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Filed on behalf of Intel Corporation

By: David L. Cavanaugh, Reg. No. 36,476  
Richard Goldenberg, Reg. No. 38,895  
Wilmer Cutler Pickering Hale and Dorr LLP  
60 State Street  
Boston, Massachusetts 02109  
Email: david.cavanaugh@wilmerhale.com  
richard.goldenberg@wilmerhale.com

UNITED STATES PATENT AND TRADEMARK OFFICE

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**BEFORE THE PATENT TRIAL AND APPEAL BOARD**

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Intel Corporation  
Petitioner

v.

Qualcomm Incorporated  
Patent Owner

Case IPR2018-01240

**PETITION FOR *INTER PARTES* REVIEW OF  
U.S. PATENT NO. 8,698,558  
CHALLENGING CLAIMS 10 AND 11**

**TABLE OF CONTENTS**

|      |  |    |
|------|--|----|
| I.   | INTRODUCTION .....                                 | 1  |
| II.  | MANDATORY NOTICES .....                            | 2  |
|      | A. Real Party-in-Interest .....                    | 2  |
|      | B. Related Matters.....                            | 2  |
|      | C. Counsel .....                                   | 3  |
|      | D. Service Information .....                       | 3  |
| III. | CERTIFICATION OF GROUNDS FOR STANDING .....        | 4  |
| IV.  | OVERVIEW OF CHALLENGE AND RELIEF REQUESTED .....   | 4  |
|      | A. Prior Art Patents and Printed Publications..... | 4  |
|      | B. Grounds for Challenge .....                     | 6  |
| V.   | BRIEF DESCRIPTION OF TECHNOLOGY .....              | 6  |
|      | A. Radio Frequency (RF) Power Amplifiers .....     | 6  |
|      | B. Power Supplies for Power Amplifiers.....        | 7  |
|      | 1. Envelope Amplifiers .....                       | 8  |
|      | 2. Switchers .....                                 | 10 |
|      | 3. Hybrid Supply Generators .....                  | 11 |
|      | 4. Boost Converters.....                           | 16 |
|      | C. Multiplexers.....                               | 19 |
| VI.  | OVERVIEW OF THE '558 PATENT .....                  | 21 |
|      | A. The Alleged Problem in the Art .....            | 21 |
|      | B. The Alleged Invention of the '558 Patent .....  | 22 |
|      | C. Relevant Prosecution History.....               | 29 |
|      | 1. November 23, 2012 Office Action .....           | 29 |
|      | 2. February 19, 2013 Amendment .....               | 30 |
|      | 3. May 10, 2013 Office Action .....                | 30 |
|      | 4. April 15, 2015 Patent Issuance .....            | 31 |
|      | 5. June 27, 2017 Certificate of Correction.....    | 31 |
| VII. | OVERVIEW OF THE PRIOR ART REFERENCES .....         | 31 |
|      | A. Chu .....                                       | 31 |

|       |  |    |
|-------|--|----|
| B.    | Choi 2010 .....  | 36 |
| VIII. | CLAIM CONSTRUCTION .....   | 38 |
| A.    | “envelope signal” (claim 11).....  | 39 |
| B.    | “means for generating a boosted supply voltage based on a first<br>supply voltage” (claim 10) .....  | 40 |
| C.    | “means for generating a second supply voltage based on the<br>envelope signal and the boosted supply voltage” (claim 10).....  | 43 |
| D.    | “means for generating the second supply voltage based on an<br>envelope signal and either the boosted supply voltage or the<br>first supply voltage” (claim 11)..... | 46 |
| IX.   | LEVEL OF ORDINARY SKILL IN THE ART .....   | 49 |
| X.    | SPECIFIC GROUNDS FOR PETITION .....  | 50 |
| A.    | Ground I: Claim 10 is obvious in view of Chu combined with<br>Choi 2010 and Hanington .....  | 51 |
| 1.    | Claim 10 .....   | 51 |
| B.    | Ground II: Claim 11 is obvious over Chu combined with Choi<br>2010, Hanington, and Myers .....   | 72 |
| 1.    | Claim 11 .....   | 72 |
| XI.   | CONCLUSION.....  | 82 |

Petitioner Intel Corporation (“Intel”) respectfully requests *Inter Partes* Review of claims 10 and 11 of U.S. Patent No. 8,698,558 (the “’558 patent”) (Ex. 1301) pursuant to 35 U.S.C. §§ 311-19 and 37 C.F.R. § 42.1 *et seq.*

## **I. INTRODUCTION**

The ’558 patent claims various structures for “efficiently generating a power supply for a power amplifier.” Ex. 1301, 1:30-31. Power supply generators for power amplifiers, however, were well-known at the time of the claimed invention, and the challenged claims either are not novel or are obvious variations of known power supply generators. The aspects of the ’558 patent that are identified by the patent as inventive and that the Patent Owner *itself* has identified as inventive in parallel litigation (*i.e.*, the addition of a boost converter to an envelope amplifier and the use of an “offset” current to generate a larger supply current) were known in the prior art at the time of the claimed invention, and they provide only known and predictable results that cannot justify a patent.

Moreover, the primary prior art reference, Chu and Kwak, relied upon in this and related petitions—neither of which was before the Patent Office during prosecution—disclose the key elements that the Examiner found to be allegedly missing from the prior art during prosecution. For example, the Examiner allowed claims 10 and 11 because he found that the prior art of record did not disclose the

required operational amplifier, driver, and PMOS and NMOS transistors. The Chu reference cited in this Petition discloses those limitations.

Accordingly, the prior art cited in this Petition renders obvious claims 10 and 11 of the '558 patent.

## **II. MANDATORY NOTICES**

### **A. Real Party-in-Interest**

Intel Corporation ("Petitioner") is a real party-in-interest and submits this *inter partes* review Petition for review of certain claims of U.S. Patent No. 8,698,558 (the "'558 patent"). Petitioner also identifies Apple Inc. ("Apple") as a real party-in-interest.

### **B. Related Matters**

Qualcomm Incorporated ("Qualcomm" or "Patent Owner") has asserted the '558 patent against Apple in *Certain Mobile Electronic Devices and Radio Frequency and Processing Components Thereof*, Investigation No. 337-ITC-1065, currently pending before the International Trade Commission. Qualcomm also has asserted the '558 patent against Apple in *Qualcomm Inc. v. Apple Inc.*, No. 3:17-cv-1375 (S.D. Cal.).

Concurrently with this *inter partes* review Petition, Petitioner is also filing *inter partes* review petitions for claims 12-14 of the '558 patent (IPR2018-01152), claims 1-9 of the '558 patent (IPR2018- 01153), and claims 15-20 of the '558

patent (IPR2018- 01154). Petitioner requests that these petitions be assigned to the same panel.

**C. Counsel**

Lead Counsel: David L. Cavanaugh (Registration No. 36,476)

Backup Counsel: Richard Goldenberg (Registration No. 38,895), Nina Tallon (*pro hac vice* to be requested), Joseph Mueller (*pro hac vice* to be requested), Todd Zubler (*pro hac vice* to be requested), and Kathryn Zalewski (*pro hac vice* to be requested), Theodoros Konstantakopoulos (Registration No. 74,155)

**D. Service Information**

E-mail: [david.cavanaugh@wilmerhale.com](mailto:david.cavanaugh@wilmerhale.com)  
[richard.goldenberg@wilmerhale.com](mailto:richard.goldenberg@wilmerhale.com)  
[nina.tallon@wilmerhale.com](mailto:nina.tallon@wilmerhale.com)  
[joseph.mueller@wilmerhale.com](mailto:joseph.mueller@wilmerhale.com)  
[todd.zubler@wilmerhale.com](mailto:todd.zubler@wilmerhale.com)  
[kathryn.zalewski@wilmerhale.com](mailto:kathryn.zalewski@wilmerhale.com)  
[theodoros.konstantakopoulos@wilmerhale.com](mailto:theodoros.konstantakopoulos@wilmerhale.com)

Post and hand delivery: Wilmer Cutler Pickering Hale and Dorr LLP

60 State Street

Boston, Massachusetts 02109

Telephone: (617) 526-6000

Fax: (617) 526-5000

Petitioner consents to email delivery on lead and backup counsel.

### **III. CERTIFICATION OF GROUNDS FOR STANDING**

Petitioner certifies pursuant to Rule 42.104(a) that the patent for which review is sought is available for *inter partes* review and that Petitioner is not barred or estopped from requesting an *inter partes* review challenging the patent claims on the grounds identified in this Petition.

### **IV. OVERVIEW OF CHALLENGE AND RELIEF REQUESTED**

Pursuant to Rules 42.22(a)(1) and 42.104(b)(1)-(2), Petitioner challenges claims 10 and 11 of the '558 patent.

#### **A. Prior Art Patents and Printed Publications**

The '558 patent was filed June 23, 2011 and does not claim priority to any prior applications.

The following references are pertinent to the grounds of unpatentability explained below:

1. Chu, W.Y. et al., "*A 10 MHz Bandwidth, 2 mV Ripple PA Regulator for CDMA Transmitters*," IEEE Journal of Solid-State Circuits 2809-2819 (2008) ("Chu") (Ex. 1304). Chu was published in 2008 and is prior art under at least 35 U.S.C. § 102(b). Ex. 1305 at ¶14.

2. Choi, J. et al., “*Envelope Tracking Power Amplifier Robust to Battery Depletion*,” Microwave Symposium Digest (MTT), 2010 IEEE MTT-S International 1332-36 (2010) (“Choi 2010”) (Ex. 1306). Choi 2010 has been available from the IEEE *Xplore* website at <http://ieeexplore.ieee.org/abstract/document/5517825/> since July 23, 2010 and is therefore prior art under at least 35 U.S.C. § 102(a). Ex. 1307 at ¶11. Choi 2010 is also prior art under 35 U.S.C. § 102(b). Choi 2010 was presented in May 2010 at a leading technical conference of skilled artisans, the IEEE International Microwave Symposium (“IMS”) 2010 conference, in Anaheim, California. Ex. 1308; Ex. 1306 at cover; Ex. 1309 at ¶¶4-5; Ex. 1307 at ¶11. Choi 2010 was distributed to hundreds of conference attendees via USB drives in May 2010. Ex. 1308 at ¶17; Ex. 1309 at ¶¶6-9.
3. Hanington, Gary et al., “*High-Efficiency Power Amplifier Using Dynamic Power-Supply Voltage for CDMA Applications*,” IEEE Transactions on Microwave Theory and Techniques 47:8 (1999) (“Hanington”) (Ex. 1324). Hanington was published in 1999 and is prior art under at least 35 U.S.C. § 102(b). *See* Ex. 1304 at 1077 (Choi 2010 citing Hanington).



4. U.S. Patent No. 5,929,702, “Method and Apparatus for High Efficiency High Dynamic Range Power Amplification,” to Myers et al. (“Myers”) (Ex. 1312). Myers was filed on November 28, 1997 and issued on July 27, 1999, making it prior art under at least 35 U.S.C. § 102(a), (b), and (e).

**B. Grounds for Challenge**

Petitioner requests cancellation of claims 10 and 11 of the ’558 patent as unpatentable under 35 U.S.C. § 103. This Petition, supported by the declaration of Dr. Alyssa Apsel (Ex. 1303) filed herewith, demonstrates that there is a reasonable likelihood that Petitioner will prevail with respect to cancellation of at least one challenged claim. *See* 35 U.S.C. § 314(a).

**V. BRIEF DESCRIPTION OF TECHNOLOGY**

The challenged claims of the ’558 patent are directed to an apparatus for generating a power supply signal for a power amplifier. The apparatus includes several components that were well known in the art—envelope amplifiers, boost converters, and power amplifiers—as explained below.

**A. Radio Frequency (RF) Power Amplifiers**

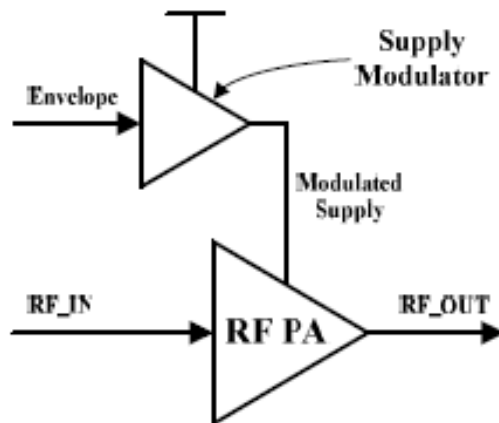
In wireless communications, mobile devices exchange information (such as phone calls, text messages, or other data to and from the Internet) with a base station that connects the mobile devices to other devices and a wider network.

This information is transmitted using radio frequency (“RF”) signals. To reach a base station or a mobile device, RF signals require a certain amount of power. Mobile devices and base stations therefore commonly contain a component known as a “power amplifier” (or “PA”) that increases the power of RF signals to a level sufficient to reach the receiving base station or mobile device. Typically, the further the device moves from a base station, the more power amplification is needed to ensure successful transmission of the RF signal. Ex. 1303 at ¶¶36-37.

In operation, a PA accepts an input signal (such as the signal that carries voice data for a cell phone call) and produces an output signal that, ideally, replicates the input signal but with proportionally greater power. Ex. 1303 at ¶38.

#### **B. Power Supplies for Power Amplifiers**

A PA needs to receive power sufficient to amplify the input signal. A PA typically receives its power in the form of a supply voltage from a power supply generator/modulator. For example, in the prior-art structure shown below, the PA receives a supply voltage (“Modulated Supply”) from a power supply generator/modulator:



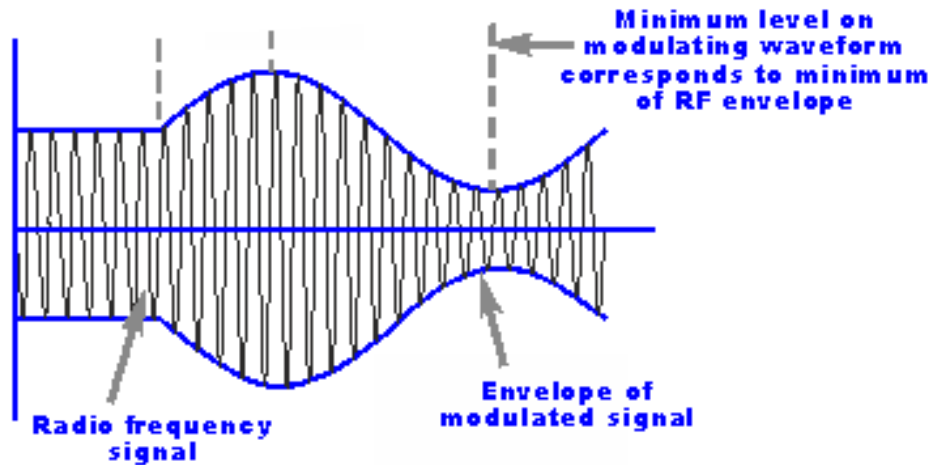
**Kim – Figure 1(b)**

Ex. 1313 [Kim, D. et al., “*High Efficiency and Wideband Envelope Tracking Power Amplifier with Sweet Spot Tracking*,” Radio Frequency Integrated Circuits Symposium (RFIC): 255-258 (2010) (“Kim”)] at 255. In this case, the supply voltage provides the PA with sufficient power to transmit an output signal (“RF\_OUT”) based on the input signal (“RF\_IN”) that the PA receives, without degrading the quality of the signal or wasting power through resistive losses. The amount of power required at the RF PA depends on the RF signal that must be transmitted. Ex. 1303 at ¶¶39-40.

### **1. Envelope Amplifiers**

An envelope amplifier—also sometimes referred to as a “linear amplifier”—is one type of power supply generator for a PA. As shown in the diagram above, the envelope amplifier (the “Supply Modulator”) receives an “envelope” signal, which is a signal that tracks the RF signal to be transmitted. As shown in the

diagram below, the envelope signal (shown in blue) tracks the outermost points of the oscillating RF signal (shown in black):



Ex. 1303 at ¶41-42. The envelope amplifier receives the envelope signal and uses it to provide a supply voltage to the PA that increases and decreases as the amplitude of the envelope signal increases and decreases. Ideally, the power provided to the PA will match the envelope signal as closely as possible—thereby providing the power that the PA needs to transmit the RF signal, but without providing more power than necessary. Ex. 1303 at ¶42.

Envelope amplifiers have many advantages: they have a simple circuit configuration; they can generate output signals that are accurate copies of the input signals, even when the input changes rapidly (i.e., when the RF signal has a high

bandwidth); and they do not generate significant noise that could affect other circuits. Ex. 1303 at ¶43.

Envelope amplifiers, however, are also energy inefficient and generate considerable heat. To generate a voltage for the PA, an envelope amplifier requires its own input supply voltage. An envelope amplifier is a type of “linear regulator,” which is a device that takes an input voltage and reduces (or “steps-down”) that voltage as necessary to generate the output supply voltage for the PA. This step-down in voltage is necessarily inefficient because it involves dissipating the power difference between the input and output voltages in the form of heat. Using an envelope amplifier alone to supply power to a PA therefore consumes more power than desired. Ex. 1303 at ¶43.

## **2. Switchers**

Another prior art device for supplying power to a PA is a “switcher,” also sometimes referred to as a “switching regulator” or “switching amplifier.” A switcher takes small chunks of energy from an input voltage source and stores them in energy-storing elements (such as an inductor) that will transform the energy into an output. A switcher accomplishes this task by alternately connecting and disconnecting the input supply voltage (*e.g.*, the battery of the mobile device) to the energy-storage element. When the switcher connects the input supply voltage to the energy storage element, energy is added to the storage element. The

storage element can then release this energy in the form of a steady current to the PA. By controlling the timing of these alternating connections / disconnections to increase the energy in the storage element, a switcher can supply energy to a PA without dissipating voltage as heat, like an envelope amplifier does. The energy losses involved in moving chunks of energy around in this way are thus relatively small. Ex. 1303 at ¶¶44-45.

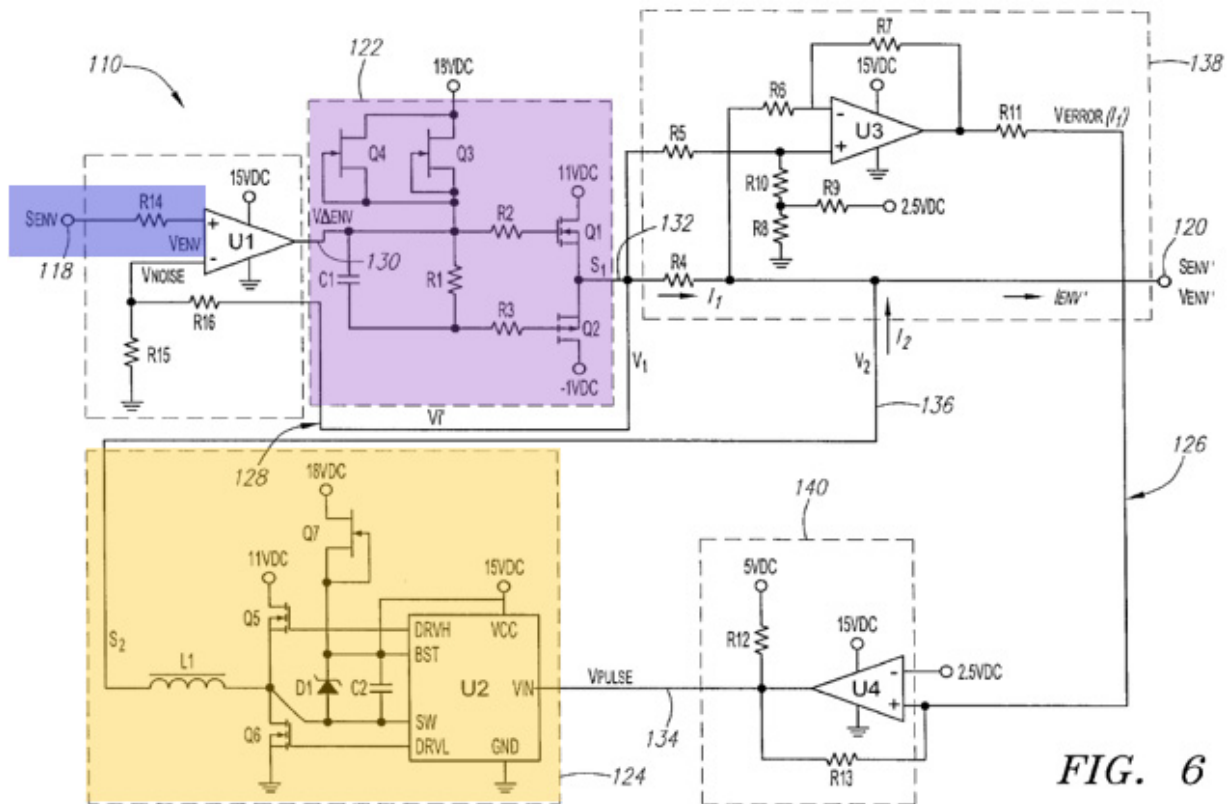
As a result, switchers generally achieve higher efficiency than envelope amplifiers. But there are limits on the frequency at which switchers can operate. Because of this, switchers were generally known to have higher efficiency, but lower operating bandwidth, than envelope amplifiers. Ex. 1303 at ¶45.

### **3. Hybrid Supply Generators**

Hybrid supply generators combine envelope amplifiers and switchers to gain the benefits of both. A hybrid supply generator can use the envelope amplifier and/or the switcher, as appropriate, to supply the power to a power amplifier, thereby obtaining both (a) the high frequency response of an envelope amplifier, and (b) the high efficiency of a switcher. Ex. 1303 at ¶46.

Hybrid supply generators were well known in the art at the time of the purported invention of the '558 patent. For example, another patent filed eleven years earlier by the lead inventor of the '558 patent discloses combining a linear amplifier with a type of switcher known as a synchronous buck DC/DC converter.

Ex. 1314 [U.S. Patent No. 6,300,826, “Apparatus and Method for Efficiently Amplifying Wideband Envelope Signals” (filed May 5, 2000) (“Mathe ’826”)]. As shown below, circuit 110 in Mathe ’826 is a buffer amplifier circuit that includes (1) an envelope amplifier (“an AB-type RF amplifier 122” highlighted in purple), which is described as “a moderately power efficient device having high bandwidth capabilities”, and (2) a switcher (“synchronous buck DC/DC converter 124” highlighted in yellow), which is described as “a highly efficient device having low bandwidth capabilities.” *Id.* at 5:17-22; Ex. 1303 at ¶47.



Mathe ’826 – Figure 6

A paper by Ertl from 1997 also discloses a hybrid supply generator. Ex. 1316 [Ertl, H. et al., “*Basic Considerations and Topologies of Switched-Mode Assisted Linear Power Amplifiers*,” IEEE Transactions on Industrial Electronics 44.1 (1997): 116-123 (“Ertl”)]. Ertl presents “a combined power amplifier system” consisting of an envelope amplifier (“linear amplifier unit”) and a switcher (“a switched-mode (class D) current dumping stage”), as shown in Figure 2 below:

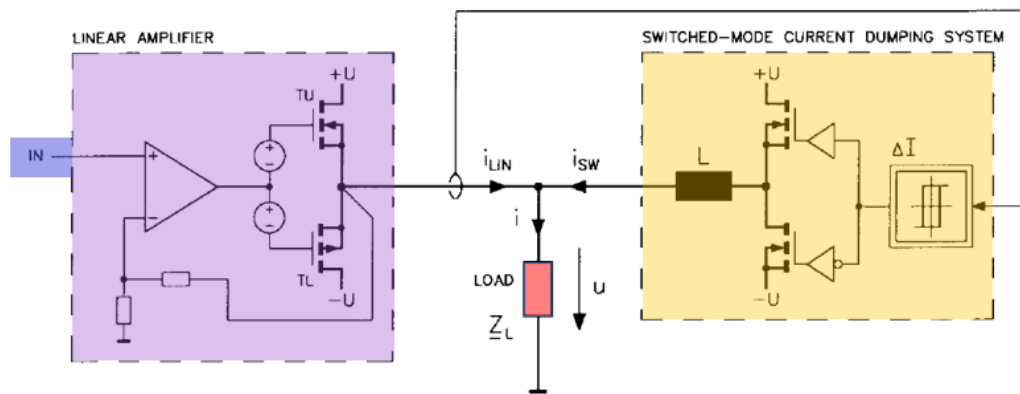


Fig. 2. Circuit diagram of a switched-mode assisted linear power amplifier.

## Ertl – Figure 2

Ex. 1316 at 117. Ertl touts this combination as providing the best of both worlds: (a) “the fundamental drawback of conventional linear power amplifiers—the high loss—is avoided;” and (b) “[c]ompared to a pure class D (switching) amplifier, the presented system needs no output filter to reduce the switching frequency harmonics.” *Id.*; Ex. 1303 at ¶48.

Blanken also proposes a hybrid supply modulator for a PA, combining “a high-bandwidth class-AB linear regulator [envelope amplifier] with an efficient



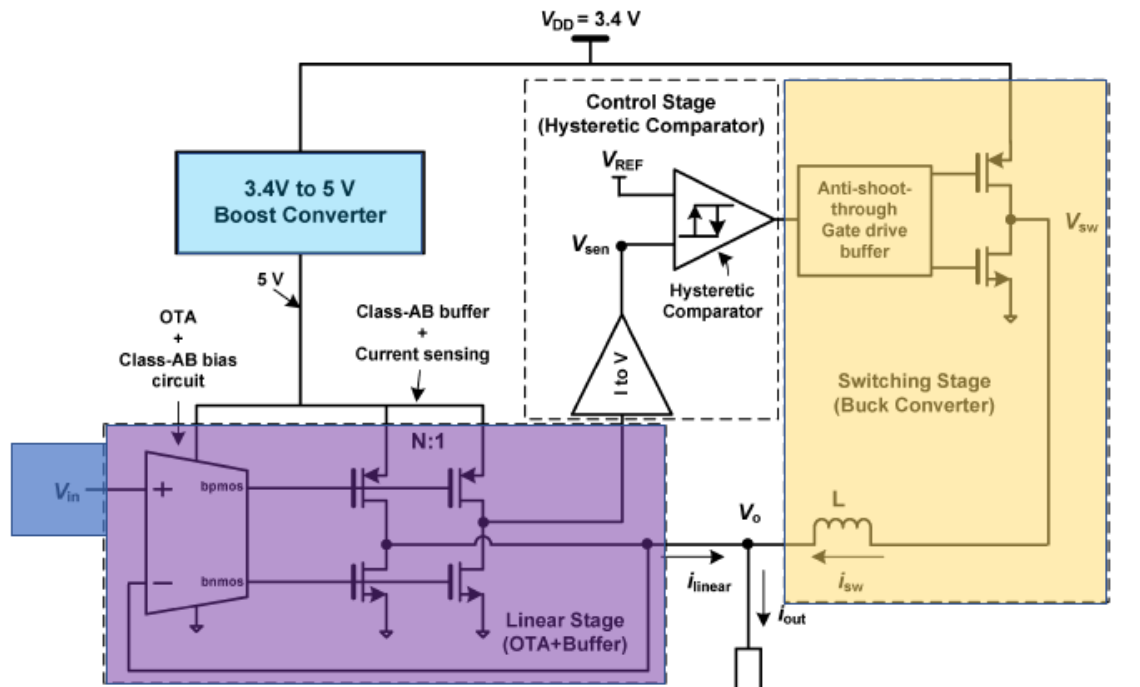
DC/DC converter [switcher] in a master-slave configuration.” Ex. 1310 [Blanken, P.G. et al., “*A 50MHz bandwidth multi-mode PA supply modulator for GSM, EDGE and UMTS application*,” 2008 Radio Frequency Integrated Circuits Symposium (IEEE) 401-04 (2008) (“Blanken”)] at 401. Blanken explains that:

[h]igh-efficiency voltage conversion can be obtained with a switched-mode inductive DC/DC buck converter, but its bandwidth is limited due to practical limits to the switching frequency. Alternatively, linear regulators enable higher bandwidth at the cost of efficiency. As a good compromise between efficiency and bandwidth, hybrid supply modulators have been proposed combining a switched-mode DC/DC converter in parallel to a linear regulator.

*Id.*; see also *id.* (“The supply-modulator topology is shown in Fig. 1. It contains a linear regulator and a DC/DC converter in master-slave configuration. The linear regulator is formed by a Miller-compensated two-stage amplifier built with class-A input transconductor  $g_{in}$  and class-AB output transconductor  $g_o$ . ... [T]he DC/DC converter supplies the DC and low-frequency part of the load current, and the linear regulator supplies the high-frequency part.”). Ex. 1303 at ¶49.

Finally, a 2010 paper by Kang describes “a highly efficient supply modulator” that combines an envelope amplifier with a switcher. Ex. 1317 [Kang, D. et al., “*A Multimode/Multiband Power Amplifier With a Boosted Supply Modulator*,” IEEE Transactions on Microwave Theory and Techniques 58.10

(2010): 2598-2608 (“Kang”)]. Kang acknowledges the disadvantages of both linear amplifiers (i.e., envelope amplifiers) and switching amplifiers (i.e., switchers): “the limited BW [bandwidth] of switching amplifiers and the low efficiency of wideband linear amplifiers.” Ex. 1317 at 2599. Kang explains that researchers therefore have utilized both envelope amplifiers and switchers in hybrid systems that are “suitable for the envelope signal of modern wireless communication systems, which has the most power in the low-frequency region.” *Id.* at 2599. Kang specifically proposes “a hybrid switching amplifier (HSA) for multistandard applications.” *Id.* As shown in Figure 4 below, Kang’s hybrid supply generator includes not only an envelope amplifier (“linear stage”) and a switcher (“switching stage”), but also a boost converter (highlighted in light blue and discussed further in the next section):



### Kang – Figure 4

*Id.* at 2602; Ex. 1303 at ¶50.

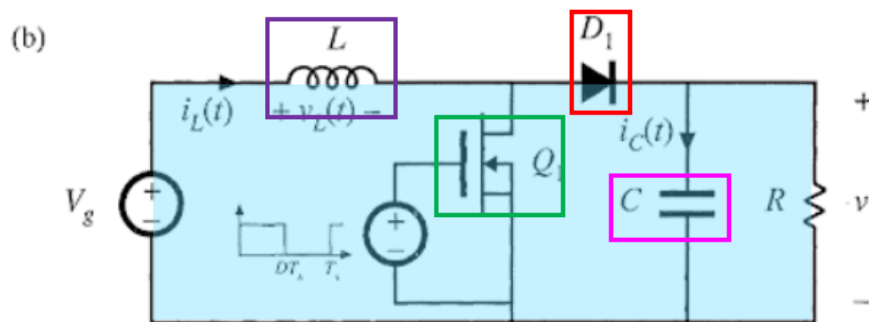
## 4. Boost Converters

If the supply voltage from a device's battery is too low, the output signal from the PA can be distorted. A boost converter (also known as a “step-up” converter) can prevent this by boosting the battery voltage to a higher voltage, which the envelope amplifier can then use to provide power to the PA. This boosting capability is achieved by storing energy in a storage element, and then releasing the energy in the form of a higher voltage. Ex. 1303 at ¶51.

Boost converters have been standard components in power electronics since well before the earliest alleged priority date of the '558 patent. For example, a

patent from the 1990s discloses a boost (“step-up”) converter that provides increased voltage to a power amplifier to prevent distortion. Ex. 1318 [U.S. Patent No. 5,834,977, “Amplifying Circuit with Power Supply Switching Circuit” (filed October 30, 1996 and issued November 10, 1998) (“Maehara”)] at Abstract (“An amplifying circuit according to the present invention has an amplifying unit for amplifying an input signal to produce an amplified signal, a battery for generating a constant voltage (a first voltage), a step-up converter for always generating an increased voltage (or a second voltage) by increasing the constant voltage .... [B]ecause the increased voltage is always generated by the step-up converter ... any distortion of the amplified signal can be prevented.”). Ex. 1303 at ¶52.

Boost converters typically include a transistor, a diode, an inductor, and a capacitor. For example, the book *Fundamentals of Power Electronics*, published in 2001, describes a boost converter with these components:



**Fig. 2.13** Boost converter: (a) with ideal switch, (b) practical realization using MOSFET and diode.

Ex. 1324 [Erickson et al., *Fundamentals of Power Electronics, Second Edition* (Kluwer Academic Publisher) (2001) (“Erickson”)] at Fig. 2.13(b), 22-24. The boost converter in Erickson includes a switch implemented with a MOSFET (outlined in green) and a diode (outlined in red) that connects the inductor (outlined in purple) either to ground or to a capacitor (outlined in fuchsia) and the output (resistor R). The operation of this circuit allows the transfer of energy to the capacitor through the diode so that the output voltage is higher than the input voltage. *Id.* at 24. Ex. 1303 ¶53.

It is well known that boost converters can be used in a hybrid supply generator. As noted in the preceding section, the Kang paper from 2010 discloses a hybrid supply generator that includes a boost converter connected to the envelope amplifier. Ex. 1317 at 2602 (“An HSA [hybrid switching amplifier] consists of a boost converter, linear stage, hysteretic comparator, and switching stage, as shown in Fig. 4. The boost converter is connected to the linear stage to boost the output voltage swing.”). Ex. 1303 at ¶54.

Finally, during prosecution, the Examiner found that Kim disclosed a hybrid supply generator with a boost converter, as required by the ’558 patent. *See* Ex. 1313. The Examiner initially rejected patent claims 6-8 and 10-11 (prosecution claims 10-12, 14-15) because Kim disclosed, among other things, the required boost converter. Ex. 1302 at 61-62. The applicant did not dispute the Examiner’s

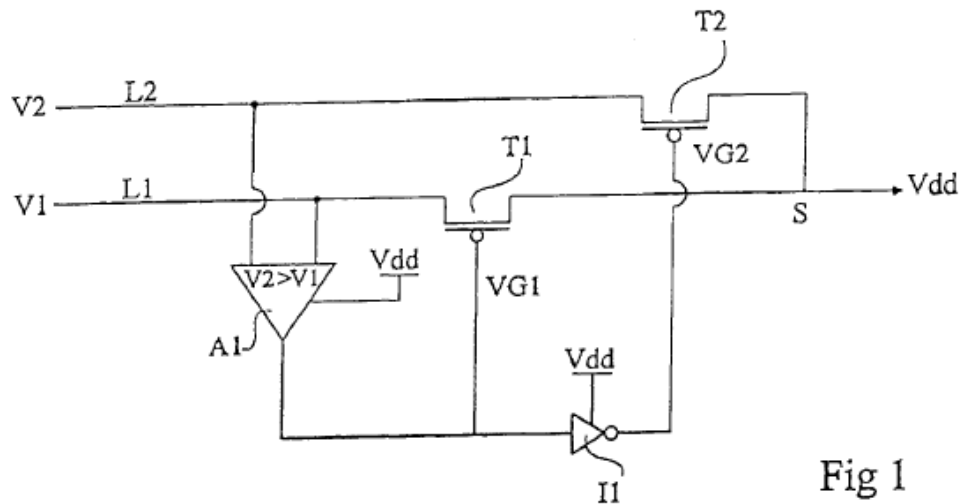
rejection on this ground but instead made a narrowing amendment. *Id.* at 81-82, 86-87; Ex. 1303 at ¶55.

### **C. Multiplexers**

A multiplexer is a circuit with several input signals and a single selectable output signal. As U.S. Patent No. 5,870,340 to Ohsawa explains, “a signal line is selected from the plurality of signal lines, and the selected signal line is electrically connected to the single signal line.” Ex. 1319 [U.S. Patent No. 5,870,340, “Multiplexer” (filed July 8, 1997 and issued February 9, 1999) (“Ohsawa”)] at 1:17-20. At the time of the alleged invention, it was well known that multiplexers could be used for data selection in many electronic devices. Ex. 1303 at ¶56.

For example, Ohsawa discloses a multiplexer circuit using PMOS transistors. Each input signal is connected to the gate of a PMOS transistor, and the drain of each transistor is connected to a common node. Ex. 1319 at 4:50-5:5, Fig. 4. When an input signal is to be selected, the PMOS transistor associated with that signal turns on, which sends the signal to the common node. *Id.*; Ex. 1303 at ¶57.

Such multiplexers have been used to select between multiple power supplies. A two-input multiplexer for selecting between power supplies V1 and V2 is shown in Figure 1 of U.S. Patent No. 6,566,935 to Renous:



**Renous – Figure 1**

Ex. 1320 [U.S. Patent No. 6,566,935, “Power Supply Circuit With a Voltage Selector” (filed August 28, 2000 and issued May 20, 2003) (“Renous”)] at Fig. 1. Renous explains that Figure 1 “shows a conventional power supply circuit receiving two supply voltages V1 and V2 on two respective supply lines L1 and L2, and providing a voltage Vdd on an output node S.” Ex. 1320 at 1:14-17; Ex. 1303 at ¶58.

The multiplexer uses two PMOS transistors (T1 and T2) to implement the selection between the two supply voltages (V1 and V2). A comparator A1 determines which voltage supply should be used. The comparator A1 sends one control signal to the gate of transistor T1 and a second control signal (which is an inverted version of the first control signal) to the gate of transistor T2. This will

activate one or the other of the transistors and thereby send one of the supply voltages (V1 or V2) to the output node S. *Id.* at 1:17-25 (“[T]he output of comparator A1 is at a low level when voltage V1 is greater than voltage V2 and at a high level otherwise. The output of comparator A1 is directly connected to the gate of transistor T1, and is connected to the gate of transistor T2 via an inverter I1.”). Ex. 1303 at ¶59.

## **VI. OVERVIEW OF THE ’558 PATENT**

### **A. The Alleged Problem in the Art**

The ’558 patent describes “techniques for efficiently generating a power supply for a power amplifier and/or other circuits.” Ex. 1301 at 1:30-31. The ’558 patent explains that although it is advantageous to operate a wireless device using a low battery voltage to reduce power consumption and extend battery life, a power amplifier sometimes “may need to operate with a PA supply voltage (e.g., 3.2V) that is higher than the battery voltage.” *Id.* at 3:51-52. The ’558 patent also acknowledges that it was known to use boost converters to generate the necessary higher PA supply voltage. *Id.* at 3:52-54. But the ’558 patent says using a boost converter to “directly supply the PA supply voltage” may “increase cost and power consumption.” *Id.* at 3:54-56; Ex. 1303 at ¶60. These alleged problems, however, had already been identified and solved in the prior art before the filing of the ’558 patent, as discussed below.



**B. The Alleged Invention of the '558 Patent**

The challenged claims of the '558 patent comprise combinations of well-known components in the field: specifically, PAs, envelope amplifiers, switchers, hybrid supply generators (envelope amplifier + switcher), and boost converters. The '558 patent does not claim to have invented any of these components, all of which were known in the prior art years before the filing date of the '558 patent, as explained above. Ex. 1303 at ¶61.

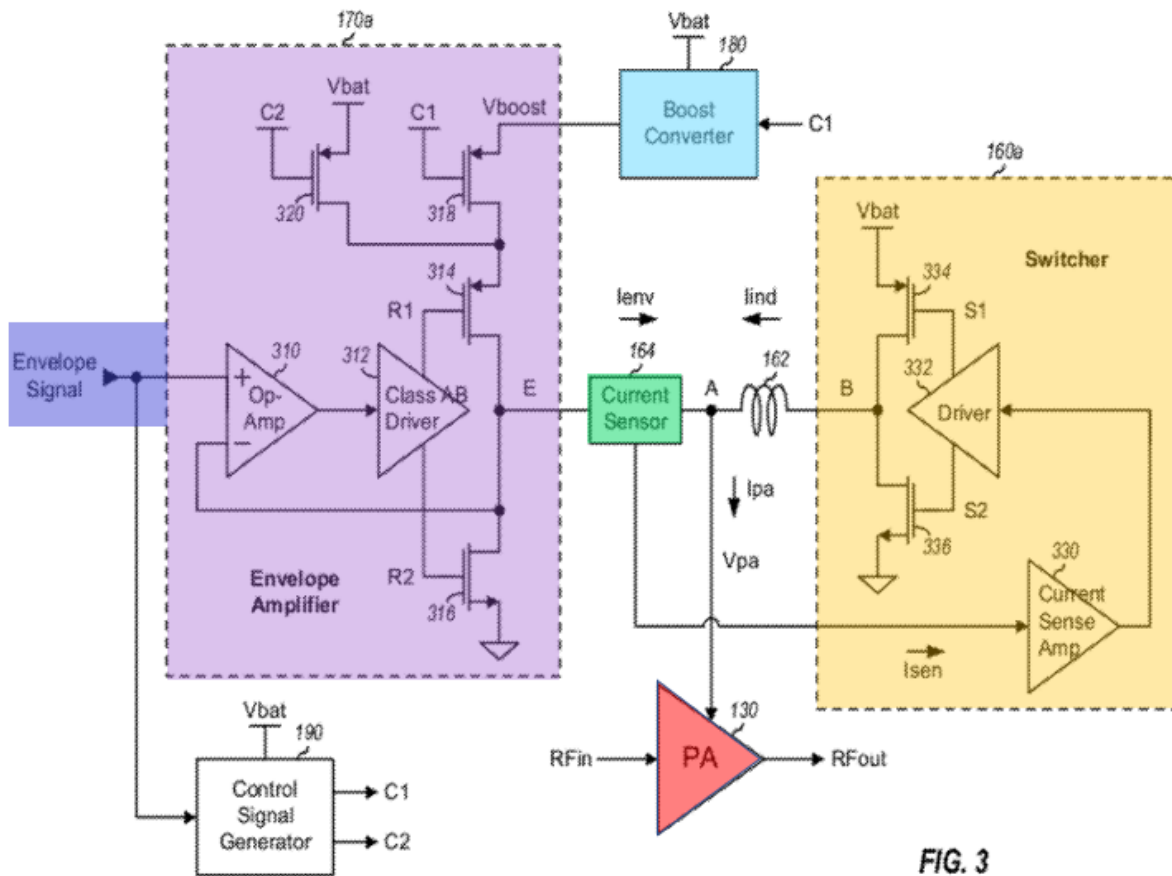
The '558 patent purports to provide two alleged improvements to hybrid supply generators: (1) connecting a boost converter to the envelope amplifier; and (2) adding an “offset” current to the switcher’s input current to increase the amount

of current generated by the switcher.<sup>1</sup> Ex. 1303 at ¶61. As explained in this Petition, each of these techniques was known in the prior art.

**First**, the '558 patent proposes a hybrid supply generator with a specific type of envelope amplifier—i.e., one connected to a boost converter, as shown below in Figure 3 from the '558 patent:

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<sup>1</sup> These are the only two allegedly inventive aspects that the Patent Owner has identified in the parallel ITC litigation. *See* Ex. 1322 at 12-15 (“*First*, the ‘558 patent discloses connecting a boost converter (which “boosts” or increases the battery voltage to a higher level) only with the envelope amplifier, and not the switcher, to reduce overall usage of the boost converter. ... *Second*, the ‘558 patent discloses that an “offset” may be used to increase the amount of current generated by the switcher.”).

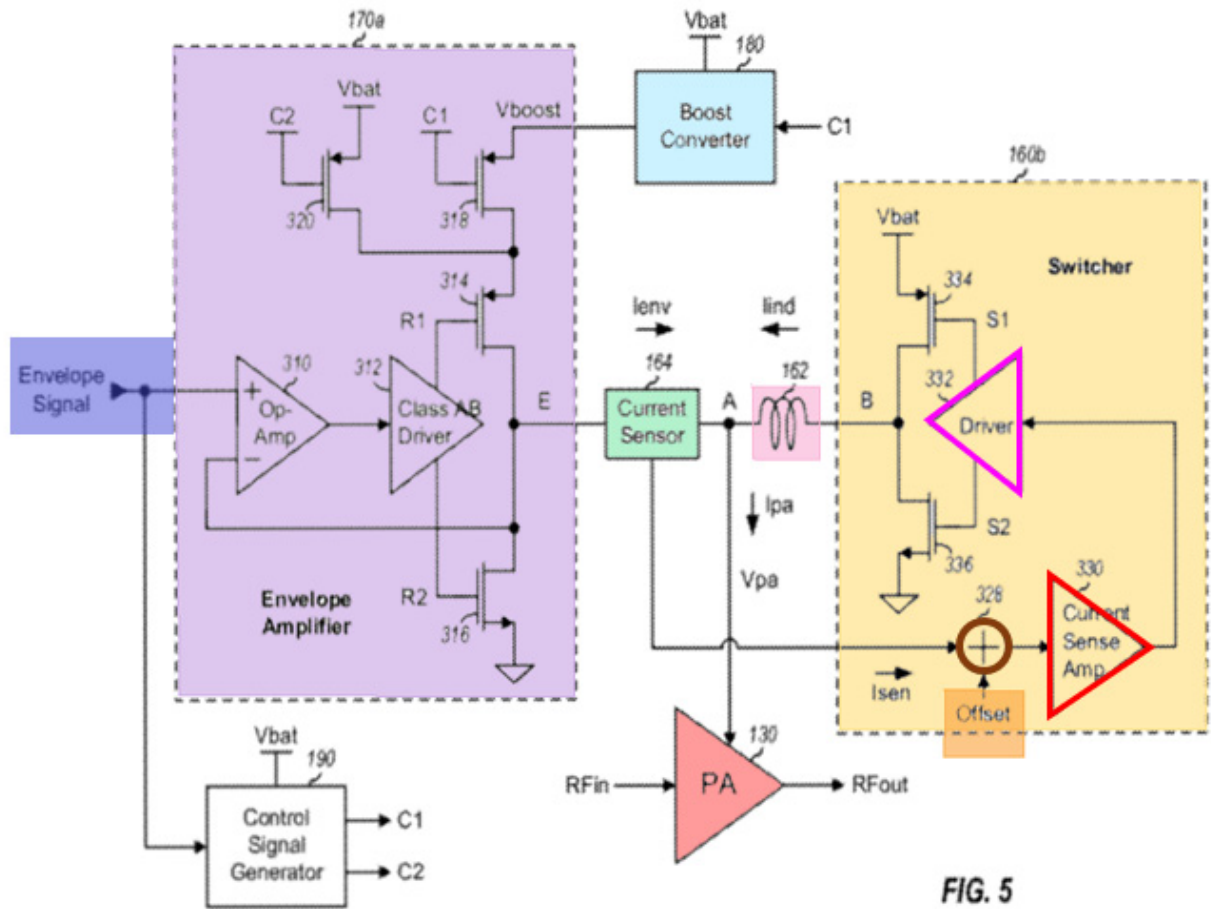


**'558 Patent – Figure 3**

The envelope amplifier 170a (highlighted in purple) and switcher 160a (highlighted in yellow) cooperate to provide power to power amplifier 130 (highlighted in red). The envelope amplifier receives an envelope signal (highlighted in blue). The boost converter 180 (highlighted in light blue) is connected to the envelope amplifier and adds extra voltage to the envelope amplifier when needed. According to the patent, this configuration is efficient because the boost converter will provide extra voltage only when the envelope

amplifier needs it. Ex. 1301 at 3:57-67 (“PA supply generator 150 can efficiently generate the PA supply voltage with envelope tracking to avoid the disadvantages of using a boost converter to directly provide the PA supply voltage. Switcher 160 may provide the bulk of the power for power amplifier 130 and may be connected directly to the battery voltage. Boost converter 180 may provide power to only envelope amplifier 170. PA supply generator 150 can generate the PA supply voltage to track the envelope of the RFin signal provided to power amplifier 130, so that just the proper amount of PA supply voltage is supplied to power amplifier 130.”); *id.* at 6:29-33 (“[E]fficiency may be improved by operating envelope amplifier 170 based on the Vboost voltage only when needed for large amplitude envelope and based on the Vbat voltage the remaining time, as shown in FIG. 3 and described above.”). Ex. 1303 at ¶62.

**Second**, the ’558 patent also proposes a hybrid supply generator with a particular type of switcher—one that can use an “offset” current to increase the amount of current generated by the switcher, as shown in Figure 5:



**'558 Patent – Figure 5**

See Ex. 1301 at 7:5-48. The envelope amplifier 170a (highlighted in purple) and switcher 160b (highlighted in yellow) again cooperate to provide power to PA 130 (highlighted in red). But in the embodiment of Figure 5, an offset (highlighted in

orange) is used to increase the amount of current provided to the PA.<sup>2</sup> Ex. 1303 at ¶63.

When the switcher is on, it provides a current (“I<sub>ind</sub>”) via inductor 162 (highlighted in pink). That current is joined with the current from the envelope amplifier (“I<sub>env</sub>”) to provide a combined current (“I<sub>pa</sub>”) to the PA. Ex. 1301 at 3:21-27 (“Envelope amplifier 170 ... provides a second supply current (I<sub>env</sub>) comprising high frequency components at node A. The PA supply current (I<sub>pa</sub>) provided to power amplifier 130 includes the I<sub>ind</sub> current from switcher 160 and the I<sub>env</sub> current from envelope amplifier 170.”). The offset proposed by the ’558 patent causes the switcher to remain on longer and thereby increases the amount of current that the switcher provides to the PA. Ex. 1303 at ¶64.

The switcher’s operation begins with the receipt of output current I<sub>sen</sub> from the envelope amplifier at summer 328 (outlined in brown). Ex. 1301 at 4:60-63 (“Sensor 164 passes most of the I<sub>env</sub> current to node A and provides a small sensed current (I<sub>sen</sub>) to switcher 160a. The I<sub>sen</sub> current is a small fraction of the I<sub>env</sub> current from envelope amplifier 170a.”). Summer 328 receives and adds an

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<sup>2</sup> The offset is present only in claims 15-20, which are not challenged by this Petition.

“offset” current (highlighted in orange) to the Isen current, which changes the Isen current sent to the current sense amplifier 330 (outlined in red). The current sense amplifier provides a voltage to driver 332 (outlined in fuchsia) to turn the switcher on or off. The addition of the offset changes the voltage that the current sense amplifier provides, thereby allegedly causing the switcher to remain on longer and increasing the amount of current that the switcher provides to the PA via the inductor 162. *Id.* at 7:19-21 (“[A] progressively larger offset may be used to generate a progressively larger inductor current than without the offset.”); *id.* at 7:29-30 (“An offset to increase the inductor current may be added via summer 328, as shown in FIG. 5.”). Ex. 1303 at ¶65.

The ’558 patent explains that the offset may be added “via any suitable mechanism,” Ex. 1301 at 7:29-32, and the offset’s magnitude may be determined in a variety of ways based on particular design goals, *id.* at 7:21-27 (“In one design, the offset may be a fixed value selected to provide good performance, e.g., good efficiency. In another design, the offset may be determined based on the battery voltage. For example, a progressively larger offset may be used for a progressively lower battery voltage. The offset may also be determined based on the envelope signal and/or other information.”). Ex. 1303 at ¶66.

**C. Relevant Prosecution History**

The '558 patent issued from U.S. Appl. No. 13/167,659, which was filed on June 23, 2011. The application was published on December 27, 2012 as US 2012/0326783 A1.

**1. November 23, 2012 Office Action**

The Examiner initially rejected prosecution claims 10-12 and 14-15 based on Kim, which the Examiner found disclosed a hybrid switching supply modulator with the required boost converter. Ex. 1302 at 61-64.

The Examiner explained that prosecution claims 4, 5, and 18 would be allowable if rewritten because they required certain internal components of the envelope amplifier and switcher that apparently were not disclosed in Kim: (1) an operational amplifier (op-amp) operative to receive the envelope signal and provide an amplified signal; (2) a driver operative to receive the amplified signal and provide a first control signal and a second control signal; (3) a PMOS transistor with certain characteristics; and (4) an NMOS transistor with various characteristics. *Id.* at 63-64.

The Examiner also explained that prosecution claims 22 and 23 would be allowable if rewritten because they required other elements relating to the required “offset” current that apparently were not present in Kim: (1) a summer operative to sum the input current and an offset current and provide a summed current; (2) a



current sense amplifier operative to receive the summed current and provide a sensed signal; and (3) a driver operative to receive the sensed signal and provide at least one control signal used to generate the switching signal for the inductor. *Id.*

## **2. February 19, 2013 Amendment**

In response to the initial office action, the applicant amended the claims to rewrite prosecution claims 4, 5, 18, 22, and 23 as requested. *Id.* at 79-84.

The applicant also amended prosecution claims 10, 12, and 14 to include the internal components of the envelope amplifier that the Examiner had found were not disclosed in Kim, specifically, the operational amplifier, the driver, the PMOS transistor, and the NMOS transistor. The applicant also argued that Kim did not disclose these elements. *Id.* at 81-82, 86-87.

## **3. May 10, 2013 Office Action**

In response to the applicant's amendments, the Examiner allowed the rewritten prosecution claims 4, 5, 10, 12, 14, 18, 22, and 23, which ultimately issued as patent claims 1, 3, 6, 8, 10, 12, 15, and 17. The Examiner also allowed the claims that depended from these claims, including prosecution claims 11, 15, 17, 19, 21, and 24-26, which issued as patent claims 7, 11, 13, 14, 16, and 18-20. *Id.* at 134.

**4. April 15, 2015 Patent Issuance**

After various miscellaneous prosecution actions not relevant here, the '558 patent issued on April 15, 2014. Ex. 1301 at Cover.

**5. June 27, 2017 Certificate of Correction**

In response to a request from the applicant, the Patent Office issued a Certificate of Correction to correct a “cut and paste error” that appeared in patent claim 12. Ex. 1321.

**VII. OVERVIEW OF THE PRIOR ART REFERENCES**

There is nothing inventive or non-obvious in any of the claims of the '558 patent. The references cited in this Petition disclose all of the alleged inventive elements of the '558 patent. In fact, the primary prior art reference cited here (Chu) was not before the Examiner during prosecution and discloses all the elements that the Examiner found to be missing from the prior art of record. Ex. 1303 at ¶72.

**A. Chu**

Chu is a 2008 paper that, like the '558 patent, discloses a hybrid supply generator—a linear amplifier and switcher that work together to supply an envelope-tracking supply voltage to the power amplifier. Ex. 1304 at 2809 (“A combined class-AB [linear amplifier] and switch-mode regulator based supply modulator with a master–slave architecture achieving wide bandwidth and low

ripple is presented.”). Chu discloses the miscellaneous claim elements that the Examiner found were missing in the prior art during prosecution (operational amplifier, driver, and PMOS and NMOS transistors). Ex. 1303 at ¶73.

Chu first describes a conventional power supply regulator for a PA, which tracks the envelope variations of a modulated waveform at the PA, as shown below in Figure 2:

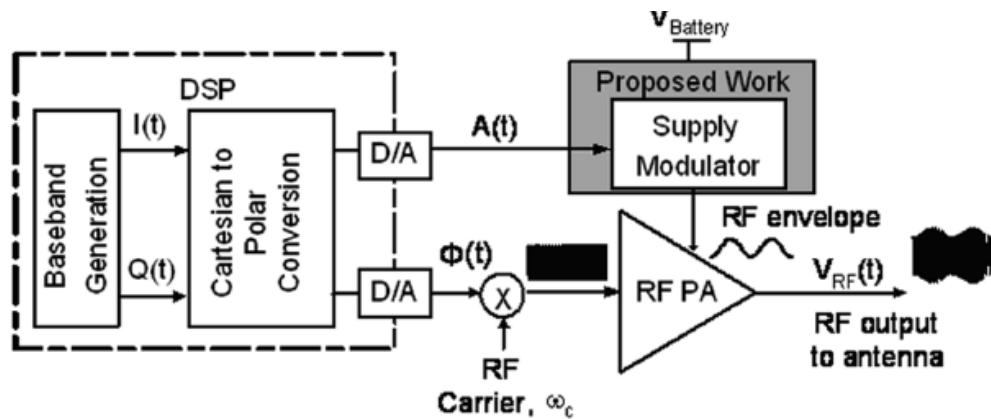


Fig. 2. Typical polar modulation based transmitter block diagram.

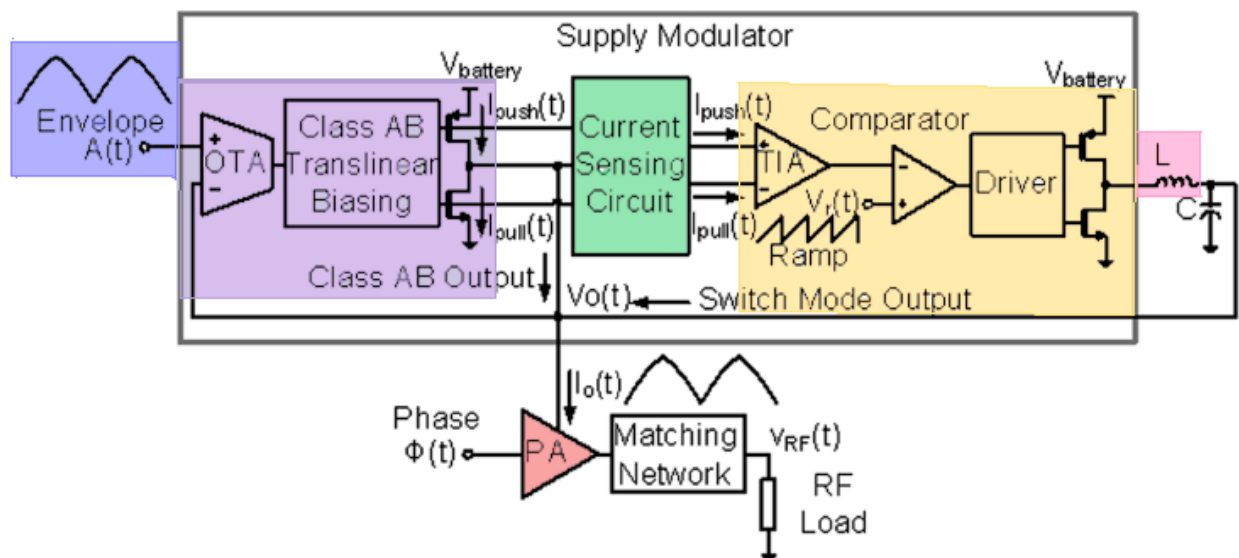
### Chu – Figure 2

Ex. 1304 at 2809 (“An envelope detector extracts the envelope waveform and this is applied as input to a wideband supply regulator, as shown in Fig. 2 [1], [2].”).

Chu identifies disadvantages of the system in Figure 2, and notes that switchers (“switch-mode supply regulators”) can be used to increase efficiency. *Id.* But Chu notes that switchers have disadvantages as well, most notably their limited operating bandwidth. *Id.* at 2809 (“Although switch-mode supply regulators boost

efficiency of the PA, their operating bandwidth is limited by the switching frequency.”). Ex. 1303 at ¶¶74-75.

Chu explains that “combined linear and switch-mode supply modulation techniques are gaining attention for RF PA supply implementations” to solve these issues. Ex. 1304 at 2809. Chu proposes such a combined “supply modulator” system, which is shown in Figure 4:

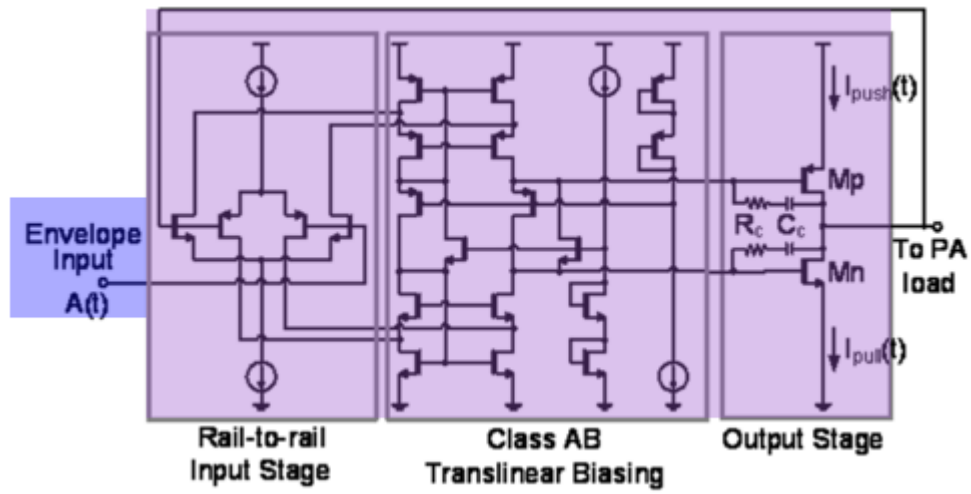


**Chu – Figure 4**

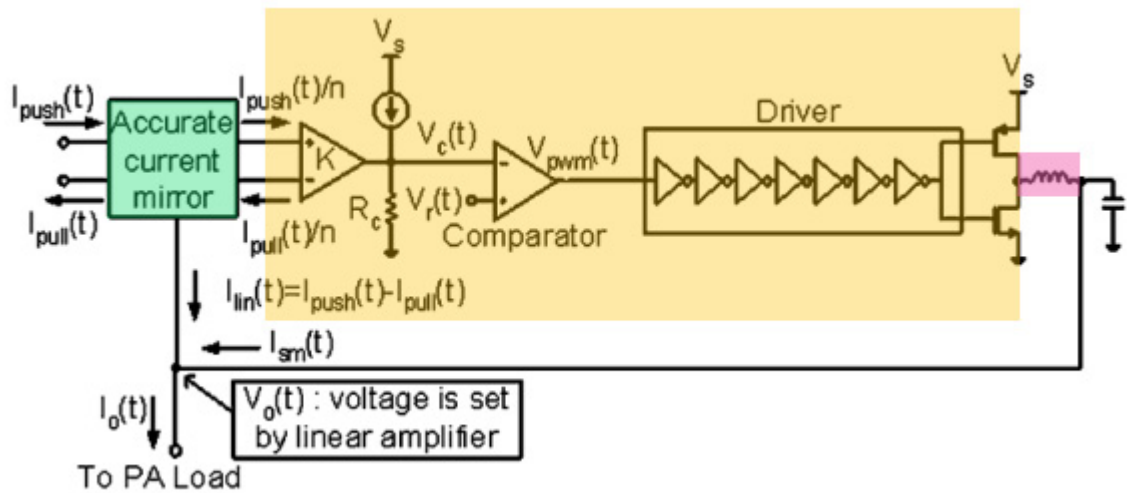
As can be seen in Figure 4, the supply modulator (a hybrid supply generator) receives an envelope signal (highlighted in blue) and provides power to a power amplifier (highlighted in red). The system includes an envelope amplifier (“high GBW [gain–bandwidth] linear amplifier” highlighted in purple) that “ensures that output node tracks the reference envelope voltage.” *Id.* at 2810. The system also

includes a switch-mode regulator or switcher (highlighted in yellow) that provides “a large portion of the load current” based on the operation of the current sensing circuit (highlighted in green). The current sensing circuit receives a current from the linear amplifier, and when the signal is within the switcher’s bandwidth, the supply modulator “suppresses the current output from the [lower efficiency] linear amplifier within the switch-mode regulator bandwidth.” *Id.* at 2810. The envelope amplifier and switcher thereby work together to provide power to the PA. *Id.* at 2811 (“At low frequencies, the linear amplifier current output is suppressed and the switch-mode regulator dominates the output current. Conversely, at high frequencies, the switch-mode regulator current response starts rolling off and the linear amplifier takes over the output current. The switch-mode regulator and linear amplifier current response combine and form a flat frequency response for the master–slave regulator.”). Ex. 1303 at ¶¶76-77.

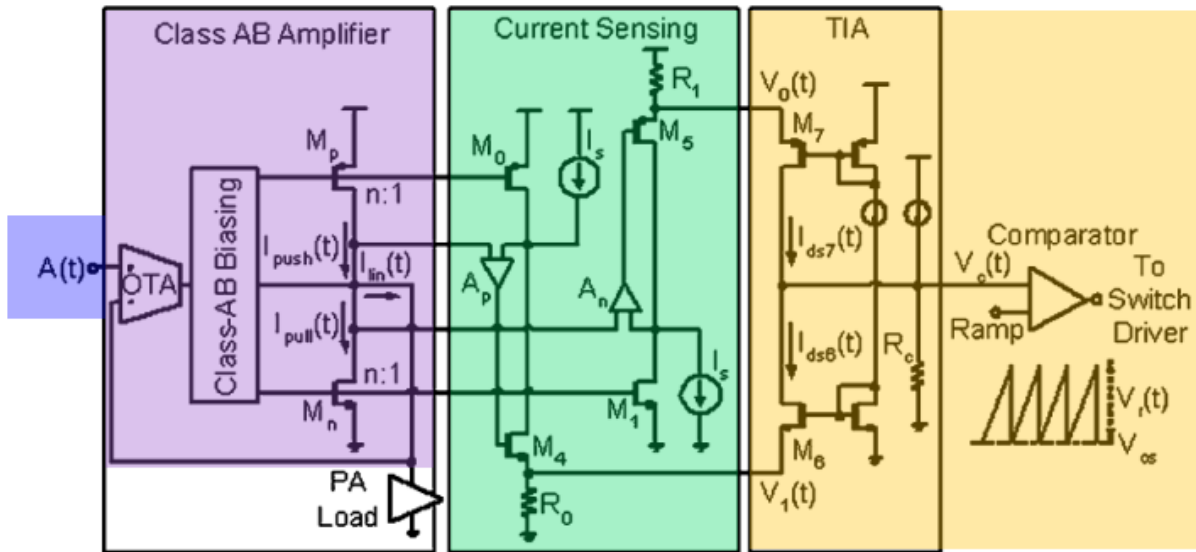
As shown in Figure 4 (and as explained in detail in the specific grounds section below), Chu discloses the internal structure of the supply generator, including the miscellaneous claim elements that the Examiner found were missing from the prior art during prosecution (operational amplifier, driver, and PMOS and NMOS transistors). Even more detailed views of Chu’s envelope amplifier, switcher, and current sensing circuit are shown in Figures 14, 15, and 16, respectively:



Chu – Figure 14



Chu – Figure 15



**Chu – Figure 16**

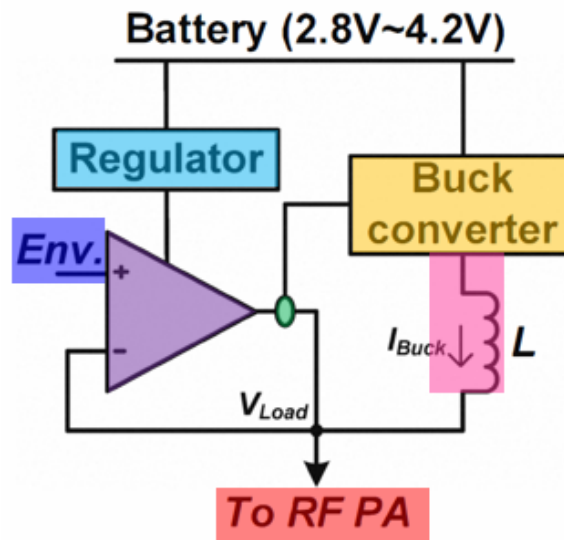
Ex. 1304 at 2814 (“A two-stage class-AB amplifier with a common-source output stage, as shown in Fig. 14, is used for the linear amplifier.”); *id.* at 2815 (“In the master–slave regulator configuration, the switch-mode regulator serves as the slave stage, as shown in Fig. 15, and is driven by the class-AB amplifier sensed output currents.”); *id.* at 2815 (“[T]he proposed accurate current sensing circuit shown in Fig. 16 ... [has] two low-loss accurate current mirrors sensing output push and pull currents  $I_{push}(t)$  and  $I_{pull}(t)$  from the class-AB amplifier.”). Ex. 1303 at ¶78.

## **B. Choi 2010**

Choi 2010 also discloses a hybrid “supply modulator” for a PA. The supply modulator of Choi 2010 includes not only an envelope amplifier and a switcher, but also a boost converter that is connected to the envelope amplifier. Ex. 1307 at

1074 (“[A] new supply modulator architecture employing a hybrid switching amplifier and a boost converter is proposed.”). Ex. 1303 at ¶79.

Figure 5 shows the Choi 2010 hybrid supply modulator and its components:



**Choi 2010 – Figure 5**

As annotated above, Figure 5 shows a purple linear amplifier (also referred to as a “low drop-out (LDO) regulator”), which is a type of envelope amplifier. This envelope amplifier works together with a buck converter (highlighted in yellow), which is a type of a switcher, to provide a supply voltage to a PA (highlighted in red). *See id.* at 1074 (“The hybrid switching amplifier (HSA) combines the advantage of the LDO [low drop-out regulator (i.e., envelope amplifier)] and buck converter [i.e., switcher] and simultaneously achieves high efficiency and linearity.”); *id.* at 1075 (“[T]he LDO [envelope amplifier] operates as an



independent voltage source with a low output impedance, while the switching buck converter [switcher] roles as a dependent current source with a high output impedance and supplies most of the current needed at the output. The current sensing unit detects the current flowing from the linear amplifier to the output and it changes the state of the switching amplifier according to the magnitude and polarity of the sensed current.”). Ex. 1303 at ¶79.

Figure 5 also shows a “regulator” (highlighted in light blue) that is a “boost converter”: the regulator is used to keep the power supply to the envelope amplifier stable and robust even when the battery is depleted. Ex. 1307 at 1074 (“A wideband envelope tracking power amplifier, which is robust to battery depletion, is introduced. An integrated boost converter keeps a stable operation of the PA supply modulator.”); *id.* at 1075 (“As the load voltage is regulated by the linear amplifier, boosting up the supply voltage of the linear amplifier results in a stable supply voltage to the RF PA regardless of the battery depletion. Thus, the additional 5V boost converter ... is coupled to the supply of the linear amplifier, while that of the switching amplifier is directly connected to the battery as illustrated in Fig. 5.”). Ex. 1303 at ¶80.

## **VIII. CLAIM CONSTRUCTION**

Claims of an unexpired patent should be construed using the broadest reasonable interpretation in light of the specification. 37 C.F.R. §42.100(b); *see*

*Cuozzo Speed Techs., LLC v. Lee*, 136 S. Ct. 2131, 2142 (2016). Should the Patent Owner, to avoid the prior art, contend that any claim term has a construction different from its broadest reasonable interpretation, the appropriate course is for the Patent Owner to seek to amend the claim to expressly correspond to its contentions in this proceeding. *See* 77 Fed. Reg. 48764 (Aug. 14, 2012).

The invalidity analysis in this Petition does not depend on whether the claims are analyzed under the broadest reasonable interpretation standard or the standard established by *Phillips v. AWH Corp.*, 415 F.3d 1303, 1312 (Fed. Cir. 2005). The claim constructions addressed below and applied in this Petition are either the correct claim construction under *Phillips* or are even narrower constructions proposed by the Patent Owner. The challenged claims are invalid under these constructions and also would be invalid under any broader construction based on the broadest reasonable interpretation standard.

**A. “envelope signal” (claim 11)**

The ITC ALJ construed “envelope signal” to mean “signal indicative of the upper bound of the output RF signal,” which is the construction proposed by Patent Owner in the ITC litigation. Petitioner applies the ALJ’s construction in this Petition. This construction is slightly narrower (and thus only more favorable to the Patent Owner here) than the construction proposed by Apple in the ITC

litigation (i.e., plain meaning or, in the alternative, “signal indicative of the upper boundary of *another* signal”). Ex. 1323 at 13-14.

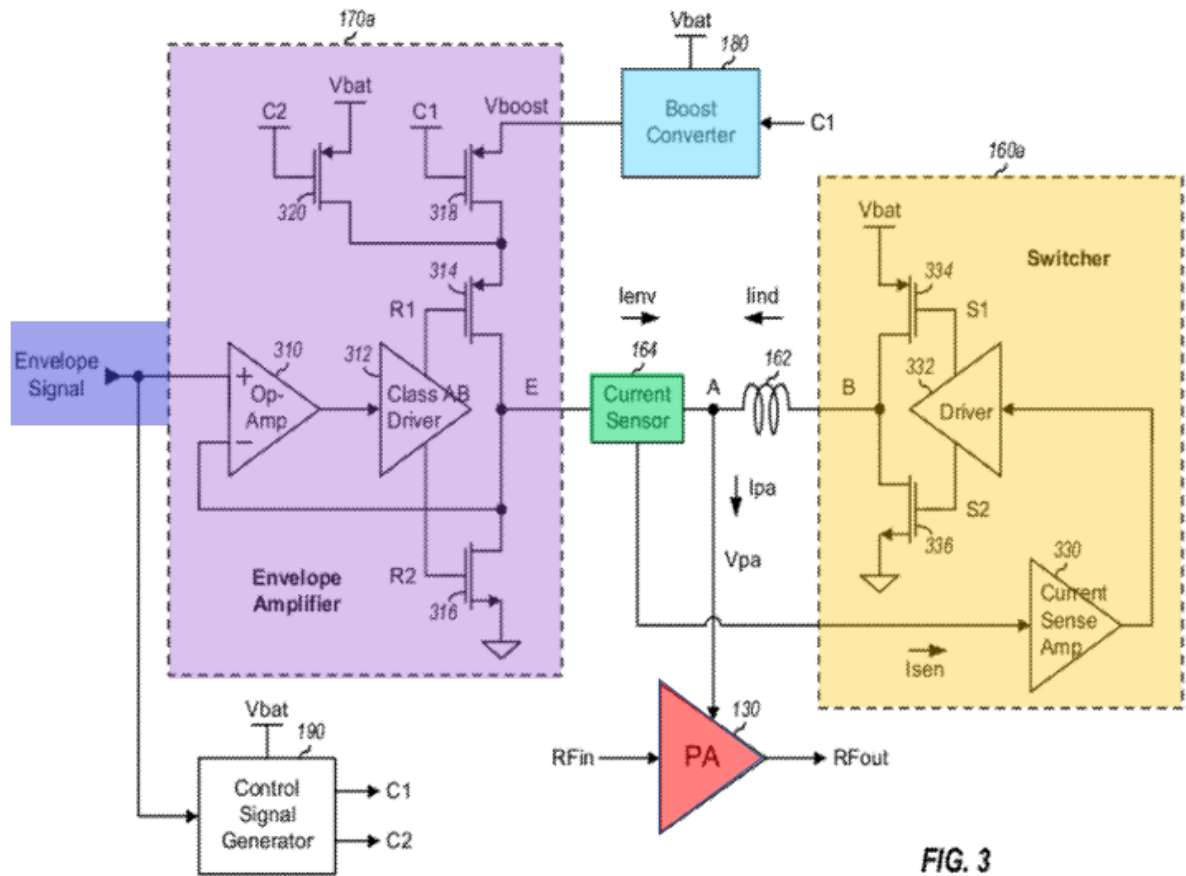
**B. “means for generating a boosted supply voltage based on a first supply voltage” (claim 10)**

This claim term is a means-plus-function limitation governed by 35 U.S.C. § 112, ¶ 6.

The claimed function in this limitation is “generating a boosted supply voltage based on a first supply voltage.” The structure that performs this function is boost converter 180, as shown in Figures 3, 5, and 6. Boost converter 180 includes (1) an inductor 612, with one end receiving Vbat and the other coupled to node D; (2) NMOS transistor 614, with its source coupled to ground, its gate receiving the Cb control signal, and its drain coupled to node D; (3) diode 616, with its anode coupled to node D and its cathode coupled to the output of the boost converter; and (4) capacitor 618, with one end coupled to ground and the other end coupled to the output of the boost converter. Ex. 1303 ¶85.

The specification describes this structure as performing the claimed function of generating a boosted supply voltage based on a first supply voltage, i.e., Vbat. The ’558 patent describes the function of “[b]oost converter 180” as “receiv[ing] the Vbat voltage and generat[ing] a boosted supply voltage (Vboost) that is higher than the Vbat voltage.” Ex. 1301 at 3:19-21; *see also id.* at 1:34-37, 7:50-8:9,

8:42-46, 9:31-34. Figure 3 shows that Vbat is the first supply voltage and is the input to boost converter 180 (highlighted in light blue):



**'558 Patent – Figure 3**

Figure 6 “shows a schematic diagram of a design of boost converter 180”:

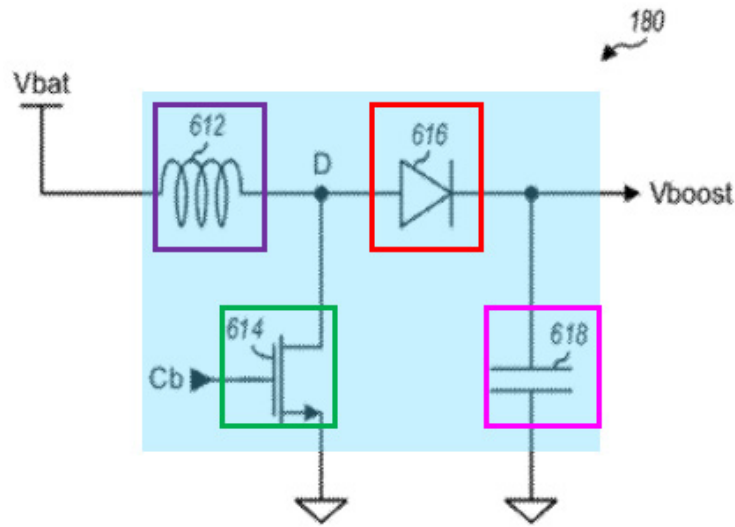


FIG. 6

**'558 Patent – Figure 6**

The patent explains that “[w]ithin boost converter 180,” “inductor 612 [outlined in purple] has one end receiving the Vbat voltage and the other end coupled to node D.” Ex. 1301 at 7:51-53. NMOS transistor 614 (outlined in green) has “its source coupled to circuit ground, its gate receiving a Cb control signal, and its drain coupled to node D.” *Id.* at 7:53-55. Diode 616 (outlined in red) has “its anode coupled to node D and its cathode coupled to the output of boost converter 180.” *Id.* at 7:55-57. Capacitor 618 (outlined in fuchsia) has “one end coupled to circuit ground and the other end coupled to the output of boost converter 180.” *Id.* at 7:57-59. Ex. 1303 ¶86.

As discussed above, boost converters were well known in the art as a means for generating a higher voltage supply long before the purported invention of the

'558 patent. No other structure for performing the claimed function is disclosed in the '558 patent. Ex. 1303 ¶87.

**C. “means for generating a second supply voltage based on the envelope signal and the boosted supply voltage” (claim 10)**

This claim term is a means-plus-function limitation governed by 35 U.S.C. § 112, ¶ 6.

The claimed function in this limitation is “generating a second supply voltage based on the envelope signal and the boosted supply voltage.” The structure that performs this function is envelope amplifier 170, as depicted in Figs. 3 and 5. The relevant portions of envelope amplifier 170 that perform the required function—generating a second supply voltage based on the envelope signal and the boosted supply voltage—are operational amplifier 310; driver amplifier 312; NMOS transistor 316 with its drain providing the second supply voltage and its source coupled to circuit ground; and PMOS transistor 314 with its source receiving the boosted supply voltage and its drain providing the second supply voltage. Ex. 1303 ¶89.

Figure 3 of the '558 patent shows, and the specification discloses, that envelope amplifier 170 receives an envelope signal (highlighted in blue) and a boosted supply voltage ( $V_{boost}$ , circled in red) and generates a second supply

voltage ( $V_{pa}$ , circled in red) based on those two inputs:

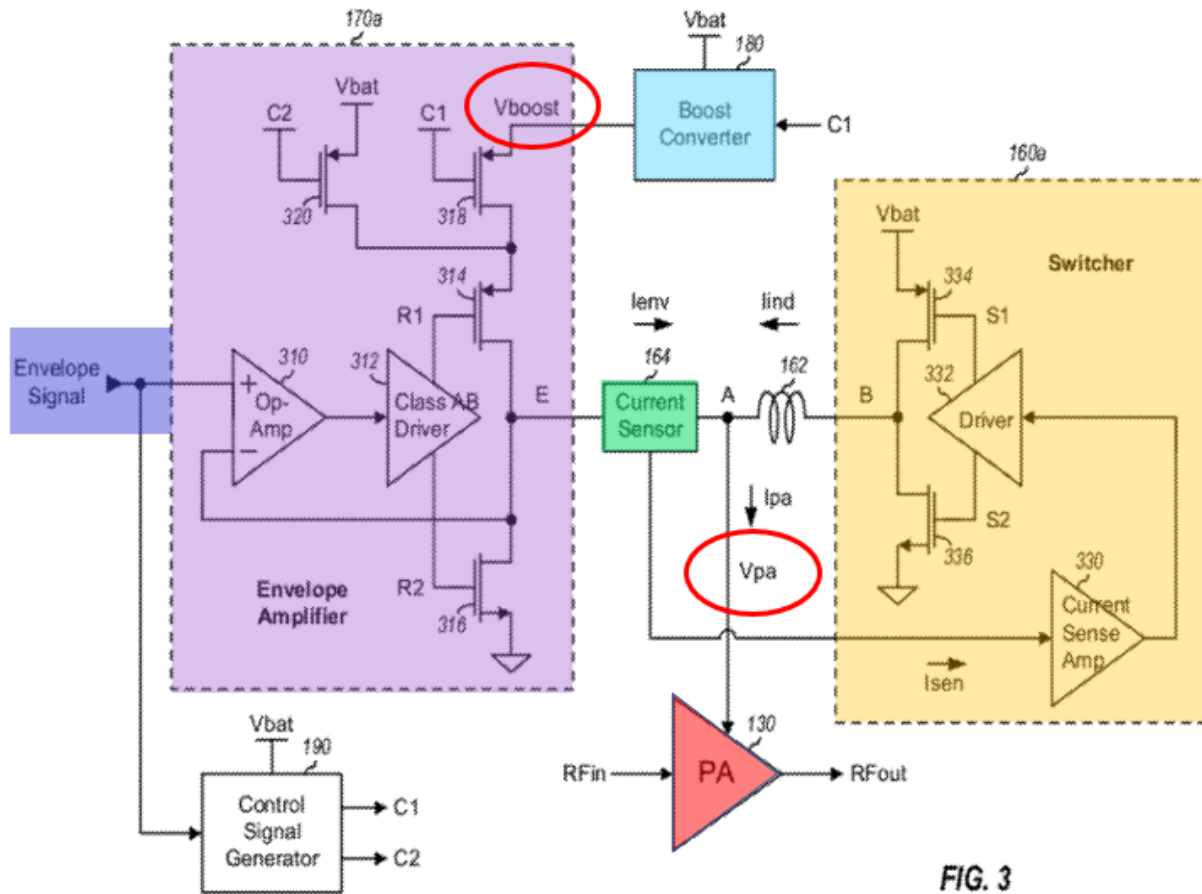


FIG. 3

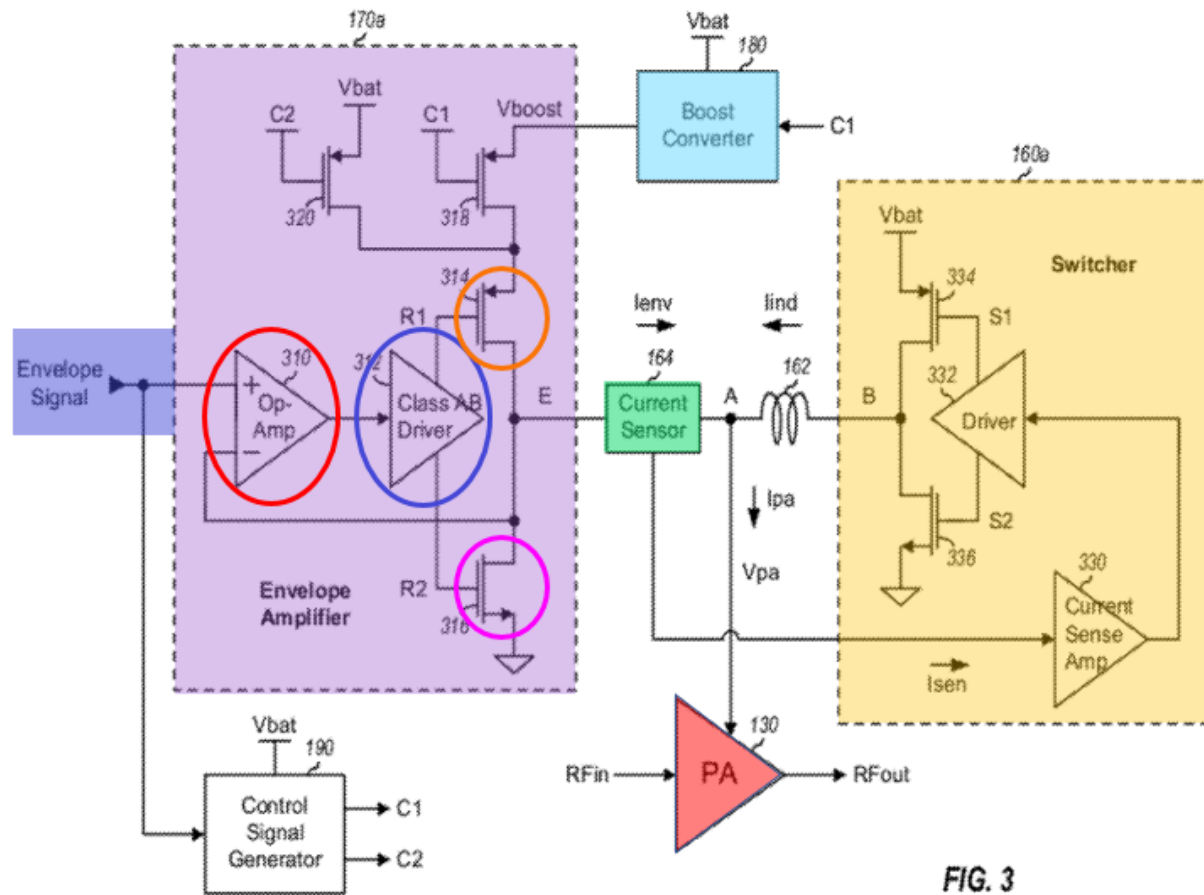
### '558 Patent – Figure 3

Ex. 1301 at Fig. 3, 3:21-29 (“Envelope amplifier 170 receives the envelope signal at its signal input, receives the  $V_{bat}$  voltage and the  $V_{boost}$  voltage at its two power supply inputs, and provides a second supply current ( $I_{env}$ ) comprising high frequency components at node A. ... Envelope amplifier 170 also provides the proper PA supply voltage ( $V_{pa}$ ) at Node A for power amplifier 130.”); *id.* at 8:46-50 (“The envelope amplifier may receive an envelope signal and the boosted

supply voltage and may generate a second supply voltage (e.g., the  $V_{pa}$  voltage in FIG. 3) based on the envelope signal and the boosted supply voltage.”); *id.* at 3:21-29; 4:39-57; 5:31-6:18; 8:46-50; 8:55-9:17; 9:24-36; 10:19-29. Ex. 1303 ¶90.

Figure 3 also shows that envelope amplifier 170a has operational amplifier 310 (circled in red), driver amplifier 312 (circled in blue), NMOS transistor 316 (circled in fuchsia) with its drain providing the second supply voltage and its source coupled to circuit ground, and PMOS transistor 314 (circled in orange) with its source receiving the boosted supply voltage and its drain providing the second supply voltage ( $V_{pa}$ ) via node E:





### '558 Patent – Figure 3

*Id.* at Fig. 3, 4:42-53. Ex. 1303 ¶¶91.

**D. “means for generating the second supply voltage based on an envelope signal and either the boosted supply voltage or the first supply voltage” (claim 11)**

This claim term is a means-plus-function limitation governed by 35 U.S.C.

§ 112, ¶ 6.

The claimed function in this limitation is “generating the second supply voltage based on an envelope signal and either the boosted supply voltage or the

first supply voltage.” Ex. 1303 ¶93. The structure that performs this function is envelope amplifier 170, as shown in Figures 3 and 5. Envelope amplifier 170 includes an operational amplifier 310; a driver amplifier 312; a first PMOS transistor 314 with its source coupled to the drains of second and third PMOS transistors 318 and 320 and its drain providing the second supply voltage; a second PMOS transistor 318 with its source receiving the boosted supply voltage; a third PMOS transistor 320 with its source receiving the first supply voltage; and an NMOS transistor 316 with its drain providing the second supply voltage and its source coupled to circuit ground. Ex. 1303 ¶93.

Figure 3 shows, and the specification discloses, that envelope amplifier 170 receives an envelope signal, a boosted supply voltage (Vboost), and a first supply voltage (Vbat), and then generates a second supply voltage based on the envelope signal and either Vboost or Vbat:

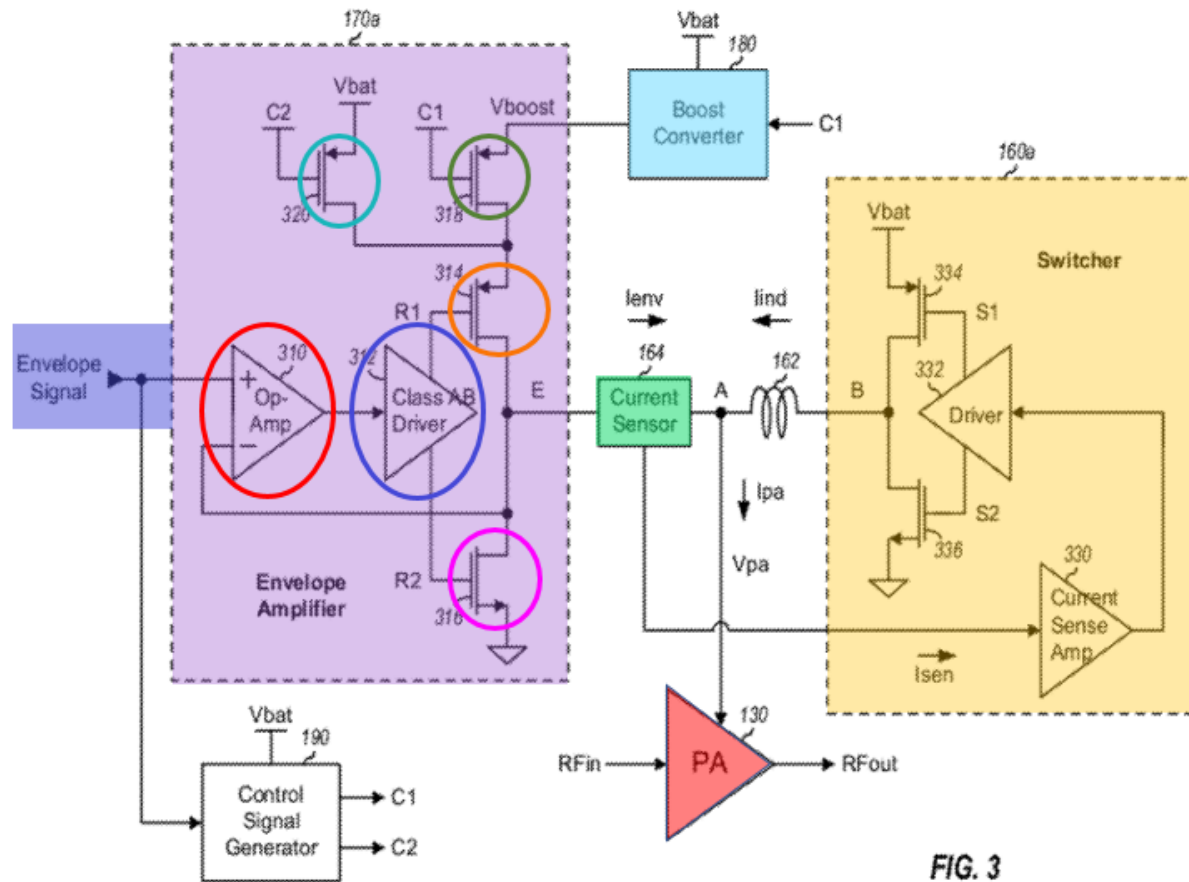


FIG. 3

### '558 Patent – Figure 3

Ex. 1301 at Fig. 3, 3:27-29 (“Envelope amplifier 170 also provides the proper PA supply voltage ( $V_{pa}$ ) at Node A for power amplifier 130.”); *id.* at 8:55-62 (“In one design, the envelope amplifier may further receive the first supply voltage and may generate the second supply voltage based on the first supply voltage or the boosted supply voltage. For example, the envelope amplifier may generate the second supply voltage (i) based on the boosted supply voltage if the envelope signal exceeds a first threshold, or if the first supply voltage is below a second threshold,

or both or (ii) based on the first supply voltage otherwise.”); *see also id.* at 1:37-46, 3:21-29; 4:39-57, 5:31-6:18, 8:46-50, 8:55-9:17, 9:24-36, 10:19-29. Ex. 1303 ¶94.

Figure 3 also shows that envelope amplifier 170a has operational amplifier 310 (circled in red), driver amplifier 312 (circled in blue), NMOS transistor 316 (circled in fuchsia) with its drain providing the second supply voltage and its source coupled to circuit ground, and PMOS transistor 314 (circled in orange) with its source coupled to the drains of PMOS transistors 318 (circled in green) and 320 (circled in teal), so that it can receive either the first supply voltage from PMOS transistor 320 or the boosted supply voltage from PMOS transistor 318, and its drain providing the second supply voltage ( $V_{pa}$ ) via node E. *Id.* at Fig. 3, 4:42-57. Ex. 1303 ¶95.

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

A person of ordinary skill in the art (“POSA”) would have had, at the time the ’558 patent was filed in June 2011: a Master’s degree in Electrical Engineering, Computer Engineering, or Computer Science plus at least two years of relevant experience, or a Bachelor’s degree in one of those fields plus at least four years of relevant experience. “Relevant experience,” in the context of the asserted patent, refers to experience with mobile device architecture as well as transmission and power circuitry for radio frequency devices. *See* ’558 patent (Ex. 1301) at Abstract at 1:7-9, 30-31 (“Techniques for efficiently generating a power

supply for a power amplifier and/or other circuits are described herein.”). Ex.

1303 ¶¶96-97.

## **X. SPECIFIC GROUNDS FOR PETITION**

Pursuant to Rule 42.104(b)(4)-(5), the following sections (as confirmed in Dr. Apsel’s declaration, Ex. 1303 ¶¶98-148) demonstrate in detail how the prior art discloses each and every limitation of claims 10 and 11 of the ’558 patent, and how those claims are therefore anticipated and/or rendered obvious by the prior art. To summarize:

Claim 10 requires a supply generator that can generate a boosted supply voltage and generate a second supply voltage based on an envelope signal and the boosted supply voltage. As explained above, the Examiner found that Kim disclosed the required boost converter but not the detailed limitations that the applicant added regarding the envelope amplifier that produces the second supply voltage. The boost converter is also disclosed by Choi 2010 and Hanington (which Choi 2010 cites), and Chu discloses the details of the envelope amplifier. This claim would have been obvious over Chu combined with Choi 2010 and Hanington (Ground I).

Dependent claim 11 further requires the supply generator to be able to select between the boosted supply voltage and a first supply voltage. The concepts of using a boosted voltage and being able to select between two power sources were

basic, well-known concepts disclosed by Choi 2010, Hanington, and Myers. This claim would have been obvious over Chu combined with Choi 2010, Hanington, and Myers (Ground II).

**A. Ground I: Claim 10 is obvious in view of Chu combined with Choi 2010 and Hanington**

**1. Claim 10**

Claim 10 is obvious in view of Chu combined with Choi 2010 and Hanington, as explained below. Ex. 1303 ¶¶99, 131.

**(a) “An apparatus for generating supply voltages, comprising:”**

Chu in combination with Choi 2010 discloses a supply modulator and a power amplifier—i.e., “an apparatus.” Ex. 1304 at 2811 (“Fig. 4 shows the block diagram of the proposed master–slave linear and switch-mode combined supply modulator loaded with a PA.”). Ex. 1303 at ¶100. As discussed in limitations 10(b) and 10(c), Chu combined with Choi 2010 discloses an apparatus for generating a boosted supply voltage and a second supply voltage. Ex. 1303 ¶100.

**(b) “means for generating a boosted supply voltage based on a first supply voltage, the boosted supply voltage having a higher voltage than the first supply voltage; and”**

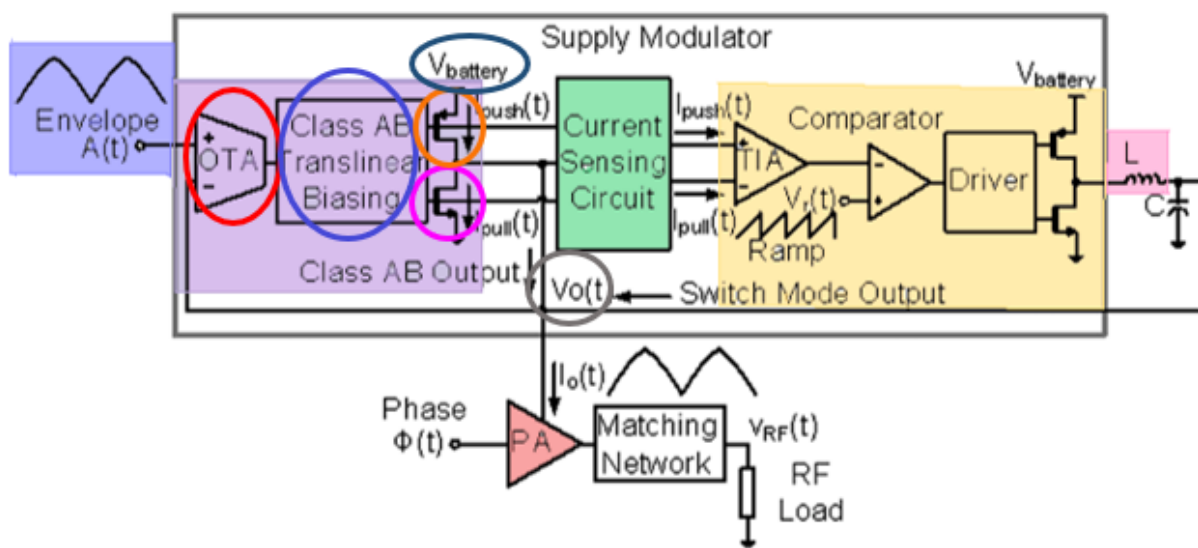
Chu combined with Choi 2010 and Hanington discloses this limitation. As explained above in Section VIII.B, the function of this means-plus-function limitation is “generating a boosted supply voltage based on a first supply voltage,

the boosted supply voltage having a higher voltage than the first supply voltage.”

The structure is boost converter 180, which includes an inductor 612 with one end receiving  $V_{bat}$  and the other coupled to node D; NMOS transistor 614 with its source coupled to ground, its gate receiving the  $C_b$  control signal, and its drain coupled to node D; diode 616 with its anode coupled to node D and its cathode coupled to the output of the boost converter; and capacitor 618 with one end coupled to ground and the other end coupled to the output of the boost converter.

Ex. 1303 ¶101.

Chu as modified by Choi 2010 and Hanington comprises a structure that is equivalent (and nearly identical) to the structure required by the claim. Ex. 1303 ¶102. Chu discloses a “supply generator” (the “Supply Modulator”) as shown in Figure 4 below.



Chu – Figure 4

Ex. 1304 at Figure 4. The supply generator receives “an envelope signal” ( $A(t)$ , highlighted in blue at the left) and a “first supply voltage” ( $V_{\text{battery}}$  circled in dark blue at the top). Chu generates an output supply voltage ( $V_O(t)$  circled in gray) for the PA (highlighted in red) based on the envelope signal and  $V_{\text{battery}}$ . *Id.* at 2810 (“Fig. 4 shows the block diagram of the proposed master–slave linear and switch-mode combined supply modulator loaded with a PA. A high GBW linear amplifier in voltage follower configuration ensures that output node  $V_O(t)$  tracks the reference envelope voltage  $A(t)$ .”). Ex. 1303 at ¶102.

Choi 2010 (like Chu) discloses a supply generator (“supply modulator”) for a PA, and Choi 2010’s supply generator (like Chu’s) includes an envelope amplifier (highlighted in purple) that receives an envelope signal Env:

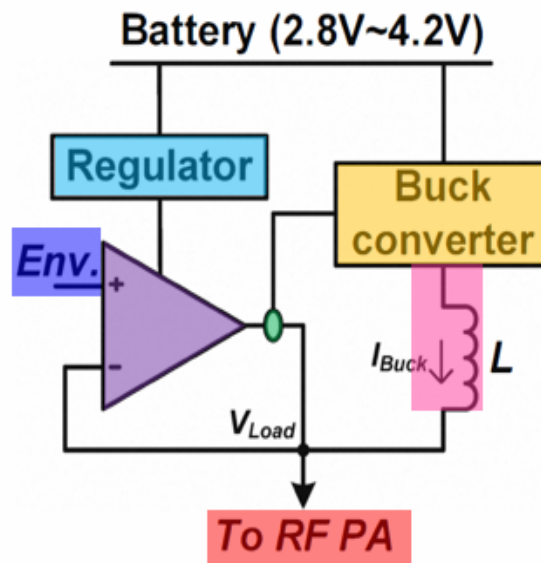


Fig. 5. Battery-to-5V boosting PA supply modulator.

## Choi 2010 – Figure 5



Ex. 1307 at Figure 5. The boost converter in Choi performs the identical function of this limitation: the supply modulator receives a first supply voltage (“Battery (2.8V-4.2V)”) and employs a boost converter (“Regulator,” highlighted in blue) to generate a boosted supply voltage greater than the first supply voltage. *Id.* at 1074 (“To prevent the degradation of the output power, a boost converter, whose output voltage is always higher than the input voltage, can be utilized.”), 1075 (“Thus, the additional 5V boost converter, whose input range is from 2.8V to 4.2V, is coupled to the supply of the linear amplifier ... as illustrated in Fig. 5. . . As the supply voltage of the modulator is boosted up to the 5V, considering the 0.5V drop across the modulator, the PA now operates with 4.5V supply voltage.”). Ex. 1303 at ¶103.

Boost converters were standard components well known in the field at the time of the '558 patent. It would have been obvious to a POSA to implement the Choi 2010 boost converter using the design of the boost converter disclosed in Hanington, which Choi 2010 notes “can be utilized” to “prevent the degradation of the output power.” Ex. 1307 at 1074. The Hanington boost converter has the same basic structure as the boost converter disclosed in the '558 patent, as shown below:

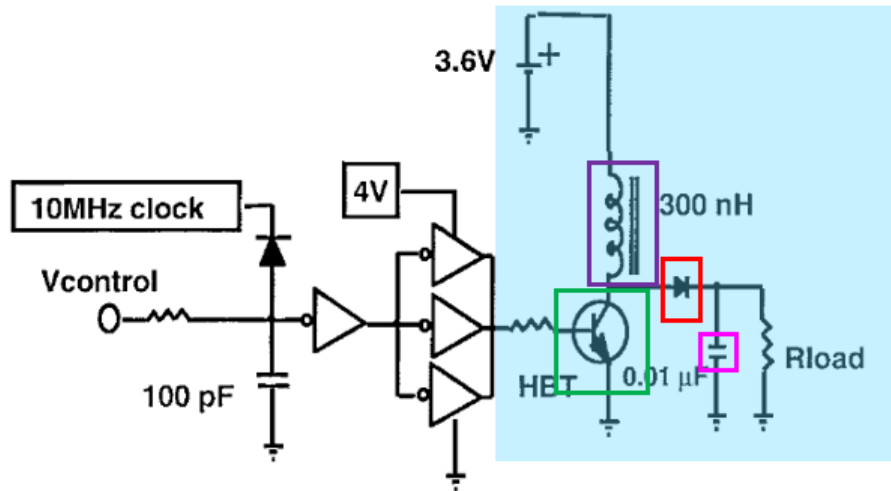


Fig. 5. Schematic diagram of boost converter with driver.

### Hanington – Figure 5

Ex. 1325 at 1473, Figure 5.

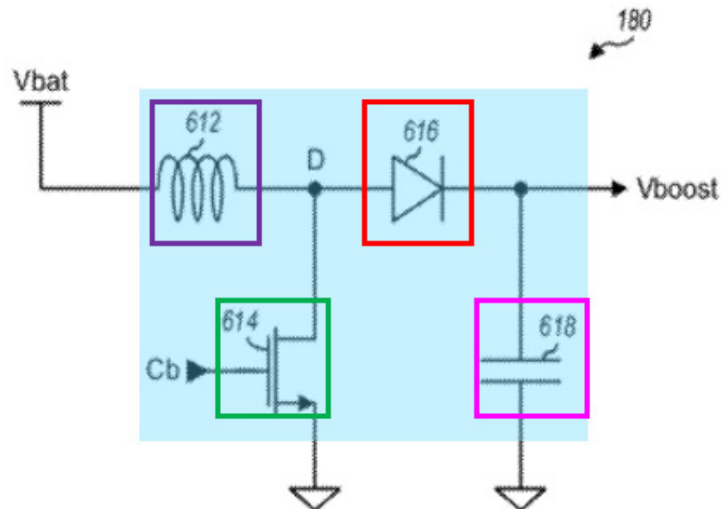


FIG. 6

### '558 Patent – Figure 6

Ex. 1301 at Fig. 6; Ex. 1303 at ¶104.

Like the '558 patent, the boost converter of Hanington has: an inductor (outlined in purple) coupled between the battery and a node and that stores energy and releases it; a transistor (outlined in green) with its gate coupled to a control signal  $V_{\text{control}}$ , its source connected to ground, and its drain connected to the same node as the inductor; a diode (outlined in red) coupled to the node and to the output of the boost converter; and a capacitor (outlined in fuchsia) coupled to ground and the output of the boost converter. Ex. 1325 at Fig. 5. Like the boost converter in the '558 patent, the inductor stores energy when the transistor is closed, and transfers that energy to the capacitor and the load of the output when the transistor opens, resulting in an output voltage that is greater than the battery voltage. *Id.* at 1473 (“The boost or ringing-choke converter used is schematically shown in Fig. 5. Here, energy is stored in a magnetic field during the on-time of the switch. During the off-time, this energy is released and used to charge the output capacitor to the peak of the ring voltage and provide energy to the load.”); *id.* (“[A]s the input voltage drops, due to battery depletion, the required high-voltage level can still be maintained, even as the battery is running toward exhaustion.”); *see also* Ex. 1301 at 7:60-66 (“Boost converter 180 operates as follows. In an On state, NMOS transistor 614 is closed, inductor 612 is coupled between the  $V_{\text{bat}}$  voltage and circuit ground, and the current via inductor 612 increases. In an Off state, NMOS transistor 614 is opened, and the current from

inductor 612 flows via diode 616 to capacitor 618 and a load at the output of boost converter 180 (not shown in FIG. 6).”). Although Hanington uses a heterojunction bipolar transistor for the switch rather than a MOSFET, the structure of the boost converter in Hanington is otherwise identical to that described in the ’558 patent. and could have been substituted without modification for the ’558 patent structure. Ex. 1303 at ¶105.

Hanington’s boost converter (as implemented in Chu combined with Choi 2010) would be equivalent to boost converter 180 of the ’558 patent. It would operate in the same, standard way to achieve substantially the same result as the ’558 patent’s boost converter: it would be positioned in the same relative location as boost converter 180 (between the battery voltage and the envelope amplifier), and it would transform a battery voltage into a higher voltage for the envelope amplifier. Ex. 1303 at ¶106.

**(i) Motivation to Combine Chu with Choi 2010 and Hanington**

It would have been obvious to modify Chu to incorporate the boost converter of Choi 2010 and Hanington. All three references are from the same field of endeavor and disclose supply modulators for PAs. Moreover, Choi 2010 cites Chu as prior art that Choi 2010’s apparatus builds upon (Ex. 1307 at 1074, 1077 (reference [7])), and Choi 2010 cites Hanington as disclosing a boost

converter that “can be utilized” to “prevent the degradation of the output power” (Ex. 1307 at 104). Ex. 1303 at ¶107.

A POSA would have been motivated to use a boost converter in conjunction with the Chu architecture to prevent distortion as the battery becomes depleted and the voltage provided by the battery falls. Specifically, it would have been desirable to operate Chu’s linear amplifier with a boosted voltage so that (1) when the battery voltage starts depleting, Chu’s linear amplifier is more robust, and/or (2) when the battery voltage is lower than the peak voltage magnitude of the amplified reference envelope voltage  $A(t)$ , distortion of the amplified reference envelope voltage is prevented. These advantages are specifically taught by Choi 2010, and would have motivated a POSA to modify Chu accordingly. *See* Ex. 1307 at 1074 (“An integrated boost converter keeps a stable operation of the PA supply modulator. Even at the battery depletion from 4.2V to 2.8V, there is no significant degradation of output power and linearity in the power amplifier.”); *id.* (“By boosting up the supply voltage of the linear amplifier to 5V regardless of the battery voltage variation, ...the supply modulator dynamically regulates the PA with the peak voltage of 4.5V.”); *id.* at 1077 (“For the additional boost converter, the proposed supply modulator presents the robust performance over the battery voltage variation while the efficiency degradation is minimized.”). Ex. 1303 at ¶108.

Using a boost converter to power a PA to prevent distortion of the amplified signal was also common and well known in the prior art. The Maehara patent, for example, taught using a boost converter (“step-up converter”) in an amplifying circuit to prevent distortion. *See* Ex. 1318 at Abstract (“An amplifying circuit according to the present invention has an amplifying unit for amplifying an input signal to produce an amplified signal, a battery for generating a constant voltage (a first voltage), ***a step-up converter for always generating an increased voltage*** (or a second voltage) by increasing the constant voltage .... [B]ecause the increased voltage is always generated by the step-up converter ... ***any distortion of the amplified signal can be prevented.***”).<sup>3</sup> Similarly, a 2008 datasheet for a Maxim amplifier taught using a boost converter to extend battery life and maintain output levels when the battery voltage drops. Ex. 1315 [MAX9738 –16VP-P Class G Amplifier with Inverting Boost Converter Datasheet (March 2008) (“Maxim”)] at 8 (“The MAX9738 Class G power amplifier with inverting boost converter is the latest in linear amplifier technology. The Class G output stage offers improved performance over a Class AB amplifier while increasing efficiency to extend battery life. The integrated inverting boost converter generates a negative supply

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<sup>3</sup> All emphasis has been added, except where otherwise noted.

capable of delivering up to 400mA. The negative supply is only used when the output signal requires a larger supply voltage differential. As the battery voltage drops, the boost converter output becomes more negative to maintain amplifier output swing all the way down to  $V_{BAT} = 2.7V$ .”). Ex. 1303 at ¶¶109-111.

Maehara and Maxim are examples of references that would have further confirmed for a POSA the advantages of modifying Chu’s supply modulator to incorporate the boost converter of Choi 2010. Because a boost converter had been used to improve numerous similar devices, a POSA would have recognized that the results of incorporating a boost converter such as Choi 2010’s boost converter into Chu’s supply modulator were entirely predictable and would improve Chu’s supply modulator. Ex. 1303 at ¶110.

A POSA also would have been motivated to use the specific boost converter design disclosed in Hanington. Choi 2010 cites Hanington as a boost converter that “can be utilized” in its proposed envelope tracking power amplifier. Ex. 1307 at 104. As discussed above (*see* Section V.B.4), the components used in Hanington were typical, well-known components widely used in boost converters. Ex. 1303 at ¶112.

Finally, adding the boost converter disclosed in Choi 2010 and Hanington to Chu’s supply generator would have yielded only expected, predictable results. Combining the teachings of Choi 2010 with Chu and Hanington would have been:

(a) a combination of prior-art elements according to known methods to yield predictable results, because a POSA would have understood, for example, the effect on the output of an envelope amplifier from modifying that amplifier to receive a boosted supply voltage; (b) a simple substitution of one known element (a boosted supply or a combination of a boosted supply and battery voltage) for another (a battery supply) to obtain predictable results; (c) a use of a known technique (operating an envelope amplifier with a boosted power supply with the components disclosed in Hanington) to improve a similar device (Chu’s envelope amplifier) in the same way disclosed by Choi 2010; (d) an application of a known technique (providing a boosted voltage) to a known device (Chu’s envelope amplifier) that was ready for improvement to yield predictable results; and (e) obvious to try—a choice of different envelope trackers, from a finite number of identified, predictable solutions, with a reasonable expectation of success. Ex. 1303 at ¶113.

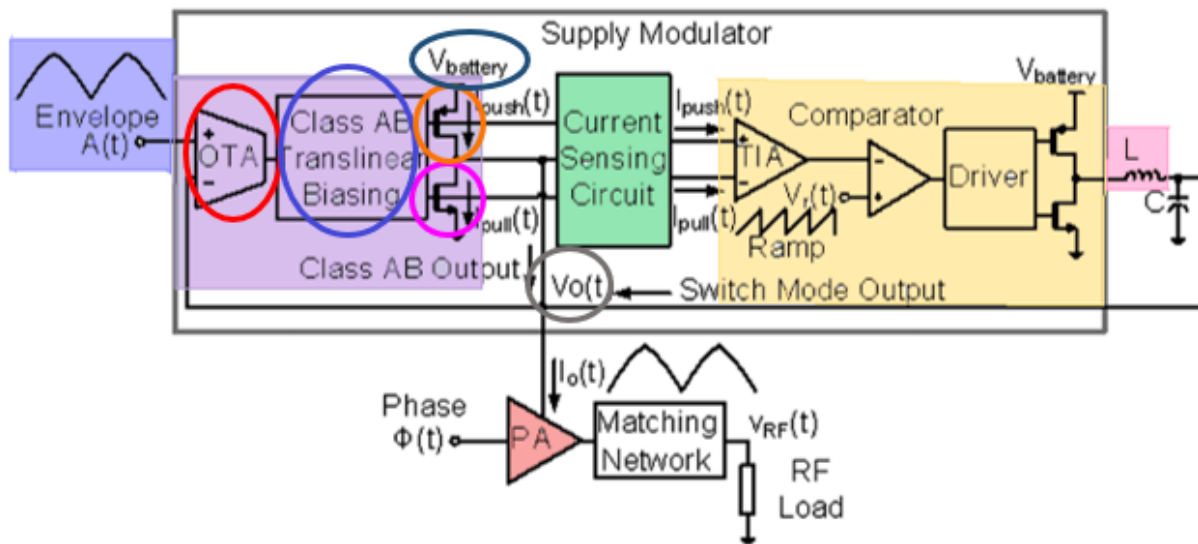
**(c) “means for generating a second supply voltage based on the envelope signal and the boosted supply voltage,”**

Chu in combination with Choi 2010 discloses this limitation. As explained above in Section VIII.C, the function of this means-plus-function limitation is “generating a second supply voltage based on the envelope signal and the boosted supply voltage.” The structure must be identical or equivalent to envelope



amplifier 170, including an operational amplifier 310; a driver amplifier 312; an NMOS transistor 316 with a drain providing the second supply voltage and its source coupled to circuit ground; and one PMOS transistor 314 with its source receiving the boosted supply voltage and its drain providing the second supply voltage. Ex. 1303 at ¶114.

Chu in combination with Choi 2010 discloses an envelope amplifier that performs the required function. Chu discloses a supply generator (“Supply Modulator”) containing an envelope amplifier (highlighted in purple):



### Chu – Figure 4

The supply generator receives envelope signal  $A(t)$  and a supply voltage ( $V_{\text{battery}}$  above the orange circled transistor). Chu generates an output supply voltage ( $V_{\text{O}}(t)$  circled in gray) for the PA (highlighted in red) based on the envelope signal and  $V_{\text{battery}}$ . Ex 1304 at 2811 (“Fig. 4 shows the block diagram of the proposed master–

slave linear and switch-mode combined supply modulator loaded with a PA. A high GBW linear amplifier in voltage follower configuration ensures that output node  $V_O(t)$  tracks the reference envelope voltage  $A(t)$ .”). Ex. 1303 at ¶115.

The envelope amplifier in Choi 2010 (highlighted in purple) likewise generates a supply voltage ( $V_{Load}$ ) based on the envelope signal and the boosted supply voltage, and provides the second supply voltage to the PA. Ex. 1307 at 1075 (“[T]he additional 5V boost converter, whose input range is from 2.8V to 4.2V, is coupled to the supply of the linear amplifier ... as illustrated in Fig. 5; *id.* (“By boosting up the supply voltage of the linear amplifier to 5V regardless of the battery voltage variation, ...the supply modulator dynamically regulates the PA with the peak voltage of 4.5V.”). Ex. 1303 at ¶116.

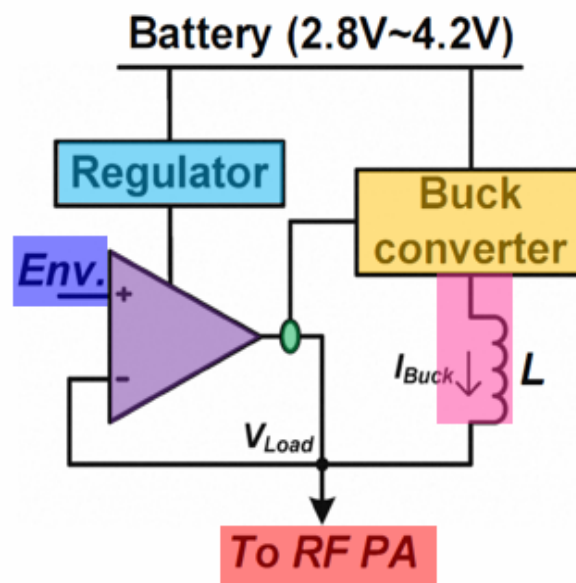
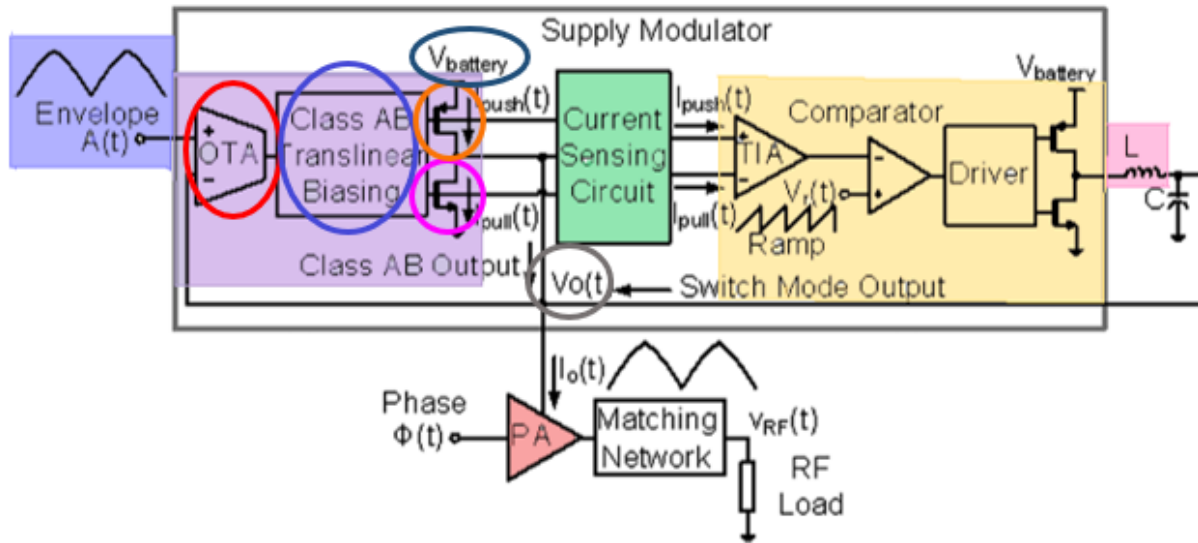


Fig. 5. Battery-to-5V boosting PA supply modulator.

**Choi 2010 – Figure 5**

As explained above regarding limitation 10(b), it would have been obvious to modify Chu's envelope amplifier to add a boost converter such as that described in Choi 2010 so that the envelope amplifier received a boosted supply voltage from a boost converter. *See* Section X.A.1(b). Such an envelope amplifier would perform the claimed function of generating a second supply voltage based on the envelope signal and the boosted supply voltage (rather than the battery voltage). Ex. 1303 at ¶117.

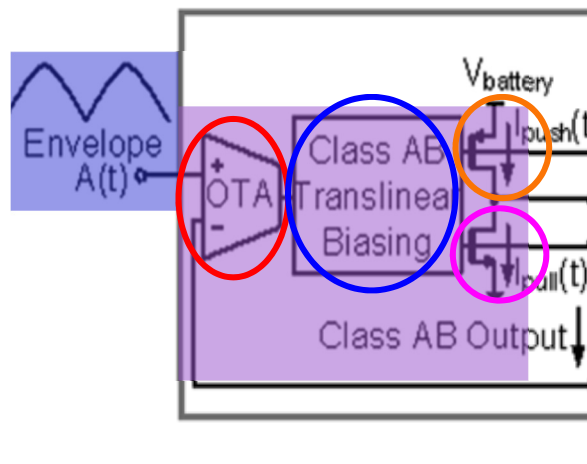
The structure of Chu's envelope amplifier as modified in view of Choi 2010 would also be identical or, at a minimum, equivalent to the relevant structures within envelope amplifier 170 in the '558 patent. First, as shown below, Chu's "supply generator" ("Supply Modulator") includes an envelope amplifier (highlighted below in purple). The envelope amplifier includes an "operational amplifier" (OTA, circled below in red) that receives the envelope signal ( $A(t)$ , highlighted in blue) and provides an amplified signal to the Class AB Translinear Biasing circuitry (circled in blue):



**Chu – Figure 4**

Ex. 1304 at 2811, Figure 4. OTA stands for “*operational* transconductance *amplifier*,” which is a type of operational amplifier. An operational amplifier (or op-amp) has two inputs and one output and behaves like a high-gain difference amplifier—amplifying the difference between two input voltages and producing an output current. Ex. 1303 at ¶118.

Second, Chu’s envelope amplifier includes a driver (“Class AB Translinear Biasing” circuit, circled in blue), which corresponds to Class AB driver 312 in the ’558 patent:



Ex. 1304 at 2811, Figure 4. The Class AB Translinear Biasing circuitry receives the amplified signal from the operational amplifier (OTA). Ex. 1303 at ¶119.

Fourth, as explained further below in Section X.A.1(f), Chu's envelope amplifier includes a PMOS transistor (circled in orange) with its source (the top terminal) receiving the first supply voltage ( $V_{\text{battery}}$ ), and its drain (the bottom terminal) providing the second supply voltage. As modified by Choi 2010, this PMOS transistor would be connected to the boosted supply voltage supplied by the Choi 2010 boost converter. Ex. 1303 at ¶121.

The structure of Chu's envelope amplifier as modified in view of Choi 2010 would thus be identical or, at a minimum, equivalent to the envelope amplifier 170 in the '558 patent and its components. The modified Chu envelope amplifier would perform the same function in substantially the same way to achieve substantially the same result: it would receive an envelope signal that is then processed by an operational amplifier and a driver, and based on the envelope signal and a boosted supply voltage received from a boost converter, it would generate a new voltage for powering a PA. Ex. 1303 at ¶122.

- (d) **“wherein the means for generating the second supply voltage incorporates an envelope amplifier that produces the second supply voltage using an operational amplifier (op-amp) that receives the envelope signal and provides an amplified signal,”**

Chu discloses this limitation. As explained above regarding limitation 10(c) and shown in Figure 4, Chu discloses an envelope amplifier that generates the second supply voltage using an operational amplifier that receives the envelope signal. *See* Section X.A.1(c). The operational amplifier provides an amplified signal. Ex. 1303 at ¶123.

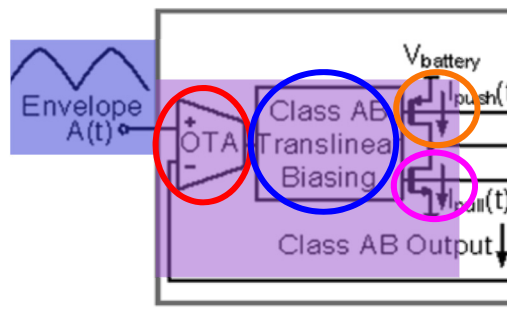
- (e) **“a driver that receives the amplified signal and provides a first control signal and a second control signal,”**

Chu discloses this limitation. As described above regarding limitation 10(c), Chu discloses an envelope amplifier that includes a driver (“Class AB Translinear

Biassing” circuit, circled in blue) that receives the amplified signal from the operational amplifier (OTA). *See* Section X.A.1(c). The driver, in turn, provides two signals that control two transistors coupled to the driver. Ex. 1303 at ¶124.

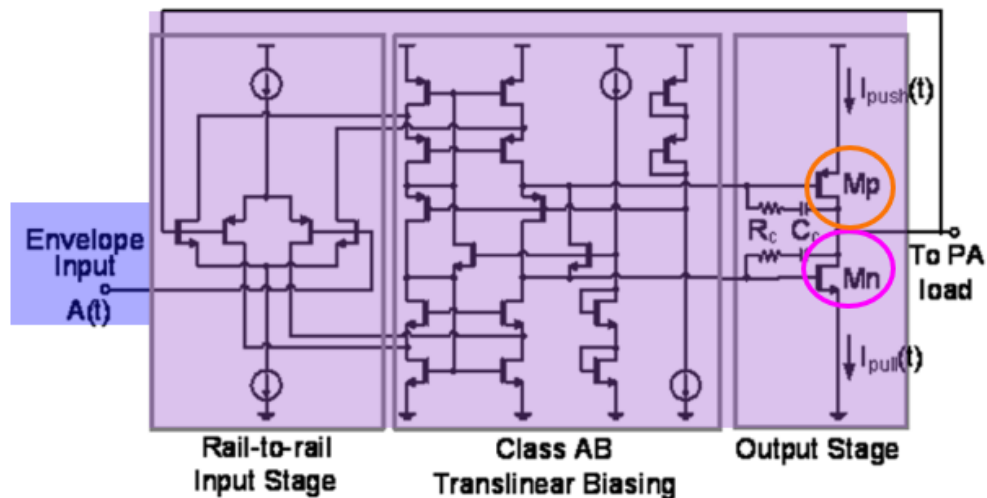
- (f) **“a P-channel metal oxide semiconductor (PMOS) transistor that receives the first control signal, a source that receives the boosted supply voltage or the first supply voltage, and a drain providing the second supply voltage and”**

Chu as modified by Choi 2010 discloses this limitation. As shown below, Figure 4 of Chu discloses a supply generator (“Supply Modulator”) that includes a PMOS transistor (circled below in orange) that receives the first control signal from the driver (the Class AB Translinear Biasing circuitry):



**Chu – Figure 4**

Ex. 1304 at 2811, Figure 4. This same transistor is labeled Mp in Figure 14 below; the “p” stands for PMOS. *Id* at 2814 Figure 14:



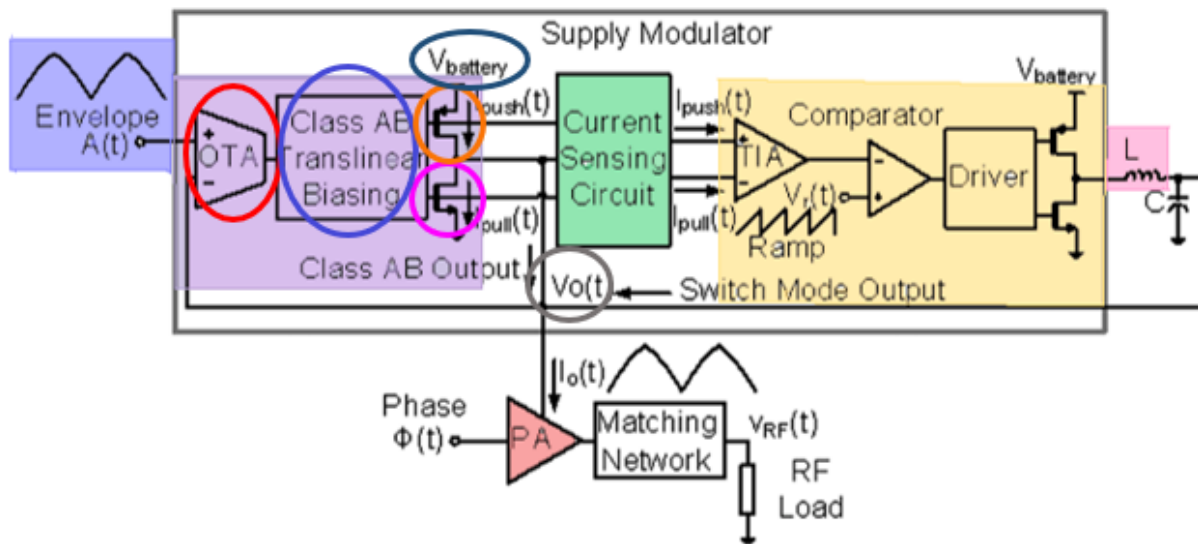
**Chu – Figure 14**

The transistor is shown in Figure 4 with the common symbol for PMOS transistors, with the arrow pointing into the transistor, as also can be seen in Figure 3 of the '558 patent. Ex. 1303 at ¶125.

This PMOS transistor also has a source (the higher terminal on the drawing of the PMOS transistor) that receives the first supply voltage ( $V_{battery}$ ) from the battery. As explained above regarding limitation 10(b), Choi 2010 discloses the use of a boost converter to generate a boosted supply voltage that can be supplied to the envelope amplifier instead of a battery voltage, and it would have been obvious to modify Chu to incorporate Choi 2010's boost converter. As modified by Choi 2010, the source of Chu's PMOS transistor "receiv[es] the boosted supply voltage," as required by this limitation. Ex. 1303 at ¶126.



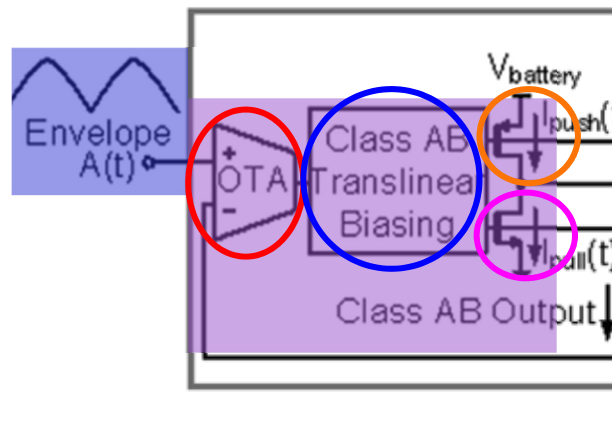
Finally, the drain of the PMOS transistor circled in the excerpt of Figure 4 above and the full Figure 4 below (the lower terminal on the PMOS transistor) provides the second supply voltage ( $V_O(t)$ ) to the PA. Figure 4 shows that the drain of the PMOS transistor is connected directly to the output node  $V_O(t)$  (circled below in gray) from the envelope amplifier to the PA, and the drain and output node therefore will have the same voltage ( $V_O(t)$ ). Ex. 1304 at 2810 (“output node  $V_O(t)$ ”); *id.* at Fig. 15 (“ $V_O(t)$ : voltage is set by linear amplifier”). Ex. 1303 at ¶127.



Chu – Figure 4

- (g) “an N-channel metal oxide semiconductor (NMOS) transistor that receives the second control signal at a gate and provides a second supply voltage through a drain, and a source for circuit grounding.”

Chu discloses this limitation. Chu discloses a supply generator (“Supply Modulator”) comprising an NMOS transistor, as shown below in Figure 4 (circled below in fuchsia):



**Chu – Figure 4**

Ex. 1304 at 2811, Figure 4. This same transistor is labeled  $M_n$  in Figure 14, where the “n” stands for NMOS. Also, the transistor is shown in Figure 4 with the common symbol for NMOS transistors, with the arrow pointing out of the transistor. Ex. 1303 at ¶128.

The NMOS transistor has a gate that receives the second control signal from the Class AB Translinear Biasing circuitry. The NMOS transistor also has a drain (the higher terminal on the drawing of the NMOS transistor) that provides the

second supply voltage ( $V_O(t)$ ) to the PA: the node between the two transistors is connected directly to the output of the envelope amplifier to the PA and therefore will have the second supply voltage ( $V_O(t)$ ). Ex. 1303 at ¶129.

Finally, the NMOS transistor in Chu has a source (the lower terminal of the NMOS transistor) coupled to ground, as shown by the standard downward-pointing arrow notation. Ex. 1303 at ¶130.

**B. Ground II: Claim 11 is obvious over Chu combined with Choi 2010, Hanington, and Myers**

**1. Claim 11**

Claim 11 is obvious in view of Chu combined with Choi 2010, Hanington, and Myers, as explained below. Ex. 1303 at ¶¶132, 148.

- (a) “The apparatus of claim 10, wherein the means for generating the second supply voltage comprises means for generating the second supply voltage based on an envelope signal and either the boosted supply voltage or the first supply voltage.”**

Chu combined with Choi 2010, Hanington, and Myers renders this limitation obvious. As explained above regarding claim 10, Chu combined with Choi 2010 and Hanington discloses the apparatus of claim 10. Ex. 1303 at ¶133.

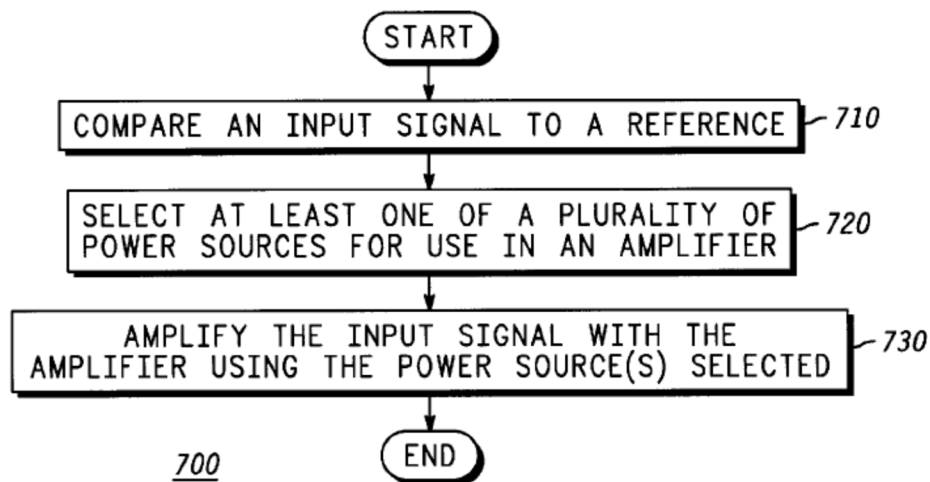
Chu combined with Choi 2010 and Myers discloses the remaining limitations of claim 11. As explained above in Section VIII.D, the claimed function for this means-plus-function limitation is “generating the second supply

voltage based on an envelope signal and either the boosted supply voltage or the first supply voltage.” The structure performing the function is envelope amplifier 170, including having an operational amplifier 310; a driver amplifier 312; three PMOS transistors, wherein the first PMOS transistor 314 has its source coupled to the drains of the second and third PMOS transistors and its drain providing the second supply voltage; the second PMOS transistor 318 has a source receiving the boosted supply voltage, the third PMOS transistor 320 has a source receiving the first supply voltage; and an NMOS transistor 316 with its drain providing the second supply voltage and its source coupled to circuit ground. Ex. 1303 at ¶134.

The envelope amplifier in Chu as modified in view of Choi 2010 and Myers would be at least equivalent to envelope amplifier 170 in the ’558 patent. As explained above regarding limitation 10(b), Chu includes an envelope amplifier that generates a second supply voltage based on an envelope signal and a battery voltage. As explained above regarding limitations 10(b) and (c), Chu in combination with Choi 2010 discloses an envelope amplifier that generates a second supply voltage based on a boosted supply voltage. When further combined with Myers, the Chu envelope amplifier would also be able to operate selectively to choose either the boosted voltage generated by the boost converter provided by Choi 2010 or the battery supply voltage already disclosed in Chu and generate the

second supply voltage based on an envelope signal and on *either* of those voltages, as circumstances warrant. Ex. 1303 at ¶135.

Myers discloses a power supply modulator for a PA that “efficiently amplifies the envelope of the input signal” by selecting among different power sources based on operating conditions. Ex. 1312 at Abstract. The input signal is compared to a reference voltage ( $V_{REF}$ ), and based on that comparison, one of multiple power sources is selected for use by the amplifier, as shown below:



**FIG. 7**

**Myers – Figure 7**

Ex. 1312 at 9:8-21 (“FIG. 7 shows a flowchart for a method of amplifying a signal in accordance with a preferred embodiment of the present invention. Method 700 begins with step 710 when an input signal is compared to a reference. Then in step 720, as a result of the comparison in step 710, *at least one of a plurality of power*

*sources is selected for use in an amplifier.* Then in step 730, the input signal is amplified with the amplifier that uses the power sources selected. Method 700 as shown in FIG. 7 is a method which *selects a power source to be used* in an amplifier where the selection is a function of the amplitude of the input signal. This allows an amplifier to be operated in a more efficient range because a power source can be chosen close to the amplitude of the input signal.”); *see also id.* Fig. 8; *id.* at 9:22-41; Ex. 1303 at ¶136.

A POSA would have understood that combining the selection capability of Myers with Chu’s envelope amplifier and Choi 2010’s boost converter would allow Chu’s envelope amplifier to choose between supply voltages, based on a comparison of an input to a reference. A POSA would have understood that because the power amplification apparatus in Myers can be used in a communications device, which uses a battery, the reference used in the comparison could be based on the battery voltage, as the ’558 patent discloses. Ex. 1312 at 9:18-21, 1:19-23 (“High dynamic range allows the communications devices to communicate more reliably over a variety of distances, and high efficiency allows the devices to operate longer on a single battery.”); Ex. 1301 at 6:4-5 (“The first threshold may be a fixed threshold or may be determined based on the Vbat voltage.”). Such an implementation would allow Chu’s envelope amplifier to generate the second supply voltage based on either the first supply voltage (battery

voltage) or the boosted supply voltage, based on the comparison. Ex. 1303 at ¶137.

The structure of Chu's envelope amplifier, as implemented with Choi 2010's boost converter and Myers's selection capability, would be identical or, at a minimum equivalent, to the structure disclosed in the '558 patent. As explained above regarding limitations 10(d) through 10(g), Chu's envelope amplifier includes an operational amplifier, a driver amplifier, a first PMOS transistor with its drain providing the second supply voltage, and an NMOS transistor with its drain providing the second supply voltage and its source coupled to circuit ground. When modified in view of Choi 2010 and Myers to allow the selection between the first supply voltage (battery voltage) and the boosted supply voltage, Chu's envelope amplifier would also have the required two additional PMOS transistors to perform the selection—and thus would have the same structure as envelope amplifier 170 in the '558 patent. Ex. 1303 at ¶138.

A POSA would have known that the standard way to implement the selection feature of Myers would have been to use a multiplexer. *See* Ex. 1301 at 5:31-49 (describing the PMOS transistor operation). As discussed above in Section V.C, at the time of the alleged invention, multiplexers using two PMOS transistors were commonly used for selecting a single input signal among several input signals, as disclosed by Myers. Such a multiplexer would have included the

structure required by this limitation: two PMOS transistors, each of which has a gate receiving a control signal that performs the selection, each of which has a source coupled to one of the power supply voltages, and each of which has a drain connected to the output node. The output node would be the source of the first PMOS transistor (from claim 10) that provides the second supply voltage to the power amplifier. Ex. 1303 at ¶139.

In sum, the structure of Chu's envelope amplifier (as modified in view of Choi 2010 and Myers to allow the selection between voltages) would be identical or, at a minimum, equivalent to envelope amplifier 170 in the '558 patent. The envelope amplifier would have all the same structures as explained above, and it would operate in the same standard way to achieve substantially the same result. It would implement a selection between a battery voltage and the boosted supply voltage using a standard two-transistor multiplexer. And the result would be a supply voltage from the envelope amplifier that is based on an envelope signal and the voltage that was selected. Ex. 1303 at ¶140.

**(i) Motivation to Combine Chu with Choi 2010 and Myers**

It would have been obvious to a POSA to modify Chu's envelope amplifier (in view of Choi 2010 and Myers) so that it operated selectively with either a battery supply or boosted voltage. Ex. 1303 at ¶141.



All three references—Chu, Choi 2010, and Myers—are from the same field of endeavor (power supply modulators for power amplifiers). Combining the Chu envelope tracker with the Choi 2010 boost converter would have been obvious for the reasons stated above regarding limitation 10(b). Combining the Chu envelope amplifier (as modified by Choi 2010) with the selection functionality of Myers would have had further advantages: Myers “selects a power source to be used in an amplifier where the selection is a function of the amplitude of the input signal,” i.e., how much power is needed for the specific input signal, which “allows an amplifier to be operated in a more efficient range because a power source can be chosen close to the amplitude of the input signal.” Ex. 1312 at 9:18-21. Consequently, choosing a power source close to the amplitude of the input signal avoids the waste of power that would occur by supplying an unnecessarily high voltage. Ex. 1303 at ¶142.

A POSA would have understood, when combining Chu, Choi 2010, and Myers, that the selection of the power source may be based on the battery voltage. For example, a POSA would have understood that, when the voltage requirements of the amplified envelope signal is *lower* than the battery voltage, the envelope tracker of Chu (as modified with the boost converter of Choi 2010) should use the battery voltage, because the battery voltage is sufficient to support the voltage

needs of the PA, and using the boosted the voltage would unnecessarily provide extra power and deplete the battery more quickly. Ex. 1303 at ¶143.

Conversely, a POSA would also have understood the common-sense notion that, when the voltage magnitude of the amplified envelope signal is *greater* than the battery voltage—such as when the battery voltage is experiencing roll-off (as described above)—then it would be necessary to operate the envelope tracker of Chu (as modified by Choi 2010) with a boosted voltage closer to the amplitude of the input signal, in order to supply the PA with the necessary output voltage. A POSA would have understood that using a boosted supply in this circumstance prevents distortion of the amplified envelope signal. Ex. 1303 at ¶144.

Myers expressly teaches that choosing the power source based on the amplitude of the input signal “allows an amplifier to be operated in a more efficient range,” and suggests that high efficiency is important to battery life. Ex. 1312 at 9:16-21, 1:19-23 (“High dynamic range allows the communications devices to communicate more reliably over a variety of distances, and high efficiency allows the devices to operate longer on a single battery.”). Myers also discloses that the second power supply Vdd2 is larger than Vdd1, and that (like the apparatus in the ’558 patent) the second power source will be used only when needed and the first power source will be used the rest of the time. *Id.* at 3:47-59 (“The operation of multi-range modulator 200 differs based on whether the

amplitude of the envelope signal is below or above the reference voltage shown as  $V_{ref}$  in FIG. 2. When the amplitude of the envelope signal is below  $V_{ref}$ , multi-range modulator 200 operates in a first mode. When the amplitude of the envelope signal is above  $V_{ref}$ , multi-range modulator 200 operates in a second mode. Multi-range modulator 200 changes from the first mode of operation to the second as the amplitude of the envelope signal increases, and changes from the second mode of operation to the first as the amplitude of the envelope signal decreases.”); *see also id.* at 3:60-4:43 (describing the switch between  $V_{dd1}$  and  $V_{dd2}$ ); *see also* Ex. 1301 at 5:31-33 (“In one design, envelope amplifier 170a operates based on the  $V_{boost}$  voltage only when needed and based on the  $V_{bat}$  voltage the remaining time in order to improve efficiency.”). A POSA would have known that one purpose of implementing selection between a battery voltage and a boosted supply voltage was to preserve battery voltage, which is limited. Ex. 1303 at ¶145.

Therefore, a POSA would have been motivated to combine the selection functionality of Myers with the Chu envelope amplifier, as modified by Choi 2010, so that: (1) when a boosted voltage is not required, Chu’s linear amplifier operates efficiently with the battery voltage, and (2) when the battery voltage is lower than the peak voltage magnitude of the amplified reference envelope voltage  $A(t)$  (e.g., due to roll-off of the battery), Chu’s linear amplifier operates with the boosted voltage to prevent distortion of the amplified reference envelope voltage  $A(t)$ .

Modifying Chu to selectively use either the battery or boosted voltages as taught by Myers would have been a particularly obvious approach in view of the well-known state of battery technology, i.e., that batteries do not operate solely at a fixed output voltage level and instead start out operating at an initial fully charged level and then experience reduced output voltage over time as the battery is discharged. Ex. 1303 at ¶146.

Finally, adding the selectable power sources of Myers to the Chu amplifier (in view of Choi 2010) would have yielded only expected, predictable results. Using the power selection method disclosed in Myers with Chu, as modified by Choi 2010 to include the boost converter, would have been: (a) a combination of prior-art elements (providing a battery supply and a boosted supply) according to known methods to yield predictable results, because a POSA would have understood, for example, allowing the envelope amplifier to selectively receive either a battery supply or a boosted supply would satisfy the power requirements of the power amplifier while improving battery preservation; (b) a simple substitution of one known element (switching operation between two power supplies) for another (operating with one power supply) to obtain predictable results; (c) a use of a known technique (operating an envelope amplifier with either a boosted power supply or a battery power supply) to improve a similar device (the envelope amplifier of Chu) in the same way; (d) an application of a known technique

(selectively receive either a boosted power supply or a battery power supply) to a known device (the envelope amplifier of Chu) ready for improvement to yield predictable results; and (e) obvious to try—a choice of one type of power supply from a finite number of identified, predictable solutions, with a reasonable expectation of success. Ex. 1303 at ¶147.

## **XI. CONCLUSION**

Based on the foregoing, claims 10 and 11 of the '558 patent recite subject matter that is unpatentable. Petitioner requests institution of an *inter partes* review to cancel these claims.

Respectfully Submitted,

/David L. Cavanaugh/

David L. Cavanaugh  
Registration No. 36,476

**Table of Exhibits for U.S. Patent 8,698,558 Petition for *Inter Partes* Review**

| Exhibit | Description   |
|---------|---|
| 1301    | U.S. Patent No. 8,698,558   |
| 1302    | File History for U.S. Patent No. 8,698,558  |
| 1303    | Declaration of Dr. Alyssa B. Apsel  |
| 1304    | Chu, W.Y. et al., “ <i>A 10 MHz Bandwidth, 2 mV Ripple PA Regulator for CDMA Transmitters</i> ,” IEEE Journal of Solid-State Circuits 2809-2819 (2008) (“Chu”)  |
| 1305    | Declaration of IEEE regarding Chu, Kwak, Kim, and Blanken (“IEEE Chu Decl.”)  |
| 1306    | Choi, J. et al., “ <i>Envelope Tracking Power Amplifier Robust to Battery Depletion</i> ,” Microwave Symposium Digest (MTT), 2010 IEEE MTT-S International 1332-36 (2010) (“Choi 2010”)                   |
| 1307    | Declaration of IEEE regarding Choi 2010 (“IEEE Choi Decl.”)   |
| 1308    | Declaration of Debabani Choudhury (“Choudhury Decl.”)   |
| 1309    | Declaration of Jinsung Choi (“Choi Decl.”)  |
| 1310    | Blanken, P.G. et al., “ <i>A 50MHz Bandwidth Multi-Mode PA Supply Modulator for GSM, EDGE and UMTS Application</i> ,” 2008 Radio Frequency Integrated Circuits Symposium (IEEE) 401-04 (2008) (“Blanken”) |
| 1311    | Kwak, T.W. et al., “ <i>A 2 W CMOS Hybrid Switching Amplitude Modulator for EDGE Polar Transmitters</i> ,” IEEE Journal of Solid-State Circuits 2666-76 (2007) (“Kwak”)                                   |
| 1312    | U.S. Patent No. 5,929,702, “Method and Apparatus for High Efficiency High Dynamic Range Power Amplification,” to Myers et al. (“Myers”)   |
| 1313    | Kim, D. et al., “ <i>High Efficiency and Wideband Envelope Tracking Power Amplifier with Sweet Spot Tracking</i> ,” Radio Frequency Integrated Circuits Symposium (RFIC): 255-258 (2010) (“Kim”)          |

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| 1314 | U.S. Patent No. 6,300,826, “Apparatus and Method for Efficiently Amplifying Wideband Envelope Signals” (filed May 5, 2000) (“Mathe ’826”)  |
| 1315 | Maxim Integrated Products, Inc., <i>MAX9738 –16VP-P Class G Amplifier with Inverting Boost Converter</i> , Datasheet 19-3700, Rev. 0 (March 2008) (“Maxim”)  |
| 1316 | Ertl, H. et al., “ <i>Basic Considerations and Topologies of Switched-Mode Assisted Linear Power Amplifiers</i> ,” IEEE Transactions on industrial electronics 44.1 (1997): 116-123 (“Ertl”)                   |
| 1317 | Kang, D. et al., “ <i>A Multimode/Multiband Power Amplifier With a Boosted Supply Modulator</i> ,” IEEE Transactions on Microwave Theory and Techniques 58.10 (2010): 2598-2608 (“Kang”)                       |
| 1318 | U.S. Patent No. 5,834,977, “Amplifying Circuit with Power Supply Switching Circuit” (filed October 30, 1996 and issued November 10, 1998) (“Maehara”)  |
| 1319 | U.S. Patent No. 5,870,340, “Multiplexer” (filed July 8, 1997 and issued February 9, 1999) (“Ohsawa”)   |
| 1320 | U.S. Patent No. 6,566,935, “Power Supply Circuit With a Voltage Selector” (filed August 28, 2000 and issued May 20, 2003) (“Renous”)   |
| 1321 | Certificate of Correction for U.S. Patent No. 8,698,558 (“558 COC”)  |
| 1322 | Qualcomm Incorporated’s Initial Claim Construction Brief, <i>Certain Mobile Electronic Devices and Radio Frequency and Processing Components Thereof</i> , Investigation No. 337-TA-1065 (“Qualcomm CC Brief”) |
| 1323 | Order No. 28: Construing Terms of the Asserted Patents, <i>Certain Mobile Electronic Devices and Radio Frequency and Processing Components Thereof</i> , Investigation No. 337-TA-1065 (“Markman Order”)       |
| 1324 | Excerpts from Erickson et al., <i>Fundamentals of Power Electronics</i> , Second Edition (Kluwer Academic Publisher) (2001) (“Erickson”)   |
| 1325 | Hanington, Gary. et al., “ <i>High-Efficiency Power Amplifier Using Dynamic Power-Supply Voltage for CDMA Applications</i> ,” IEEE   |

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|  | Transactions on Microwave Theory and Techniques 47:8 (1999)<br>("Hanington") |
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**CERTIFICATE OF SERVICE**

I hereby certify that on June 28, 2018, I caused a true and correct copy of the foregoing materials:

- Petition for *Inter Partes* Review of U.S. Patent No. 8,698,558 Under 35 U.S.C. § 312 and 37 C.F.R. § 42.104
- Table of Exhibits for Petition for *Inter Partes* Review of U.S. Patent No. 8,698,558
- Exhibits 1301-1325
- Fee Authorization Page
- Intel Corp. Power of Attorney
- Word Count Certificate of Compliance

to be served via Express Mail on the following attorney of record as listed on  
PAIR:

Alan M. Lenkin  
2029 Century Park East  
Suite 3500  
Los Angeles, CA 90067-3021

/Scott Bertulli/  
Scott Bertulli  
Registration No. 75,886

**WORD COUNT CERTIFICATE OF COMPLIANCE**

I hereby certify that the foregoing Petition for *Inter Partes* Review of U.S. Patent No. 8,698,558 contains 13,997 words as measured by the word processing software used to prepare the document, in compliance with 37 C.F.R. § 42.24(d).

Respectfully submitted,

Dated: June 27, 2018

/Theodoros Konstantakopoulos/  
Theodoros Konstantakopoulos  
Reg. No. 74,155