includes at least a relay K1 as shown in FIG. 4 of Chen. Petition at 21-22; EX1003 at ¶62.



EX1006, Fig. 4 (annotated)

173. Chen teaches that the single-chip microcomputer 1 controls the relay K1 to engage to produce an instantaneous output of a high current by the high-current output unit 11. When the car battery is connected to the high-current output unit 11, the wake-up unit 122 notifies the single-chip microcomputer 1 that the car battery has been connected, the single-chip microcomputer 1 controls the high-current output unit 11 to instantly output a high current for ignition, and then a battery voltage is detected by means of the electrical device voltage detection unit 121. Chen at [0022]-[0025] and FIGS. 1 and 2.

174. Patent Owner notes that Chen's device provides a built-in relay K1 in the high-current output unit 11 to turn on or off the high current output in connection

with the electrical device voltage detection unit 121 and the wake-up unit 122 to control the relay K1 via the single-chip microcomputer 1.

175. White, on the other hand, discloses a wiring harness 10 that includes a main extension portion 12 and a utility extension portion 14 for trailer light connection systems that can be adapted to electrically couple the brake lights and back-up lights of a towing vehicle to that of the towed vehicle. See FIG. 1 in White. The main extension portion 12 connects to the electrical system 16 (such as to the terminals of a battery) of a host vehicle 18 at a first end 20 thereof. A second end 22 of the main extension portion 12 connects to one end 24 of the utility extension portion 14. The other end 26 of the utility extension portion 14 is adapted to connect to an electric load 30. The electric load 30 may be any type of electric load, including, for example, another battery, an electrical appliance, or any other accessory that requires or draws electric current.

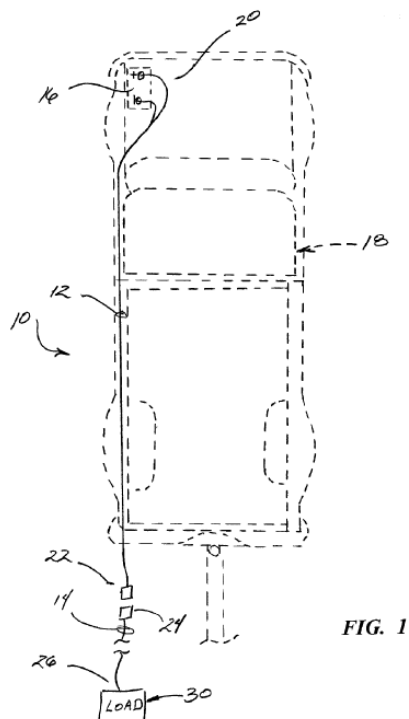
176. White's wiring harness 10 for trailer light connection systems is different from Chen's mobile power supply with the high-current output unit 11 in that White's wiring harness 10 lacks a built-in relay K1 in Chen's high-current output unit 11 and does not contain Chen's single-chip microcomputer 1, electrical device voltage detection unit 121 and wake-up unit 122 for controlling the relay K1 to turn on or off the high current path. Notably, White wiring harness 10 adopts a

fuse 48 in the main extension portion 12 to prevent damage to the wiring harness 10, the load 30 or to the host vehicle's electrical system 16. White at 2:10-63 and FIGS. 1 and 2. This fuse 48 in White is a one-time protection device and is not redundant and unnecessary in Chen's mobile power supply due to Chen's use of a built-in relay K1 in the high-current output unit 11 based on the control by the single-chip microcomputer 1 in connection with the electrical device voltage detection unit 121 and wake-up unit 122 for controlling the relay K1.

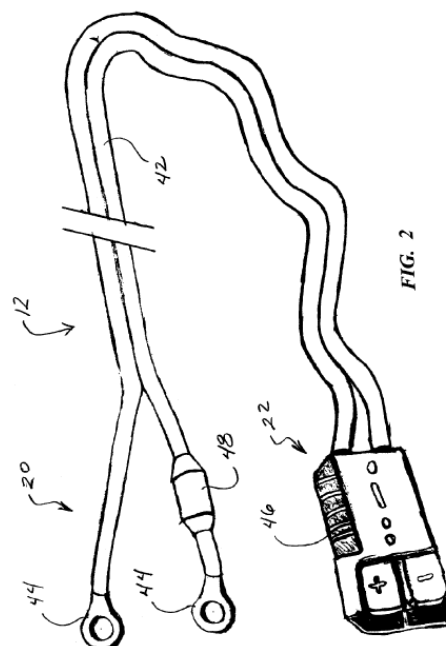
177. Therefore, Petitioner's contended combination of Chen and White contradicts express teachings of Chen and White and thus is improper under 35 USC §103.

DECLARATION OF DAVID S. RICKETTS
IN SUPPORT OF PATENT OWNER RESPONSE
IN INTER PARTES REVIEW TRIAL OF
U.S. PATENT NO. 9,643,506 B2 - IPR2024-00222

U.S. Patent Oct. 9, 2007 Sheet 1 of 11 US 7,279,640 B2



U.S. Patent Oct. 9, 2007 Sheet 2 of 11 US 7,279,640 B2



**C. Ground 1C: §103 –Chen in view of Richardson
(US2009/0218988)**

1. Claim 10

178. Claims 10, which depends on independent claim 1, is not rendered obvious at least for the reason that Chen fails to disclose all of the requirements of independent claim 1, as explained in Section IX.A, and this ground does not rely on any additional teachings of Richardson to address these deficiencies.

179. Claim 10 is a dependent claim of Claim 9 which depends on Claim 1 of the ‘506 patent. Claim 1 recites “a second protection circuit coupled to the battery pack and **configured to prevent overcurrent condition of the second current** when the battery pack is working in the second operating mode.”

180. However, Chen alone does not disclose or suggest “a second protection circuit coupled to the battery pack and **configured to prevent overcurrent condition of the second current.**”

181. Chen discloses control of its built-in relay K1 in the high-current output unit 11 by the single-chip microcomputer 1 in connection with detection by the electrical device voltage detection unit 121 for sensing the voltage of a connected device and by operation of wake-up unit 122 to close the relay K1. Chen at [0023] and [0025]. Nothing in Chen discloses detection of the current amplitude to control the relay K1 to prevent an overcurrent condition. Therefore, the Petition fails to

identity any teaching in Chen to disclose or suggest “a second protection circuit coupled to the battery pack and *configured to prevent overcurrent condition of the second current*” in Claims 1, 9 and 10.

182. More specifically, the Petition relies on Chen’s teaching on detection by the electrical device voltage detection unit 121 for sensing the voltage of a connected device for controlling the relay K1 in its analysis of claimed element [1.5]. See Petition at 21-22 and EX1003 at ¶¶61-62.

Element [1.5]

Chen describes the recited structure/functionality of Element [1.5]. EX1003, ¶61. For example, Chen discloses a second protection circuit coupled to the internal battery 4 that operates in the second mode (high-current output to the car battery) “to automatically turn off” the output current and thereby “prevent long-term high-current output from damaging the lithium battery 4.” EX1006, [0025], [0035], FIG. 4. As shown in FIG. 4, which depicts the circuit diagram of the “high-current instantaneous output module” ([0018]), the second protection circuit is connected to the battery (“BAT+”) and includes at least a relay switch. *Id.* Chen teaches “[w]hen the battery voltage returns to normal, the relay K1 is automatically turned off to prevent long-term high-current output from damaging the lithium battery 4” while operating in its “ignition output” mode of operation. EX1006, [0026]; EX1003, ¶¶61-62.

183. In Petitioner’s contended combination of Chen and Richardson against Claim 10, the entirety of Petitioner’s cited teachings (including a portion of FIGS. 2C¹ and 7) in Richardson to combine with Chen is within EX1003 at 138-139 and Petition at 44-45:

¹ Petitioner incorrectly labels “FIG. 2B” for the cited upper portion of FIG. 2C in Richardson including relay 34, temperature sensor 41 and jump cables 60.

Richardson (EX1014)

138. Richardson, like Chen, also describes technologies for a portable power source that can jumpstart a vehicle engine. EX1014, [0002], [0007]; EX1007, [0025]. Richardson suggests the conventional practice of monitoring the time that the jumpstarting current is output and cutting off the jumpstarting current if the time limit is exceeded. EX1014, [0037]. In particular, Richardson suggests cutting off the current after “500 ms” for a “preset maximum” and outputting an “Over MAX” error, and also suggests cutting off the jumpstarting current if the jumpstarting current exceeds a different (lower) threshold amperage for an extended “predetermined period of time such as 15 seconds”:

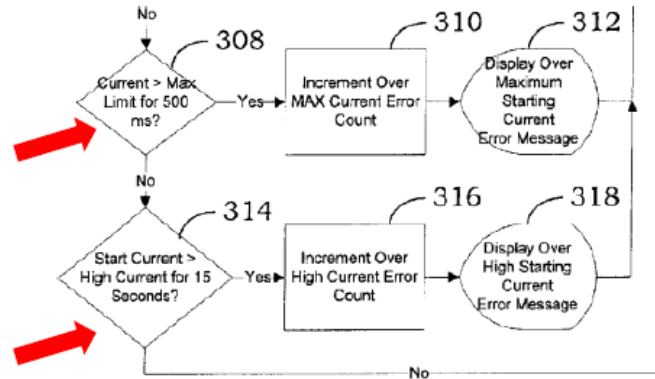
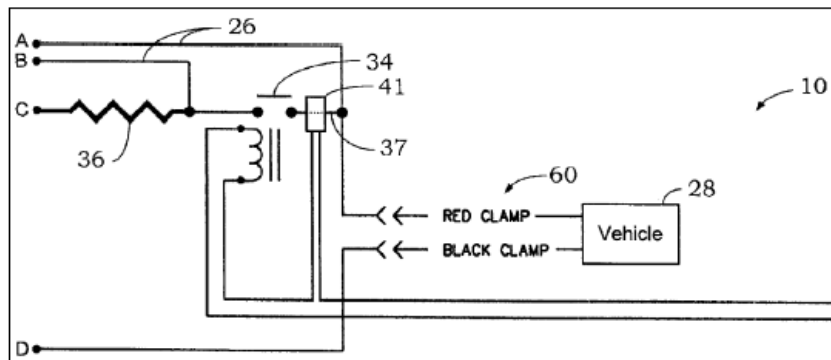


Fig. 7

Predictable Combination of Chen and Richardson

139. As I previously noted in my analysis of Element [9] (Ground 1A), Chen teaches the use of a “relay” to cut off the jumpstarting current when the car battery returns to a normal voltage. Additionally, a POSITA would have been motivated to implement Chen’s relay K1 (Ground 1A, Element [9]) in accordance with Richardson’s suggested safety monitoring/time limits to avoid damage or critical exhaustion of the internal lithium battery—especially for the scenario in which the car battery does not immediately return to a normal voltage. For example, a POSITA would have been prompted to implement Chen’s relay so that the switching module ceased the jumpstarting current after a predetermined time period (as suggested by Richardson), which would avoid the unsafe scenario of the high-amperage current being output over an extended time period, thereby preserving the internal lithium battery and avoiding an overheating condition (e.g., at the connection or in the car battery).



EX1014, FIG. 2B (excerpt).

184. Under Petitioner's combination of Chen and Richardson, Petitioner has cited circuits in FIGS. 1, 2 and 4 of Chen to combine with the cited upper portion of FIG. 2C in Richardson including relay 34, temperature sensor 41 and jump cables

60. Under this combination, the Petition fails to explain how the cited upper portion of FIG. 2C in Richardson may be used to modify circuits in FIGS. 1, 2 and 4 of Chen in its contended combination to the claimed invention in Claim 10. The Petition provides no explanation how relay 34, temperature sensor 41 and jump cables 60 in cited upper portion of FIG. 2C in Richardson to connect with circuit elements in FIGS. 1, 2 and 4 of Chen.

185. Neither does the IPR Petition explain how the hardware circuit elements in both the cited upper portion of FIG. 2C in Richardson and FIGS. 1, 2 and 4 of Chen can be combined to perform the functions or operations of the cited portion of FIG. 7 in Richardson. Specifically, there is no current sensor in any part of the cited upper portion of FIG. 2C in Richardson and FIGS. 1, 2 and 4 of Chen. Therefore, the Petitioner's proposed combination of the cited upper portion of FIG. 2C in Richardson and FIGS. 1, 2 and 4 of Chen would not be able to measure or monitor the amplitude of a current to determine whether a particular threshold amperage is reached by the current in order to perform the functions or operations in the cited portion of the flowchart in FIG. 7 in Richardson.

186. Therefore, Petitioner has not demonstrated a challenged claim is unpatentable.

D. Ground 1D: §103 –Chen in view of Gozdz (US7,348,101)

1. Claims 15 and 29

187. Claims 15 and 29, which depend on independent claims 1 and 21, are not rendered obvious at least for the reason that Chen fails to disclose all of the requirements of independent claims 1 and 21, as explained in Section IX.A, and this ground does not rely on any additional teachings of Gozdz to address these deficiencies.

E. Ground 2A: §103 – Inskeep (US2010/0301800) in view of Johnson (US4,969,834)

1. Claims 1 and 21

188. Petitioner’s Ground 2A based on Inskeep and Johnson is defective for failing to disclose or suggest at least Claim Elements [1.2], [1.3] and [1.4] (and similar elements [21.2], [21.3] and [21.4]). These elements are reproduced below

[1.2] at least one output port coupled to the battery pack, wherein the battery pack is configured to output a first current through one or more output ports of the at least one output port in a first operating mode;

[1.3] a pair of output terminals coupled to the battery pack and having a current path to the battery pack different from that of the at least one output port to the battery pack, wherein the battery pack is

configured to output a second current capable of starting a vehicle engine through the pair of output terminals in a second operating mode, wherein *the second current is higher than the first current*;

[1.4] a first protection circuit coupled to the battery pack and *configured to protect the battery pack* when the battery pack is working in the first operating mode;

189. Under Claim Elements [1.2] and [1.3], each claimed output port in the first operating mode of “one or more output ports of the at least one output port in a first operating mode” outputs a first current, and that a second current capable of starting a vehicle engine through the pair of output terminals in a second operating mode is higher than the first current.

190. The Petition cites the USB port and the DC 12V port P1 in FIG. 3 and FIGS. 2 and 4 in Inskip as “one or more output ports of the at least one output port in a first operating mode” but only shows the USB port outputs a first current of 0.5A which is less than the second current of 500A output by the pair of output terminals. Petition at 53-56 and EX1003 at ¶¶159-161. Specifically, the Petition fails to show whether the current via the DC 12V port P1 in Inskip is greater or less than the second current of 500A output by the pair of output terminals. Petition at 56 and EX1003 at ¶161.

191. Therefore, the disclosure for the DC 12V port P1 in Inskeep fails to meet the claim limitations for the “one or more output ports of the at least one output port in a first operating mode” and, accordingly, only the USB port in Inskeep is analyzed below with respect to the Claim Element [1.4].

192. Claim Element [1.4] recites “a first protection circuit coupled to the battery pack and *configured to protect the battery pack* when the battery pack is working in the first operating mode” with added emphasis. The Petition cites the disclosed “low voltage protection circuit” for the USB port (USB1) in [0032] of Inskeep as the disclosure for the “first protection circuit.”

A [0032] The apparatus in formed in a stylized housing **100** having a handle **101** for ease of portability and a panel **102** including accessories outputs namely the USB port (USB1) **104** that is electrically coupled to the internal battery BT1. The USB port has a low voltage protection circuit to prevent operation of the USB port at voltages below 5 volts. The output voltage level can be made adjustable, however, in the preferred embodiment a 5 volt level is maintained by use of step-down transformer L1 with the signal stabilized by capacitors C3 and C4. ;.

193. However, [0032] of Inskeep teaches that the low voltage protection circuit for the USB port is “to prevent operation of the USB port at voltages below

5 volts” and, additionally, the output voltage level “can be made adjustable, however, in the preferred embodiment a 5 volt level is maintained by use of step-down transformer L1 with the signal stabilized by capacitors C3 and C4.” See the lower right-hand portion of the circuitry in FIG. 3 of Inskeep.

194. The above teaching in [0032] and FIG. 3 in Inskeep constitutes the entire evidence cited by the Petition on the claimed first protection circuit. This teaching, however, is directed to a circuit for maintain the USB port output voltage only and does not suggest any feature or function with respect to “to protect the battery pack” when the battery pack is working in the first operating mode.”

195. Therefore, Inskeep fails to discloses or renders obvious Claim Element [1.4].

196. In the contended combination of Inskeep and Johnson, the Petition does not cites any teaching in Johnson with respect to the claimed “one or more output ports of the at least one output port in a first operating mode” and the claimed “first protection circuit” in Claim Elements [1.2]-[1.4].

197. Therefore, the Petition fails to demonstrate that the combination of Inskeep and Johnson discloses or renders obvious of Claim Elements [1.2]-[1.4].

198. Accordingly, Claim 1 and its dependent claims are patentable over the combination of Inskeep and Johnson as presented in the Petition.

199. Claims [21.2]-[21.4] rely on the same evidence and recite similar limitations, and thus are not met for the same reasons. Thus, the Petition does not show that independent Claim 21 and its dependent claims are obvious over the combination of Inskip and Johnson.

200. Moreover, the Petition does not explain all how the Inskip/Johnson combination meets all the requirements of the “first operating mode” / “second operating mode” recited in limitations [1.2]/[1.3] and limitations [21.2]/[21.3].

201. I have provided the construction for the “first operating mode” and “second operating mode” limitations in Sections VII.1 and VII.2, respectively. Specifically, a “first operating mode” is “an operating mode of the portable backup charger wherein the battery pack is configured to output a first current through one or more output ports of the at least one output port, and outputting a second current capable of starting a vehicle engine through the pair of output terminals is inhibited.” A “second operating mode” is “an operating mode of the portable backup charger wherein the battery pack is configured to output a second current capable of starting a vehicle engine through the pair of output terminals, and outputting a first current through one or more output ports of the at least one output port is inhibited.”

202. The Petition described USB output port functionality with respect to limitations [1.2] and [21.2] without identifying any disclosure in Inskip or

Johnson that described what the output terminals were configured to do or capable of doing during this alleged “first operating mode.” Similarly, the Petition described output terminal functionality with respect to limitations [1.3] and [21.3] without identifying any disclosure in Innskeep or Johnson that described what the identified USB port was configured to do or capable of doing during this alleged “second operating mode.” As such, the IPR petition did not account for all of the requirements of the “first operating mode” and “second operating mode” under the proper construction of those limitations.

2. Dependent Claims 3, 6-14, 16-17, 20, 23, 25-28, 30-31

203. Claims 6-14, 16-17, 20, 23, 25-28, 30-31 depend on either independent claim 1 or claim 21, and thus, are not invalid for the same reasons above explaining why claims 1 and 21 are valid in view of Innskeep and Johnson.

F. Ground 2B: §103 – Innskeep in view of Johnson and Durando (US2012/0068662)

1. Claims 19 and 33

204. This combination fails to invalidate Claims 19 and 33 at least for the reason that Innskeep and Johnson fails to disclose all of the requirements of independent claims 1 and 21, as explained in Section IX.E, and this ground does not rely on any additional teachings of Durando to address all of these deficiencies.

205. Durando is cited for its suggestion for using “one or more batteries having the type of primary lithium-metal, rechargeable lithium-ion, and/or lithium polymer” in the combination of Inskeep and Johnson. Durando does not cure the above discussed defects in the combination of Inskeep and Johnson. Claims 19 and 33 depend on Claims 1 and 21, respectively. In light of the above analyses, the combination of Inskeep, Johnson and Durando does not render Claims 19 and 33 obvious.

G. Ground 3A: §102 – Nook (WO2016/003471)

1. Nook is not prior art for Claims 1, 2, 6, 8, 11-16, 19-22, 27-30, 33

206. As discussed above in Section VIII, challenged claims 1–3, 6–8, 11-23, and 25, 27–33 of the ’506 Patent are entitled to the December 9, 2011 priority date of China patent application number 201110409190.9 cited on the face of the ’506 Patent.

207. Thus, Nook does not qualify as prior art against claims 1, 2, 6, 8, 11-16, 19-22, 27-30, 33 presented in this ground, and thus, cannot be used in a Ground to invalidate these claims.

**2. The Petition Did Not Identify a “First Operating Mode” /
“Second Operating Mode” in Nook (Limitations [1.2]/[1.3],
Limitations [21.2]/[21.3])**

208. The IPR petition’s analysis of limitations [1.2] and [1.3], and [21.2] and [21.3], appear on pages 70-71 and 79, respectively. I have provided the construction for the “first operating mode” and “second operating mode” limitations in Sections VII.1 and VII.2, respectively. Specifically, a “first operating mode” is “an operating mode of the portable backup charger wherein the battery pack is configured to output a first current through one or more output ports of the at least one output port, and outputting a second current capable of starting a vehicle engine through the pair of output terminals is inhibited.” A “second operating mode” is “an operating mode of the portable backup charger wherein the battery pack is configured to output a second current capable of starting a vehicle engine through the pair of output terminals, and outputting a first current through one or more output ports of the at least one output port is inhibited.”

209. The Petition described USB output port functionality with respect to limitations [1.2] and [21.2] without identifying any disclosure in Nook that described what the output terminals were configured to do or capable of doing during this alleged “first operating mode.” Similarly, the Petition described output terminal functionality with respect to limitations [1.3] and [21.3] without identifying any

disclosure in Nook that described what the identified USB port was configured to do or capable of doing during this alleged “second operating mode.” As such, the IPR petition did not account for all of the requirements of the “first operating mode” and “second operating mode” under the proper construction of those limitations.

210. Moreover, the disclosure of Nook concerning the USB port indicates that the port is always enabled to output a current unless the battery voltage is too low, in which case the USB port is disabled. Ex. 1012 at 11 (“Control circuit 57 from the microcontroller 1 allows the USB Out 56 to be turned on and off by software control to prevent the internal lithium battery getting too low in capacity.”). In this circumstance of low battery voltage, switch closure is prevented to prevent current from flowing to the output terminals, preventing over-discharge of the lithium battery. Ex. 1012 at 8 (“A lithium battery voltage measurement circuit 24 monitors the voltage of the lithium battery pack 32 to prevent the voltage potential from rising too high during a charging operation and from dropping too low during a discharge operation.”) In accordance with this disclosure, Nook could not disclose a second operating mode, because the USB port is always active whenever the jumpstart output terminals can output a second current.

3. Nook does not disclose a “ a second protection circuit ... configured to prevent overcurrent condition when the battery pack is working in the second operating mode” (Limitations [1.5]/[21.5])

211. Limitation [1.5] recites “a second protection circuit coupled to the battery pack and configured to prevent overcurrent condition of the second current when the battery pack is working in the second operating mode” and limitation [1.3] explains that “the battery pack is configured to output a second current capable of starting a vehicle engine through the pair of output terminals in a second operating mode.”

212. The IPR Petition identifies three possible second protection circuits, none of which meet the requirements of the claim limitation. The Petition on page 73 first describes a MCU “1” and circuit elements “10” and “12” that work together to prevent switch closure and thus outputting of a second current, thus avoiding an overcurrent condition. However, does not measure any current, and thus cannot constitute a prevention of an overcurrent. Moreover, this circuit operates before the device configured to output a second current to the output terminals (because the switch remains turned off) and thus is inapplicable.

213. The Petition then cites a temperature sensor 20 that “that cuts off the jumpstarting current to prevent overheating from an ‘overextended current draw during jump starting.’” Petition at 73 (citing EX1012, 7-8). However, this circuit

does not detect a current or protect against an overcurrent condition -- the second current being provided in the second path exceeding a maximum current value -- as required by the claims. Rather, the circuit detects a temperature to determine whether the battery is too hot, a condition associated with the battery providing a unknown jumpstart current for too long of a period of time.

214. The Petition then cites “charge protection diodes 28,” but these devices do not provide an overcurrent when the battery is “*output[ing]* a second current capable of starting a vehicle engine” in a second operating mode, as described in limitations [1.3] and [1.5], but rather, as admitted in the IPR petition act to protect against an **input of current to the battery** (that would charge the battery in a potentially dangerous, unregulated manner) during a jumpstart operation after a vehicle has started and a vehicle alternator voltage may be higher than the jumpstarter voltage, causing current to flow in the opposite direction. Ex. 1012 at 10. Again, backcharging is not an overcurrent condition associated with the battery *outputting* a current to the output terminals as required by the claim limitations, but the exact opposite – a condition where current is flowing *into* the battery via the output terminals. As such this is not the required protection circuit either.

4. Dependent Claims 2, 6, 8-16, 19-20, 22, 26-30, 33

215. Claims 9, 11-14, 16-19, 26-28, 30-33 depend on either independent claim 1 or claim 21, and thus, are not invalid for the same reasons above explaining why claims 1 and 21 are valid in view of Nook.

H. Ground 3B: §103 – Nook in view of White

1. Nook is not prior art for Claims 1, 2, 6, 8, 11-16, 19-22, 27-30, 33

216. As discussed above in Section VIII, challenged claims 1–3, 6–8, 11-23, and 25, 27–33 of the '506 Patent are entitled to the December 9, 2011 priority date of China patent application number 201110409190.9 cited on the face of the '506 Patent.

217. Thus, Nook does not qualify as prior art against claims 1, 2, 6, 8, 11-16, 19-22, 27-30, 33 presented in this ground, and thus, cannot be used in a Ground to invalidate these claims.

2. Claims 1, 2, 6-16, 19-22, 25-30, 33

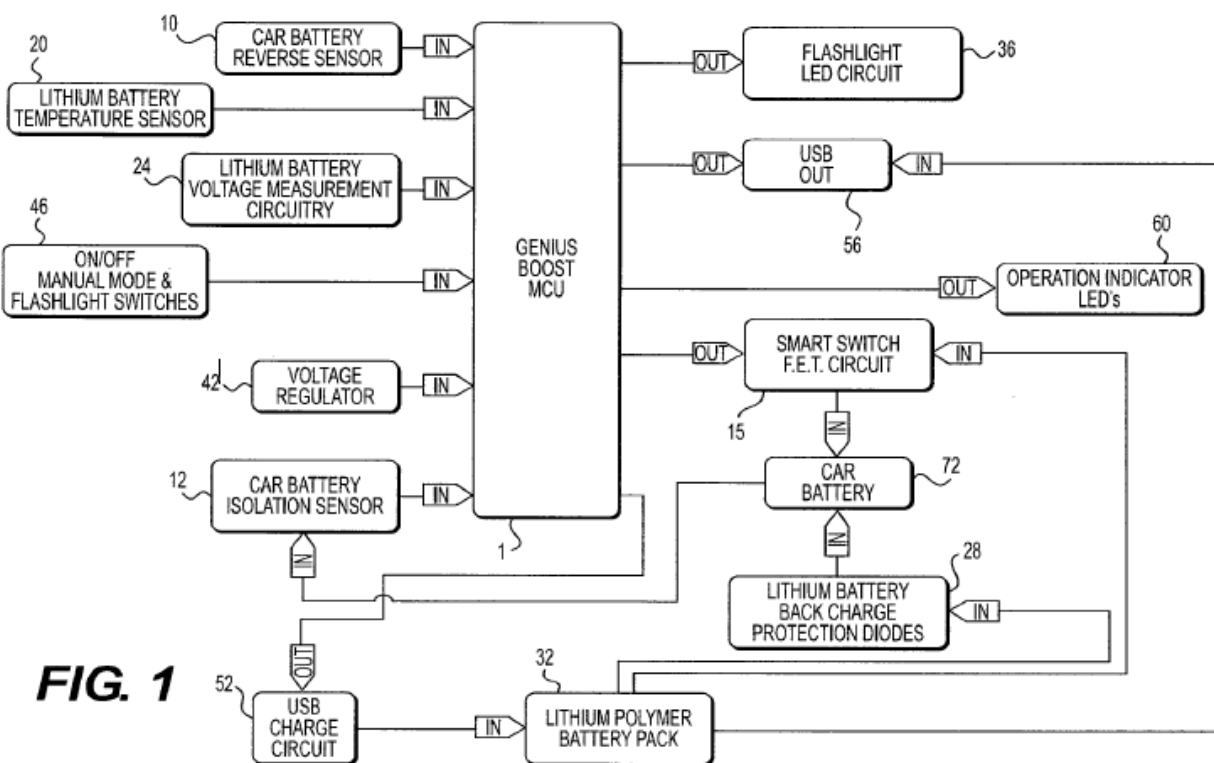
218. Petitioner's Ground 1B contends a combination of Nook and White under 35 USC §103.

219. This combination fails to invalidate Claims 1, 2, 6-16, 19-22, 25-30, 33 at least for the reason that Nook fails to disclose all of the requirements of

independent claims 1 and 21, as explained in Section IX.G, and this ground does not rely on any additional teachings of White to address all of these deficiencies.

220. Moreover, this contended combination of Nook and White is improper because the teachings in Nook and White refute such combination.

221. Nook discloses a mobile power supply a smart FET switch 15 that selectively connects power from the lithium battery to 32 to car battery 72 connected to the device via a clamp assembly, as shown in Fig. 1 below.



222. Petitioner acknowledges this functionality in the Petition at pages 75-76.

223. Nook teaches that the MCU 1 controls the smart switch 15 to connect or disconnect power (and the flow of current) between the lithium battery pack 32 and the clamps of the device, and describes the circumstances in which the switch is opened and closed in response to sensor input. Ex. 1012 at 8-10.

224. White, on the other hand, discloses a wiring harness 10 that includes a main extension portion 12 and a utility extension portion 14 for trailer light connection systems that can be adapted to electrically couple the brake lights and back-up lights of a towing vehicle to that of the towed vehicle. See FIG. 1 in White. The main extension portion 12 connects to the electrical system 16 (such as to the terminals of a battery) of a host vehicle 18 at a first end 20 thereof. A second end 22 of the main extension portion 12 connects to one end 24 of the utility extension portion 14. The other end 26 of the utility extension portion 14 is adapted to connect to an electric load 30. The electric load 30 may be any type of electric load, including, for example, another battery, an electrical appliance, or any other accessory that requires or draws electric current.

225. White's wiring harness 10 for trailer light connection systems is different from Nook's mobile power supply in that White's wiring harness 10 lacks

a built-in smart switch 15 in Nook's jumpstarter device and does not contain Nooks MCU 1 and sensors 10 and 12 for controlling the smart switch 15 to turn on or off internal battery power to the clamps. Notably, White wiring harness 10 adopts a fuse 48 in the main extension portion 12 to prevent damage to the wiring harness 10, the load 30 or to the host vehicle's electrical system 16. White at 2:10-63 and FIGS. 1 and 2. This fuse 48 in White is a one-time protection device and is not redundant and unnecessary in Nook's mobile power supply due to Nook's use of a built-in switch 15 based on the control by the MCU 1 in connection with operation of the device.

226. Therefore, Petitioner's contended combination of Nook and White contradicts express teachings of Nook and White and thus is improper under 35 USC §103.

I. Ground 3C: §103 – Nook in view of Miller (US2016/0072329)

1. Nook is not prior art for Claims 3, 23

227. As discussed above in Section VIII, challenged claims 1–3, 6–8, 11-23, and 25, 27–33 of the '506 Patent are entitled to the December 9, 2011 priority date of China patent application number 201110409190.9 cited on the face of the '506 Patent.

228. Thus, Nook does not qualify as prior art against claims 3, 23 presented in this ground, and thus, cannot be used in a Ground to invalidate these claims.

2. Claims 3, 23

229. This combination fails to invalidate Claims 3 and 23 at least for the reason that Nook fails to disclose all of the requirements of independent claims 1 and 21, as explained in Section IX.G, and this ground does not rely on any additional teachings of White to address all of these deficiencies. Specifically, the Petition only relies on Miller's disclosure allegedly relevant to the additional requirements of Claims 3 and 23.

J. Ground 3D: §103 – Nook in view of Richardson (US2009/0218988)

1. Nook is not prior art for Claim 10

230. As discussed above in Section VIII, challenged claims 1–3, 6–8, 11–23, and 25, 27–33 of the '506 Patent are entitled to the December 9, 2011 priority date of China patent application number 201110409190.9 cited on the face of the '506 Patent.

231. Thus, Nook does not qualify as prior art against claim 10 presented in this ground, and thus, cannot be used in a Ground to invalidate these claims.

2. Claim 10

232. This combination fails to invalidate Claim 10 at least for the reason that Nook fails to disclose all of the requirements of independent claims 1 and 21, as explained in Section IX.G, and this ground does not rely on any additional teachings of Richardson to address all of these deficiencies.

K. Ground 3E: §103 –Nook in view of Shoji (US6,404,168)

1. Nook is not prior art for Claims 17-18, 31-32

233. As discussed above in Section VIII, challenged claims 1–3, 6–8, 11-23, and 25, 27–33 of the '506 Patent are entitled to the December 9, 2011 priority date of China patent application number 201110409190.9 cited on the face of the '506 Patent.

234. Thus, Nook does not qualify as prior art against claim 17-18, 31-32 presented in this ground, and thus, cannot be used in a Ground to invalidate these claims.

2. Claims 17-18, 31-32

235. This combination fails to invalidate Claims 17-18, 31-32 at least for the reason that Nook fails to disclose all of the requirements of independent claims 1 and 21, as explained in Section IX.G, and this ground does not rely on any additional teachings of Shoji to address all of these deficiencies.

X. CONCLUSION

236. In signing this declaration, I recognize that the declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross examination in the case and that cross examination will take place within the United States. If cross examination is required of me, I will appear for cross examination within the United States during the time allotted for cross examination.

237. 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 18 U.S.C. § 1001.

238. I declare under the penalty of perjury that the foregoing is true and correct.

DECLARATION OF DAVID S. RICKETTS
IN SUPPORT OF PATENT OWNER RESPONSE
IN INTER PARTES REVIEW TRIAL OF
U.S. PATENT NO. 11,376,971 B2 - IPR2024-00222

Executed October 30, 2024 in Cary, North Carolina.



David Ricketts, Ph.D.

Dr. David S. Ricketts
Full Professor

I.B BRIEF RESUME

1. Education background:

Ph.D., Electrical Engineering, 2006, Harvard University
M.Sc., Electrical Engineering, 1997, Worcester Polytechnic Institute
B.Sc., Electrical Engineering, 1995, Worcester Polytechnic Institute

2. Professional experience:

Full Professor, 2012 – present, Department of Electrical and Computer Engineering North Carolina State University, Raleigh, NC

Visiting Researcher (Research Scientist), 7/2012 – 8/2013, MTL-ECE Massachusetts Institute of Technology, Cambridge, MA

Visiting Associate Professor, 9/2012-12/2012, School of Engineering and Applied Science Harvard University, Cambridge, MA

Assistant Professor, 2006 – 2012, Department of Electrical and Computer Engineering Carnegie Mellon University, Pittsburgh, PA

Manager of New Product Development & Advanced System Engineering, 2001 – 2003, ON Semiconductor, East Greenwich, RI

Principal Consultant, 1999-2001, Renaissance Design, Inc., Warwick, RI

IC Technology Unit Manager, 1995-1999, American Power Conversion, Billerica, MA

3. Scholarly and creative activities:

<i>Type</i>	<i>Number</i>
<i>Books</i>	<u>3</u>
<i>Book Chapters</i>	<u>2</u>
<i>Refereed Journal Article</i>	<u>52</u>
<i>Other Journal Article (submitted)</i>	<u>0</u>
<i>Conference Paper, Refereed</i>	<u>81</u>
<i>Conference Presentation, (no paper)</i>	<u>7</u>
<i>Patent (filed)</i>	<u>2</u>
<i>Academic Workshops Chaired</i>	<u>20</u>
<i>Research Presentations, Invited</i>	<u>66</u>

4. Membership in professional organizations:

IEEE, 1997-present (senior member since 2015)

5. Scholarly and professional honors:

- 2022 Chancellors Innovation Fund
- 2021 William F. Lane Outstanding Teaching Award

- Best Paper Award, IEEE Asia-Pacific Microwave Conference 2016.
- IEEE Senior Member, 2015
- Certificate of Teaching Excellence, Derek Bok Center, Harvard University, 2013
- **NSF CAREER AWARD, 2011.**
- Wimmer Teaching Fellow, Carnegie Mellon University, 2009.
- George Tallman Ladd Research Award, Carnegie Mellon University, 2009.
- National Academy of Engineers Frontiers of Engineering Education Recipient, 2009.
- **DARPA Young Faculty Award, 2008.**
- McGraw Hill Yearbook of Science and Technology, 2008.

6. Professional service on campus:

Faculty Teaching Evaluation Committee (ECE Department) 2022-present
 Faculty Search Committee (ECE Department) – Fall/Spring 2021/22 & 2019/20
 Course Curricula Committee (ECE Department) - 2015-present
 Faculty Search Committee (ECE Department) – Fall/Spring 2016/2017
 Senior Design Director Search Committee (ECE Department) - 2014
 Participated in Engineering Open House (ECE Department), 2014

7. Professional service off campus:

Advisor DARPA Commercialization Office - 2023-24

Topic Editor, IEEE JMW 2022-2023

Track Editor, IEEE T-MTT Oct 2019-2022

Chair, IEEE Chapter ACME (Joint chapter of Antennas and Propagation (AP), Electronic Packaging Society (EP), Microwave Theory and Techniques (MTT), and Electron Devices (ED) 2019-

Technical Committee **Chair** for IEEE T-MTT 9 Society 2020-2022

Technical Committee **Vice-chair** for IEEE T-MTT 7 Society 2015-2019

Technical Program **Chair**: Enabling Nanomanufacturing for Rapid Innovation, TRC/NSF Workshop, Aug. 2013

Technical Program Committee (member) – IEEE International Microwave Symposium 2014-;

Technical Program Committee IEEE BioWireless 2012-2015.

Session Chair - Nanotechnology, CMOS Emerging Technologies Conf., Banff, Canada 2009; NANO-DDS, Chemically-Synthesized, Biomimetic Systems and Biologically-Inspired Architectures Session, August 2011.

II.B. INSTRUCTIONAL DEVELOPMENT

Include innovations in courses and curricula.

Creation of a new STEM portal interactRF.org (supported by ONR research grant) to teach RF and microwave engineering. This portal supports national education workshops and a full semester online course using an e-learning platform.

ECE 592 Analog Laboratory (graduate). Introduced graduate version of ECE 426 to allow for more advanced hands-on projects.

ECE 426 Analog Laboratory. Re-booted a retired course with Dr. Besnoff (teaching professor). Developed 12 new lectures and an entirely new course project where students build a drone from scratch, making their own printed circuit boards and coding an Arduino for flight control

ECE 714 Advanced Analog IC Design (ADCs). CAF Completed S18. (NCSU) Fall 2015. Developing new course for advanced analog IC design. Includes ~ 35 online lectures, and 10 interactive labs/workshops for students to practice hands on design. Full course, including labs, are available online for the public.

ECE 424/524 – CAF completed S17- 492(592) Radio Systems Design: (NCSU) Spring 2014+. Developed new experiential undergraduate course in radio system design. Includes 34 online lectures, and 10 interactive labs/workshops for students to practice hands on design. Full course, including labs, are available online for the public.

ECE 592 Analog-to-digital Converters: (NCSU) Fall 2013. Developed new course for ADCs as part of ECS circuit's curriculum.

ES139/239 Innovation in Science and Technology (Harvard): Fall 2012. Co-developed new format, assignments and teaching materials for primarily undergraduate innovation course.

ECE 18-605/606 Innovation in Science and Technology (CMU): Fall 2009. Developed interdisciplinary course on innovation between ECE and CMU's Engineering Technology Innovation Management masters program.

ECE 18-513 RF Circuits and Antennas for Wireless Systems (CMU): Fall 2008. Co-developed w. D. Stancil a new capstone design course in RF circuits & antennas.

ECE 18-610 Fundamentals of Modern CMOS Devices (CMU): Spring 2008, Developed introductory graduate course in CMOS device physics.

ECE 18-310 Fundamentals of Semiconductor Devices (CMU): Spring 2007. Developed entirely new content for undergraduate device physics course.

II.C. MENTORING ACTIVITIES

Include undergraduate academic advising and assessments thereof, if applicable, graduate committees, postdoctoral advising, advising student organizations, special projects with students, and Department of Public Instruction assessments of supervising student teaching.

Currently, member of 4 PhD and 0 MS committees.

1. Participated in 29 Masters/PhD graduate committees.
2. Advisor to 6 nonthesis MS students.

POST-DOCTORAL RESEARCHER SUPERVISION

1. Jordan Besnoff (F2020, now research Prof NCSU 2021-)
2. Morteza Abbasi (2013-2016, research Prof. NCSU, 2016-18)
3. Jordan Besnoff (2014, now at Oakridge National Labs)
4. Junfeng Xu (2013, now at SpaceX)
5. Mathew Trotter (2013, Disney Research)
6. Mathew Chabalko (2012, now at Disney Research)
7. Darmin Arumugum (2012, now at JPL)
8. Limin Cao (2010,2012)
9. Joshua Smith (2010-2012, now at NRL)
10. Shingo Tamaru (2008-2010, now at AIST, Japan)

GRADUATE STUDENT SUPERVISION NCSU

1. Prya Darshni (PhD Canddiate, 2026)
2. Hongtao Zhong (PhD Candidate, 2025)
3. Shian Su (PhD Candidate, 2025)
4. Joe Zhou (PhD Candiate 2023)
5. Karan Maru F20-S21 RA
6. Sriraj Kandala, Summer 2020 RA
7. Bhaumik Jain Summer-Fall 2020 RA
8. Matt Dwyer Summer-Fall 2020. RA
9. William Harris (PhD candidate, 2019)
10. Junyu Shen (PhD candidate, 2019)
11. Hangjin Liu (PhD Candidate, 2021)
12. You Zhou (PhD Candidate, 2021)
13. Deeksha Lal (PhD 2018)
14. Samyak Parakh (MS, 2018)
15. Rafael de Silva (PhD candidate, 2020)
16. Michael Aiken (MS 2017, PhD Candidate)
17. Viswanath Ramesh (Initial PhD work 2015-2016)

GRADUATE STUDENT SUPERVISION CMU

1. Emre Karagozler, PhD 2013
2. Wei Tai, PhD 2012
3. Darmin Arumugam, PhD 2012
4. Weihua Hu, PhD 2012
5. Chongzhe Li, MS 2012
6. Zacherias George, MS 2012
7. En Shi, MS 2010
8. Qianyu Liu, MS 2009

GRADUATE COMMITTEES

1. Yongduk Oh (PhD Candidate 2023)
2. Jaewoo Kim (MS 2021)
3. Sarah Colebaugh

4. Weifu Li (PhD Candidate 2019)
5. Kirti Bhanushali (PhD candidate 2018)
6. Weihu Wang (PhD candidate 2018)
7. Yunjia Zhu (MS candidate Textiles 2017)
8. Junan Zhu (PhD candidate 2016)
9. Yunjia Zhu (MS candidate 2016)
10. Anirban Sarkar, (PhD candidate 2016)
11. Sandeep Hari, (PhD candidate 2018)
12. Kevin Green (PhD candidate 2016)
13. Ying Yi Tang, PhD 2015 (CMU)
14. Mohammad Noman, PhD 2013 (CMU)
15. Erkan Alpman, PhD 2007 (CMU)

UNDERGRADUATE STUDENT SUPERVISION

1. Bryan Wilson – S24
2. Jason Apsell F22-
3. Zander Selleseth F-22-
4. Jonathan Weeks – S32-
5. Yiyang Ye – S23/Summer
6. Maya Clinton F22-S23 (MechE)
7. Cole Contos F22
8. Jason Abell F22-S23
9. Landon Calton F22
10. Frank di Lustro S21
11. Alan Davila Summer 2020
12. Casey Crouse Spring 2020-Summer 2020
13. Jacob Abramow Spring 2020
14. Jeremy Peterson Spring 2020-Summer 2020
15. Laura Walker Spring 2020
16. Ryan Hardy REU Spring 2020-Spring 2021
17. Matt Dwyer Connor Walker REU Fall/Spring 2019
18. Matt Dwyer REU 2019 Summer.
19. Casey Crouse REU 2019 Summer.
20. Zack Miller, Felix Chamielec, Danny Krafft, Grason Humphrey, Sufian Ahmad (NCSU UG Senior Design: Qi Charger, 2019)
21. Matt Dwyer, S19 (NCSU, Undergrad Research)
22. Shakti Reddy, F18/S19 (NCSU, Undergrad Research)
23. Shane Reagan, Zach Cline, Daniel Robson, Andrew Cragg, (NCSU UG Senior Design: Pringles Radar 2017/18)
24. Christian Burke, F17/S18 (NCSU, Undergrad Research)
25. Bill Zhou (BSEE) Fall 2016 (NCSU, Undergrad Research)
26. Akshay Iyer, Stephen Kerr, William Stepp, Kirk Weston, (NCSU UG Senior Design: Magnetic Sports Tracking, 2015/16)
27. Shaunak Turaga (BSEE), Fall/Spring 2014/15 (NCSU, Undergrad Research)
28. Mathew Briley (BSEE), Fall/Spring 2014/15 (NCSU, Undergrad Research)
29. Adeola Salu (BS), Spring 2013 (Harvard, Independent Study)
30. Zackary Hamad (BS), Spring 2011 (Harvard, independent Study)
31. Andrew Hillenius (BS), Summer/Fall, 2011 (CMU, Independent Study)
32. Chongzhe Li (BS), Spring 2010 (CMU, Independent Study)

33. Christopher Heidelberger (BS), Summer 2009, (CMU) NSF REU
34. Yue Lu (BS), Summer 2007 (CMU Independent Study)

SPECIAL STUDENT ADVISING

1. Karan Maru, S20 (NCSU MSEE Research)
2. Bhaumik Jain, F19 (NCSU, MSEE Research)
3. Sriraj Kandala, F19 (NCSU, MSEE Research)
4. Sandesh Shanmukha, S19 (NCSU, MSEE Research)
5. Shubhankar Patwardham F17/S18/F18 (NCSU, Ind. Study)
6. Amrutha Anantha S18 (NCSU, Ind. Study)
7. David Philpott S2017 (NCSU, Ind. Study)
8. Shenoy Akshat S2017 (NCSU, Ind. Study)
9. Sayan Das Fall 2016 (NCSU, Ind. Study)
10. Rounak Lokare Spring 2016 (NCSU, Ind. Study)
11. Swaroop Mohapatra Spring 2016 (NCSU, Ind. Study)
12. Ganapati Pai Spring 2016 (NCSU, Ind. Study)
13. Mahmoud Metwally 2015 (NCSU, MS research)
14. Ashwin Thyagarajan Spring 2015 (NCSU Ind. Study)
15. Reza Chavoshisani 2015 (PhD – 1 year visiting scholar)
16. Abhishek Malhotra (MS), Spring/Summer, 2013 (NCSU, Independent Study)
17. Syed Saad (MS), Summer 2011 (CMU, Independent Study)
18. Brian Lee (MS), Summer 2011 (CMU, Independent Study)
19. Ashwath Krishnan (MS), Summer 2010 (CMU, Independent Study)
20. Akshat Gupta (MS), Fall 2009 (CMU, Independent Study)
21. Heer Ghandi (MS), Fall 2007 (CMU, Independent Study)

GRADUATE COMMITTEES: 2023 ones listed

Student name	Degree [defense]	Chair	Member	Comment
Shian Su	PhD	X		Qual S21
Hongtao Zhong	PhD	X		Qual S22

II.D. MASTER'S AND DOCTORAL THESES DIRECTED AND BEING DIRECTED

Show numbers and dates in each category

I am actively directing the theses of 2 Ph.D. students and 0 Master with Thesis option (MST) students.

I have graduated 8 PhD and 4 MST students. I was the sole chair of 5 of the 7 PhD committees; I was the sole chair of 4 of the 4 MST committees.

Master's and Doctoral Theses Currently under direction

Student name	Degree	Committee Approved	POW Approved	Qualifying Review (date)	Preliminary Exam (date)	Notes
Shian Su	PhD			S21		RA
Hongtao Zhong	PhD			S21		RA

Doctoral Theses Directed

Student name	Degree [date]
Joe Zhou	May 2024
Carter Harris	May 2020
Junyu Shen	Aug 2019
Deeksha Lal	May 2019
Emre Karagozler	Jan 2013
Wei Tai	May 2012
Darmin Arumugam	Jan 2012
Weihua Hu	Aug 2012

Master's Directed

Student name	Degree [date]
Samyak Parakh	Dec. 2017
Fenglan Yang	May 2015
Chongzhe Li (CMU)	Dec. 2012
Zacharias George (CMU)	Aug 2005
En Shi (CMU)	May 2010
Qianyu Liu (CMU)	May 2009

III. SCHOLARSHIP

III.A. PUBLICATIONS, AWARDS, AND ED. BOARD/PROGRAM COMMITTEE

List items as applicable, e.g., original research articles and research review articles in peer-reviewed journals, refereed articles that are pedagogy or extension-related, research abstracts, books; interdisciplinary/multidisciplinary works; invited and contributed research presentations; appointments or election to study sections and editorial boards; creative or professional works; exhibitions; juried shows, honors; awards, fellowships, prizes, competitions, and other pertinent evidence.

BOOKS

1. Radio System Design, D. S. Ricketts, Igram Spark, 2015.
2. Electrical Solitons: Theory, Design and Applications, D. S. Ricketts and D. Ham, CRC Press, 2010.
3. The Designers Guide to Jitter in Ring Oscillators, J. A. McNeill and D. S. Ricketts, Springer Verlag, 2009.

BOOK CHAPTERS

1. D. S. Ricketts, Xiaofeng Li, and Donhee Ham, "Soliton Electronics," in Circuits for Emerging Technologies - CMOS and Beyond, CRC Press 2008.
2. X. Li, D. S. Ricketts, and D. Ham, "Solitons in electrical networks," McGraw-Hill 2008 Yearbook of Science and Technology, McGraw-Hill, 2008.

DISCUSSION PI'S WORK

1. Nature, News & Views article by Thomas H. Lee, "Electrical solitons come of age," Nature, vol. 440, 36-37, Mar. 2006.

JOURNAL PUBLICATIONS

Graduate student author; undergraduate author

1. J. Besnoff, H. Zhong, S. Su, R. Kaveti, N. Maiya, S. Krishna, N. Garland, A. Bandekar and D. S. Ricketts, "Sweat-powered, mm scale, continuous time sensor systems with Bluetooth Low Energy2 (BLE) Backscatter. *Nature Electronics*, submitted.
2. W. C. Harris and D. S. Ricketts, "Maximum Gain Enhancement n Wireless Power Transfer using Anisotropic Metamaterials," Scientific Reports, Sci Rep 13, 7726 (2023). <https://doi.org/10.1038/s41598-023-32415-9>
3. J. Shen and D. S. Ricketts, "Compact W-Band "Swan Neck" Turnstile Junction Orthomode Transducer Implemented by 3-D Printing," in IEEE Transactions on Microwave Theory and Techniques, vol. 68, no. 8, pp. 3408-3417, Aug. 2020
4. **M. Dwyer** and D. S. Ricketts, "The North Carolina state university rabbit radar: Build a frequency-modulated continuous-wave radar in a day [application notes]," IEEE Microwave Magazine, vol. 21, no. 5, pp. 136–145, 2020..[Invited]
5. D. S. Ricketts, "A modern 16-qam digital radio you can design and build at home [application notes]," IEEE Microwave Magazine, vol. 21, no. 7, pp. 10–22, 2020.
6. **W. C. Harris**, D. D. Stancil, and David S. Ricketts, "Improved wireless power transfer efficiency with non-perfect lenses," Applied Physics Letters 114:14, April 2019.
7. D. S. Ricketts, E. Shi, X. Li, N. Sun, O.O. Yildirim and D. Ham, "Electrical Solitons for Microwave Systems," IEEE Microwave Magazine, April 2019 [Invited].

8. **J. Shen** and D. S. Ricketts, "Additive Manufacturing of Complex Millimeter-Wave Waveguides Structures Using Digital Light Processing," in IEEE Transactions on Microwave Theory and Techniques, vol. 67, no. 3, pp. 883-895, March 2019.
9. D. S. Ricketts, **J. Shen**, J. Dunn, "Expanding the Antenna Frontier With Antenna Synthesis and 3D Printing", (Cover article), Microwave Engineering Europe, Sept. 2018.
10. **D. Lal**, A. M. A. Ali and D. S. Ricketts, "Analysis and Comparison of High-Resolution GS/s Samplers in Advanced BiCMOS and CMOS," in IEEE Transactions on Circuits and Systems II: Express Briefs, vol. 65, no. 5, pp. 532-536, May 2018.
11. J. Besnoff, M. Abbasi and D. S. Ricketts, "Ultrahigh-Data-Rate Communication and Efficient Wireless Power Transfer at 13.56 MHz," in IEEE Antennas and Wireless Propagation Letters, vol. 16, pp. 2634-2637, 2017.
12. M. Abbasi, B. Wang, S. Tamaru, H. Kubota, A. Fukushima and D. S. Ricketts, "Accurate De-Embedding and Measurement of Spin-Torque Oscillators," in IEEE Transactions on Magnetics, vol. 53, no. 11, pp. 1-4, Nov. 2017.
13. **V. Pasku** et al., "Magnetic Field-Based Positioning Systems," in IEEE Communications Surveys & Tutorials, vol. 19, no. 3, pp. 2003-2017, thirdquarter 2017.
14. W. Tai, M. Abbasi and D. S. Ricketts, "Analysis and design of high-power and efficient, millimeter-wave power amplifier systems using zero degree combiners," IET J. of Electronics, pp. 1-11, Jul. 2017.
15. M. Chabalko, J. Besnoff, M. Laifenfeld and D. S. Ricketts, "Resonantly Coupled Wireless Power Transfer for Non-Stationary Loads With Application in Automotive Environments," in IEEE Transactions on Industrial Electronics, vol. 64, no. 1, pp. 91-103, Jan. 2017.
16. Abbasi M, Ricketts DS. A high-power, broadband 245-285 GHz balanced frequency doubler in 45 nm SOI CMOS Microwave and Optical Technology Letters. 58: 423-426, 2016.
17. **M. E. Karagozler**, S. C. Goldstein and D. S. Ricketts, "Scalable self-assembly process for the fabrication of sub-millimetre three-dimensional cylindrical tubes," in IET Micro & Nano Letters, vol. 11, no. 1, pp. 4-8, 1 2016.
18. M. Abbasi, D. S. Ricketts, "A 275 GHz-285 GHz Balanced Frequency Quadrupler in 45nm SOI CMOS," Electronic Letters, vol. 51, no. 18, pp. 1424-1426, Sept 2015.
19. J. Besnoff, M. Abbasi and D. S. Ricketts, "High Data-Rate Communication in Near-Field RFID and Wireless Power Using Higher Order Modulation," in IEEE Transactions on Microwave Theory and Techniques, vol. 64, no. 2, pp. 401-413, Feb. 2016.
20. J. Besnoff, M. Chabalko and D. S. Ricketts, "A Frequency-Selective Zero-Permeability Metamaterial Shield for Reduction of Near-Field Electromagnetic Energy," in IEEE Antennas and Wireless Propagation Letters, vol. 15, pp. 654-657, 2016.
21. M. J. Chabalko, J. Besnoff and D. S. Ricketts, "Magnetic Field Enhancement in Wireless Power With Metamaterials and Magnetic Resonant Couplers," in IEEE Antennas and Wireless Propagation Letters, vol. 15, pp. 452-455, 2016.
22. M. Chabalko and D. S. Ricketts, "Experimental characterization of Fabry-Perot resonances of magnetostatic volume waves in near-field metamaterials", Applied Physics Letters, 106, 062401 (2015).
23. **Ozcan, O.; Weihua Hu**; Sitti, M.; Bain, J.; Ricketts, D.S., "Investigation of tip current and normal force measured simultaneously during local oxidation of titanium using dual-mode scanning probe microscopy," Micro & Nano Letters, IET , vol. 9, no. 5, pp. 332, 336, May 2014
24. Ricketts, D.S.; Chabalko, M.; **Hillenius, A.**, "Tri-Loop Impedance and Frequency Matching With High-Q Resonators in Wireless Power Transfer," Antennas and Wireless Propagation Letters, IEEE , vol. 13, no., pp. 341, 344, Jan. 2014.
25. **D. Arumugam**, J. Griffin, D. Stancil and D. S. Ricketts, "Three-Dimensional Position and Orientation Measurements using Magnetoquasistatic Fields and Complex Image Theory," Antennas and Propagation Magazine, IEEE, vol. 56, no. 1, pp. 160, 173, Feb. 2014
26. Williams, D.F.; Corson, P.; Sharma, J.; Krishnaswamy, H.; **Tai, W.**; George, Z.; Ricketts, D.S.; Watson, P.M.; Dacquay, E.; Voinigescu, S.P., "Calibrations for Millimeter-Wave Silicon Transistor Characterization," Microwave Theory and Techniques, IEEE Transactions on , vol. 62, no. 3, pp. 658, 668, Mar. 2014.
27. **Tai, W.**; Ricketts, D.S., "A compact, 36 to 72 GHz 15.8 dBm power amplifier with 66.7% fractional bandwidth in 45 nm SOI CMOS," Microw. And Opt. Tech Lett. , vol. 56, pp. 1098-2760, Nov. 2013.
28. J. Xu and D. S. Ricketts, "An Efficient, Watt-Level Microwave Rectifier Using an Impedance Compression Network (ICN) With Applications in Outphasing Energy Recovery Systems," Microwave and Wireless Components Letters, IEEE , vol. 23, no. 10, pp. 542, 544, Oct. 2013.

29. Arumugam, D.D.; Ricketts, D.S., "Passive orientation measurement using magnetoquasistatic fields and coupled magnetic resonances," *Electronics Letters*, vol.49, no.16, pp.999,1001, Aug. 2013.
30. Williams, D.F.; Corson, P.; Sharma, J.; Krishnaswamy, H.; **Wei Tai**; George, Z.; Ricketts, D.; Watson, P.; Dacquay, E.; Voinigescu, S.P., "Calibration-Kit Design for Millimeter-Wave Silicon Integrated Circuits," *Microwave Theory and Techniques, IEEE Transactions on*, vol.61, no.7, pp.2685,2694, July 2013.
31. **Tai, W.**; Ricketts, D.S., "74 GHz, 17.2 dBm power amplifier in 45 nm SOI CMOS," *Electronics Letters*, vol.49, no.12, pp.758,759, June 2013.
32. S. Tamaru and D. S. Ricketts, "Measurement of ultra-low power oscillators using adaptive drift cancellation with applications to nano-magnetic spin torque oscillators," *Rev. of Scien. Instr.*, vol. 84, p. 054704-7, May 2013.
33. **Arumugam, D.D.**; Ricketts, D.S., "Passive Magnetoquasistatic Position Measurement Using Coupled Magnetic Resonances," *Antennas and Wireless Propagation Letters, IEEE*, vol.12, no., pp.539,542, Apr. 2013
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PEER-REVIEWED CONFERENCE/WORKSHOP PUBLICATIONS

Graduate student author; undergraduate author

1. G. Garner, B. Byars, J. Wetherington, J. Besnoff and D. S. Ricketts, "Radio Disruption of Electronic Systems," GOMACTech, Charleston SC 2024
2. H. Zhong and D. S. Ricketts, "14dB Active Gain Magnetic Negative Permeability Metamaterial Cell with Self-coupling Compensation," 2023 53rd European Microwave Conference (EuMC), Berlin, Germany, 2023, pp. 424-427, doi: 10.23919/EuMC58039.2023.10290148.
3. J. Besnoff and D. S. Ricketts, "Teaching 100 remote students hands-on microwave design: Building a 16 QAM radio at home by hand," 2021 51st European Microwave Conference (EuMC), London, United Kingdom, 2022, pp. 1-4
4. J. Shen and D. S. Ricketts, "Advances in 3D additive manufacturing for complex mm-wave components and sub-systems." IEEE Radio Wireless Week, Jan 2020. **Invited.**
5. **M. Aiken** and D. S. Ricketts, "Simple Laminated PCB Artificial Dielectrics for mm-Wave Quasioptical Lenses," 2019 49th European Microwave Conference (EuMC), Paris, 2019.
6. J. Besnoff, Y. Buchbut, K. Scheim and D. S. Ricketts, "A 50% Fractional Bandwidth, Wireless Power Communication System Achieving 6.78 Mbps at 13.56 MHz Carrier," 2018 48th European Microwave Conference (EuMC), Madrid, 2018, pp. 178-181.
7. J. Besnoff, Y. Buchbut, K. Scheim and D. S. Ricketts, "Dynamic Impedance Matching of Multiple Loads in Wireless Power Transfer using a Genetic Optimization Approach," 2018 IEEE/MTT-S International Microwave Symposium - IMS, Philadelphia, PA, 2018, pp. 1272-1274.
8. **J. Shen, D. P. Parekh**, M. D. Dickey and D. S. Ricketts, "3D Printed Coaxial Transmission Line Using Low Loss Dielectric and Liquid Metal Conductor," 2018 IEEE/MTT-S International Microwave Symposium - IMS, Philadelphia, PA, 2018, pp. 59-62.
9. **J. Shen**, M. Abbasi, and David S. Ricketts, "3D Printed Antennas: Enabling Complex Antenna Structures," USNC-URSI, Jan 2018.
10. J. Besnoff, D. S. Ricketts, Y. Buchbut, G. Castillo, M. Laifendfeld and K. Scheim, "Smart wireless power: A wireless power and bi-directional LIN communication system," 2017 IEEE International Conference on Microwaves, Antennas, Communications and Electronic Systems (COMCAS), Tel-Aviv, 2017, pp. 1-3.
11. **J. Shen, M. Aiken**, M. Abbasi, **D. P. Parekh, X. Zhao**, M. D. Dickey, David S. Ricketts, "Rapid prototyping of low loss 3D printed waveguides for millimeter-wave applications," 2017 IEEE MTT-S International Microwave Symposium (IMS), Honolulu, HI, 2017, pp. 41-44.
12. D. S. Ricketts, "Analog limitations for high-speed digital radios: Where the bits stop working," 2017 IEEE 60th International Midwest Symposium on Circuits and Systems (MWSCAS), Boston, MA, 2017, pp. 37-40. **(Invited)**
13. M. Abbasi, B. Wang, S. Tamaru, H. Kubota, A. Fukushima and D. Ricketts, "Precision power measurement of spin-torque nano-oscillators using an accurate de-embedding structure and analysis," 2017 IEEE International Magnetism Conference (INTERMAG), Dublin, 2017, pp. 1-1.
14. D. Ricketts and M. Abbasi, "Analytical limits to maximum RF performance of spin torque nano-oscillators," 2017 IEEE International Magnetism Conference (INTERMAG), Dublin, 2017, pp. 1-1.
15. **J. Shen, M. Aiken**, C. Ladd, M. Dickey and D. S. Ricketts, "A Simple Electroless Plating Solution for 3D Printed Microwave Components," *IEEE Asia Pacific Microw.Conf.*, Dec 2016. **(Best paper award)**
16. **W. Harris**, T. Nichols, M. Abbasi and D. S. Ricketts, "A Simple Electroless Plating Solution for 3D Printed Microwave Components A Versatile mm-Wave Micromachined Anti-Reflective Layer," *IEEE Asia Pacific Microw.Conf.*, Dec 2016.
17. M. Abbasi and D. S. Ricketts, "W-Band Conical and Corrugated Horn Antennas Using Stereolithography 3D-Printing Technology," *IEEE Asia Pacific Microw.Conf.*, Dec 2016.
18. M. Abbasi and D. S. Ricketts, "mm-Wave and THz Multipliers: Advances and Opportunities," *IEEE Asia Pacific Microw.Conf.*, Dec 2016. **(Invited)**

19. **D. Lal**, M. Abbasi and D. S. Ricketts, "A broadband, compact 140–170GHz double side-band receiver in 90nm SiGe technology," 2016 46th European Microwave Conference (EuMC), London, 2016, pp. 687-690.
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21. Besnoff, J. and D. S. Ricketts, "Wide bandwidth for high-speed communication in mid-range, resonant WPT and RFID systems," Microwave Conference (EuMC), 2015 European.
22. Besnoff, J.; Ricketts, D.S., "Near field wireless power transfer and quadrature amplitude modulated (QAM) communication link," in Wireless Power Transfer Conference (WPTC), 2015 IEEE , vol., no., pp.1-4, 13-15 May 2015.
23. Besnoff, J.; Ricketts, D., "Quadrature amplitude modulated (QAM) communication link for near and mid-range RFID systems," in RFID (RFID), 2015 IEEE International Conference on , vol., no., pp.151-157, 15-17 April 2015.
24. **Wei Tai**; Ricketts, D.S., " A Compact, High-gain Q-Band Stacked Power Amplifier in 45nm SOI CMOS With 19.2dBm Psat and 19% PAE, IEEE PAWR Conference, Jan 2015," IEEE PAWR Conference, Jan 2015.
25. M. J. Chabalko, **W. C. Harris**, D. D. Stancil and D. S. Ricketts, "Experimental Characterization of Volume-mode Waves in Near-field Anisotropic Metamaterials with Application to Wireless Power Transfer," Asia-Pacific Microwave Conference, Nov 2014.
26. Junfeng Xu; Ricketts, D.S., "Broadband W-band On-Chip Yagi Antenna Using Superstrate for High Efficiency and Endfire Radiation" Asia Pacific Microwave Conference, Nov. 2014
27. Chabalko, M.J.; Laifenfeld, M.; Buchbut, Y.; Ricketts, D.S., "Resonantly-coupled wireless powered seat locomotion in automotive applications," European Microwave Conference (EuMC), 2014 44th , vol., no., pp.421,424, 6-9 Oct. 2014.
28. Chabalko, M.J.; Ricketts, D.S., "The effects of magneto-static resonances in metamaterials on the quality factor of coils in near field applications," Antennas and Propagation Society International Symposium (APSURSI), 2014 IEEE , vol., no., pp.426,427, 6-11 July 2014.
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31. **Wei Tai**; Ricketts, D.S., "A W-band 21.1 dBm power amplifier with an 8-way zero-degree combiner in 45 nm SOI CMOS," Microwave Symposium (IMS), 2014 IEEE MTT-S International , vol., no., pp.1,3, 1-6 June 2014
32. **Wei Tai**; Ricketts, D.S., "Watt-Level, All-Silicon mm-Wave Power Amplifiers Using Zero-Degree Combiners" GOMACTech (Government Microcircuit Applications and Critical Technology) Conference, April 2014
33. **Wei Tai**; Ricketts, D.S., "A Q-band power amplifier with high-gain pre-driver and 18.7 dBm output power for fully integrated CMOS transmitters," Power Amplifiers for Wireless and Radio Applications (PAWR), 2014 IEEE Topical Conference on , vol., no., pp.34,36, 19-23 Jan. 2014
34. **Chen, M.W.**; Carley, L.R.; Ricketts, D.S., "A process-technology-scaling-tolerant pipelined ADC architecture achieving 6-bit and 4 GS/s ADC in 45nm CMOS," Silicon Monolithic Integrated Circuits in Rf Systems (SiRF), 2014 IEEE 14th Topical Meeting on , vol., no., pp.16,18, 19-23 Jan. 2014
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36. Junfeng Xu; **Wei Tai**; Ricketts, D.S., "Microwave watt-level rectifiers for power recycling applications," Microwave Integrated Circuits Conference (EuMIC), 2013 European, pp.516,519, 6-8 Oct. 2013.
37. Ricketts, D.S.; Chabalko, M.J.; **Hillenius, A.**, "Optimization of wireless power transfer for mobile receivers using automatic digital capacitance tuning," Microwave Conference (EuMC), 2013 European , vol., no., pp.515,518, 6-10 Oct. 2013.
38. M. Chabalko and D. S. Ricketts, "The Effects of Magneto-static Surface Resonances in Metamaterials on the Quality Factor of Coils in Near Field Applications," Antennas and Propagation Society International Symposium (APSURSI), July, 2014.
39. Trotter, M.S.; Ricketts, D.S.; Griffin, J.D., "Experimental demonstration of complex image theory for vertical magnetic dipoles with applications to remote sensing and position tracking," Electromagnetics in Advanced Applications (ICEAA), 2013 International Conference on , vol., no., pp.1248,1251, 9-13 Sept. 2013.

40. **O. Ozcan, W. Hu, M. Sitti, J. A. Bain and D.S. Ricketts**, "Experimental Investigation of Force, Conduction and Growth in Nano-oxidation using scanning probe microscopy," Enabling Nanomanufacturing for Rapid Innovation, Aug. 2013. [Best Poster]
41. **D. S. Ricketts and M. Chabalko**, "Distributed Resonant Coil Systems for Efficient Wireless Power Transfer," Progress in Electromagnetics Research Symposium (PIERS), Aug. 2013.
42. **J. Xu and D. S. Ricketts**, "A Transmission line based resistance compression network (TRCN) for microwave applications," Microwave Symposium Digest (IMS), 2013 IEEE MTT-S International , vol., no., pp.1,3, 2-7 June 2013
43. **D. S. Ricketts and M. Chabalko**, "On the efficient wireless power transfer in resonant multi-receiver systems," Circuits and Systems (ISCAS), 2013 IEEE International Symposium on , vol., no., pp.2779,2782, 19-23 May 2013
44. **Arumugam, D.D.; Sibley, M.**; Griffin, J.D.; Stancil, D.D.; Ricketts, D.S., "An active position sensing tag for sports visualization in American football," RFID (RFID), 2013 IEEE International Conference on , vol., no., pp.96,103, April 30 2013.
45. **W. Tai, L. R. Carley and D. S. Ricketts**, "A 0.7W Fully Integrated 42GHz Power Amplifier with 10% PAE in 130nm SiGe BiCMOS," Solid-State Circuits Conference Digest of Technical Papers (ISSCC), 2013 IEEE International , vol., no., pp.142,143, 17-21 Feb. 2013
46. **M. W. Chen, D. Tian, S. Phatak, L. R. Carley, D. S. Ricketts**, "A 4GHz-Bandwidth Op-Amp Free Track-and-Hold and 6-bit Flash ADC in 45nm SOI CMOS" Silicon Monolithic Integrated Circuits in RF Systems (SiRF), 2013 IEEE 13th Topical Meeting on , vol., no., pp.126,128, 21-23 Jan. 2013
47. **D. Birt, K. An, M. Tsoi, S. Tamaru, D. Ricketts, K.L. Wong, P.K. Amiri, K.L. Wang and X. Li**, "Oscillatory Spatial Intensity Pattern for Spin Waves Excited with a Coplanar Waveguide Antenna," Conference on Magnetism and Magnetic Materials, Chicago, IL, paper EC-02, Jan. 2013.
48. **C. Li and D. S. Ricketts**, "A low-loss, compact, $\lambda/4$ power combiner architecture," Microwave Integrated Circuits Conference (EuMIC), 2012 7th European , vol., no., pp.147,150, 29-30 Oct. 2012
49. **D. S. Ricketts and A. Hillenius**, "Equivalence of inductive coupling and strongly coupled Magnetic resonance in wireless power transfer," Progress in Electromagnetics Research Symposium (PIERS), Aug. 2012.
50. **D. Arumugam, J. Griffin, D. Stancil and D. S. Ricketts**, "Experimental study on the effects of groups of people on magnetoquasistatic positioning accuracy," Antennas and Propagation Society International Symposium (APSURSI), 2012 IEEE , vol., no., pp.1,2, 8-14 July 2012
51. **D. S. Ricketts**, "A dispersion-tapered reflection soliton oscillator," Microwave Symposium Digest (MTT), 2012 IEEE MTT-S International , vol., no., pp.1,3, 17-22 June 2012
52. **D. Tian, L. R. Carley and D. S. Ricketts**, "Frequency Scaling of Power Reclamation Networks in Outphasing PA Architectures," Circuits and Systems (ISCAS), 2012 IEEE International Symposium on , vol., no., pp.1058,1061, 20-23 May 2012
53. **S. Tamaru and D. S. Ricketts**, "Origin of variation in the oscillation characteristics of point contact based spin torque oscillators," Magnetism Letters, IEEE , vol.3, no., pp.3000504,3000504, 2012
54. **W. Hu J. A. Bain and D. S. Ricketts**, "In-situ characterization using AFM probes in multiple modes," Int. Conf. Electron, Ion, Photon Beam Technology and Nanofabrication, May, 2012.
55. **Lee, B.J.; Hillenius, A.**; Ricketts, D.S., "Magnetic resonant wireless power delivery for distributed sensor and wireless systems," Wireless Sensors and Sensor Networks (WiSNet), 2012 IEEE Topical Conference on , vol., no., pp.13,16, 15-18 Jan. 2012.
56. **D. Arumugam, J. Griffin, D. Stancil and D. S. Ricketts**, "A wireless orientation sensor using magnetoquasistatic fields and complex image theory," Radio and Wireless Symposium (RWS), 2012 IEEE , vol., no., pp.251,254, 15-18 Jan. 2012
57. **W. Tai, L. R. Carley and D. S. Ricketts**, "A Q-band SiGe Power Amplifier with 15.5 dBm Saturated Output Power and 26% Peak PAE," Bipolar/BiCMOS Circuits and Technology Meeting (BCTM), 2011 IEEE , vol., no., pp.146,149, 9-11 Oct. 2011
58. **D. Arumugam, D. Stancil and D. S. Ricketts**, "Proximity and Orientation Sensing Using Magnetoquasistatic Fields and Complex Image Theory" Vehicular Technology Conference (VTC Fall), 2011 IEEE , vol., no., pp.1,5, 5-8 Sept. 2011
59. **W. Hu, J. Gu, Z. George and D. S. Ricketts**, "Directed scanning probe nanomanufacturing of lateral Ti-TiO₂-Ti junctions for low capacitance MIM rectenna diodes," Micro and Nano Engineering Conf., Berlin, Sept. 2011.
60. **D. Arumugam, J. Griffin, D. Stancil and D. S. Ricketts**, "2-Dimensional Position Measurement using Magnetoquasistatic Fields," Antennas and Propagation in Wireless Communications (APWC), 2011 IEEE-APS Topical Conference on , vol., no., pp.1193,1196, 12-16 Sept. 2011

61. **W. Hu, Y. Tang, Y. Zhang**, J. Gu, S. Tamaru, J. A. Bain, L. R. Carley, R. F. Davis, G. K. Fedder and D. S. Ricketts, "TI/TIO₂ nanodevice fabrication using compliant probes and CMOS probe-arrays," Technologies for Future Micro-Nano Manufacturing, Napa Valley, CA, Aug. 2011.
62. **D. Arumugam**, J. Griffin, D. Stancil and D. S. Ricketts, "Higher Order Loop Corrections for Short Range Magnetoquasistatic Position Tracking," Antennas and Propagation (APSURSI), 2011 IEEE International Symposium on , vol., no., pp.1755,1757, 3-8 July 2011
63. **M. E. Karagozler, A. M. Thaker**, S. Goldstein and D. S. Ricketts, "Electrostatic-actuation generation and control of micro robots in a post-processed HV SOI CMOS," Circuits and Systems (ISCAS), 2011 IEEE International Symposium on , vol., no., pp.2509,2512, 15-18 May 2011
64. **W. Hu**, S. Tamaru, J. A. Bain and D. S. Ricketts, "High Current Pulse Generation for Thermal Surface Modification using Standard STM," Int. Conf. Electron, Ion, Photon Beam Technology and Nanofabrication, May. 2011.
65. J. R. Smith, D. S. Ricketts and J. A. Bain, "Localized thermal modification of surfaces via pulsed electron bombardment from an STM tip," Int. Conf. Electron, Ion, Photon Beam Technology and Nanofabrication, May. 2011.
66. **D. Arumugam**, J. Griffin, D. Stancil and D. S. Ricketts, "Long Range Magnetoquasistatic Position Tracking using a Simple Active RFID Tag," IEEE Int. Conf. RFID, Apr. 2011.
67. S. Tamaru and D. S. Ricketts, "Influence of the bias field orientation on the interaction strength between two closely formed spin torque oscillators," Int. Magnetism Conf., paper CO-05, Taiwan, Apr 2011.
68. **E.R. Evarts, R.A. Booth, L.R. Shah, Y. Tang**, S. Tamaru, D.S. Ricketts, J.A. Bain, S.A. Majetich,"Sub-30 nm Magnetic Tunnel Junction and Spin Valve Nanopillar Analysis Using Conductive Atomic Force Microscopy," Int. Magnetism Conf., paper BB-03, Taiwan, Apr 2011.
69. J. R. Smith, **W. Hu, Y-Y Dang, O. Ozcan**, M. Sitti, J. A. Bain, D. S. Ricketts, R. Davis, "Scanning Probe Nanomanufacturing on Si: Surface Characterization of the Process Technique," Materials Research Symposium, paper G1.5, Nov. 2010
70. **E. R. Evarts**, M. Moneck, R. A. Booth, C. Hogg, D. S. Ricketts, J-G Zhu, J.A. Bain, and S. A. Majetich, "Spin Torque Switching of 26 nm Diameter Magnetic Tunnel Junction Using a Conductive Atomic Force Microscope," Conference on Magnetism and Magnetic Materials, Atlanta, GA, paper FC-13, Nov. 2010.
71. **E. R. Evarts, T.T. Farkas, B. Tsukerman**, L. Cao, D. S. Ricketts, G. Markovich, J.A. Bain, and S.A. Majetich, "Noise Measurements on Magnetic Tunnel Junction Nanopillars using Conductive Atomic Force Microscopy," Conference on Magnetism and Magnetic Materials, Atlanta, GA, paper CB-10, Nov. 2010.
72. **M. W. Chen** and D. S. Ricketts, "An 8.6GHz 42ps Pulse-Width Electrical Mode-Locked Oscillator," International Solid-State Circuits Conference (ISSCC), pp. 500-501, Feb. 2010.
73. D. S. Ricketts, L. Cao and S. Tamaru, "Spin-torque oscillator arrays as a solution for line width reduction in RF applications", Conference on Magnetism and Magnetic Materials, paper EY-01, Washington D.C., Dec. 2009.
74. D. S. Ricketts, T. Schlesinger, Y. Luo and J. Bain, "Materials and Devices for Hybrid CMOS Circuits: Expanding the Functionality of Nanoscale CMOS," Nano-DDS Conference, Ft. Lauderdale, FL, Oct. 2009 (Invited).
75. D. S. Ricketts and S. Bruck, "Stochastic Logic", NRI-MIND, Architectures for post- CMOS switches (Invited), Notre Dame, IN, Oct. 2009.
76. D. S. Ricketts, X. Li and D. Ham, "Soliton Electronics," CMOS Emerging Technology Workshop, Whistler, Canada, 2007. (invited)
77. W. F. Andress, D. S. Ricketts, X. Li, and D. Ham, "Passive & active control of regenerative standing & soliton waves," (Invited) Proc. of the IEEE Custom Integrated Circuits Conference, pp. 29-36, Sept. 2006.
78. D. S. Ricketts, X. Li and D. Ham, "Taming the electrical soliton: A new direction in picosecond electronics," Radio Frequency Integrated Circuits (RFIC) Symposium, 2006 IEEE , vol., no., pp.4 pp.,24, 11-13 June 2006
79. D. S. Ricketts and D. Ham, "A chip-scale electrical soliton modelocked oscillator," IEEE International Solid-State Circuits Conference (ISSCC), pp. 432-433, Feb 2006.
80. D. S. Ricketts, X. Li, M. DePetro, and D. Ham, "A self-sustained electrical soliton oscillator," Microwave Symposium Digest, 2005 IEEE MTT-S International , vol., no., pp.4 pp., 12-17 June 2005
81. D. Ham, W. Andress, and D. S. Ricketts, "Phase noise in oscillators," (Invited) Int. Workshop on Sip/SoC Integration of MEMS and Passive Components with RF-ICs, March 2004.

INVITED CONFERENCE PRESENTATIONS (WITHOUT PAPERS)

Graduate student author; undergraduate author

1. D. S. Ricketts, W. Harris, J. Zhu, D. Baron, "Dynamic artificial surfaces for mm-wave imaging using photon induced plasmas in silicon lenses." DMI Online Workshop on Energy/Quantum/Metamaterials, Dec, 2020.
2. D. S. Ricketts, "Lessons from Build-a-Radio/Radar in a Day: The Ins and Outs of Experiential Design for Students," European Microwave Week, Teaching Microwave Engineering Special Session, Sept 2020.
3. M. Abbasi and D. S. Ricketts, "100 Gb/s All-electronic Radios: Opportunities and Challenges", GomacTech, Mar. 2014
4. **W. Tai, C. Li, Z. Li, G. Yahalom**, D.S. Ricketts, V. Stojanovic and J. Dawson, "A 45 GHz Asymmetric Multilevel Outphasing Transmitter in 45nm SOI CMOS," Student Research Int. Solid-State Circuits Conf, IEEE, Feb. 2012.
5. J.R. Smith, **W. Hu, Y.Y. Dang, O. Ozcan**, M. Sitti, J. Bain, R. Davis and D. S. Ricketts, "Writing Si nanowires on Si (100) with an STM tip: surface preparation and initial results," Materials Research Symposium, M11.50, Boston, MA, Nov. 2009
6. R. S. Friedman, M. C. McAlpine, D. S. Ricketts, D. Ham, C. M. Lieber, "Fully integrated high frequency nanowire ring oscillators," Materials Research Symposium, Mar. 2005.
7. D. S. Ricketts, "Current sensing and accuracy for CPU multi-phase DC-DC converters: the sub 20 mV challenge," IBM Power Delivery Symposium, 2002.

ACADEMIC WORKSHOPS and SHORT COURSES (Chair or Co-Chair)

1. RF and Electronic Warfare Workshop with NSA. Dec. 2023.
2. "Build a Foxhole Radio" International Microwave Symposium, San Diego, CA June, 2023
3. RF Engineering workshop, US Navy Academy, May 2023
4. RF Bootcamp in residence course, delivered at UT Dallas in collaboration with Texas Analog Center of Excellence. May 2023.
5. 12th Tom Brazil Doctoral School of microwaves "Build a Frequency Modulated Continuous Wave Radar in 1-day" IEEE European Microwave Week, Milan, Italy, Sept 2022.
6. 11th Tom Brazil Doctoral School of microwaves "Build a modern digital radio" IEEE European Microwave Week, London, UK, June 2021.
7. "Build a NIST Atomic Clock Radio" International Microwave Symposium, Denver, Co June, 2022.
8. 5th European Microwave Student and Doctoral School: "Build a Frequency Modulated Continuous Wave Radar in 1-day" IEEE European Microwave Week, Utrecht, NL 2020 (virtual).
9. Frequency-Modulated Continuous Wave Radar in 1-day", European Microwave, Utrecht, NL, 2020.
10. "4th European Microwave Student and Doctoral Schools: Build a modern digital radio," IEEE , IEEE European Microwave Week, Paris, France, Oct 2019.
11. "Build a 950 MHz radar in a day," IEEE Int. Microwave Symposium, Boston, MA, June 2019.
12. "Design, Fab and Test Your Own Microwave Component," Industry Workshop, IEEE Int. Microwave Symposium, Boston, MA, June 2019..
13. "From Bits to Waves: Building a Modern Digital Radio in 1 Day – Hand-on Workshop," IEEE Asia Pacific Microwave Conference, Kyoto, Japan, 2018.
14. "4th European Microwave Student and Doctoral Schools: Build a modern digital radio," IEEE , IEEE European Microwave Week, Madrid, Spain, Sep 2017.
15. "Build a 16 QAM Radio – Student Design Competition," IEEE Int. Microwave Symposium, Philadelphia, PA, June 2018.
16. "Design, Fab and Test Your Own Microwave Component," Industry Workshop, IEEE Int. Microwave Symposium, Philadelphia, PA, June 2018.
17. "3rd European Microwave Student and Doctoral Schools: Build a modern digital radio," IEEE , IEEE European Microwave Week, Nuremberg, Germany, Oct 2017.
18. "Build a Modern Digital Radio in a day," Int. Microwave Symposium, Honolulu, HI, June 2017.
19. "From Bits to Waves: Building a Modern Digital Radio in 1 Day – Hand-on Workshop," IEEE Asia Pacific Microwave Conference, New Delhi, India, Nov 2016.
20. "From Bits to Waves: Building a Modern Digital Radio in 1 Day – Hand-on Workshop," IEEE European Microwave Week, London, UK, Oct 2016.
21. "From Bits to Waves: Building a Modern Digital Radio in 1 Day – Hand-on Workshop," EDICON, Boston, MA, Sep. 2016.
22. "Emerging devices for Microwave Circuits and Systems," IEEE Int. Microwave Symposium, San Francisco CA,, May 2016.

23. "Build a Modern Digital Radio in a day," IEEE Int. Microwave Symposium, San Francisco, CA, May 2016.
24. "Build a Modern Digital Radio in a day," IEEE Radio Wireless Week, Austin, Texas, Jan, 2016.

INVITED RESEARCH PRESENTATIONS, Universities and Industry

1. "From one to one million Volts," ECE Colloquim, NCSU Apr. 2024
2. "Live from Faraday's Lab": An Intuitive and Historical Perspective on Electromagnetism" IEEE MTT Webinar, May 2022.
3. "NCSU Rabbit Radar: Design, Simulation & Building your own Frequency Modulated Continuous Wave Radar at Home," IEEE MTT-S Virtual Lecture, Sept, 2020
4. "From Bits to Waves - Building a Modern Digital Radio," Cadence Live, August 2020.
5. "Data, Sensors and New Technologies for Smart Cities," RMIT, Melbourne Australia, Mar 2019.
6. "New Approaches to IoT in Smart Cities," Western Sydney University, Sydney, Australia, Mar 2019.
7. "Enhancing, Shaping and Steering WPT Fields," WPT NSF ERC Industry Workshop, Alexandria, VA, Dec 2018.
8. "High-speed GaN RF DC-DC Converter design," Power America Webinar, NCSU, Oct. 2018.
9. "High-speed Communication & Field Enhancement Using Artificial Materials," Pennsylvania State University, Oct 2018.
10. "Modern Digital Radios," EuMW Microapp Lecture, Madrid Sept. 2018.
11. "Sensors and Networks for Smart Cities," City of San Diego, CA, Apr 2018.
12. "Emerging Technologies in Sensors for Smart Cities," Facebook, Dublin, Feb 2018.
13. "Science in Microwaves," NSF Workshop at IMS2017, June 2017.
14. "Magic with Magnetic Fields: NFL Football Tracking", Raleigh Engineers Club, Raleigh, NC, June 2017.
15. "Maximum power and phase noise in spin-torque oscillators," AIST Dec 2016.
16. "High-power, broadband multipliers for high-speed microscale radios," IEEE IMS invited workshop presentation, May 2016.
17. "Advances in wireless power transfer research: challenges and opportunities," General Motors, Feb. 2016.
18. "Magic with magnetic fields: NFL football tracking and advances in wireless power transfer & communication," Univ. of Washington, Feb, 2015.
19. "State of the art and future of high-speed wireless transceivers: Opportunities and challenges for near-THz communication," CMOS Emerging Technologies Conference, **Plenary, Invited**, May 2015.
20. "Advances in wireless power transfer research from academia: Challenges and opportunities," Wireless Power Summit, **Invited**, Berkeley, CA, Nov 2014.
21. "Advances in high-speed integrated and nanoelectronics," AIST Nov 2014.
22. "Watt-level, Highly Efficient, Fully Integrated all-Silicon Linear Power Amplification for mm-Wave Radar and Communications," Berkeley Nov. 2014.
23. "High-speed integrated circuits: From water waves to optical sampling," Analog Devices, Oct 2014.
24. "Advanced RF substrates: Applications in mm-wave electronics," DuPont 2014.
25. "Advanced mm-wave Circuits and Systems," Nuvotronics, 2014.
26. "Watt-level, Highly Efficient, Fully Integrated all-Silicon Linear Power Amplification for mm-Wave Radar and Communications," University of Delft, Netherlands, 2014
27. "Watt-level, Highly Efficient, Fully Integrated all-Silicon Linear Power Amplification for mm-Wave Radar and Communications," University of Pavia, Italy, 2014
28. "Magnetoquasistatics: Emerging Applications in Sports Visualization and Enhanced Wireless Power Transfer," University of Perugia, Italy, 2014
29. "Power, Sensing and Communication: Opportunities for a wireless world," General Motors Research, Herzlia Israel, Oct. 2013.
30. "Enabling Rapid Innovation in Nanomanufacturing," ENRI NSF workshop keynote, Napa, CA. Aug. 2013.
31. "Watt-level, Highly Efficient, Fully Integrated Linear Power Amplification for mm-Wave Radar and Communications," MIT, Boston Ma, May 2013.
32. "Watt-level, Highly Efficient, Fully Integrated Linear Power Amplification for mm-Wave Radar and Communications," Qualcomm, San Diego, CA, Jan 2013.
33. "Impedance Matched Magnetoquasistatic Wireless Power: On the equivalence of inductive and strongly coupled magnetic resonance and the challenges of multiple and mobile receivers" Qualcomm, San Diego, CA, Jan 2013.

34. RF from Kilometer to Millimeter Waves: NFL Football Tracking and High-power mm-Wave Circuits and Systems,” POSTECH, Korea Aug 2012 (Distinguished Lecturer)
35. “Watt-level, Highly Efficient, Fully Integrated Linear Power Amplification for mm-Wave Radar and Communications,” Jet Propulsion Laboratory, Pasadena, CA, Jul 2012.
36. “NFL Football Tracking, Microrobots and Nanoelectronics: Novel applications of Analog Circuits, E&M and MEMS,” University of FL, Apr 2012.
37. “RF devices, circuits & systems: from nanometers to kilometers,” University of Illinois, Urbana Champagne, Apr 2012.
38. “Applications of Analog Circuits and Electromagnetics in mm-wave RF and μ Robots,” NCSU Mar 2012.
39. “RF from Kilometer- to Millimeter-waves: NFL Football Tracking and Power Amplifier Circuits & Systems,” UMich. Mar 2012.
40. “RF devices, circuits and systems: from nanometer to kilometer” University of Utah, Feb 2012
41. “NFL Football Tracking and Microrobots: Novel Applications of Analog Circuits, MEMS and E&M,” Harvard University, Feb 2012
42. “RF devices, circuits and systems: from nanometer to kilometer,” Duke Univ, Jan 2012
43. “At the boundaries of high-frequency analog & RF ICs: Speed, energy and uncertainty”, Univ. NC State, NC, Dec 2011, (**Invited, Distinguished Lecturer**)
44. “Quasistatics in E&M: Sports Visualization, Wireless Power and Microrobots,” Ga Tech, GA Nov. 2011.
45. “RF devices, circuits and systems: from nanometer to kilometer,” Univ. of Texas, Austin, Oct 2011
46. “RF devices, circuits and systems: from nanometer to kilometer,” Princeton Univ., Oct 2011
47. “High-speed PA and ADCs,” Univ. Wisconsin, Oct. 2011
48. “At the boundaries of high-frequency analog & RF ICs: Speed, energy and uncertainty”, GA Tech, GA, May 2011
49. “RF PA’s and spin-torque oscillators for RF,” University of FL, Mar, 2011
50. “Tip-directed, Field-assisted Nanofabrication,” NIST, Mar 2011.
51. “Extending the boundaries of analog and RF electronics,” Brown Univ., Mar, 2011.
52. “Nanoscale magnetism for integrated power conversion and RF,” ARL, Jan, 2011.
53. “Ultimate limitation of conversion in conventional ADCs,” ONR Superconducting Electronics Program, San Diego, Jan. 2011.
54. “Tip-assisted, field emission nanofabrication,” Zyvex Corp., Apr., 2010.
55. “Tip-assisted Nanofabrication,” Worcester Polytechnic Institute, MA, Mar. 2010.
56. “Spin Torque Oscillators for Agile RF,” DARPA YFA Program, Oct. 2009.
57. “Perspectives on electrical oscillators,” IBM Research, NY, Apr., 2009
58. “Electrical oscillators and phase noise,” NIST, Boulder, CO, Oct. 2008
59. “Creativity in science and engineering,” Innovation in Science and Engineering, Harvard University, Oct. 2008
60. “The Double Helix, a case study in scientific discovery,” Innovation in Science & Technology, Paris University Consortium, Paris France, 2008.
61. “Creativity in science and engineering,” Innovation in Science & Technology, Paris University Consortium, Paris France, 2008.
62. “New directions : soliton mode-locking and nanowire circuits,” CMU, Sept. 2006
63. “Electrical soliton oscillators” University of Michigan, Mar, 2006
64. “Electrical soliton oscillator and nanowire Circuits,” University of California, Berkeley, Apr. 2006
65. “Electrical soliton oscillators,” Cornell University, Mar 2006.
66. “Electrical solitons,” The Cooper Union, Feb. 2006.

STEM Workshops, K-12

1. STEM workshop for middle-school students in collaboration with Naval Information Warfare Center Atlantic STEM. July 2023.
2. IEEE Project CONNECT workshop teaching High School how to build AM radio. June 2023.

III.C. ORGANIZATION PARTICIPATION

Participation in centers, consortia, institutes, interdisciplinary/multidisciplinary activities and other organized scholarly efforts between departments within and across colleges or institutions

N/A

IV. EXTENSION AND ENGAGEMENT WITH CONSTITUENCIES OUTSIDE THE UNIVERSITY

Faculty Affiliate (2023-) Bloomberg Cities Center, Kennedy School of Government
 Faculty Associate (2014-), Innovation Fellow (2011-2014) Technology and Entrepreneurship Center, School of Engineering and Applied Science (SEAS), Harvard University. Courtesy appointment in SEAS for collaboration on innovation with students and faculty. Guest lecture in ES139/239 courses and assist with program development for symposia.

IV.A ACCOMPLISHMENTS

List accomplishments as applicable, e.g., bulletins, brochures, reports, pamphlets, non-refereed publications, computer software, educational videotapes, slide sets, popular press articles, and other pertinent evidence.

Experiential ECE Lectures – 800,000 You Tube views (two lectures)

Online dissemination of RF system design - ~**200,000 You Tube** views. Non-NCSU watch **800+ hours viewed per month** of PIs RF system design YouTube videos.

Developed two online courses including 70 video lectures and 20 laboratory assignments.

www.rickettslab.org/radiosystemdesign

www.rickettslab.org/adc

IV.B. PROGRAM IMPACTS

Describe results/impact of accomplishment.

N/A

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VI. SERVICE TO THE UNIVERSITY AND PROFESSIONAL SOCIETIES

University service (department, college, and university committees and governance organizations); state, regional, national and international professional activities and committee work, including professional associations.

DEPARTMENT SERVICE

Teaching Review Committee F22-
Promotion, Tenure Committee Co-Chair 2023
Marketing and Communication (ECE Department) – 2020-22
ECE Open House (ECE Department) – 2020-
Faculty Search Committee (ECE Department) – 2017, 2019, 2022
Course Curricula Committee (ECE Department) - 2015-present
Senior Design Director Search Committee (ECE Department) - 2014
Participated in Engineering Open House (ECE Department), 2014

UNIVERSITY SERVICE

N/A

PROFESSIONAL SOCIETIES

Chair, IEEE Chapter ACME (Joint chapter of Antennas and Propagation (AP), Electronic Packaging Society (EP), Microwave Theory and Techniques (MTT), and Electron Devices (ED) 2019-2023

Technical Committee **Chair** for IEEE T-MTT 9 Society 2020-2022

Technical Committee **Vice-chair** for IEEE T-MTT 7 Society 2015-2019

Technical Program **Chair**: Enabling Nanomanufacturing for Rapid Innovation, TRC/NSF Workshop, Aug. 2013

Technical Program Committee (member) – IEEE International Microwave Symposium 2014-;

Technical Program Committee IEEE BioWireless 2012-2015.

Session Chair - Nanotechnology, CMOS Emerging Technologies Conf., Banff, Canada 2009; NANO-DDS, Chemically-Synthesized, Biomimetic Systems and Biologically-Inspired Architectures Session, August 2011.

NSF Panelist (6 panels)

Reviewer for journals: ACS Nano Letters, Journal of Solid State Circuits (IEEE) Electron Device Letters (IEEE) Transactions on Circuits and Systems (IEEE) Proceedings of the National Academy of Sciences, MacArthur Foundation (Fellows program) Nano Letters, Sensors Journal of Applied Physics, Journal of Emerging and Selected Topics in Power Electronics, IET Circuits, Devices & Systems, IEEE Transactions on Power Electronics, IEEE Antennas and Wireless Propagation Letters, IEEE Transaction on Antennas and Propagation, IEEE Microwave and Wireless Components Letters, IEEE Transactions on Biomedical Circuits and Systems, Micromachines, IET Microwaves, Antennas & Propagation, International Journal of Circuit Theory and Applications, Scientific Reports.



The Future of Analog IC Technology[®]

MP2612

2A,24V Input, 600kHz

2-3 Cells Switching Li-Ion Battery Charger

DESCRIPTION

The MP2612 is a monolithic switching charger for 2-3 cells series Li-Ion cells battery with a built-in internal power MOSFET. It achieves up to 2A charge current with current mode control for fast loop response and easy compensation. The charge current can be programmed by sensing the current through an accurate sense resistor.

MP2612 regulates the charge current and charge voltage using two control loops to realize high accuracy CC charge and CV charge.

Fault condition protection includes cycle-by-cycle current limiting and thermal shutdown. Other safety features include battery temperature monitoring, charge status indication and programmable timer to finish the charging cycle.

The MP2612 requires a minimum number of readily available standard external components.

The MP2612 is available in 16-pin 4mm x 4mm QFN package.

FEATURES

- Charges 2-3 Cells Series Li-Ion Battery Packs
- Wide Operating Input Range
- Up to 2 A Programmable Charging Current
- $\pm 0.75\%$ V_{BATT} Accuracy
- 0.2Ω Internal Power MOSFET Switch
- Up to 90% Efficiency
- Fixed 600kHz Frequency
- Preconditioning for Fully Depleted Batteries
- Charging Operation Indicator
- Input Supply and Battery Fault Indicator
- Thermal Shutdown
- Cycle-by-Cycle Over Current Protection
- Battery Temperature Monitor and Protection

APPLICATIONS

- Distributed Power Systems
- Chargers for 2-Cell or 3-Cell Li-Ion Batteries
- Pre-Regulator for Linear Regulators
- Smart Phones
- Net-book

For MPS green status, please visit MPS website under Quality Assurance.
 "MPS" and "The Future of Analog IC Technology" are Registered Trademarks of
 Monolithic Power Systems, Inc.

TYPICAL APPLICATION

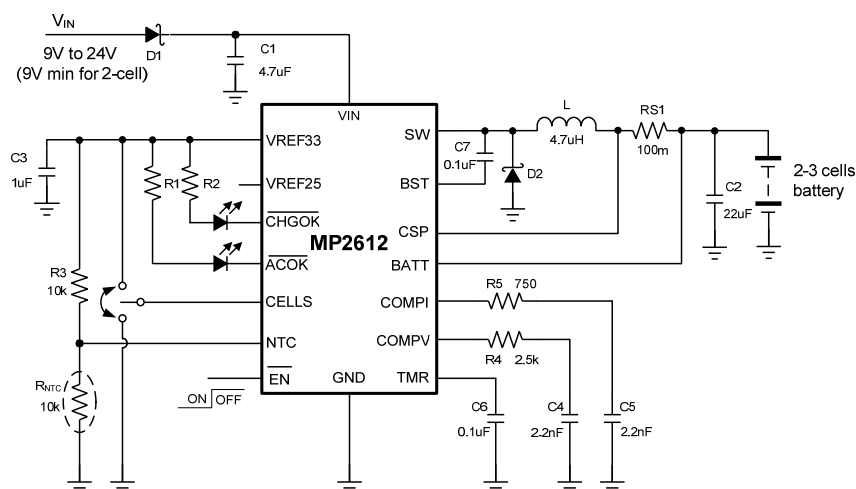


Figure 1—Standalone Switching Charger

MPS® MP2612 – 2A, 24V INPUT, 600kHz 2-3CELL SWITCHING LI-ION BATTERY CHARGER

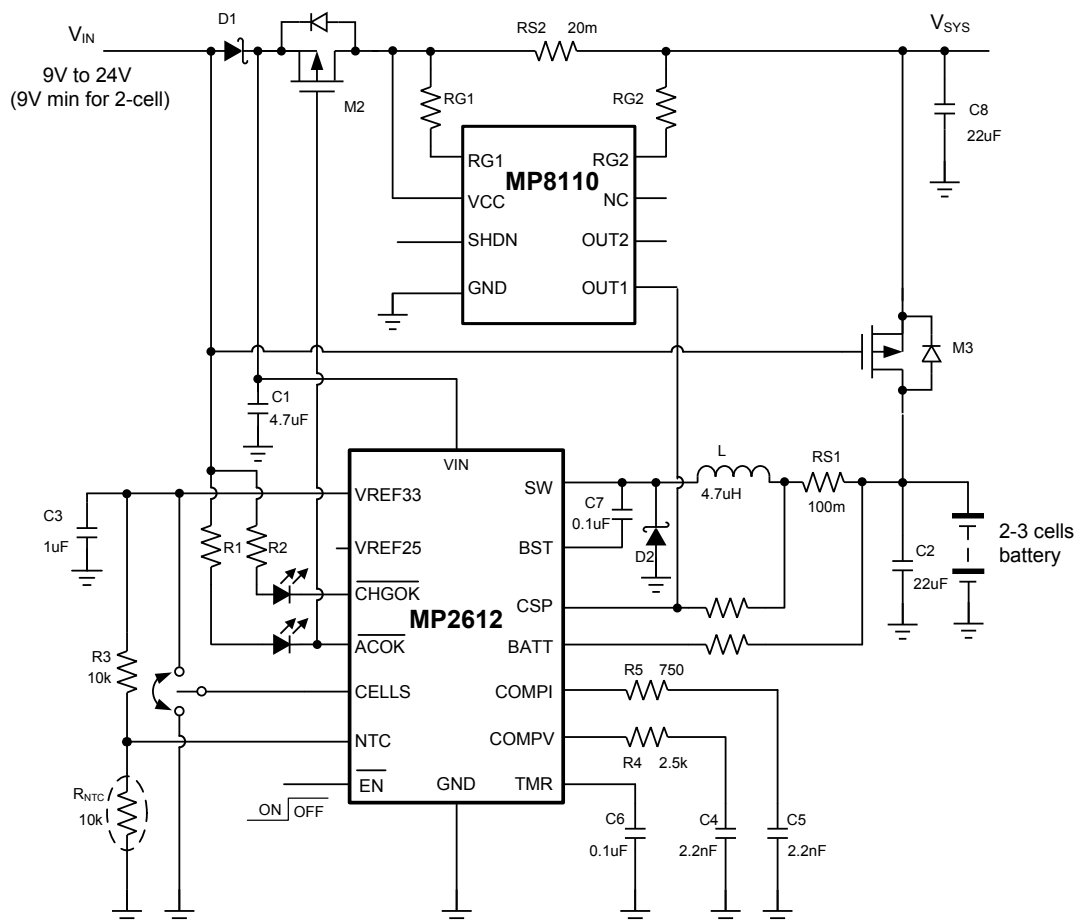


Figure 2—Switching Charger with Power Path Management ⁽¹⁾

Notes:

- 1) ACOK should be pulled up to VIN in the power path management application.

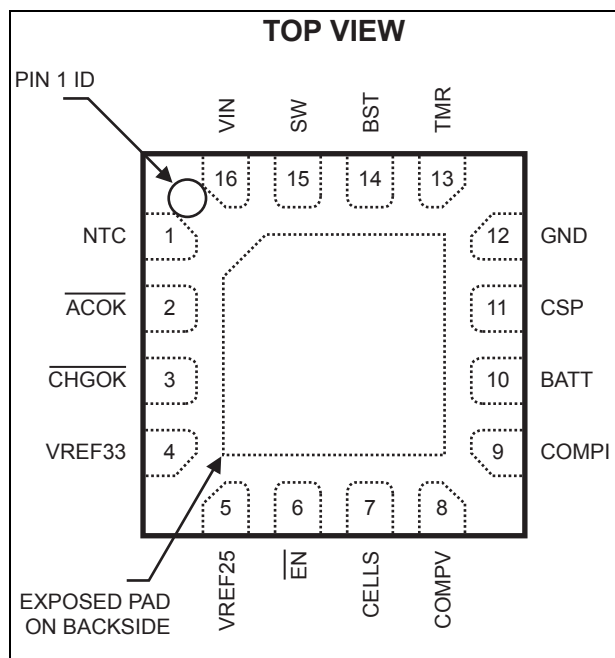
ORDERING INFORMATION

Part Number*	Package	Top Marking	Free Air Temperature (T _A)
MP2612ER	4mm x 4mm QFN16	2612ER	-20°C to +85°C

*For Tape & Reel, add suffix -Z (eg. MP2612ER-Z);

For RoHS compliant packaging, add suffix -LF (eg. MP MP2612ER-LF-Z)

PACKAGE REFERENCE



ABSOLUTE MAXIMUM RATINGS ⁽²⁾

Supply Voltage V _{IN}	26V
V _{SW}	-0.3V to V _{IN} + 0.3V
V _{BST}	V _{SW} + 6V
V _{CSP} , V _{BATT}	-0.3V to +18V
V _{ACOK} , V _{CHGOK}	-0.3V to +26V
All Other Pins	-0.3V to +6V
Continuous Power Dissipation (T _A =+25°C) ⁽³⁾	2.7W
Junction Temperature	150°C
Lead Temperature	260°C
Storage Temperature	-65°C to +150°C

Recommended Operating Conditions ⁽⁴⁾

Supply Voltage V _{IN}	9V to 24V
Maximum Junction Temp. (T _J)	+125°C

Thermal Resistance ⁽⁵⁾	θ _{JA}	θ _{JC}
4x4 QFN16	46	10

Notes:

- 2) Exceeding these ratings may damage the device.
- 3) The maximum allowable power dissipation is a function of the maximum junction temperature T_J(MAX), the junction-to-ambient thermal resistance θ_{JA}, and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P_D(MAX)=(T_J(MAX)-T_A)/ θ_{JA}. Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
- 4) The device is not guaranteed to function outside of its operating conditions.
- 5) Measured on JESD51-7 4-layer board.

ELECTRICAL CHARACTERISTICS ⁽⁶⁾

$V_{IN} = 19V$, $T_A = +25^{\circ}C$, CELLS=0V, unless otherwise noted.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Terminal Battery Voltage	V_{BATT}	CELLS=0V	8.337	8.4	8.463	V
		CELLS= VREF33	12.505	12.6	12.695	
CSP, BATT Current	I_{CSP}, I_{BATT}	Charging disabled		1		μA
Switch On Resistance	$R_{DS(ON)}$			0.2		Ω
Switch Leakage		$\overline{EN} = 4V$, $V_{SW} = 0V$		0	10	μA
Peak Current Limit	$CC^{(6)}$			4.1		A
	Trickle			2		A
CC current	I_{CC}	RS1=100m Ω	1.8	2.0	2.2	A
Trickle charge current	$I_{TRICKLE}$			10%		I_{CC}
Trickle charge voltage threshold				2.8		V/cell
Trickle charge hysteresis				350		mV
Termination current threshold	I_{BF}		5%	10%	15%	I_{CC}
Oscillator Frequency	f_{SW}	CELLS=0V, $V_{BATT} = 4.5V$		600		kHz
Fold-back Frequency		$V_{BATT} = 0V$		190		kHz
Maximum Duty Cycle			90			%
Maximum current Sense Voltage (CSP to BATT)	V_{SENSE}		170	200	230	mV
Minimum On Time ⁽⁶⁾	t_{ON}	CELLS=0V, $V_{BATT} = 5V$		100		ns
Under Voltage Lockout Threshold Rising			3	3.2	3.4	V
Under Voltage Lockout Threshold Hysteresis				200		mV
Open-drain sink current		$V_{DRAIN} = 0.3V$	5			mA
Dead-battery indication		Stay at trickle mode $C_{TMR} = 0.1\mu F$		30		min
Termination delay		Time after I_{BF} reached, $C_{TMR} = 0.1\mu F$		1		min
Recharge threshold at V_{BATT}	V_{RECHG}			4.0		V/cell
Recharge Hysteresis				100		mV
NTC Low Temp Rising Threshold		$R_{NTC} = NCP18XH103(0^{\circ}C)$		73		%VREF33
NTC High Temp Falling Threshold		$R_{NTC} = NCP18XH103(50^{\circ}C)$		30		%VREF33
VIN min head-room (reverse blocking)		VIN-VBATT		180		mV
$\overline{EN}$ Input Low Voltage					0.4	V
$\overline{EN}$ Input High Voltage			1.8			V
$\overline{EN}$ Input Current		$\overline{EN} = 4V$		4		μA
		$\overline{EN} = 0V$		0.2		

ELECTRICAL CHARACTERISTICS *(continued)*
 $V_{IN} = 19V$, $T_A = +25^{\circ}C$, CELLS=0V, unless otherwise noted.

Parameters	Symbol	Condition	Min	Typ	Max	Units
Supply Current (Shutdown)		$\overline{EN}=4V$		0.16		mA
		$\overline{EN}=4V$, Consider VREF33 pin output current, $R_3=10k, R_{NTC}=10k$		0.32		mA
Supply Current (Quiescent)		$\overline{EN}=0V$, CELLS=0V			2.0	mA
Thermal Shutdown ⁽⁶⁾				150		$^{\circ}C$
VREF25 output voltage				2.5		V
VREF33 output voltage				3.3		V
VREF33 load regulation		$I_{LOAD} = 0$ to 10mA		30		mV

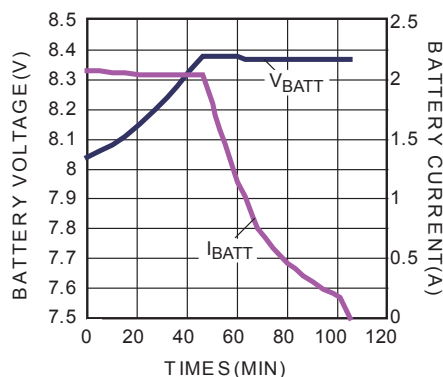
Notes:

6) Guaranteed by design.

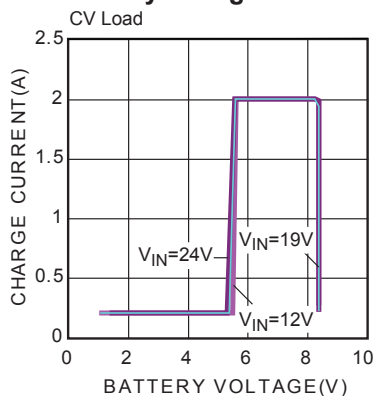
TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN}=19V$, $C1=4.7\mu F$, $C2=22\mu F$, $L=4.7\mu H$, $RS1=100m\Omega$, Real Battery Load, $T_A=25^\circ C$, unless otherwise noted.

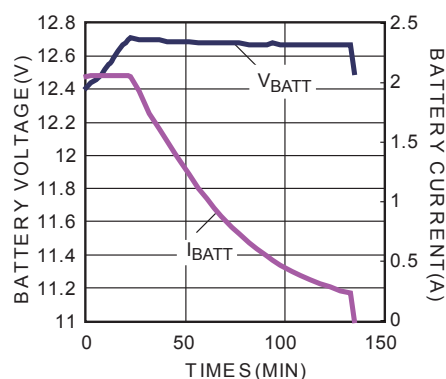
2 Cells Battery Charge Curve



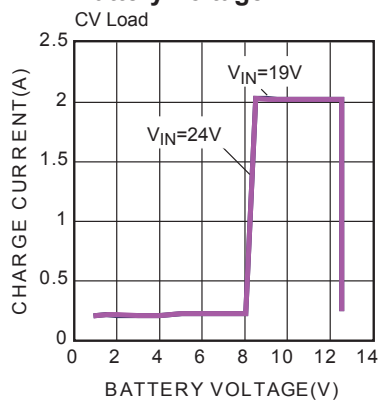
2 Cells Charge Current vs. Battery Voltage



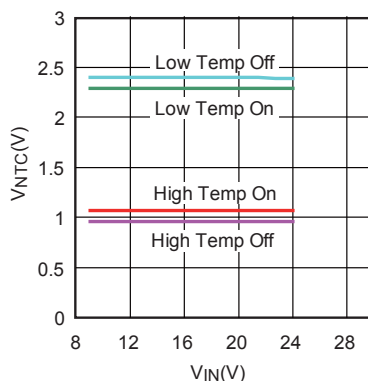
3 Cells Battery Charge Curve



3 Cells Charge Current vs. Battery Voltage

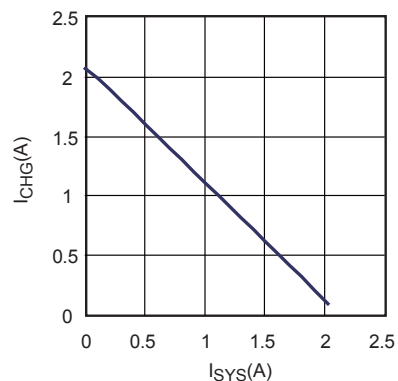


NTC Control Window



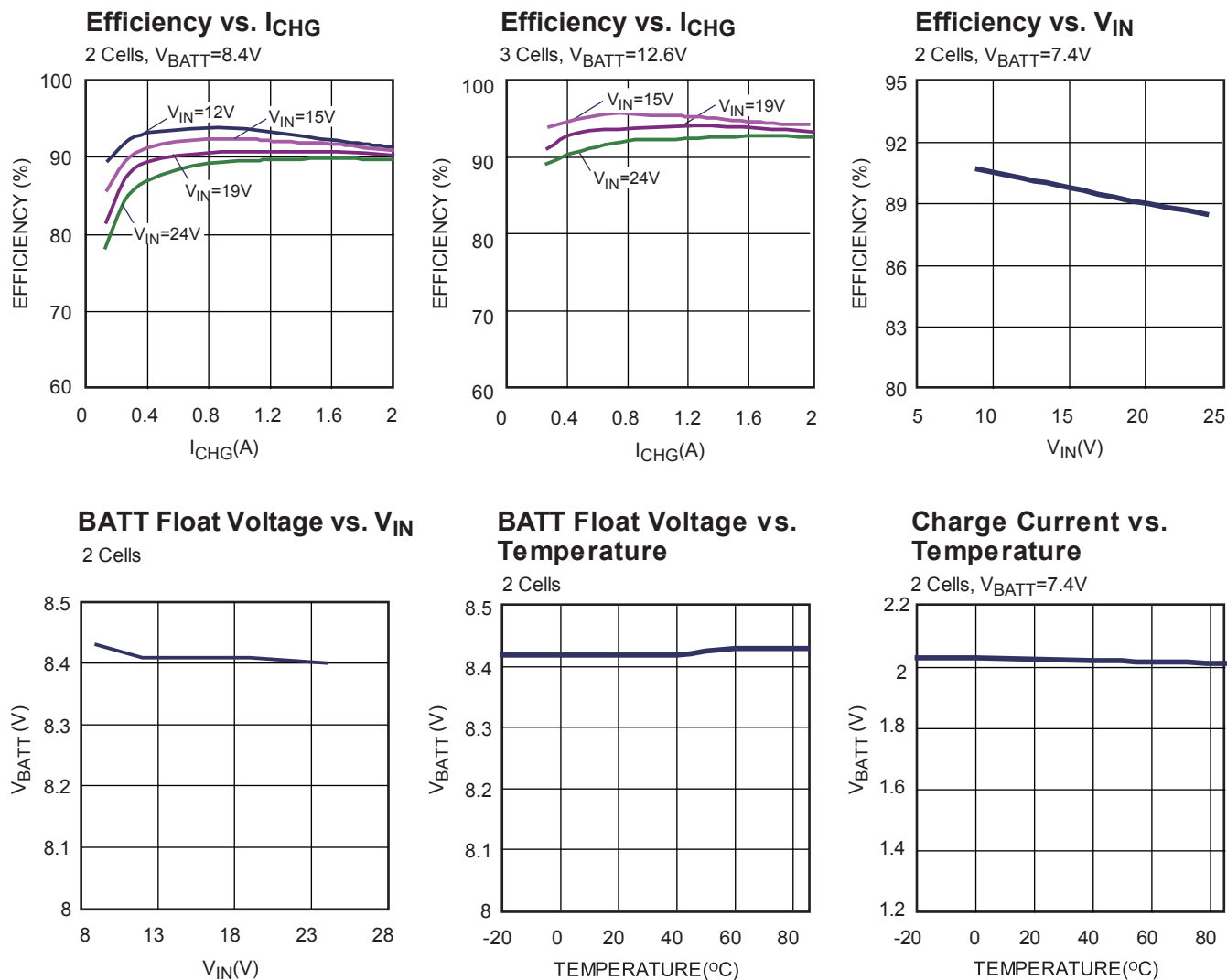
Current Sharing

Power Path Management,
 $RS1=110m\Omega$, $RS2=20m\Omega$



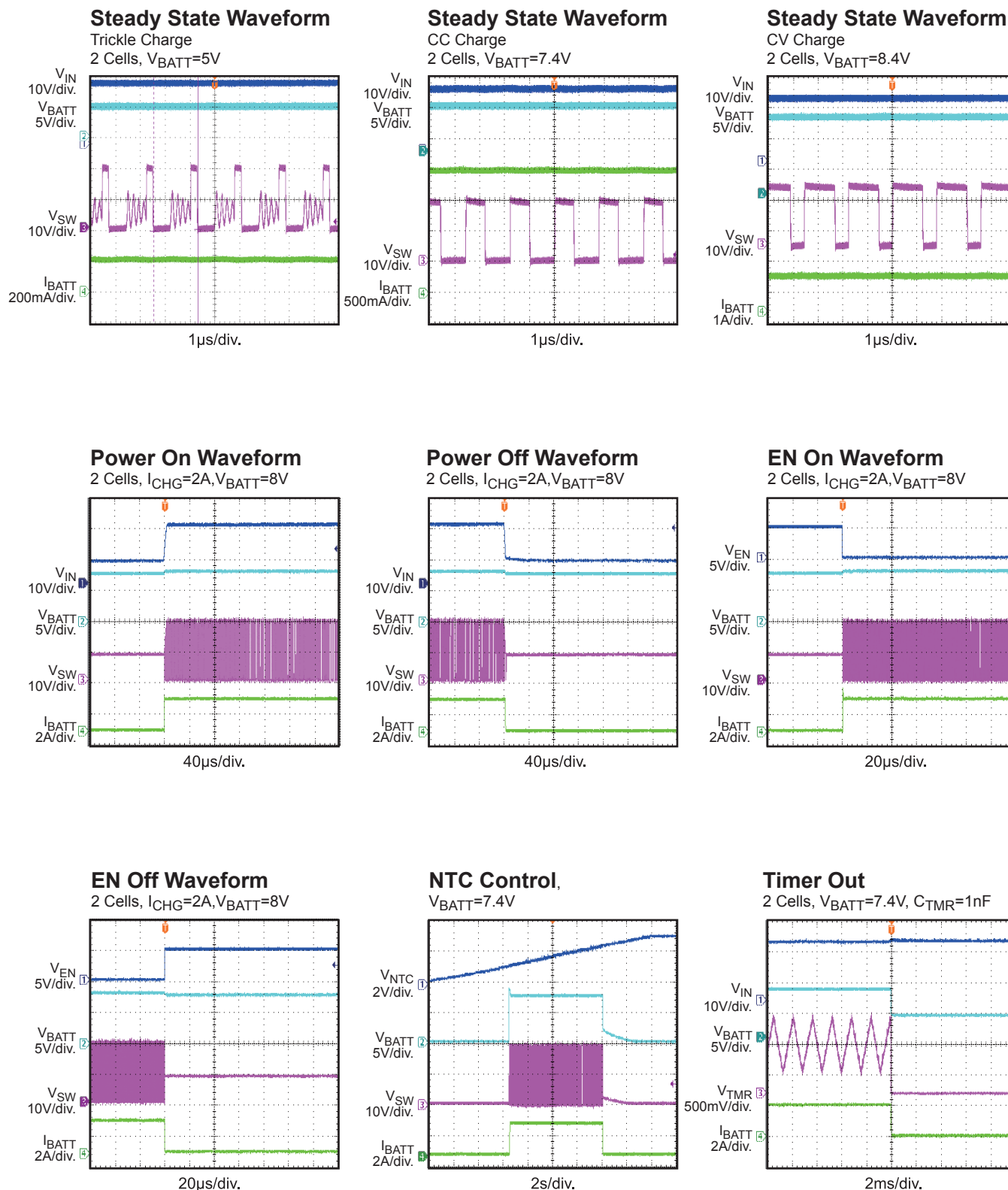
TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

$V_{IN}=19V$, $C1=4.7\mu F$, $C2=22\mu F$, $L=4.7\mu H$, $RS1=100m\Omega$, Real Battery Load, $T_A=25^\circ C$, unless otherwise noted.



TYPICAL PERFORMANCE CHARACTERISTICS (continued)

$V_{IN}=19V$, $C1=4.7\mu F$, $C2=22\mu F$, $L=4.7\mu H$, $RS1=100m\Omega$, Real Battery Load, $T_A=25^\circ C$, unless otherwise noted.

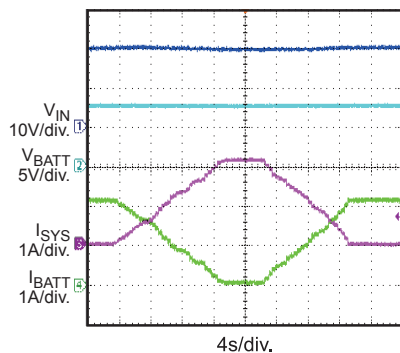


TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

$V_{IN}=19V$, $C1=4.7\mu F$, $C2=22\mu F$, $L=4.7\mu H$, $RS1=110m\Omega$, $RS2=20m\Omega$, Real Battery Load, $T_A=25^\circ C$, unless otherwise noted.

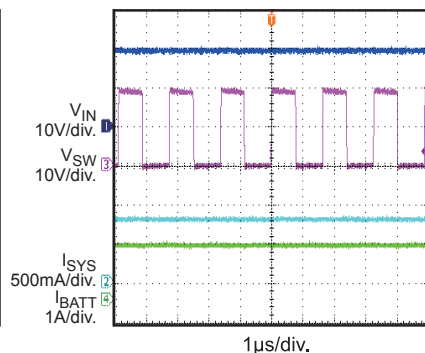
Power Path Management Current Sharing

2 Cells, $I_{CHG}=2A$, $V_{BATT}=7.4V$



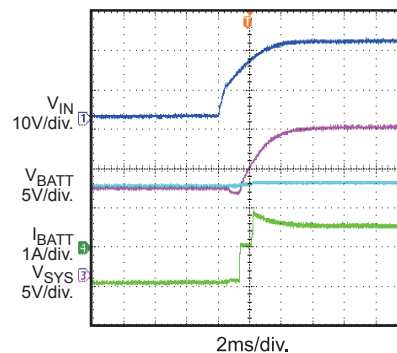
Power Path Management Steady State

2 Cells, $I_{CHG}=2A$, $V_{BATT}=8V$, $I_{SYS}=0.8A$



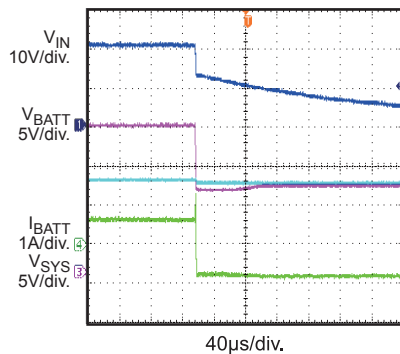
Power Path Management Power On

3 Cells, $I_{CHG}=2A$, $V_{BATT}=12V$, 10Ω SYS Load



Power Path Management Power Off

3 Cells, $I_{CHG}=2A$, $V_{BATT}=12V$, 10Ω SYS Load



PIN FUNCTIONS

Pin #	Name	Description
1	NTC	Thermistor Input. Connect a resistor from this pin to the pin VREF33 and the Thermistor from this pin to ground.
2	$\overline{\text{ACOK}}$	Valid Input Supply Indicator. A logic LOW on this pin indicates the presence of a valid input supply.
3	$\overline{\text{CHGOK}}$	Charging Completion Indicator. A logic LOW indicates charging operation. The pin will become an open drain once the charging is complete.
4	VREF33	Internal linear regulator 3.3V reference output. Bypass to GND with a 1 μ F ceramic capacitor.
5	VREF25	Internal linear 2.5V reference circuit. PLEASE KEEP THIS PIN FLOATING.
6	$\overline{\text{EN}}$	On/Off Control Input.
7	CELLS	Command Input for the number of Li-Ion Cells. Connect this pin to VREF33 for 3-cell operation or ground the pin for 2-cell operation. DO NOT LEAVE THIS PIN FLOAT.
8	COMPV	V-LOOP Compensation. Decouple this pin with a capacitor and a resistor.
9	COMPI	I-LOOP Compensation. Decouple this pin with a capacitor and a resistor.
10	BATT	Positive Battery Terminal.
11	CSP	Battery Current Sense Positive Input. Connect a resistor R_{SEN} between CSP and BATT. The full charge current is: $I_{\text{CHG}}(\text{A}) = \frac{200\text{mV}}{R_{\text{SEN}}(\text{m}\Omega)}$.
12	GND	Ground. This pin is the voltage reference for the regulated output voltage. For this reason care must be taken in its layout. This node should be placed outside of the switching diode (D2) to the input ground path to prevent switching current spikes from inducing voltage noise into the part.
13	TMR	Set time constant. 0.1uA current charges and discharges the external cap.
14	BST	Bootstrap. This capacitor is needed to drive the power switch's gate above the supply voltage. It is connected between SW and BS pins to form a floating supply across the power switch driver.
15	SW	Switch Output.
16	IN	Supply Voltage. The MP2612 operates from a 9V to 24V unregulated input to charge 2~3 cell li-ion battery. Capacitor is needed to prevent large voltage spikes from appearing at the input.

BLOCK DIAGRAM

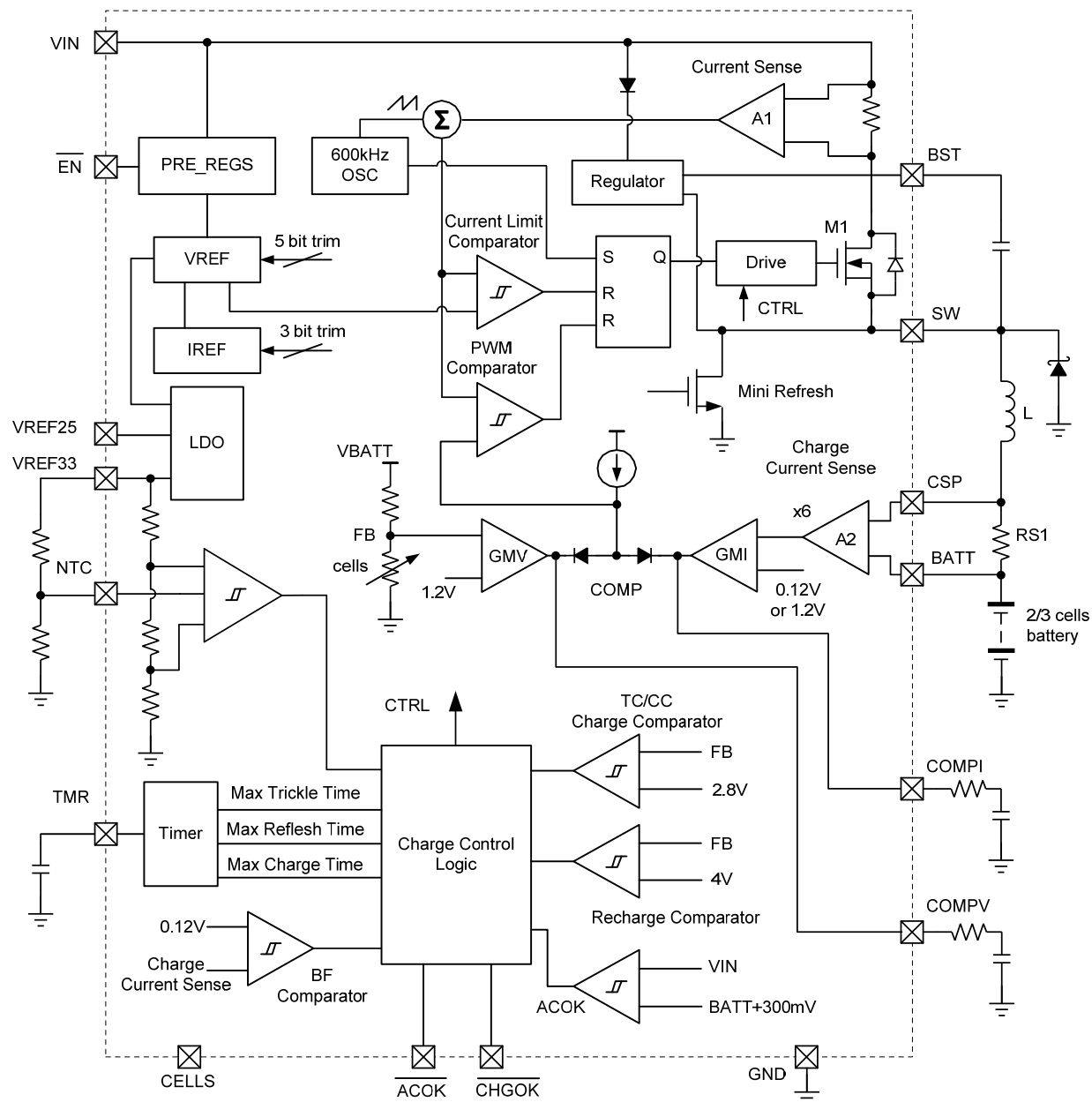


Figure 3—Function Block Diagram

OPERATION

The MP2612 is a peak current mode controlled switching charger for use with Li-Ion batteries.

Figure 3 shows the block diagram. At the beginning of a cycle, M1 is off. The COMP voltage is higher than the current sense result from amplifier A1's output and the PWM comparator's output is low. The rising edge of the 600 kHz CLK signal sets the RS Flip-Flop. Its output turns on M1 thus connecting the SW pin and inductor to the input supply.

The increasing inductor current is sensed and amplified by the Current Sense Amplifier A1. Ramp compensation is summed to the output of A1 and compared to COMP by the PWM comparator.

When the sum of A1's output and the Slope Compensation signal exceeds the COMP voltage, the RS Flip-Flop is reset and M1 is turned off. The external switching diode D2 then conducts the inductor current.

If the sum of A1's output and the Slope Compensation signal does not exceed the COMP voltage, then the falling edge of the CLK resets the Flip-Flop.

The MP2612 have two internal linear regulators power internal circuit, VREF33 and VREF25. The output of 3.3V reference voltage can also power external circuitry as long as the maximum current (50mA) is not exceeded. A 1μF bypass capacitor is required from VREF33 to GND to ensure stability. The output of 2.5V reference voltage can not carry any load.

In typical application, VREF25 should be float and no capacitor is required. It can only connect to a capacitor which is smaller than 100pF.

Charge Cycle (Mode change: Trickle→ CC→ CV)

The battery current is sensed via RS1 (Figure 3) and amplified by A2. The charge will start in "trickle charging mode" (10% of the R_{SEN} programmed current I_{CC}) until the battery voltage reaches 2.8V/cell. If the charge stays in the "trickle charging mode" till "timer out" condition is triggered, the charge is terminated. Otherwise, the output of A2 is then regulated to the level set by RS1. The charger is operating at "constant

current charging mode." The duty cycle of the switcher is determined by the COMPI voltage that is regulated by the amplifier GMI.

When the battery voltage reaches the "constant voltage mode" threshold, the amplifier GMV will regulate the COMP pin, and then the duty cycle. The charger will then operate in "constant voltage mode."

Automatic Recharge

A programmable time delay after the battery charging current drops below the termination threshold, the charger will cease charging and the CHGOK pin becomes an open drain. If for some reason, the battery voltage is lowered to 4.0V/Cell, recharge will automatically kick in.

$$\text{Termination Delay} = 1\text{min} \times \frac{C_{TMR}}{0.1\mu\text{F}}$$

Charger Status Indication

MP2612 has two open-drain status outputs: CHGOK and ACOK. The ACOK pin pulls low when an input voltage is greater than battery voltage 300mV and over the under voltage lockout threshold. CHGOK is used to indicate the status of the charge cycle. Table 1 describes the status of the charge cycle based on the CHGOK and ACOK outputs.

Table 1—Charging Status Indication

ACOK	CHGOK	Charger status
low	low	In charging
low	high	End of charge, Vin<UVLO, timer out,
high	high	thermal shutdown $\overline{\text{EN}}$ disable

Timer Operation

MP2612 uses internal timer to terminate the charge if the timer times out. The timer duration is programmed by an external capacitor at the TMR pin.

The trickle mode charge time is:

$$T_{\text{TICKLE_TMR}} = 30\text{mins} \times \frac{C_{\text{TMR}}}{0.1\mu\text{F}}$$

The total charge time is:

$$T_{\text{TOTAL_TMR}} = 3\text{hours} \times \frac{C_{\text{TMR}}}{0.1\mu\text{F}}$$

Negative Thermal Coefficient (NTC) Thermistor

The MP2612 has a built-in NTC resistance window comparator, which allows MP2612 to sense the battery temperature via the thermistor packed internally in the battery pack to ensure a safe operating environment of the battery. A resistor with appropriate value should be connected from VREF33 to NTC pin and the thermistor is connected from NTC pin to GND. The voltage on NTC pin is determined by the resistor divider whose divide ratio depends on the battery temperature. When the voltage of pin NTC falls out of NTC window range, MP2612 will stop the charging. The charger will restart if the temperature goes back into NTC window range.

Power Path Management

Using MP8110 together with MP2612 can implement a switching charger circuit with power path management function, which realizes the current sharing of the charger and system load (Figure 2). In another word, MP8110 senses the system current and feeds back to MP2612 and MP2612 reduces charge current according to the increase of the system current.

However, after the charge current decrease to 0, the system current can only be limited by the adapter.

The system current is satisfied first and always. It chooses the adapter as its power source when the adapter plugs in, and the battery is the backup power source when the adapter is removed.

Figure 4 to 8 shows the charge profile, operation waveform and flow chart, respectively.

CHARGE PROFILE AND POWER PATH MANAGEMENT FUNCTION

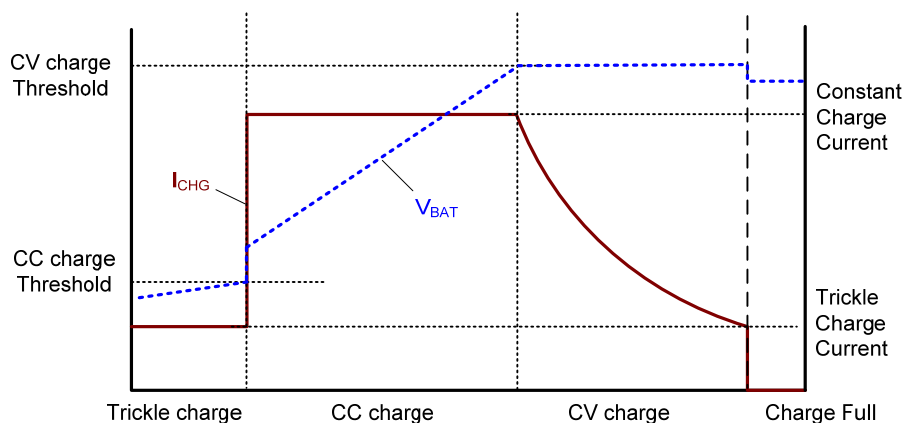


Figure 4—Li-Ion Battery Charge Profile

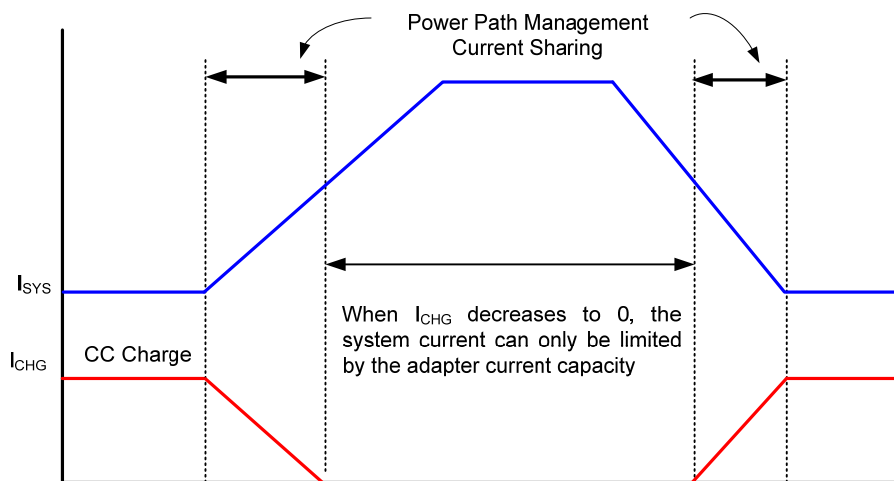


Figure 5 — Power Path Management Function- Current Sharing

OPERATION FLOW CHART

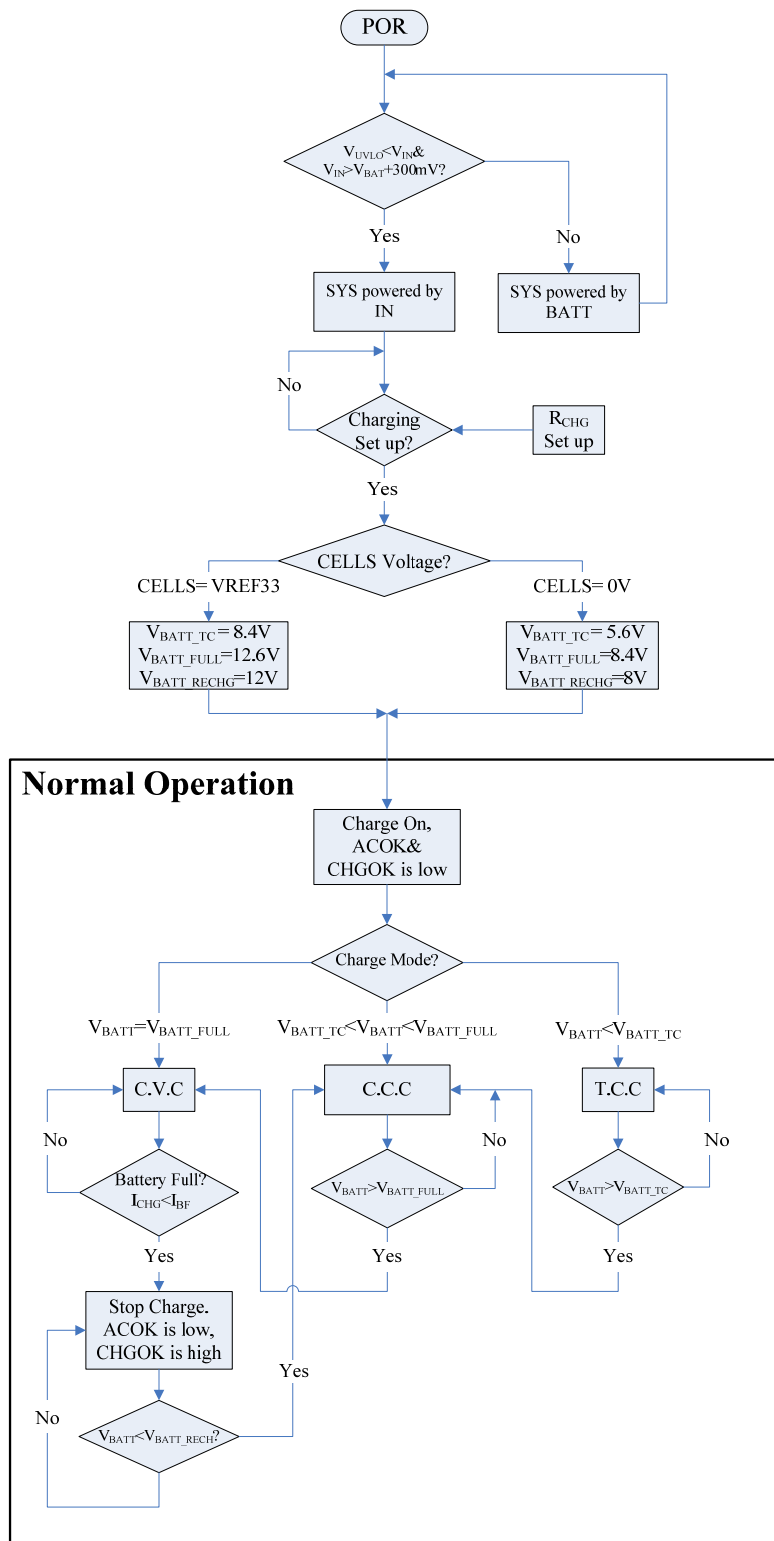


Figure 6— Normal Charging Operation Flow Chart

OPERATION FLOW CHART (continued)

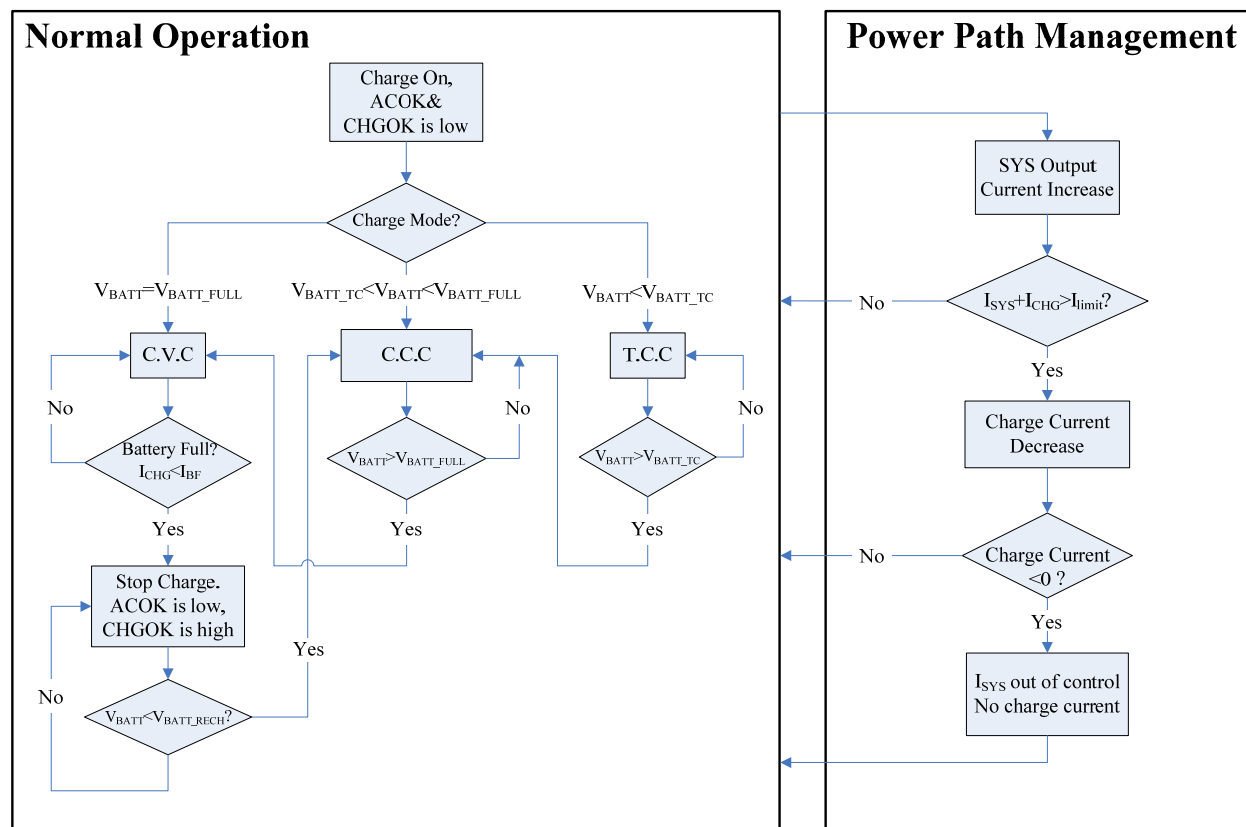


Figure 7— Power Path Management Operation Flow Chart

OPERATION FLOW CHART (continued)

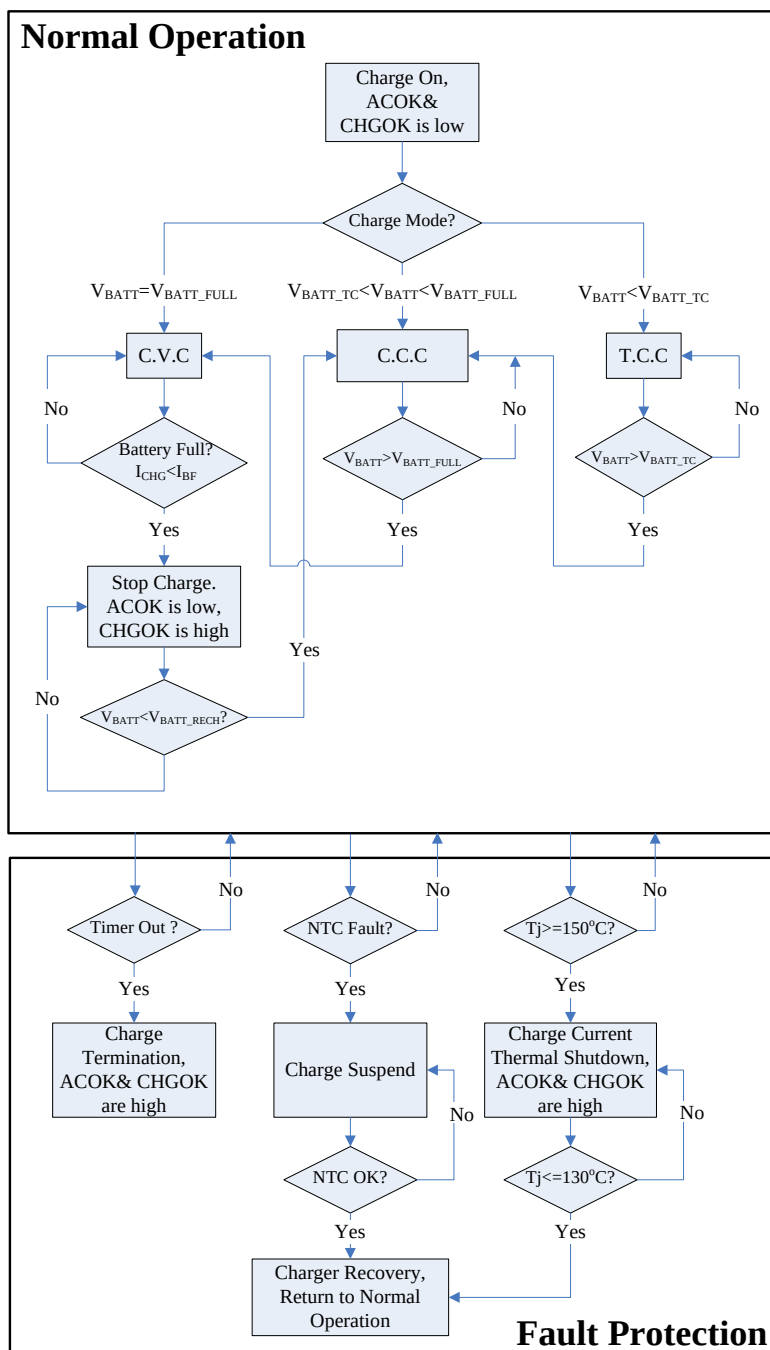


Figure 8— Fault Protection Flow Chart

Also, any relationship between ΔI_{SYS} and ΔI_{BATT} can be realized by re-calculate equation (4),(5) and (8).

Selecting the Inductor

A 1 μ H to 10 μ H inductor is recommended for most applications. The inductance value can be derived from the following equation.

$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times \Delta I_L \times f_{OSC}} \quad (10)$$

Where ΔI_L is the inductor ripple current. V_{OUT} is the 2/3 cell battery voltage.

Choose inductor current to be approximately 30% if the maximum charge current, 2A. The maximum inductor peak current is:

$$I_{L(MAX)} = I_{CHG} + \frac{\Delta I_L}{2} \quad (11)$$

Under light load conditions below 100mA, larger inductance is recommended for improved efficiency.

For optimized efficiency, the inductor DC resistance is recommended to be less than 200m Ω .

NTC Function

As Figure 9 shows, the low temperature threshold and high temperature threshold are preset internally via a resistive divider, which are 73%·VREF33 and 30%·VREF33. For a given NTC thermistor, we can select appropriate R3 and R6 to set the NTC window.

In detail, for the thermistor (NCP18XH103) noted in above electrical characteristic,

At 0°C, $R_{NTC_Cold} = 27.445k$;

At 50°C, $R_{NTC_Hot} = 4.1601k$.

Assume that the NTC window is between 0°C and 50°C, the following equations could be derived:

$$\frac{R6//R_{NTC_Cold}}{R3 + R6//R_{NTC_Cold}} = \frac{V_{TH_Low}}{VREF33} = 73\% \quad (12)$$

$$\frac{R6//R_{NTC_Hot}}{R3 + R6//R_{NTC_Hot}} = \frac{V_{TH_High}}{VREF33} = 30\% \quad (13)$$

According to equation (12) and equation (13), we can find that R3 = 9.63k and R6 = 505k.

To be simple in project, making R3=10k and R6 no connect will approximately meet the specification.

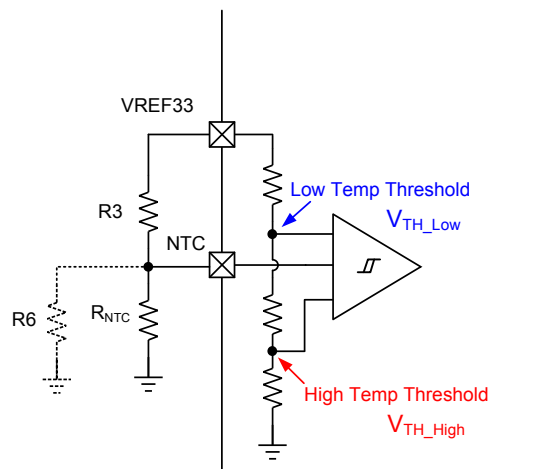


Figure 9— NTC function block

Selecting the Input Capacitor

The input capacitor reduces the surge current drawn from the input and also the switching noise from the device. The input capacitor impedance at the switching frequency should be less than the input source impedance to prevent high frequency switching current passing to the input. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. For most applications, a 4.7 μ F capacitor is sufficient.

Selecting the Output Capacitor

The output capacitor keeps output voltage ripple small and ensures regulation loop stability. The output capacitor impedance should be low at the switching frequency. Ceramic capacitors with X5R or X7R dielectrics are recommended.

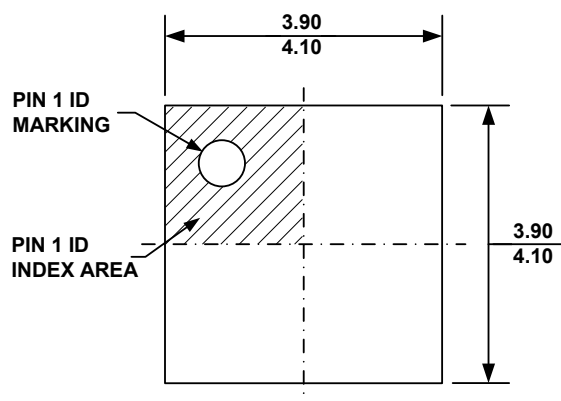
PC Board Layout

The high frequency and high current paths (GND, IN and SW) should be placed to the device with short, direct and wide traces. The input capacitor needs to be as close as possible to the IN and GND pins. The external feedback resistors should be placed next to the FB pin. Keep the switching node SW short and away from the feedback network.

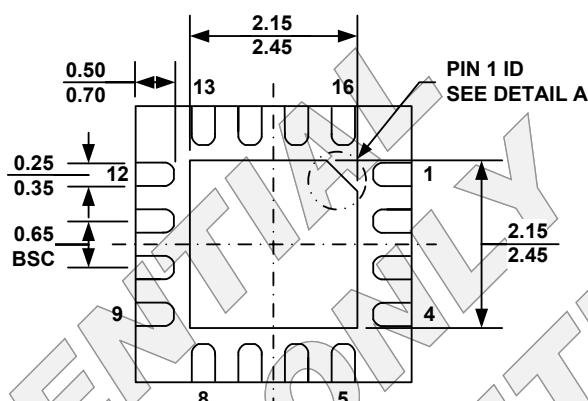


PACKAGE INFORMATION

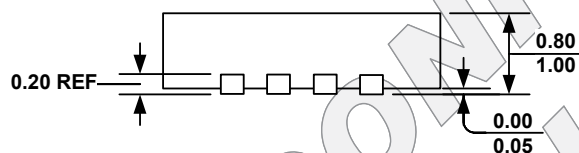
QFN16 (4mm x 4mm)



TOP VIEW



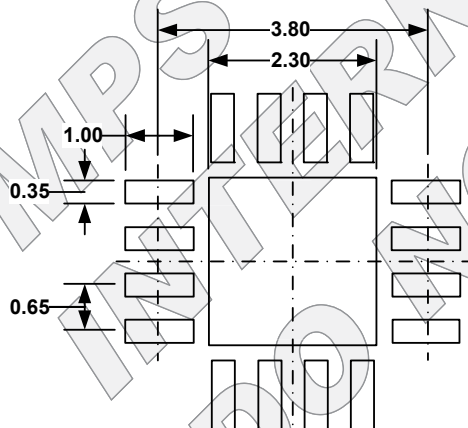
BOTTOM VIEW



SIDE VIEW

PIN 1 ID OPTION A
0.45x45° TYP.PIN 1 ID OPTION B
R0.25 TYP.

DETAIL A



RECOMMENDED LAND PATTERN

NOTE:

- 1) ALL DIMENSIONS ARE IN MILLIMETERS.
- 2) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH.
- 3) LEAD COPLANARITY SHALL BE 0.10 MILLIMETER MAX.
- 4) JEDEC REFERENCE IS MO-220, VARIATION VGGC.
- 5) DRAWING IS NOT TO SCALE.

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DESCRIPTION

The MP4462 is a high frequency step-down switching regulator with an integrated internal high-side high voltage power MOSFET. It provides 3.5A output with current mode control for fast loop response and easy compensation.

The wide 4.5V to 36V input range accommodates a variety of step-down applications, including those in an automotive input environment. A 100 μ A operational quiescent current allows use in battery-powered applications.

High power conversion efficiency over a wide load range is achieved by scaling down the switching frequency at light load condition to reduce the switching and gate driving losses.

The frequency foldback helps prevent inductor current runaway during startup and thermal shutdown provides reliable, fault tolerant operation.

In some applications, such as AM radio and ADSL applications, in which the device is sensitive to frequency band, the MP4462 can avoid the related EMI problem by setting the frequency at 4MHz.

The MP4462 is available in small 3x3mm QFN10 and SOIC8E packages.

FEATURES

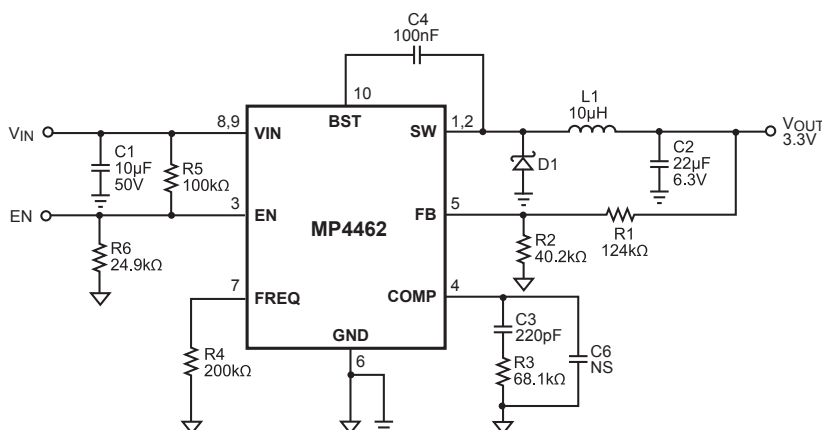
- 100 μ A Quiescent Current
- Wide 4.5V to 36V Operating Input Range
- 150m Ω Internal Power MOSFET
- Up to 4MHz Programmable Switching Frequency
- Ceramic Capacitor Stable
- Internal Soft-Start
- Internally Set Current Limit without a Current Sensing Resistor
- Output Adjustable from 0.8V to 30V
- Available in 3x3mm QFN10 and SOIC8E Packages.

APPLICATIONS

- High Voltage Power Conversion
- Automotive Systems
- Industrial Power Systems
- Distributed Power Systems
- Battery Powered Systems

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TYPICAL APPLICATION



ORDERING INFORMATION

Part Number	Package	Top Marking	Free Air Temperature (T _A)
MP4462DQ*	3x3mm QFN10	Z2	–40°C to +85°C
MP4462DN**	SOIC8E	MP4462DN	–40°C to +85°C

* For Tape & Reel, add suffix –Z (e.g. MP4462DQ–Z);

For RoHS, compliant packaging, add suffix –LF (e.g. MP MP4462DQ–LF–Z).

** For Tape & Reel, add suffix –Z (e.g. MP4462DN–Z);

For RoHS, compliant packaging, add suffix –LF (e.g. MP MP4462DN–LF–Z).

PACKAGE REFERENCE

TOP VIEW SW 1, SW 2, EN 3, COMP 4, FB 5, BST 10, VIN 9, VIN 8, FREQ 7, GND 6. EXPOSED PAD ON BACKSIDE QFN10	TOP VIEW SW 1, EN 2, COMP 3, FB 4, BST 8, VIN 7, FREQ 6, GND 5. SOIC8E
---	---

ABSOLUTE MAXIMUM RATINGS ⁽¹⁾

Supply Voltage (V _{IN})	–0.3V to +40V
Switch Voltage (V _{SW})	–0.3V to V _{IN} + 0.3V
BST to SW	–0.3V to +6V
All Other Pins	–0.3V to +6V
Continuous Power Dissipation (T _A = +25°C) ⁽²⁾	
3x3mm QFN10	2.5W
SOIC8E	2.5W
Junction Temperature	150°C
Lead Temperature	260°C
Storage Temperature	–65°C to +150°C

Recommended Operating Conditions ⁽³⁾

Supply Voltage V _{IN}	4.5V to 36V
Output Voltage V _{OUT}	0.8V to 30V
Operating Junct. Temp.	–40°C to +125°C

Thermal Resistance ⁽⁴⁾

	θ_{JA}	θ_{JC}
3x3mm QFN10	50	12... °C/W
SOIC8E	50	10... °C/W

Notes:

- Exceeding these ratings may damage the device.
- The maximum allowable power dissipation is a function of the maximum junction temperature T_J (MAX), the junction-to-ambient thermal resistance θ_{JA} , and the ambient temperature T_A. The maximum allowable continuous power dissipation at any ambient temperature is calculated by P_D (MAX) = (T_J (MAX) – T_A) / θ_{JA} . Exceeding the maximum allowable power dissipation will cause excessive die temperature, and the regulator will go into thermal shutdown. Internal thermal shutdown circuitry protects the device from permanent damage.
- The device is not guaranteed to function outside of its operating conditions.
- Measured on JESD51-7, 4-layer PCB.

ELECTRICAL CHARACTERISTICS **$V_{IN} = 12V$, $V_{EN} = 2.5V$, $V_{COMP} = 1.4V$, $T_A = +25^\circ C$, unless otherwise noted.**

Parameter	Symbol	Condition	Min	Typ	Max	Units
Feedback Voltage	V_{FB}	$4.5V < V_{IN} < 36V$	0.776	0.8	0.824	V
Upper Switch On Resistance	$R_{DS(ON)}$	$V_{BST} - V_{SW} = 5V$		150		m Ω
Upper Switch Leakage		$V_{EN} = 0V$, $V_{SW} = 0V$, $V_{IN} = 36V$		1		μA
Current Limit			4.0	4.7		A
COMP to Current Sense Transconductance	G_{CS}			9		A/V
Error Amp Voltage Gain ⁽⁵⁾				200		V/V
Error Amp Transconductance		$I_{COMP} = \pm 3\mu A$	40	60	80	$\mu A/V$
Error Amp Min Source current		$V_{FB} = 0.7V$		5		μA
Error Amp Min Sink current		$V_{FB} = 0.9V$		-5		μA
VIN UVLO Threshold			2.7	3.0	3.3	V
VIN UVLO Hysteresis				0.35		V
Soft-Start Time ⁽⁵⁾		$0V < V_{FB} < 0.8V$		1.5		ms
Oscillator Frequency		$R_{FREQ} = 45k\Omega$	1.6	2	2.4	MHz
		$R_{FREQ} = 18k\Omega$	3.2	4	4.8	MHz
Shutdown Supply Current		$V_{EN} = 0V$		12	20	μA
Quiescent Supply Current		No load, $V_{FB} = 0.9V$		100	125	μA
Thermal Shutdown				150		$^\circ C$
Thermal Shutdown Hysteresis				15		$^\circ C$
Minimum Off Time ⁽⁵⁾				100		ns
Minimum On Time ⁽⁵⁾				100		ns
EN Up Threshold			1.35	1.5	1.65	V
EN Hysteresis				300		mV

Note:

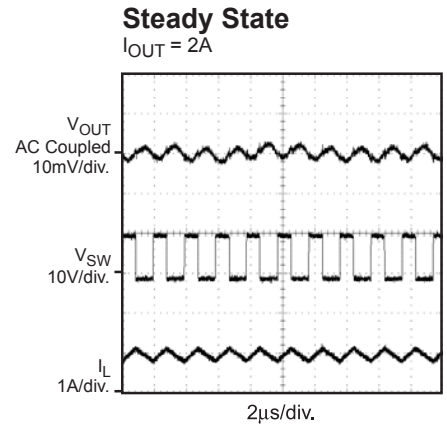
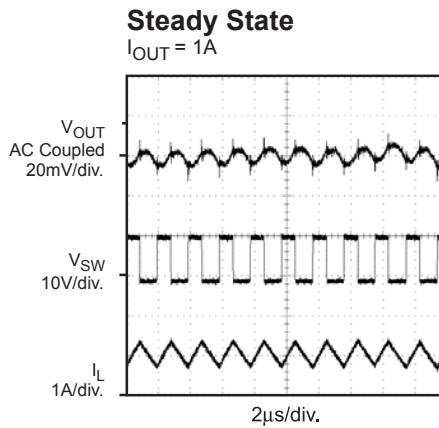
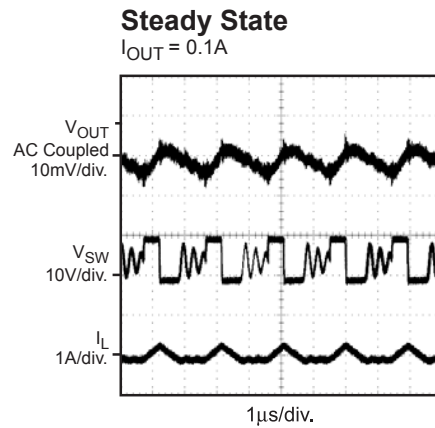
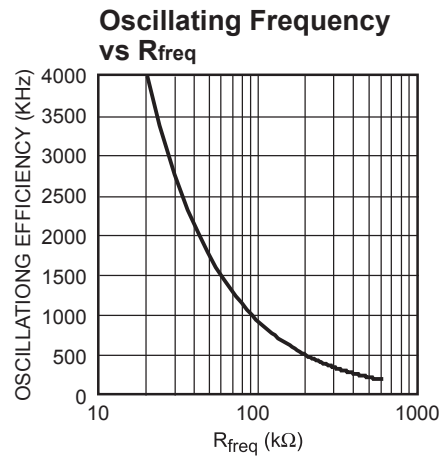
5) Guaranteed by design.

PIN FUNCTIONS

SOIC Pin #	QFN Pin #	Name	Description
1	1, 2	SW	Switch Node. This is the output from the high-side switch. A low forward drop Schottky diode to ground is required. The diode must be close to the SW pins to reduce switching spikes.
2	3	EN	Enable Input. Pulling this pin below the specified threshold shuts the chip down. Pulling it up above the specified threshold or leaving it floating enables the chip.
3	4	COMP	Compensation. This node is the output of the error amplifier. Control loop frequency compensation is applied to this pin.
4	5	FB	Feedback. This is the input to the error amplifier. The output voltage is set by a resistive divider connected between the output and GND which scales down V_{OUT} equal to the internal +0.8V reference.
5	6	GND Exposed Pad	Ground. It should be connected as close as possible to the output capacitor to shorten the high current switch paths. Connect exposed pad to GND plane for optimal thermal performance.
6	7	FREQ	Switching Frequency Program Input. Connect a resistor from this pin to ground to set the switching frequency.
7	8, 9	VIN	Input Supply. This supplies power to all the internal control circuitry, both BS regulators and the high-side switch. A decoupling capacitor to ground must be placed close to this pin to minimize switching spikes.
8	10	BST	Bootstrap. This is the positive power supply for the internal floating high-side MOSFET driver. Connect a bypass capacitor between this pin and SW pin.

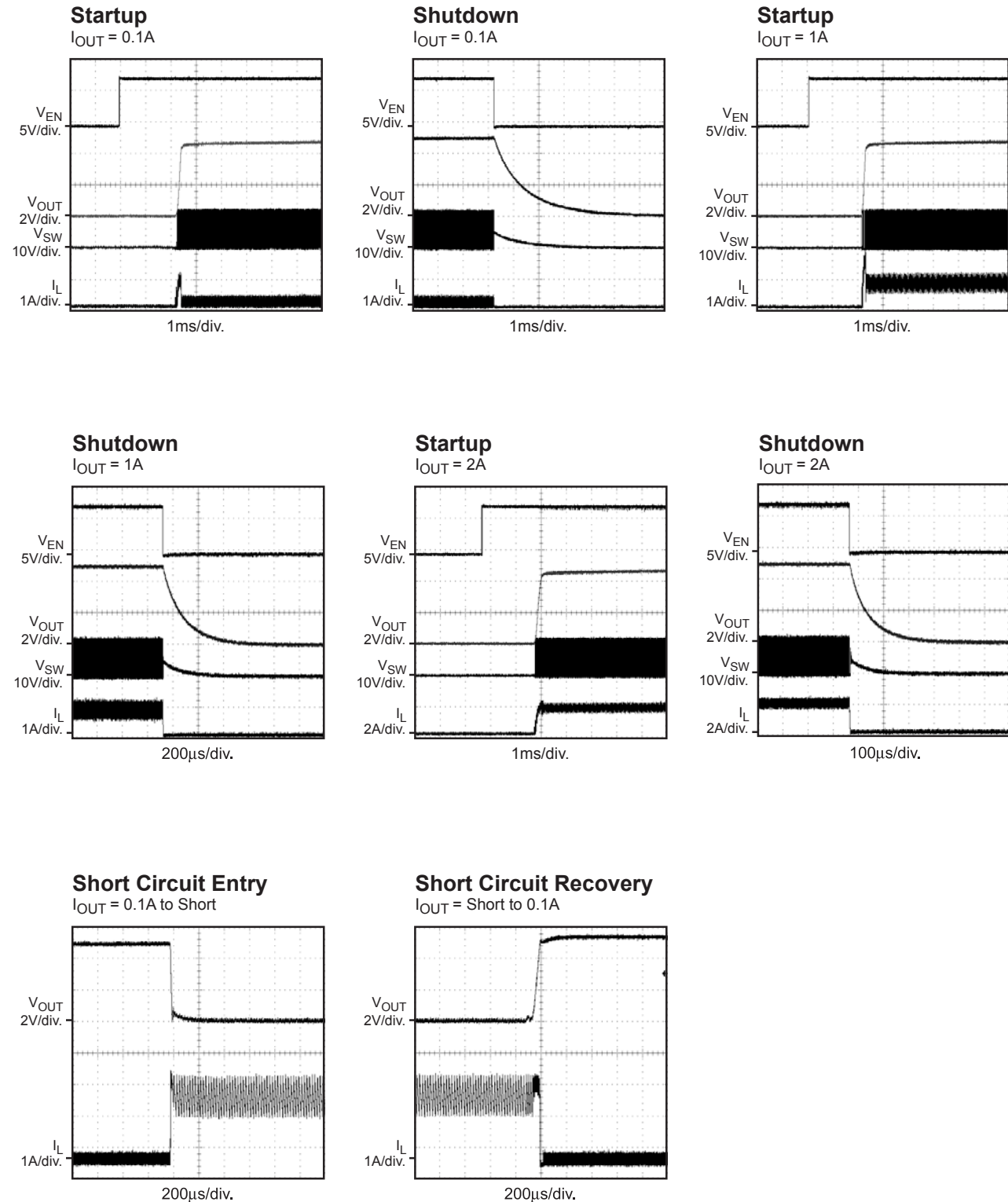
TYPICAL PERFORMANCE CHARACTERISTICS

$V_{IN} = 12V$, $C1 = 10\mu F$, $C2 = 22\mu F$, $L = 10\mu H$ and $T_A = +25^\circ C$, unless otherwise noted.



TYPICAL PERFORMANCE CHARACTERISTICS *(continued)*

$V_{IN} = 12V$, $C1 = 10\mu F$, $C2 = 22\mu F$, $L = 10\mu H$ and $T_A = +25^\circ C$, unless otherwise noted.



BLOCK DIAGRAM

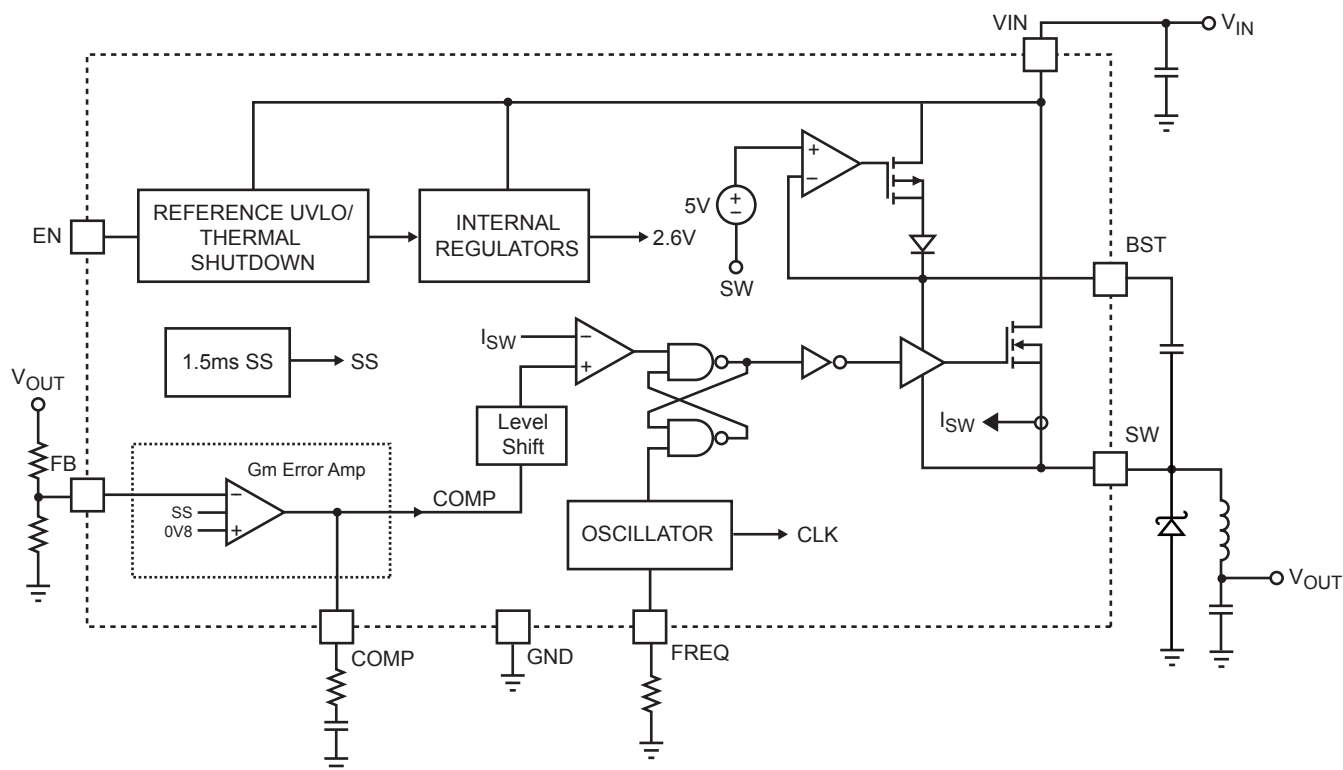


Figure 1—Functional Block Diagram

OPERATION

The MP4462 is a variable frequency, non-synchronous, step-down switching regulator with an integrated high-side high voltage power MOSFET. It provides a single highly efficient solution with current mode control for fast loop response and easy compensation. It features a wide input voltage range, internal soft-start control and precision current limiting. Its very low operational quiescent current makes it suitable for battery powered applications.

PWM Control

At moderate to high output current, the MP4462 operates in a fixed frequency, peak current control mode to regulate the output voltage. A PWM cycle is initiated by the internal clock. The power MOSFET is turned on and remains on until its current reaches the value set by the COMP voltage. When the power switch is off, it remains off for at least 100ns before the next cycle starts. If, in one PWM period, the current in the power MOSFET does not reach the COMP set current value, the power MOSFET remains on, saving a turn-off operation.

Error Amplifier

The error amplifier compares the FB pin voltage with the internal reference (REF) and outputs a current proportional to the difference between the two. This output current is then used to charge the external compensation network to form the COMP voltage, which is used to control the power MOSFET current.

During operation, the minimum COMP voltage is clamped to 0.9V and its maximum is clamped to 2.0V. COMP is internally pulled down to GND in shutdown mode. COMP should not be pulled up beyond 2.6V.

Internal Regulator

Most of the internal circuitries are powered from the 2.6V internal regulator. This regulator takes the VIN input and operates in the full VIN range. When VIN is greater than 3.0V, the output of the regulator is in full regulation. When VIN is lower than 3.0V, the output decreases.

Enable Control

The MP4462 has a dedicated enable control pin (EN). With high enough input voltage, the chip can be enabled and disabled by EN which has positive logic. Its falling threshold is a precision 1.2V, and its rising threshold is 1.5V (300mV higher).

When floating, EN is pulled up to about 3.0V by an internal 1 μ A current source so it is enabled. To pull it down, 1 μ A current capability is needed.

When EN is pulled down below 1.2V, the chip is put into the lowest shutdown current mode. When EN is higher than zero but lower than its rising threshold, the chip is still in shutdown mode but the shutdown current increases slightly.

Under-Voltage Lockout (UVLO)

Under-voltage lockout (UVLO) is implemented to protect the chip from operating at insufficient supply voltage. The UVLO rising threshold is about 3.0V while its falling threshold is a consistent 2.6V.

Internal Soft-Start

The soft-start is implemented to prevent the converter output voltage from overshooting during startup. When the chip starts, the internal circuitry generates a soft-start voltage (SS) ramping up from 0V to 2.6V. When it is lower than the internal reference (REF), SS overrides REF so the error amplifier uses SS as the reference. When SS is higher than REF, REF regains control.

Thermal Shutdown

Thermal shutdown is implemented to prevent the chip from operating at exceedingly high temperatures. When the silicon die temperature is higher than its upper threshold, it shuts down the whole chip. When the temperature is lower than its lower threshold, the chip is enabled again.

Floating Driver and Bootstrap Charging

The floating power MOSFET driver is powered by an external bootstrap capacitor. This floating driver has its own UVLO protection. This UVLO's rising threshold is 2.2V with a threshold of 150mV.

The bootstrap capacitor is charged and regulated to about 5V by the dedicated internal bootstrap regulator. When the voltage between the BST and SW nodes is lower than its regulation, a PMOS pass transistor connected from VIN to BST is turned on. The charging current path is from VIN, BST and then to SW. External circuit should provide enough voltage headroom to facilitate the charging.

As long as VIN is sufficiently higher than SW, the bootstrap capacitor can be charged. When the power MOSFET is ON, VIN is about equal to SW so the bootstrap capacitor cannot be charged. When the external diode is on, the difference between VIN and SW is largest, thus making it the best period to charge. When there is no current in the inductor, SW equals the output voltage V_{OUT} so the difference between V_{IN} and V_{OUT} can be used to charge the bootstrap capacitor.

At higher duty cycle operation condition, the time period available to the bootstrap charging is less so the bootstrap capacitor may not be sufficiently charged.

In case the internal circuit does not have sufficient voltage and the bootstrap capacitor is not charged, extra external circuitry can be used to ensure the bootstrap voltage is in the normal operational region. Refer to *External Bootstrap Diode* in Application section.

The DC quiescent current of the floating driver is about 20μA. Make sure the bleeding current at the SW node is higher than this value, such that:

$$I_O + \frac{V_O}{(R1+R2)} > 20\mu A$$

Current Comparator and Current Limit

The power MOSFET current is accurately sensed via a current sense MOSFET. It is then fed to the high speed current comparator for the current mode control purpose. The current comparator takes this sensed current as one of its inputs. When the power MOSFET is turned on, the comparator is first blanked till the end of the turn-on transition to avoid noise issues. The comparator then compares the power switch current with the COMP voltage. When the sensed current is higher than the COMP voltage, the comparator output is low, turning off the power MOSFET. The cycle-by-cycle maximum current of the internal power MOSFET is internally limited.

Startup and Shutdown

If both VIN and EN are higher than their appropriate thresholds, the chip starts. The reference block starts first, generating stable reference voltage and currents, and then the internal regulator is enabled. The regulator provides stable supply for the remaining circuitries.

While the internal supply rail is up, an internal timer holds the power MOSFET OFF for about 50μs to blank the startup glitches. When the internal soft-start block is enabled, it first holds its SS output low to ensure the remaining circuitries are ready and then slowly ramps up.

Three events can shut down the chip: EN low, VIN low and thermal shutdown. In the shutdown procedure, power MOSFET is turned off first to avoid any fault triggering. The COMP voltage and the internal supply rail are then pulled down.

Programmable Oscillator

The MP4462 oscillating frequency is set by an external resistor, R_{freq} from the FREQ pin to ground. The value of R_{freq} can be calculated from:

$$R_{freq} (K\Omega) = \frac{180000}{f_s (KHz)^{1.1}}$$

APPLICATION INFORMATION

COMPONENT SELECTION

Setting the Output Voltage

The output voltage is set using a resistive voltage divider from the output voltage to FB pin. The voltage divider divides the output voltage down to the feedback voltage by the ratio:

$$V_{FB} = V_{OUT} \frac{R2}{R1 + R2}$$

Thus the output voltage is:

$$V_{OUT} = V_{FB} \frac{(R1 + R2)}{R2}$$

About 20µA current from high side BS circuitry can be seen at the output when the MP4462 is at no load. In order to absorb this small amount of current, keep R2 under 40KΩ. A typical value for R2 can be 40.2kΩ. With this value, R1 can be determined by:

$$R1 = 50.25 \times (V_{OUT} - 0.8)(k\Omega)$$

For example, for a 3.3V output voltage, R2 is 40.2kΩ, and R1 is 127kΩ.

Inductor

The inductor is required to supply constant current to the output load while being driven by the switched input voltage. A larger value inductor will result in less ripple current that will result in lower output ripple voltage. However, the larger value inductor will have a larger physical size, higher series resistance, and/or lower saturation current.

A good rule for determining the inductance to use is to allow the peak-to-peak ripple current in the inductor to be approximately 30% of the maximum switch current limit. Also, make sure that the peak inductor current is below the maximum switch current limit. The inductance value can be calculated by:

$$L1 = \frac{V_{OUT}}{f_s \times \Delta I_L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Where V_{OUT} is the output voltage, V_{IN} is the input voltage, f_s is the switching frequency, and ΔI_L is the peak-to-peak inductor ripple current.

Choose an inductor that will not saturate under the maximum inductor peak current. The peak inductor current can be calculated by:

$$I_{LP} = I_{LOAD} + \frac{V_{OUT}}{2 \times f_s \times L1} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Where I_{LOAD} is the load current.

Table 1 lists a number of suitable inductors from various manufacturers. The choice of which style inductor to use mainly depends on the price vs. size requirements and any EMI requirement.

Table 1—Inductor Selection Guide

Part Number	Inductance (μ H)	Max DCR (Ω)	Current Rating (A)	Dimensions L x W x H (mm^3)
Würth Electronics				
7447789002	2.2	0.019	4	7.3x7.3x3.2
7447789003	3.3	0.024	3.42	7.3x7.3x3.2
7447789004	4.7	0.033	2.9	7.3x7.3x3.2
744066100	10	0.035	3.6	10x10x3.8
744771115	15	0.025	3.75	12x12x6
744771122	22	0.031	3.37	12x12x6
TDK				
RLF7030T-2R2	2.2	0.012	5.4	7.3x6.8x3.2
RLF7030T-3R3	3.3	0.02	4.1	7.3x6.8x3.2
RLF7030T-4R7	4.7	0.031	3.4	7.3x6.8x3.2
SLF10145T-100	10	0.0364	3	10.1x10.1x4.5
SLF12565T-150M4R2	15	0.0237	4.2	12.5x12.5x6.5
SLF12565T-220M3R5	22	0.0316	3.5	12.5x12.5x6.5
Toko				
FDV0630-2R2M	2.2	0.021	5.3	7.7x7x3
FDV0630-3R3M	3.3	0.031	4.3	7.7x7x3
FDV0630-4R7M	4.7	0.049	3.3	7.7x7x3
919AS-100M	10	0.0265	4.3	10.3x10.3x4.5
919AS-160M	16	0.0492	3.3	10.3x10.3x4.5
919AS-220M	22	0.0776	3	10.3x10.3x4.5

Output Rectifier Diode

The output rectifier diode supplies the current to the inductor when the high-side switch is off. To reduce losses due to the diode forward voltage and recovery times, use a Schottky diode.

Choose a diode whose maximum reverse voltage rating is greater than the maximum input voltage, and whose current rating is greater than the maximum load current. Table 2 lists example Schottky diodes and manufacturers.

Table 2—Diode Selection Guide

Diodes	Voltage/ Current Rating	Manufacturer
B340A-13-F	40V, 3A	Diodes Inc.
CMSH3-40MA	40V, 3A	Central Semi

Input Capacitor

The input current to the step-down converter is discontinuous, therefore a capacitor is required to supply the AC current to the step-down converter while maintaining the DC input voltage. Use low ESR capacitors for the best performance. Ceramic capacitors are preferred, but tantalum or low-ESR electrolytic capacitors may also suffice.

For simplification, choose the input capacitor with RMS current rating greater than half of the maximum load current.

The input capacitor (C1) can be electrolytic, tantalum or ceramic. When using electrolytic or tantalum capacitors, a small, high quality ceramic capacitor, i.e. 0.1μF, should be placed as close to the IC as possible. When using ceramic capacitors, make sure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at input. The input voltage ripple caused by capacitance can be estimated by:

$$\Delta V_{IN} = \frac{I_{LOAD}}{f_s \times C1} \times \frac{V_{OUT}}{V_{IN}} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

Output Capacitor

The output capacitor (C2) is required to maintain the DC output voltage. Ceramic, tantalum, or low ESR electrolytic capacitors are recommended. Low ESR capacitors are preferred to keep the output voltage ripple low. The output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_s \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times \left(R_{ESR} + \frac{1}{8 \times f_s \times C2}\right)$$

Where L is the inductor value and R_{ESR} is the equivalent series resistance (ESR) value of the output capacitor.

In the case of ceramic capacitors, the impedance at the switching frequency is dominated by the capacitance. The output voltage ripple is mainly caused by the capacitance. For simplification, the output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT}}{8 \times f_s^2 \times L \times C2} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right)$$

In the case of tantalum or electrolytic capacitors, the ESR dominates the impedance at the switching frequency. For simplification, the output ripple can be approximated to:

$$\Delta V_{OUT} = \frac{V_{OUT}}{f_s \times L} \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \times R_{ESR}$$

The characteristics of the output capacitor also affect the stability of the regulation system. The MP4462 can be optimized for a wide range of capacitance and ESR values.

Compensation Components

MP4462 employs current mode control for easy compensation and fast transient response. The system stability and transient response are controlled through the COMP pin. COMP pin is the output of the internal error amplifier. A series capacitor-resistor combination sets a pole-zero combination to control the characteristics of the control system. The DC gain of the voltage feedback loop is given by:

$$A_{VDC} = R_{LOAD} \times G_{CS} \times A_{VEA} \times \frac{V_{FB}}{V_{OUT}}$$

Where A_{VEA} is the error amplifier voltage gain, 200V/V; G_{CS} is the current sense transconductance, 3.7A/V; R_{LOAD} is the load resistor value.

The system has two poles of importance. One is due to the compensation capacitor (C3), the output resistor of error amplifier. The other is due to the output capacitor and the load resistor. These poles are located at:

$$f_{P1} = \frac{G_{EA}}{2\pi \times C3 \times A_{VEA}}$$

$$f_{P2} = \frac{1}{2\pi \times C2 \times R_{LOAD}}$$

Where, G_{EA} is the error amplifier transconductance, 60μA/V.

The system has one zero of importance, due to the compensation capacitor (C3) and the compensation resistor (R3). This zero is located at:

$$f_{Z1} = \frac{1}{2\pi \times C3 \times R3}$$

The system may have another zero of importance, if the output capacitor has a large capacitance and/or a high ESR value. The zero, due to the ESR and capacitance of the output capacitor, is located at:

$$f_{ESR} = \frac{1}{2\pi \times C2 \times R_{ESR}}$$

In this case (as shown in Figure 2), a third pole set by the compensation capacitor (C6) and the compensation resistor (R3) is used to compensate the effect of the ESR zero on the loop gain. This pole is located at:

$$f_{P3} = \frac{1}{2\pi \times C6 \times R3}$$

The goal of compensation design is to shape the converter transfer function to get a desired loop gain. The system crossover frequency where the feedback loop has the unity gain is important. Lower crossover frequencies result in slower line and load transient responses, while higher crossover frequencies could cause system unstable. A good rule of thumb is to set the crossover frequency to approximately one-tenth of the switching frequency. The Table 3 lists the typical values of compensation components for some standard output voltages with various output capacitors and inductors. The values of the compensation components have been optimized for fast transient responses and good stability at given conditions.

Table 3—Compensation Values for Typical Output Voltage/Capacitor Combinations

V _{OUT} (V)	L (μH)	C2 (μF)	R3 (kΩ)	C3 (pF)	C6
1.8	4.7	47	105	100	None
2.5	4.7 - 6.8	22	54.9	220	None
3.3	6.8 - 10	22	68.1	220	None
5	15 - 22	22	100	150	None
12	22 - 33	22	147	150	None

To optimize the compensation components for conditions not listed in Table 3, the following procedure can be used.

1. Choose the compensation resistor (R3) to set the desired crossover frequency. Determine the R3 value by the following equation:

$$R3 = \frac{2\pi \times C2 \times f_c}{G_{EA} \times G_{CS}} \times \frac{V_{OUT}}{V_{FB}}$$

Where f_c is the desired crossover frequency.

2. Choose the compensation capacitor (C3) to achieve the desired phase margin. For applications with typical inductor values, setting the compensation zero, f_{z1} , below one forth of the crossover frequency provides sufficient phase margin. Determine the C3 value by the following equation:

$$C3 > \frac{4}{2\pi \times R3 \times f_c}$$

3. Determine if the second compensation capacitor (C6) is required. It is required if the ESR zero of the output capacitor is located at less than half of the switching frequency, or the following relationship is valid:

$$\frac{1}{2\pi \times C2 \times R_{ESR}} < \frac{f_s}{2}$$

If this is the case, then add the second compensation capacitor (C6) to set the pole f_{P3} at the location of the ESR zero. Determine the C6 value by the equation:

$$C6 = \frac{C2 \times R_{ESR}}{R3}$$

High Frequency Operation

The switching frequency of MP4462 can be programmed up to 4MHz by an external resistor. Please pay attention to the following if the switching frequency is above 2MHz.

The minimum on time of MP4462 is about 80ns (typ). Pulse skipping operation can be seen more easily at higher switching frequency due to the minimum on time. Recommended operating voltage is 12V or below, and 24V or below at 2MHz. Refer to Figure 2 below for detailed information.

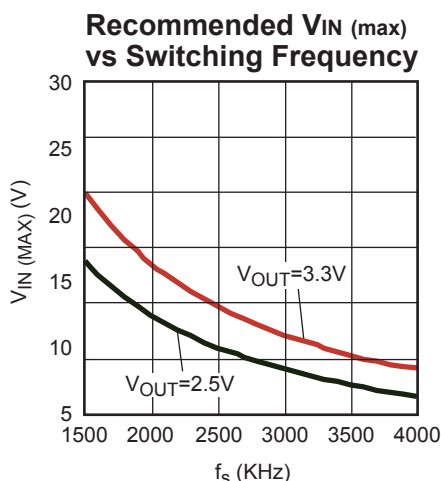


Figure 2—Recommend Max V_{IN} vs. f_s

Since the internal bootstrap circuitry has higher impedance, which may not be adequate to charge the bootstrap capacitor during each $(1-D) \times T_s$ charging period, an external bootstrap charging diode is strongly recommended if the switching frequency is above 2MHz (see External Bootstrap Diode section for detailed implementation information).

With higher switching frequencies, the inductive reactance (X_L) of capacitor comes to dominate, so that the ESL of input/output capacitor determines the input/output ripple voltage at higher switching frequency. As a result of that, high frequency ceramic capacitor is strongly recommended as input decoupling capacitor and output filtering capacitor for such high frequency operation.

Layout becomes more important when the device switches at higher frequency. It is essential to place the input decoupling capacitor, catch diode and the MP4462 (V_{in} pin, SW pin and PGND) as close as possible, with traces that are very short and fairly wide. This can help to greatly reduce the voltage spike on SW node, and lower the EMI noise level as well.

Try to run the feedback trace as far from the inductor and noisy power traces as possible. It is often a good idea to run the feedback trace on the side of the PCB opposite of the inductor with a ground plane separating the two. The compensation components should be placed closed to the MP4462. Do not place the compensation components close to or under high dv/dt SW node, or inside the high di/dt power loop. If you have to do so, the proper ground plane must be in place to isolate those. Switching loss is expected to be increased at high switching frequency. To help to improve the thermal conduction, a grid of thermal vias can be created right under the exposed pad. It is recommended that they be small (15mil barrel diameter) so that the hole is essentially filled up during the plating process, thus aiding conduction to the other side. Too large a hole can cause 'solder wicking' problems during the reflow soldering process. The pitch (distance between the centers) of several such thermal vias in an area is typically 40mil. Please refer to the layout example on EV4460 datasheet.

External Bootstrap Diode

It is recommended that an external bootstrap diode be added when the input voltage is no greater than 5V or the 5V rail is available in the system. This helps improve the efficiency of the regulator. The bootstrap diode can be a low cost one such as IN4148 or BAT54.

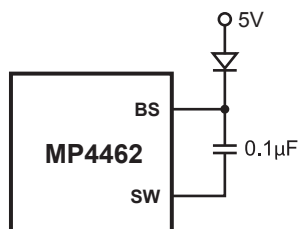


Figure 3—External Bootstrap Diode

This diode is also recommended for high duty cycle operation (when $V_{OUT}/V_{IN} > 65\%$) or low V_{IN} ($< 5V_{in}$) applications.

At no load or light load, the converter may operate in pulse skipping mode in order to maintain the output voltage in regulation. Thus there is less time to refresh the BS voltage. In order to have enough gate voltage under such operating conditions, the difference of $V_{IN} - V_{OUT}$ should be greater than 3V. For example, if the V_{OUT} is set to 3.3V, the V_{IN} needs to be higher than $3.3V + 3V = 6.3V$ to maintain enough BS voltage at no load or light load. To meet this requirement, EN pin can be used to program the input UVLO voltage to $V_{out} + 3V$.

TYPICAL APPLICATION CIRCUITS

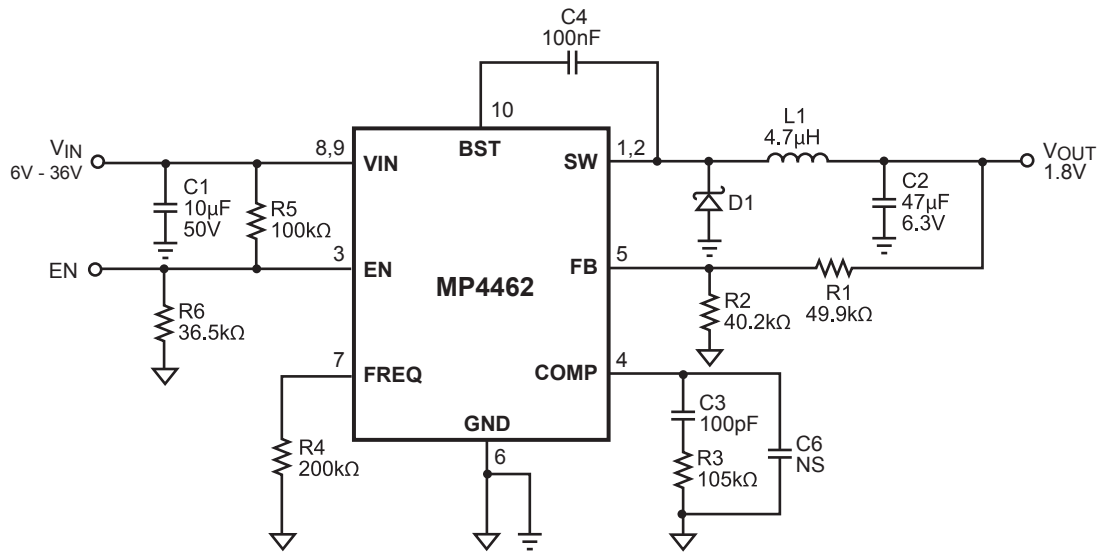


Figure 4—1.8V Output Typical Application Schematic

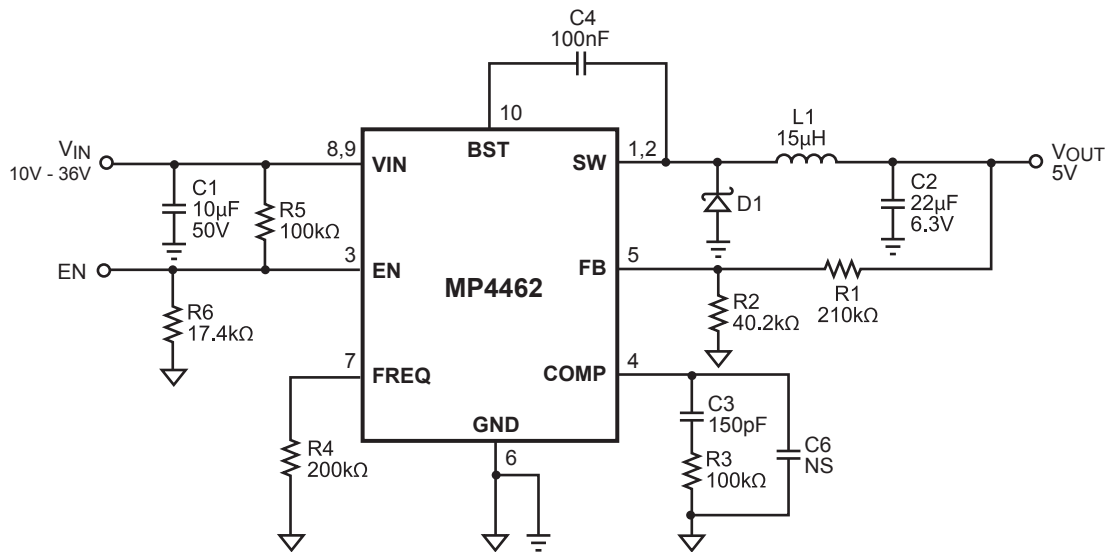


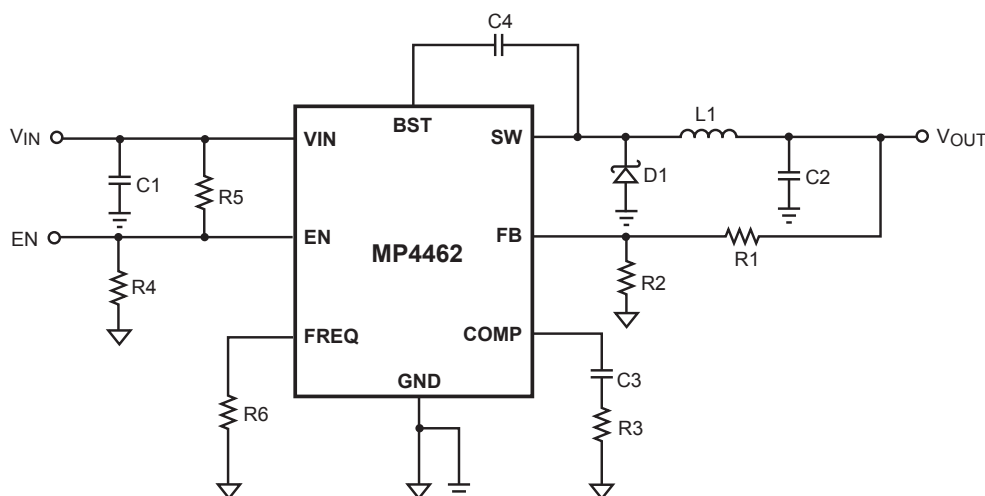
Figure 5—5V Output Typical Application Schematic

PCB LAYOUT GUIDE

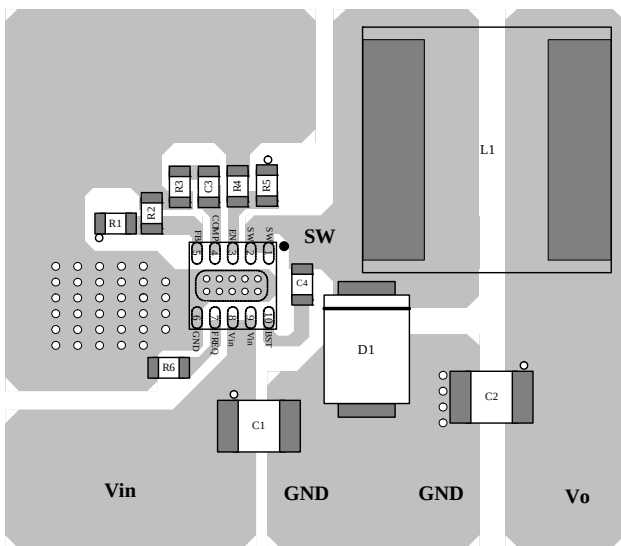
PCB layout is very important to achieve stable operation. It is highly recommended to duplicate EVB layout for optimum performance.

If change is necessary, please follow these guidelines and take Figure 6 for reference.

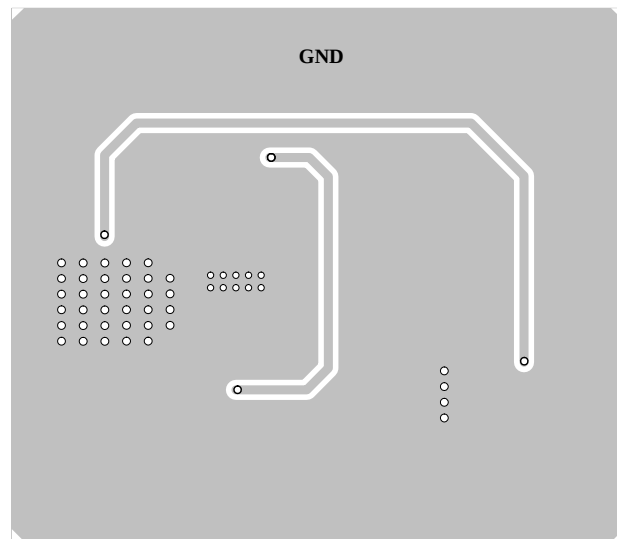
- 1) Keep the path of switching current short and minimize the loop area formed by Input cap, high-side MOSFET and external switching diode.
- 2) Bypass ceramic capacitors are suggested to be put close to the V_{IN} Pin.
- 3) Ensure all feedback connections are short and direct. Place the feedback resistors and compensation components as close to the chip as possible.
- 4) Route SW away from sensitive analog areas such as FB.
- 5) Connect IN, SW, and especially GND respectively to a large copper area to cool the chip to improve thermal performance and long-term reliability.



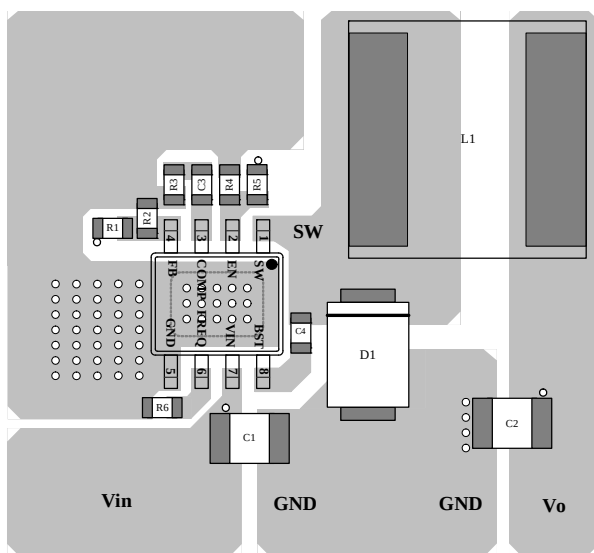
MP4462 Typical Application Circuit



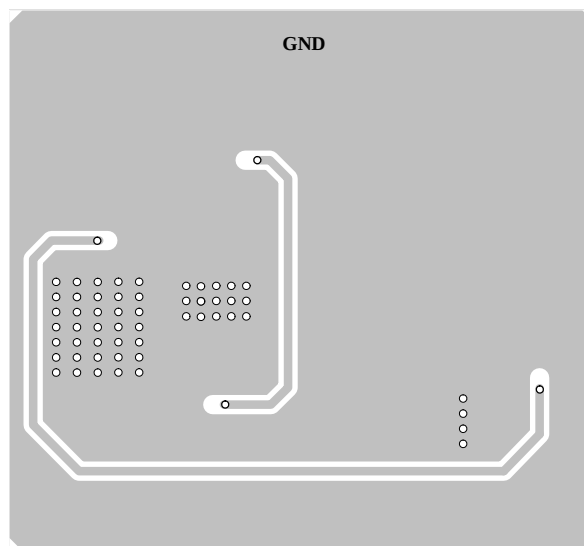
MP4462DQ Top Layer



MP4462DQ Bottom Layer



MP4462DN Top Layer

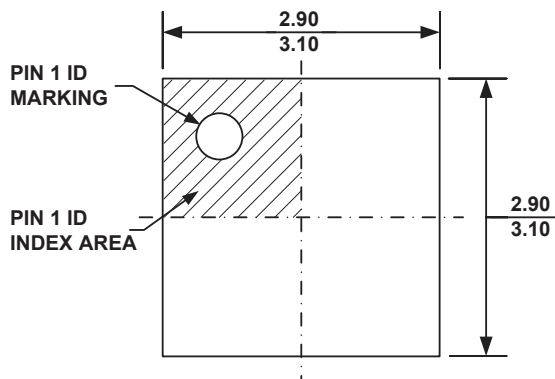


MP4462DN Bottom Layer

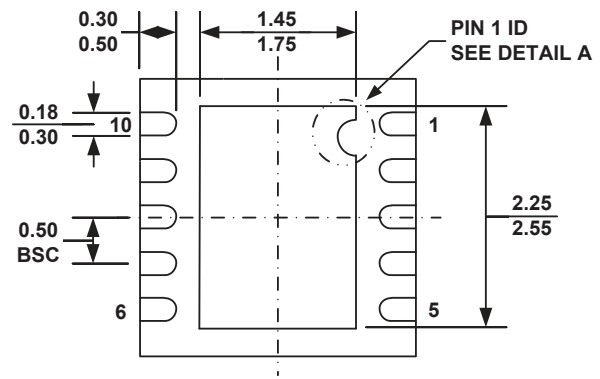
Figure 6—MP4462 Typical Application Circuit and PCB Layout Guide

PACKAGE INFORMATION

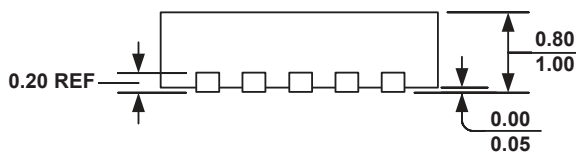
3mm x 3mm QFN10



TOP VIEW



BOTTOM VIEW



SIDE VIEW

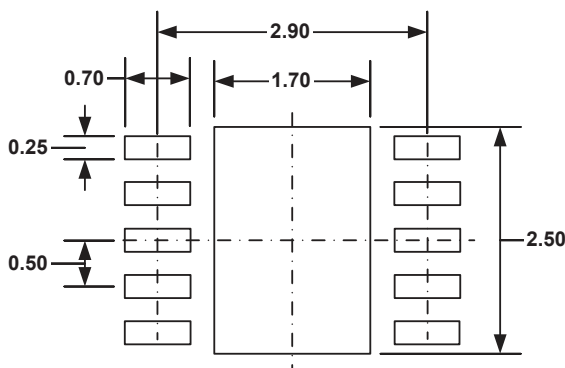
PIN 1 ID OPTION A
R0.20 TYP.



PIN 1 ID OPTION B
R0.20 TYP.



DETAIL A

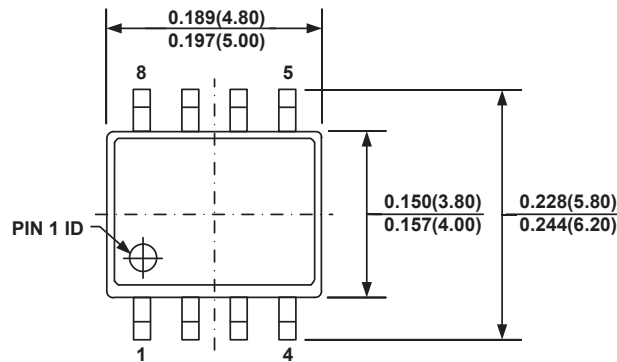


RECOMMENDED LAND PATTERN

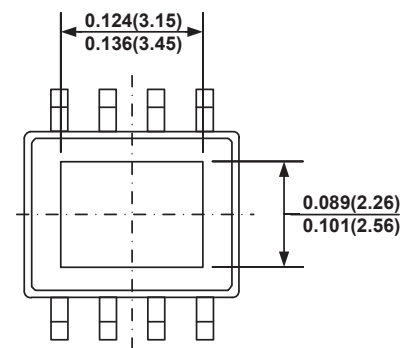
NOTE:

- 1) ALL DIMENSIONS ARE IN MILLIMETERS.
- 2) EXPOSED PADDLE SIZE DOES NOT INCLUDE MOLD FLASH.
- 3) LEAD COPLANARITY SHALL BE 0.10 MILLIMETER MAX.
- 4) DRAWING CONFORMS TO JEDEC MO-229, VARIATION VEED-5.
- 5) DRAWING IS NOT TO SCALE.

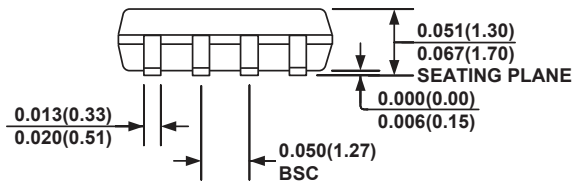
SOIC8E (EXPOSED PAD)



TOP VIEW

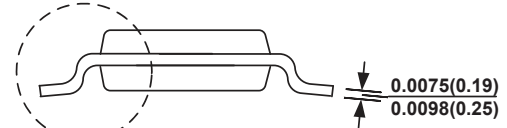


BOTTOM VIEW

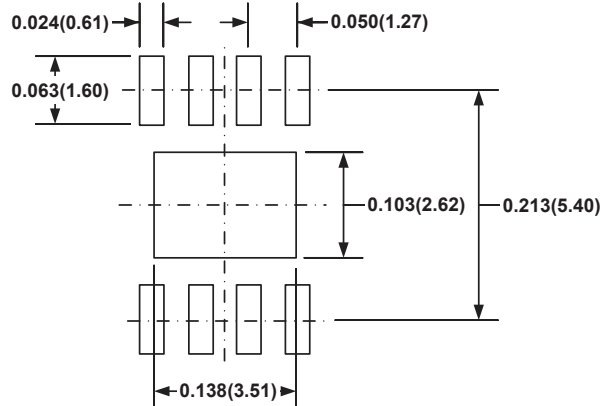


FRONT VIEW

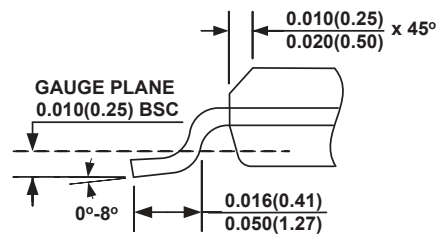
SEE DETAIL "A"



SIDE VIEW



RECOMMENDED LAND PATTERN



DETAIL "A"

NOTE:

- 1) CONTROL DIMENSION IS IN INCHES. DIMENSION IN BRACKET IS IN MILLIMETERS.
- 2) PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.
- 3) PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.
- 4) LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.004" INCHES MAX.
- 5) DRAWING CONFORMS TO JEDEC MS-012, VARIATION BA.
- 6) DRAWING IS NOT TO SCALE.

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