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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

BEFORE THE PATENT TRIAL AND APPEAL BOARD

Intel Corporation
Petitioner

v.

Qualcomm Incorporated
Patent Owner

Case IPR2018-01154

**PETITION FOR *INTER PARTES* REVIEW OF
U.S. PATENT NO. 8,698,558
CHALLENGING CLAIMS 15-20**

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Petitioner Intel Corporation (“Intel”) respectfully requests *Inter Partes* Review of claims 15-20 of U.S. Patent No. 8,698,558 (the “’558 patent”) (Ex. 1201) 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. 1201, 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 references, 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 15-20 because he found that the prior art of record did not disclose the

structures required to add an offset current. The Kwak reference cited in this Petition discloses those limitations.

Accordingly, the prior art cited in this Petition anticipates and/or renders obvious claims 15-20 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 10 and 11 of the '558

patent (IPR2018-01240). 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), Kathryn Zalewski (*pro hac vice* to be requested), and Theodoros Konstantakopoulos (Registration No. 74,155).

D. Service Information

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

Post and hand delivery: Wilmer Cutler Pickering Hale and Dorr LLP
1875 Pennsylvania Avenue, N.W.
Washington, D.C. 20006

Telephone: (202) 663-6000

Fax: (202) 663-6363

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 15-20 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. Kwak, T.W. et al., "*A 2 W CMOS hybrid switching amplitude modulator for EDGE polar transmitters*," IEEE Journal of Solid-State

Circuits 2666-76 (2007) (“Kwak”) (Ex. 1211). Kwak was published in 2007 and is prior art under at least 35 U.S.C. § 102(b).

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. 1206). 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.1207 at ¶11. Choi 2010 is also prior art under at least 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. 1208 at ¶8-9; Ex. 1206 at cover; Ex. 1209 at ¶¶4-5; Ex. 1207 at ¶11. Choi 2010 was distributed to hundreds of conference attendees via USB drives in May 2010. Ex. 1208 at ¶17; Ex. 1209 at ¶¶6-9.

B. Grounds for Challenge

Petitioner requests cancellation of claims 15-20 of the ’558 patent as unpatentable under 35 U.S.C. §§ 102 and/or 103. This Petition, supported by the declaration of Dr. Alyssa Apsel (Ex. 1203) 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.

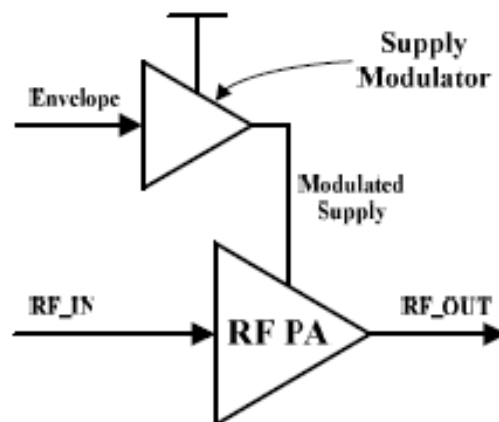
A. Radio Frequency (RF) Power Amplifiers

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. 1203 at ¶¶34-35.

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. 1203 at ¶36.

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 (“Supply Modulator”):



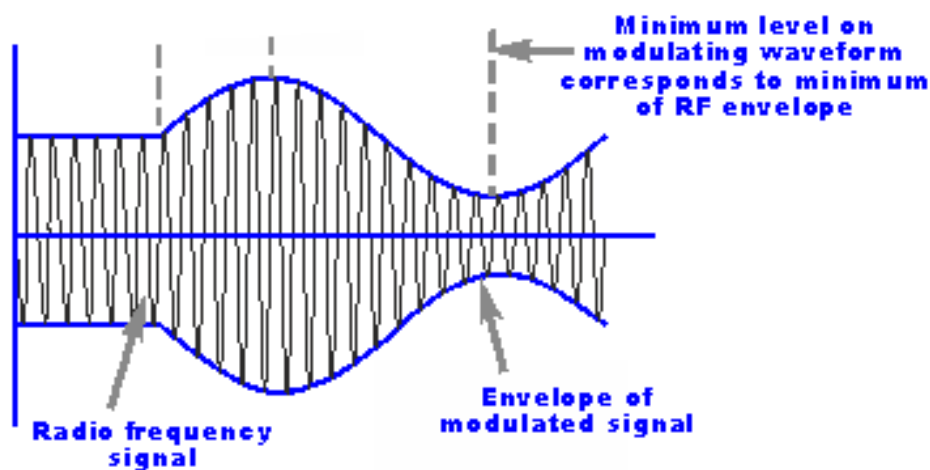
Kim – Figure 1(b)

Ex. 1213 [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. The supply voltage provides the PA with sufficient power to transmit an output signal (“RF_OUT”)

based on the input signal that the PA receives (“RF_IN”), 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 to be transmitted. Ex. 1203 at ¶¶37-38.

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. 1203 at ¶¶39-40. 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. 1203 at ¶40.

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. 1203 at ¶41.

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. 1203 at ¶41.

2. Switchers

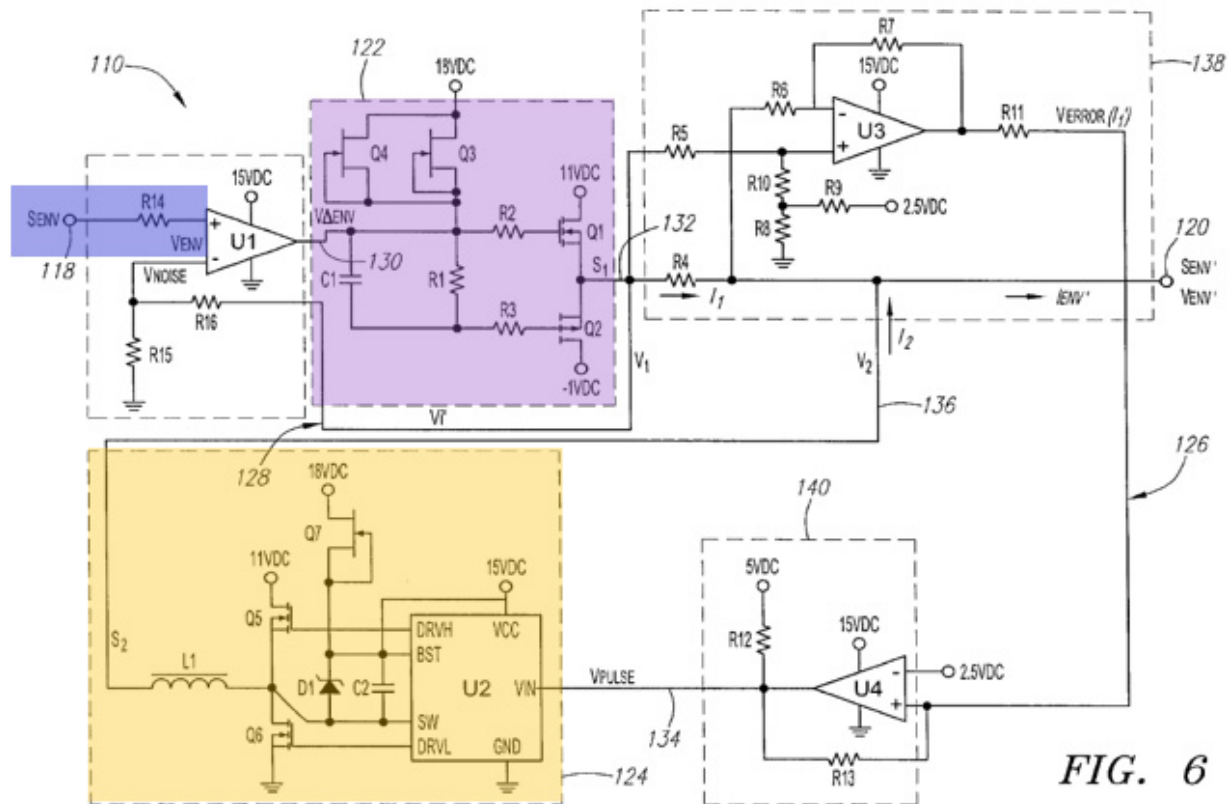
Another prior art device for supplying power to a PA is a “switcher,” also sometimes referred to as a “switching regulator” or “switching amplifier.” A switcher takes small chunks of energy from an input voltage source and stores them in energy-storing elements (such as an inductor) that will transform 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. 1203 at ¶42.

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. 1203 at ¶43.

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. 1203 at ¶44.

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. 1214 [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 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. 1203 at ¶45.



Mathe '826 – Figure 6

A paper by Ertl from 1997 also discloses a hybrid supply generator. Ex. 1216 [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:

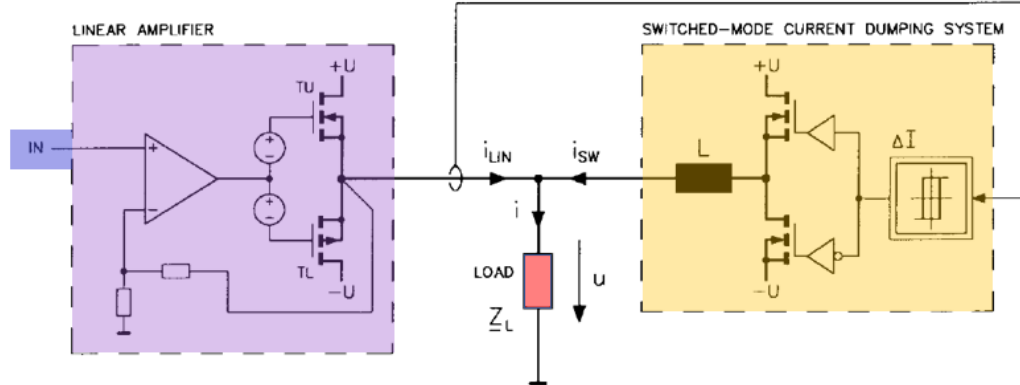


Fig. 2. Circuit diagram of a switched-mode assisted linear power amplifier.

Ertl – Figure 2

Ex. 1216 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. 1203 at ¶46.

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. 1210 [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:

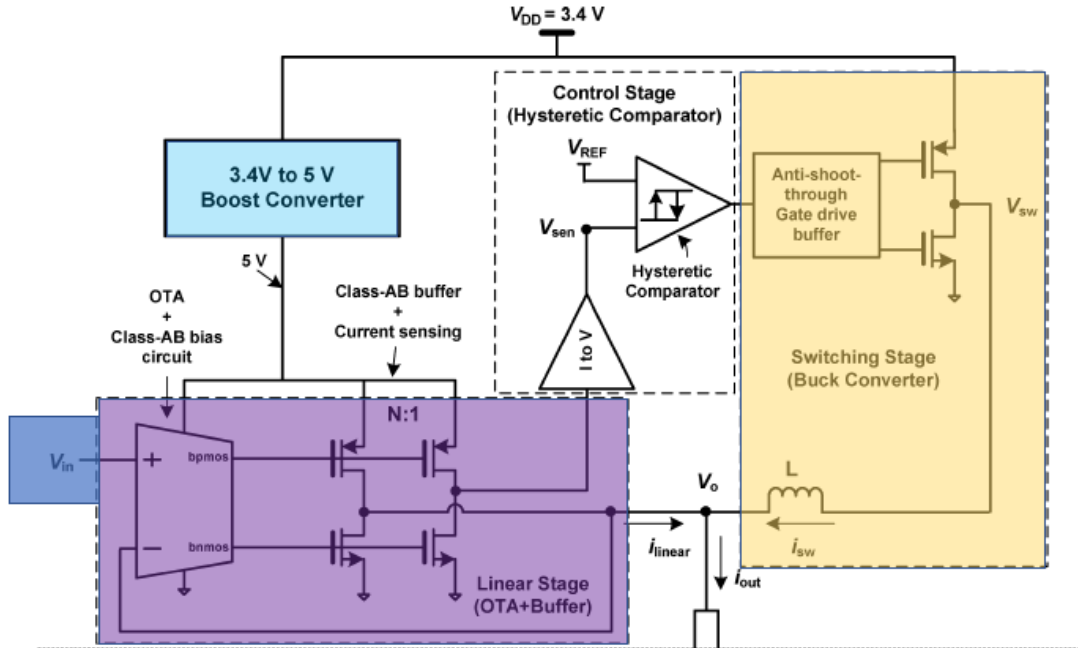
[h]igh-efficiency voltage conversion can be obtained with a switched-mode inductive DC/DC buck converter, but its bandwidth is limited

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. 1203 at ¶47.

Finally, a 2010 paper by Kang describes “a highly efficient supply modulator” that combines an envelope amplifier with a switcher. Ex. 1217 [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. 1217 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.” 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

Ex. 1217 at 2602; Ex. 1203 at ¶48.

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. 1203 at ¶49.

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. 1218 [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. 1203 at ¶50.

Similarly, 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. 1217 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. 1203 at ¶51.

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. 1213. 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. 1202 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. 1203 at ¶52.

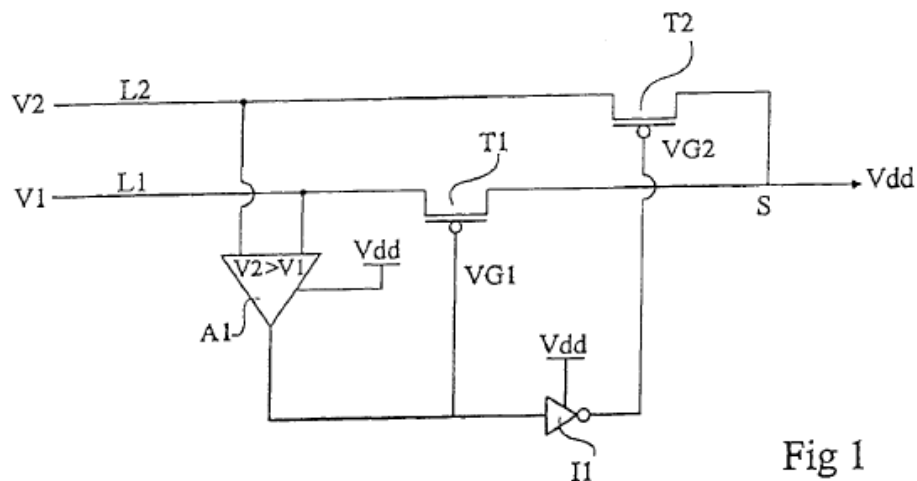
C. Multiplexers

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. 1219 [U.S. Patent No. 5,870,340, “Multiplexer” (filed July 8, 1997 and issued February 9, 1999)] 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. 1203 at ¶53.

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. 1219 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. 1203 at ¶54.

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. 1220 [U.S. Patent No. 6,566,935, “Power Supply Circuit With a Voltage Selector” (filed August 28, 2000 and issued May 20, 2003)] 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. 1220 at 1:14-17; Ex. 1203 at ¶55.

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. Ex. 1220 at 1:17-25 (“the 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. 1203 at ¶56.

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. 1201 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. *See 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. 1203 at ¶57. 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

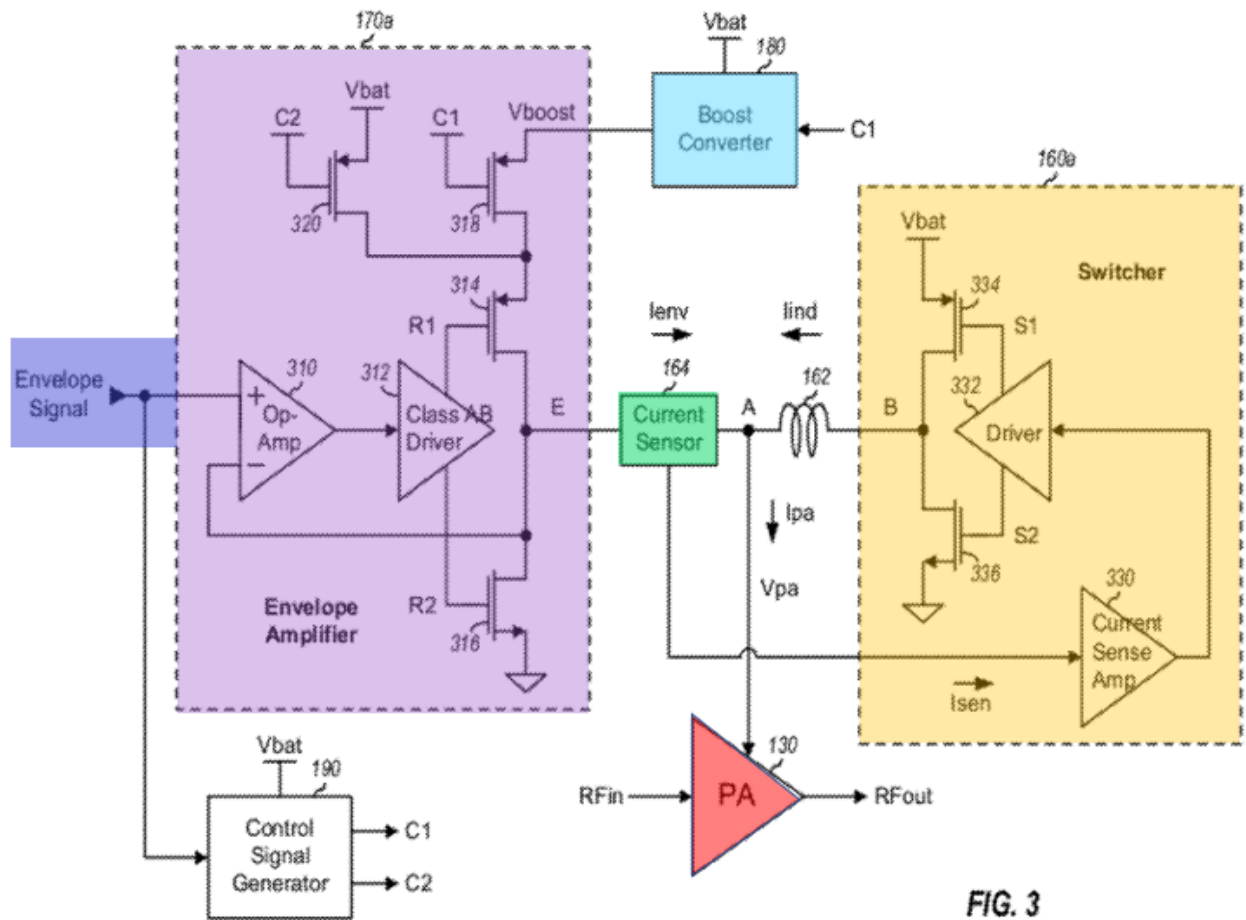
The challenged claims of the '558 patent comprise combinations of well-known components in the field: specifically, PAs, envelope amplifiers, switchers, hybrid supply generators (envelope amplifier + switcher), and boost converters. The '558 patent does not claim to have invented any of these components, all of which were known in the prior art years before the filing date of the '558 patent, as explained above. Ex. 1203 at ¶58.

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.¹ Ex. 1203 at ¶58. 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:

¹ These are the only two allegedly inventive aspects that the Patent Owner has identified in the parallel ITC litigation. *See* Ex. 1222 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.”).

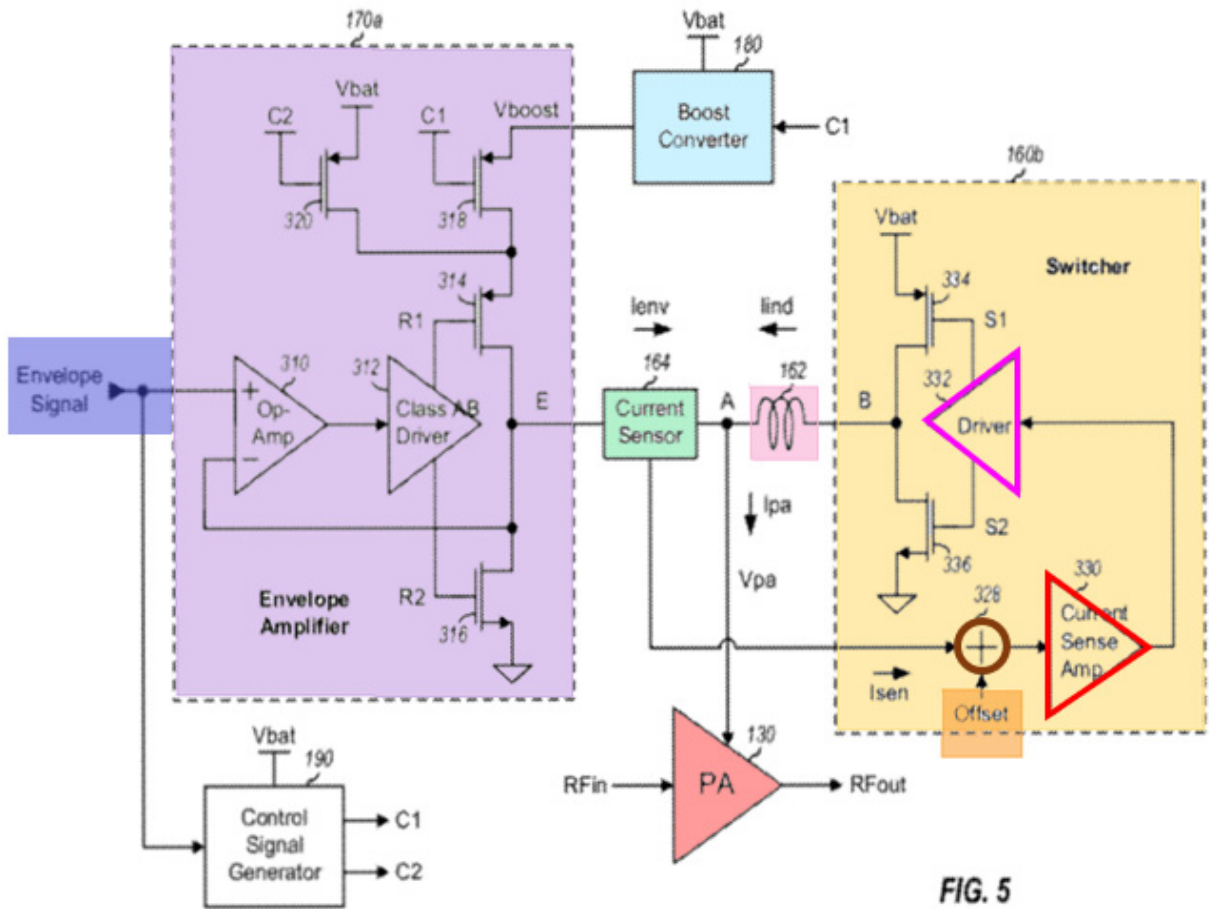


'558 Patent – Figure 3

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 dark 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. 1201 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. 1203 at ¶59.

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. 1201 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. Ex. 1203 at ¶60.

When the switcher is on, it provides a current (“Iind”) via inductor 162 (highlighted in pink). That current is joined with the current from the envelope

amplifier (“Ienv”) to provide a combined current (“Ipa”) to the PA. Ex. 1201 at 3:21-27 (“Envelope amplifier 170 ... provides a second supply current (Ienv) comprising high frequency components at node A. The PA supply current (Ipa) provided to power amplifier 130 includes the Iind current from switcher 160 and the Ienv 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. 1203 at ¶61.

The switcher’s operation begins with the receipt of output current Isen from the envelope amplifier at summer 328 (outlined in brown). Ex. 1201 at 4:60-63 (“Sensor 164 passes most of the Ienv current to node A and provides a small sensed current (Isen) to switcher 160a. The Isen current is a small fraction of the Ienv current from envelope amplifier 170a.”). Summer 328 receives and adds an “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. 1203 at ¶62.

The ’558 patent explains that the offset may be added “via any suitable mechanism,” *id.* 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. 1203 at ¶63.

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. 1202 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 its 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. 1201 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. 1221.

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 the allegedly inventive elements of the challenged claims of the '558 patent. In fact, the primary prior art

reference cited here, Kwak, was not before the Examiner during prosecution but discloses all the elements that the Examiner found to be missing from the prior art of record. Ex. 1203 at ¶69.

A. Kwak

Kwak is a 2007 paper that discloses a supply generator called a “hybrid switching amplifier” that comprises a linear amplifier and a switching amplifier. Ex. 1211 at 2666 (“To achieve both high efficiency and high speed, [the proposed hybrid switching amplifier] consists of a wideband buffered linear amplifier [envelope amplifier] as a voltage source and a PWM [pulsewidth modulation] switching amplifier [switcher] with a 2 MHz switching frequency as a dependent current source.”). Kwak discloses both (1) the miscellaneous elements found missing during prosecution of the ’558 patent (operational amplifier, driver, and PMOS and NMOS transistors), and (2) the ’558 patent’s purported invention of a switcher that uses an “offset” current to increase the current that the switcher provides to a PA. Ex. 1203 at ¶70.

Figure 5 of Kwak shows the hybrid supply generator with both an envelope amplifier (the linear amplifier highlighted below in purple) and a switcher (the PWM switching amplifier highlighted in yellow):

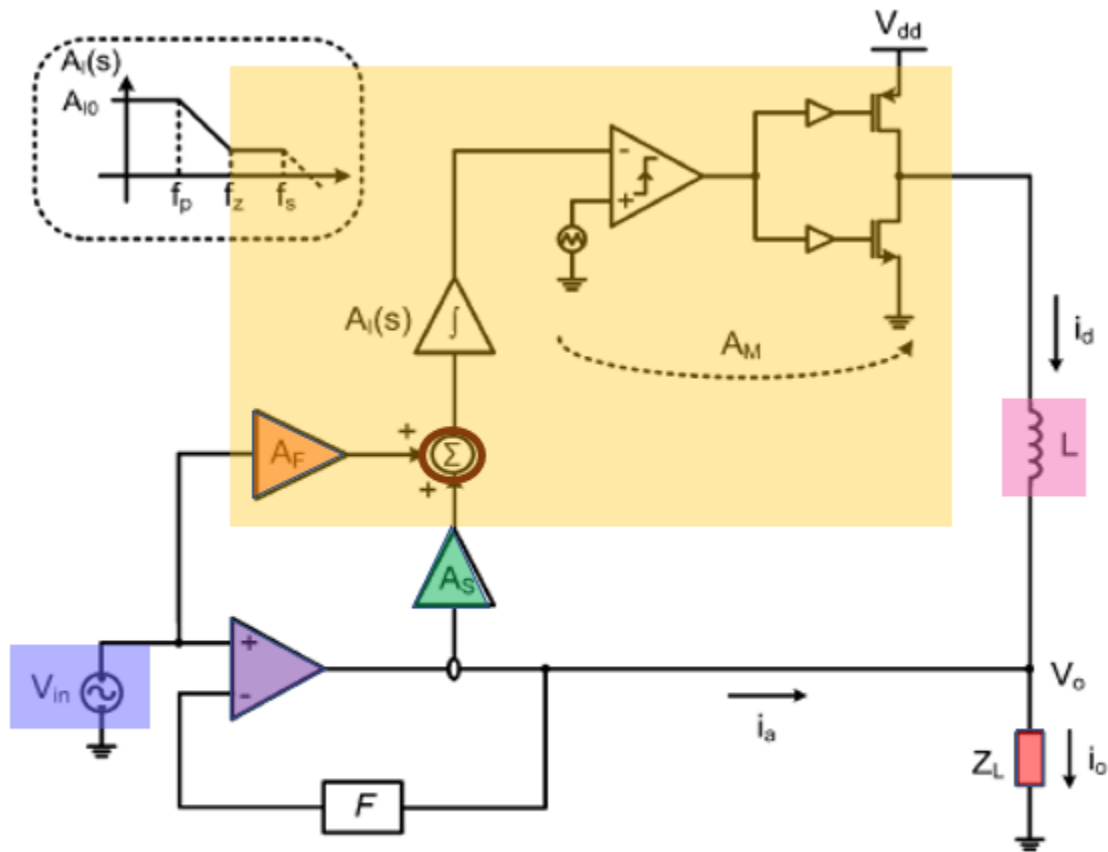


Fig. 5. Hybrid switching amplifier with the feedforward path.

Kwak – Figure 5

The envelope amplifier receives an input voltage (V_{in} highlighted in blue) and works together with the switcher to provide power (currents I_a and I_d and voltage V_o) to the PA (highlighted in red). As Kwak summarizes, this “hybrid switching amplitude modulator” consists of “a wideband linear amplifier as a voltage source and a switching amplifier as a current-controlled current source.” *Id.* at 2666 (“[t]he wideband linear amplifier accurately controls the output voltage with good linearity, and the switching amplifier efficiently supplies most of the output current

by sensing and amplifying the output current of the former.”). As shown in Figure 5 (and as explained in detail in the specific grounds section below), Kwak 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). Ex. 1203 at ¶¶71-72.

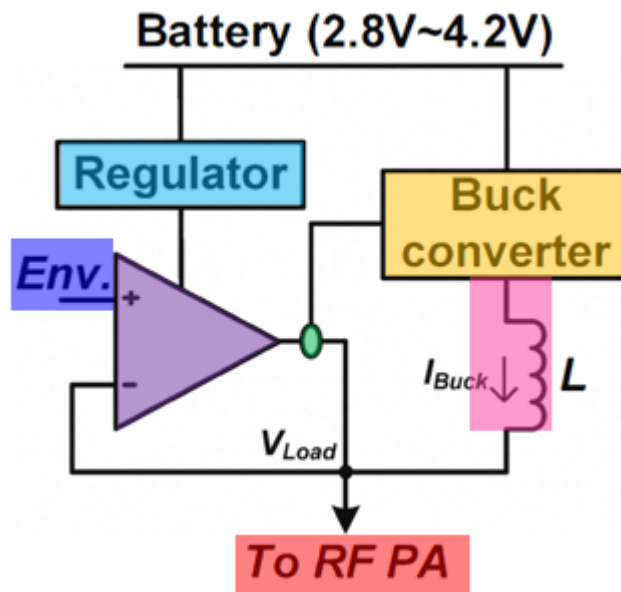
Kwak shows the “offset” feature that the Examiner found was not present in the prior art during prosecution. Kwak shows that it was known in the art to add an offset current to a switcher’s input current to increase the current that the switcher generates. In Kwak, the switcher (highlighted above in yellow) senses the output current from the linear amplifier (highlighted above in purple). More specifically, the summer (denoted by Σ , outlined in brown) within the switcher receives a sensed input current from the component labeled “ A_S ” (highlighted above in green). That sensed input current is adjusted by a different offset current that the summer receives from the component labeled “ A_F ” (highlighted in orange). The summer adds the offset current with the sensed input current. Adding the offset current to the sensed current causes the switcher to generate a greater current for the PA (highlighted in red) via the inductor L (highlighted in pink). This alleviates the burden on the linear amplifier. It also allows for quick and direct control of the switcher, because, as Kwak explains, the offset path to the switcher

is faster than the sensed current path to the switcher. Ex. 1211 at 2668-69 (“Hence, an auxiliary circuit is necessary to alleviate the burden of the linear amplifier. If we add a feedforward path, like the one shown in Fig. 5, the input signal can directly control the switching amplifier. Such a path is faster than the feedback current path formed by sensing the output current of the linear amplifier.”). Ex. 1203 at ¶73.

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. 1207 at 1074 (“[A] new supply modulator architecture employing a hybrid switching amplifier and a boost converter is proposed.”). Ex. 1203 at ¶75.

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. 1203 at ¶76.

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. 1207 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. 1203 at ¶77.

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 constructions 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 constructions based on the broadest reasonable interpretation standard.

A. “current sense amplifier” (claim 15)

In the parallel ITC litigation, the administrative law judge (ALJ) construed “current sense amplifier” to mean “amplifier that produces a voltage from a current.” Petitioner applies the ALJ’s construction in this Petition. The Patent Owner’s proposed construction in the ITC litigation (“amplifier that senses changes in current”) incorporates a limitation—i.e., that the amplifier “senses changes in current”—found nowhere in the claims. By contrast, the ALJ’s construction is consistent with the claims, specification, and knowledge of a POSA. Ex. 1201 at 4:64-66, 5:7-10, 5:18-20 (“Within switcher 160a, a current sense amplifier 330 has its input coupled to current sensor 164 and its output

coupled to an input of a switcher driver 332. . . . Switcher 160a operates as follows. Switcher 160a is in an On state when current sensor 164 senses a high output current from envelope amplifier 170a and *provides a low sensed voltage to driver 332*. . . . Conversely, switcher 160a is in an Off state when current sensor 164 senses a low output current from envelope amplifier 170a and *provides a high sensed voltage* to driver 332.”); Ex. 1223 at 11-12 (same).

B. “envelope signal” (claim 18)

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. 1223 at 13-14.

IX. LEVEL OF ORDINARY SKILL IN THE ART

A person of ordinary skill in the art 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. 1201) 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. 1203 at ¶¶84-85.

X. SPECIFIC GROUNDS FOR PETITION

Pursuant to Rule 42.104(b)(4)-(5), the following sections (as confirmed in Dr. Apsel’s declaration, Ex. 1203 ¶¶86-139) demonstrate in detail how the prior art discloses each and every limitation of claims 15-20 of the '558 patent, and how those claims are therefore anticipated and/or rendered obvious by the prior art. To summarize:

Independent claim 15 and its dependent claims 17-18, and 20 require a switcher that uses an offset current to generate a larger supply current. These claims are anticipated by Kwak (Ground I).

Claim 16, which depends from claim 15, additionally requires that the switcher operate and determine the offset based on the first supply voltage. Claim 16 is obvious in view of Kwak (Ground II).

Claim 19, which depends from claim 18, additionally requires a boost converter. Claim 19 is obvious in view of Kwak and Choi 2010 (Ground III).

A. Ground I: Claims 15, 17-18, and 20 are anticipated by Kwak

1. Claim 15

Claim 15 is anticipated by Kwak, as explained below. Ex. 1203 at ¶¶87, 124.

(a) “An apparatus comprising:”

Kwak discloses this limitation. Kwak is entitled “A 2 W CMOS Hybrid Switching Amplitude Modulator for EDGE Polar Transmitters” and describes a hybrid switching amplitude modulator apparatus and a PA. Ex. 1211 at 2666 (“[O]ur proposed CMOS hybrid switching amplifier achieves both high speed and high efficiency through the combination of a wideband linear amplifier with a very efficient switching amplifier.”). Ex. 1203 at ¶88.

(b) “an inductor operative to receive a switching signal and provide a supply current; and”

Kwak discloses this limitation. Figure 5 shows an inductor (highlighted in pink) using the standard symbol for an inductor that receives a signal (i_d , circled in green) from the switcher (highlighted in yellow):

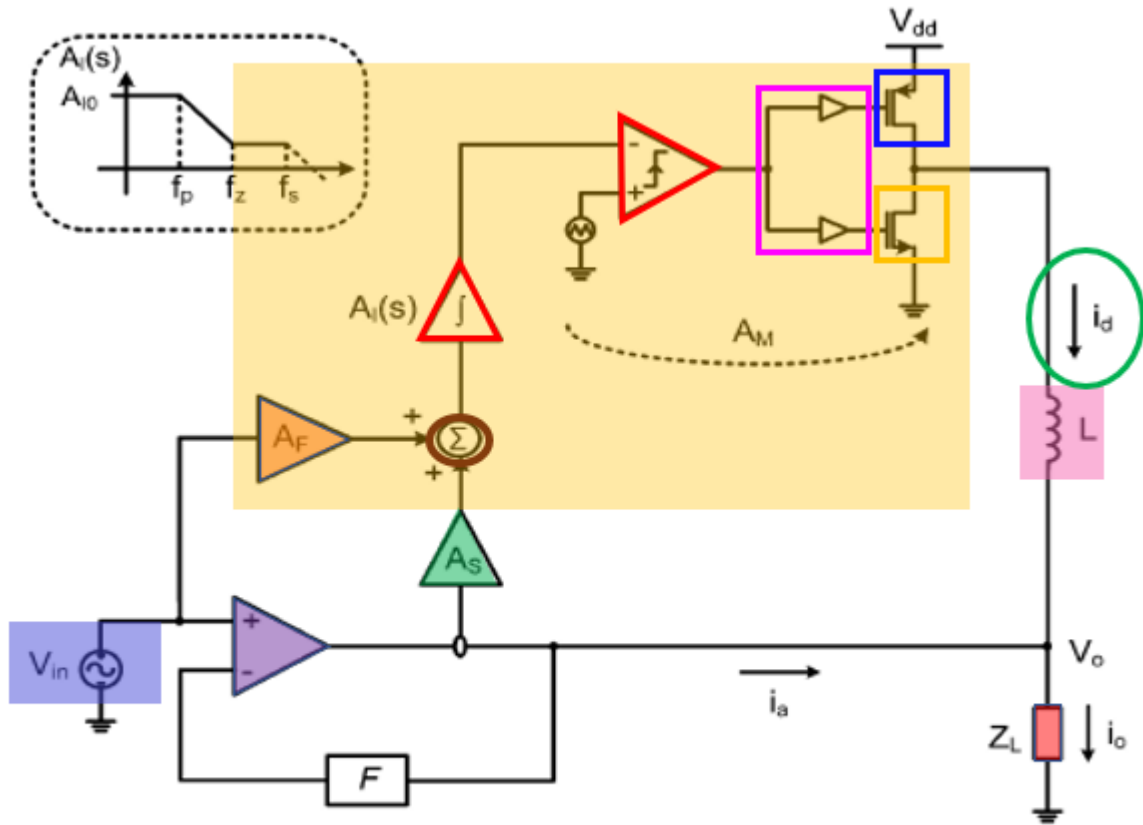


Fig. 5. Hybrid switching amplifier with the feedforward path.

Kwak – Figure 5

Ex. 1211 at 2666 (referring to “(i_d)” as “the output current of the switching amplifier”: “[T]he output current of the switching amplifier (i_d) is slower and less than the output current (i_o) because of the finite loop gain β .”). A POSA would have known that the signal i_d is a “switching signal” because, as explicitly stated in Kwak, it is the output of a “switching amplifier” and because the signal is generated by control signals that turn the PMOS and NMOS transistors (outlined in blue and orange below) on and off. *Id.* Ex. 1203 at ¶89.

As illustrated in Figure 5, the inductor provides a supply current from the switcher that will go—together with a current (i_a) from the linear amplifier (highlighted in purple)—to the PA (highlighted in red). Ex. 1211 at 2666 (“[T]he switching amplifier supplies most of the output current through the relation of $i_o = i_a + i_d = (1 + \beta) \cdot i_a$. In reality, however, as shown in Fig. 2(b), the output current of the switching amplifier (i_d) is slower and less than the output current (i_o) because of the finite loop gain β .”); *id.* (“the required output current of the linear amplifier i_a ”). Ex. 1203 at ¶90.

The inductor in Kwak is the same as the inductor 162 in the '558 patent, which (like Kwak) also receives a switching signal generated by the transistors 334 and 336 and provides a supply current (I_{ind}), as outlined in black below:

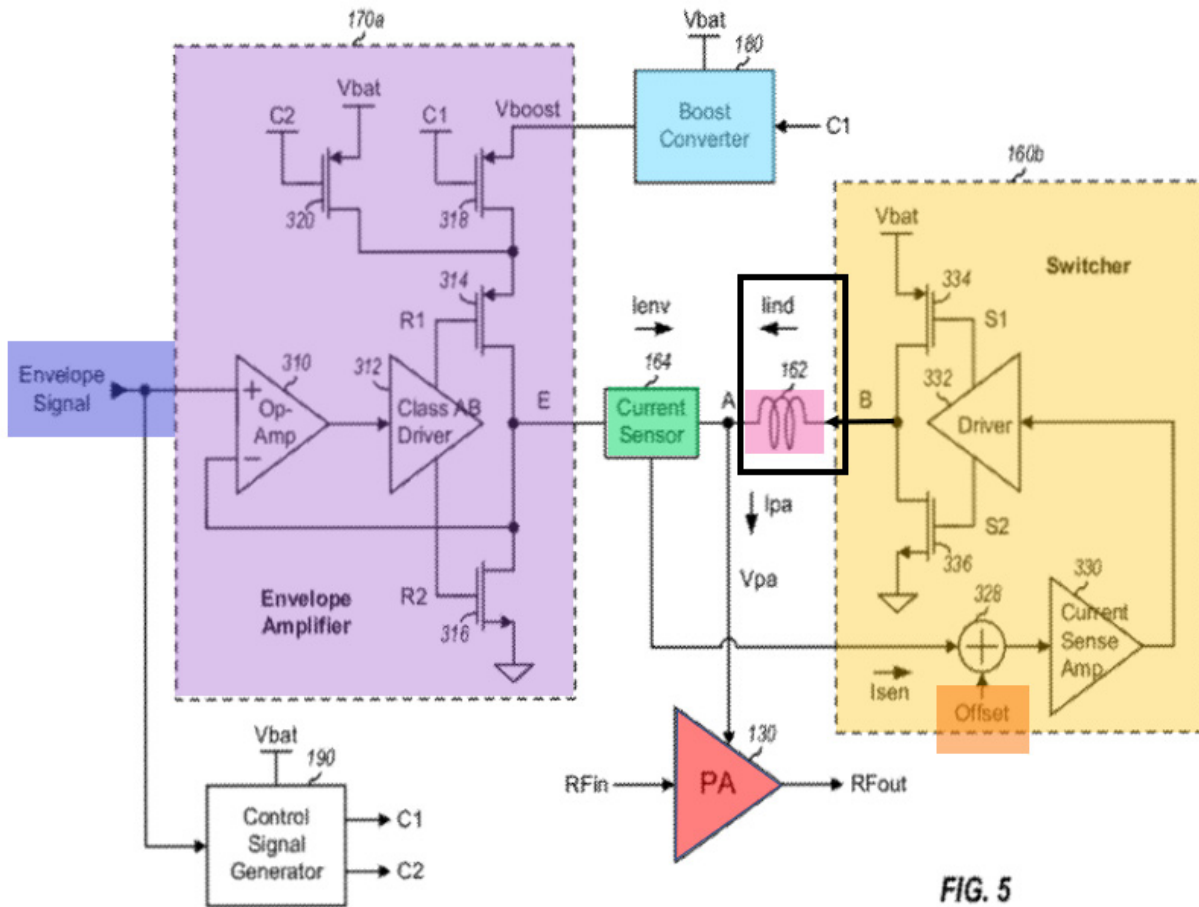


FIG. 5

Ex. 1201 at Fig. 5, 3:14-18 (“Switcher 160 receives a battery voltage (Vbat) and provides a first supply current (I_{ind}) comprising DC and low frequency components at node A. Inductor 162 stores current from switcher 160 and provides the stored current to node A on alternating cycles.”), 9:51-55 (“The inductor (e.g., inductor 162) may be coupled to the drains of the PMOS transistor and the NMOS transistor, may receive the switching signal at one end, and may provide the first supply current at the other end.”). Ex. 1203 at ¶91.

- (c) “a switcher operative to sense an input current and generate the switching signal to charge and discharge the inductor to provide the supply current, the switcher adding an offset to the input current to generate a larger supply current via the inductor than without the offset,”

Kwak discloses this limitation. Kwak discloses a switcher, highlighted in yellow below:

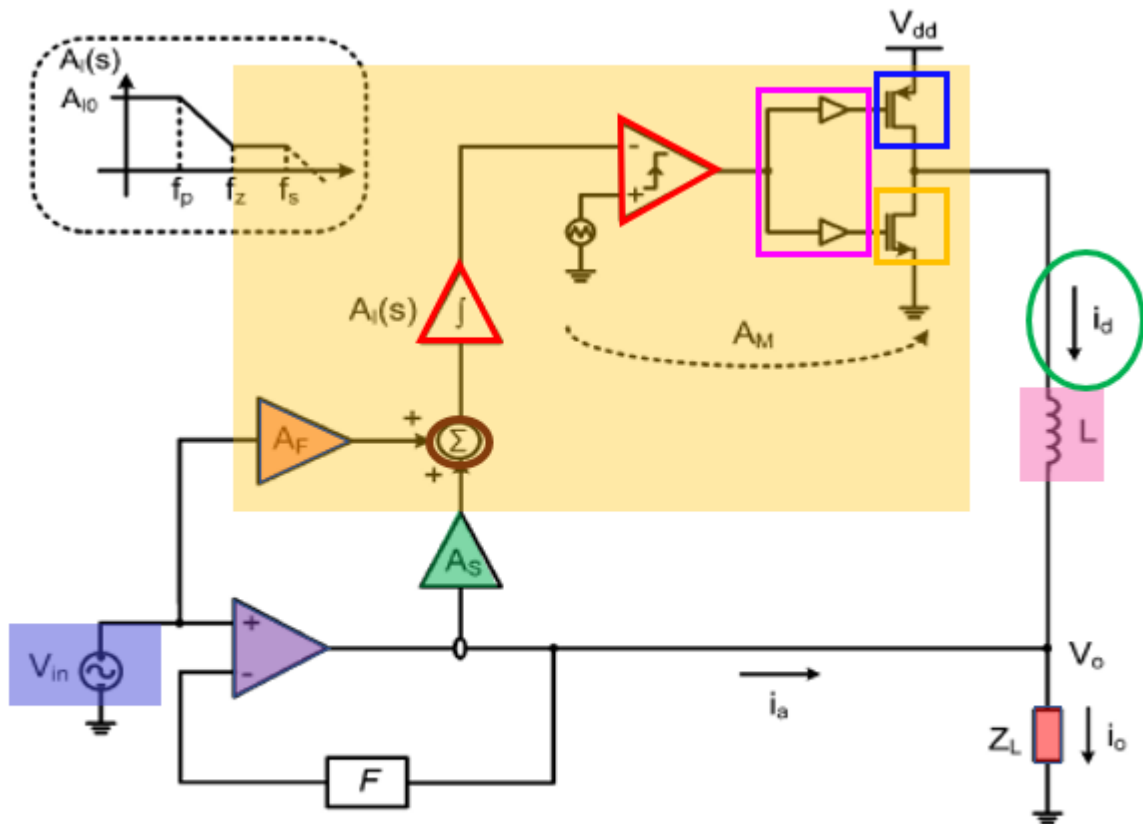


Fig. 5. Hybrid switching amplifier with the feedforward path.

Kwak – Figure 5

Ex. 1211 at 2668 (“Fig. 5. Hybrid switching amplifier with the feedforward path.”); *see also id.* at Fig. 3(a) (“Simplified block diagram of the hybrid switching

amplifier”); *id.* at Fig. 4 (“Hybrid switching amplifier with the third-order ripple filter and the current feedback”); *id.* at Fig. 6 (“Detailed block diagram of the hybrid switching amplifier”). The switcher senses an input current from the driver labeled A_S (highlighted in green). Ex. 1211 at 2668 (“current sense gain A_S ”). At the other end of the switcher, the switcher generates a switching signal (i_d , circled in green) that charges and discharges the inductor, which provides the supply current to the PA, as explained above regarding limitation 15(b). Ex. 1203 at ¶¶92-93.

The switcher adds an offset to the input current, which will ultimately generate a larger supply current via the inductor than without the offset. Kwak discloses that the driver A_F (highlighted in orange) supplies an increase in current—i.e., an offset current—in a “feed forward” path. Ex. 1211 at 2668 (“If we add a feedforward path, like the one shown in Fig. 5, the input signal can directly control the switching amplifier. Such a path is faster than the feedback current path formed by sensing the output current of the linear amplifier. Although the feedforward signal can be injected after the integrator, it is added before the integrator in Fig. 5 considering the implementation of the summing circuit and integrator”); *id.* at 2668-69 (“the gain of the feedforward path $A_F(s)$ ”). The offset current is added to the sensed signal by the summing circuit (Σ , outlined in brown), and the summing circuit’s output is sent to an integrator $A_I(s)$ (the left

triangle outlined in red, labeled with the integral sign \int). *Id.* at 2669 (“[T]he sensed output current of the linear amplifier, the feedforward current, and the high-frequency current through the ripple filter are added together and integrated at the node with the inverted polarity of the last one.”). Ex. 1203 at ¶¶94-95.

Figure 6 of Kwak—which is a detailed implementation of the type of circuit shown in Figure 5—shows these same features (with similar components in both figures highlighted using the same colors as in Figure 5):

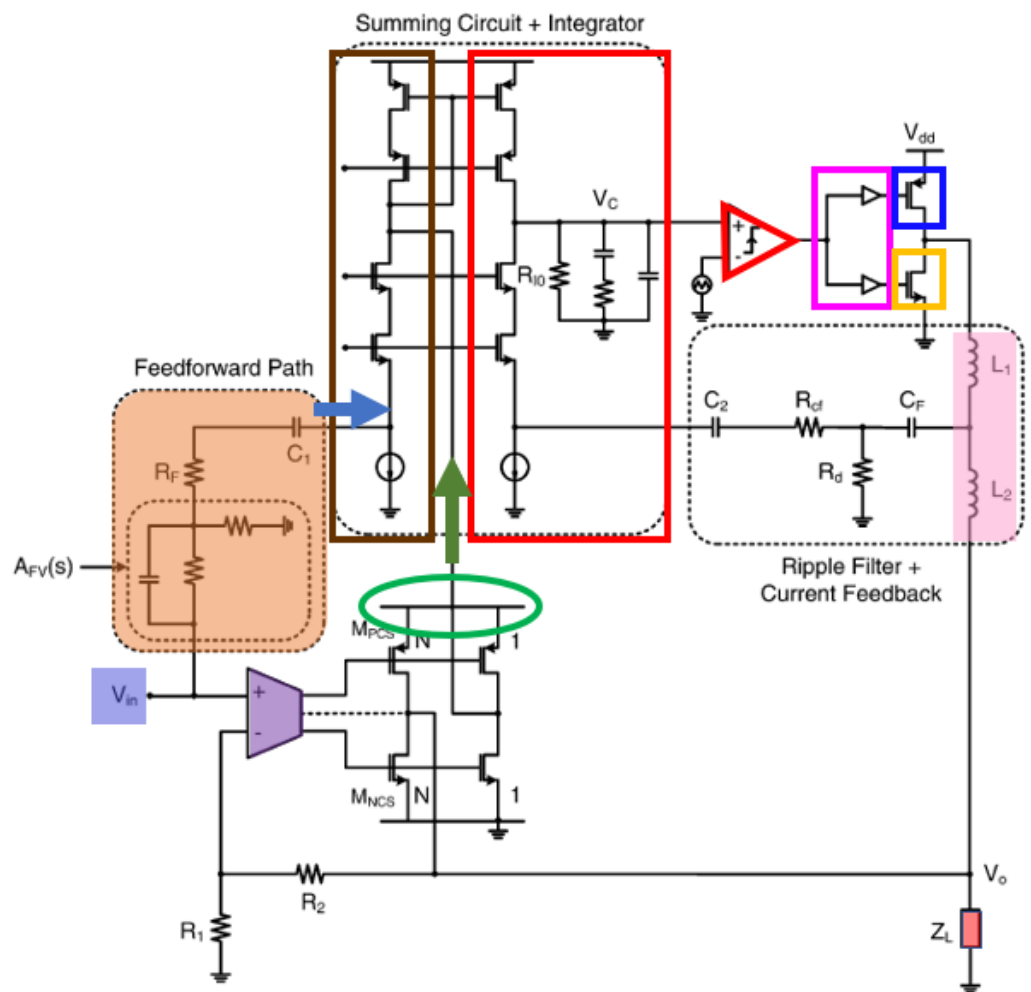


Fig. 6. Detailed block diagram of the hybrid switching amplifier.

Kwak – Figure 6

Ex. 1211 at 2669 (“Fig. 6 shows the detailed circuit of the hybrid switching amplifier.”). Figure 6 includes a “Summing Circuit + Integrator”, which is the combination of the summing circuit of Figure 5 (Σ , outlined in brown) and the integrator $A_I(s)$ in Figure 5 (outlined in red). This “Summing Circuit + Integrator” is shown to add an offset (*i.e.*, the current from the feedforward path, shown by the blue arrow) to an input current (shown by the dark green arrow). *Id.* at 2669 (“the simultaneous summation and integration of the signals at the node V_C , after the conversion of the three voltage signals into current ones, is advantageous, that is, ***the sensed output current of the linear amplifier*** [dark green arrow], the ***feedforward current*** [blue arrow], and the high-frequency current through the ripple filter ***are added together*** and integrated at the node with the inverted polarity of the last one.”).² Ex. 1203 at ¶96.

Figure 5 shows how the added offset current increases the supply current provided via the inductor, as required by claim 15:

² All emphasis has been added, except where otherwise noted.

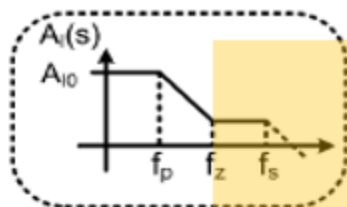
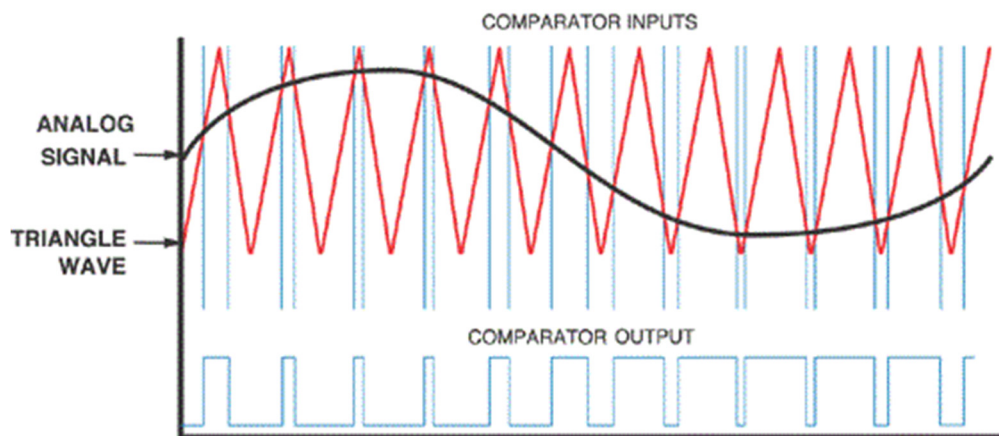


Fig. 5. Hybrid switching amplifier with the feedforward path.

Kwak – Figure 5

The operational amplifier (op-amp) comparator circuit at the top center of the switcher shown in Figure 5 (the right triangle outlined in red)) receives (1) the combined current (including the offset) from the integrator $A_I(s)$ (the left triangle outlined in red in Figure 5, labeled with the integral sign \int) at its negative input, and (2) a triangle or “sawtooth” signal (circled in teal) at its positive input. Ex.

Based on the operation of this op-amp comparator, the offset will increase the supply current via the inductor. The op-amp comparator compares the relative magnitude of its two inputs. Whenever the combined input current (including the offset) from the integrator exceeds the input triangle signal, the output of the op-amp comparator is low, as shown below:



Ex. 1203 at ¶¶99. When the comparator output is low, the PMOS transistor to the right (outlined in bright blue) is ON and the NMOS transistor (outlined in gold) is OFF, thus connecting the upper terminal of the inductor to the supply voltage V_{dd} , thereby allowing current to flow to the inductor. In contrast, when the comparator output is high, the inductor is connected to ground. Adding an offset to the input current provides more opportunity for the input current to exceed the triangle signal, and therefore increases the time that the comparator output is low. This increases the time the inductor is connected to V_{dd} , thereby increasing the supply current via the inductor. Ex. 1203 at ¶¶100-102.

That Kwak's offset current (provided by the feedforward path) causes a larger supply current from the inductor can also be seen mathematically. Figure 5 shows that the total output current (i_o) from the hybrid supply generator is the sum of the currents from the envelope amplifier (i_a) and the switcher (i_d)—that is, $i_o = i_a + i_d$. Kwak's equation (4) is another expression for the total output current (i_o):

$$i_o = \frac{A_{vf} \cdot v_{in}}{Z_L} = i_a + (A_S \cdot i_a + A_F \cdot v_{in}) \cdot A_I \cdot A_M \cdot \frac{1}{Z_L + sL} \quad (4)$$

Using basic math, the portion of the total output current provided by the switcher (i_d) must be represented by the terms *after* i_a in Kwak's equation (4):

$$(A_S \cdot i_a + A_F \cdot v_{in}) \cdot A_I \cdot A_M \cdot \frac{1}{Z_L + sL}$$

According to this expression, the supply current from the switcher (i_d) is proportional to the offset current (A_F): as the offset (A_F) increases, so will the supply current from the switcher (i_d). Ex. 1203 at ¶103.

Kwak also describes this effect of the offset when it explains “the effect of the feedforward path,” which is the structure that supplies the offset. Ex. 1211 at 2673. Kwak explains that the feedforward path causes “the output current of the linear amplifier” (i_a) to be “reduced to about half.” *Id.* This means the output current of the switcher (i_d) must increase: the overall current requirements of the PA do not change when the offset (feedforward path) is added, since they are

determined by the input signal, so when the offset causes the envelope amplifier to provide less current, the switcher must make up the difference. *See* Ex. 1201 at Fig. 4B, 4C (showing that addition of an offset in Figure 4C does not change overall current (I_{pa}) compared to Figure 4B, but only the current provided by switcher via the inductor (I_{ind})); *id.* at 6:38-44, 7:34-48. This is consistent with the purpose of the offset in the '558 patent: to reallocate a larger share of the power burden to the more efficient switcher and a smaller share to the less efficient envelope amplifier. Ex. 1203 at ¶104.

(d) “wherein the switcher comprises a summer operative to sum the input current and an offset current and provide a summed current,”

Kwak discloses this limitation. As explained above regarding limitation 15(c), Kwak’s switcher includes a summing circuit that adds the input current from the driver A_S and the offset current from the driver A_F and then provides a summed current to the integrator. Ex. 1203 at ¶105.

(e) “a current sense amplifier operative to receive the summed current and provide a sensed signal, and”

Kwak discloses this limitation.

Kwak discloses an integrator and a comparator (each outlined in red below) that together form a current sense amplifier. Ex. 1203 at ¶106. As described above regarding limitation 15(c) and as shown below in Figure 5, the integrator

$A_I(s)$ (the left triangle outlined in red, labeled with the integral sign \int) receives the summed signal, which is a current—i.e., the original input current plus the offset current—from the summing circuit (outlined in brown):

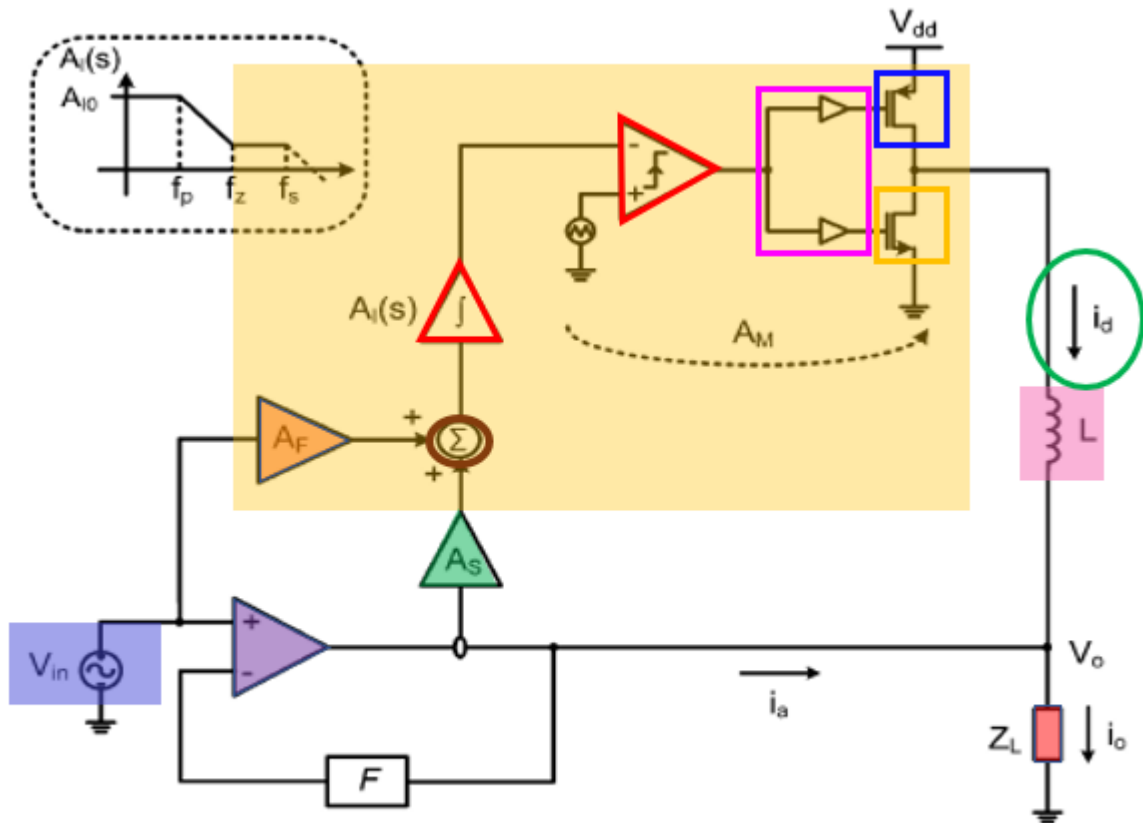


Fig. 5. Hybrid switching amplifier with the feedforward path.

Kwak – Figure 5

Ex. 1211 at Figure 5. *See* Section X.A.1(c). The integrator's output is fed to the comparator (the right triangle outlined in red), which outputs a sensed signal—a voltage for use in controlling the PMOS and NMOS transistors. Under the ALJ's construction from the parallel ITC litigation (*see supra* Section VIII), a current

sense amplifier is an “amplifier that produces a voltage from a current.” The integrator and comparator are shown with the conventional triangle shape for amplifiers, are described by Kwak as amplifiers (Ex. 1211 at 2669 (“the integrator gain $AI(s)$ ”), and they operate together to convert the current from the summer to a voltage provided to the transistors. The integrator and comparator therefore form a current sense amplifier. Ex. 1203 at ¶¶107-108.

- (f) “a driver operative to receive the sensed signal and provide at least one control signal used to generate the switching signal for the inductor.”**

Kwak discloses this limitation. Kwak discloses two buffers (outlined in fuchsia) that drive the PMOS and NMOS transistors. Each of these buffers receives the sensed voltage signal from the comparator, and each provides a control signal to the transistors, which then determine the switching signal (i_d) for the inductor. Ex. 1203 at ¶109.

2. Claim 17

Claim 17 is anticipated by Kwak, as explained below. Ex. 1203 at ¶¶110, 124.

- (a) “The apparatus of claim 15, wherein the at least one control signal comprises a first control signal and a second control signal, and”**

Kwak discloses this limitation. As explained above in the discussion about claim 15, Kwak discloses the apparatus of claim 15. Further, as explained above

with respect to limitation 15(f), the two buffers (outlined in fuchsia) each provide a control signal—a first control signal and a second control signal—and these signals drive the PMOS and NMOS transistors. Ex. 1203 at ¶111.

(b) “wherein the switcher further comprises a P-channel metal oxide semiconductor (PMOS) transistor having a gate receiving the first control signal, a source receiving a first supply voltage, and a drain providing the switching signal, and”

Kwak discloses this limitation. As described above regarding limitations 15(f) and 17(a), the switcher (highlighted in yellow) includes a PMOS transistor (outlined in bright blue) that receives the first control signal at its gate. *See* Sections X.A.1(f) and X.A.2(a). Ex. 1203 at ¶111.

As shown in Figure 5, the source (top terminal) of the PMOS transistor receives a first supply voltage (V_{dd}), while the drain (the lower terminal of the transistor) provides the switching signal (i_d) to the inductor:

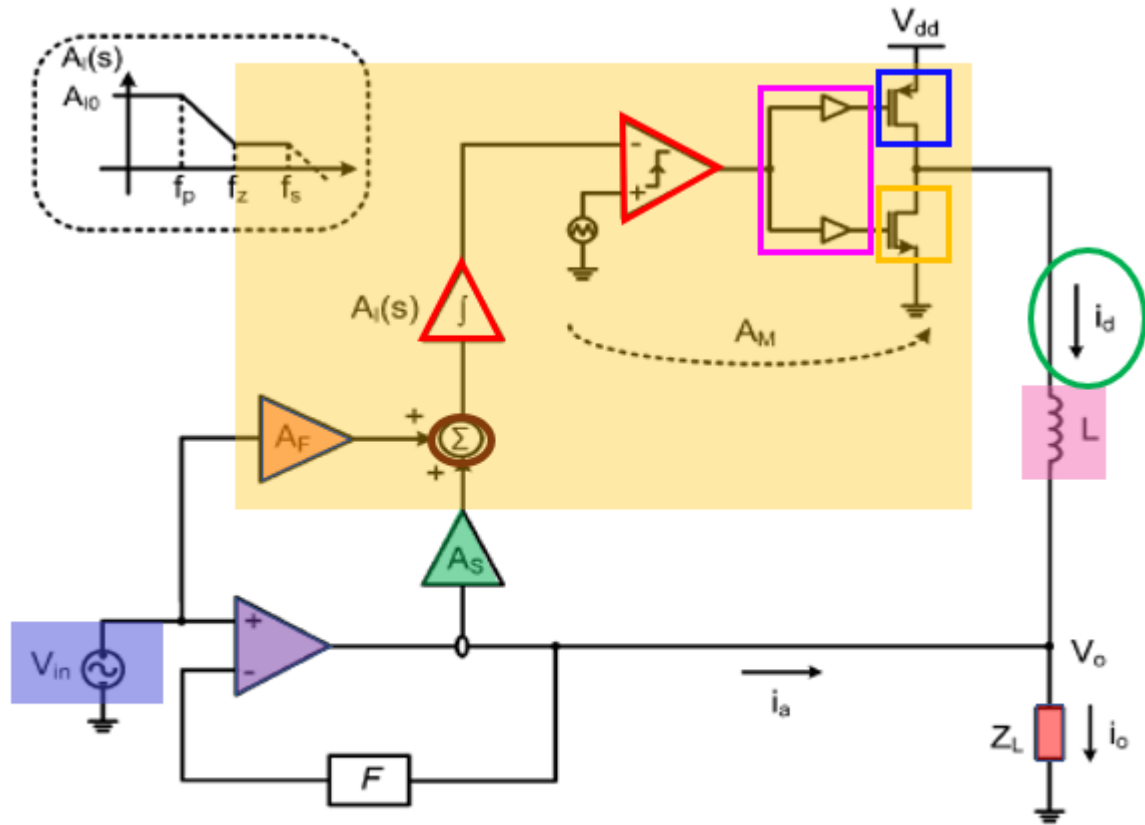


Fig. 5. Hybrid switching amplifier with the feedforward path.

Kwak – Figure 5

Ex. 1211 at 2668, Fig. 5; Ex. 1203 at ¶113.

- (c) “an N-channel metal oxide semiconductor (NMOS) transistor having a gate receiving the second control signal, a drain providing the switching signal, and a source coupled to circuit ground.”

Kwak discloses this limitation. As described above regarding limitations 15(f) and 17(a), the switcher (highlighted in yellow) includes an NMOS transistor (outlined in gold) that receives the second control signal at its gate. *See* Sections X.A.1(f) and X.A.2(a). Ex. 1203 at ¶114.

As shown in Figure 5 above, the drain (top terminal) of the NMOS transistor provides the switching signal (i_d) to the inductor. The source (bottom terminal) of the NMOS transistor is coupled to circuit ground (shown by standard notation for ground). Ex. 1203 at ¶115.

3. Claim 18

Claim 18 is anticipated by Kwak, as explained below. Ex. 1203 at ¶¶116, 124.

- (a) **“The apparatus of claim 15, further comprising: an envelope amplifier operative to receive an envelope signal and provide a second supply current based on the envelope signal,”**

Kwak discloses this limitation. As explained above regarding claim 15, Kwak discloses the apparatus of claim 15. Ex. 1203 at ¶117.

Kwak further discloses an envelope amplifier (highlighted below in purple):

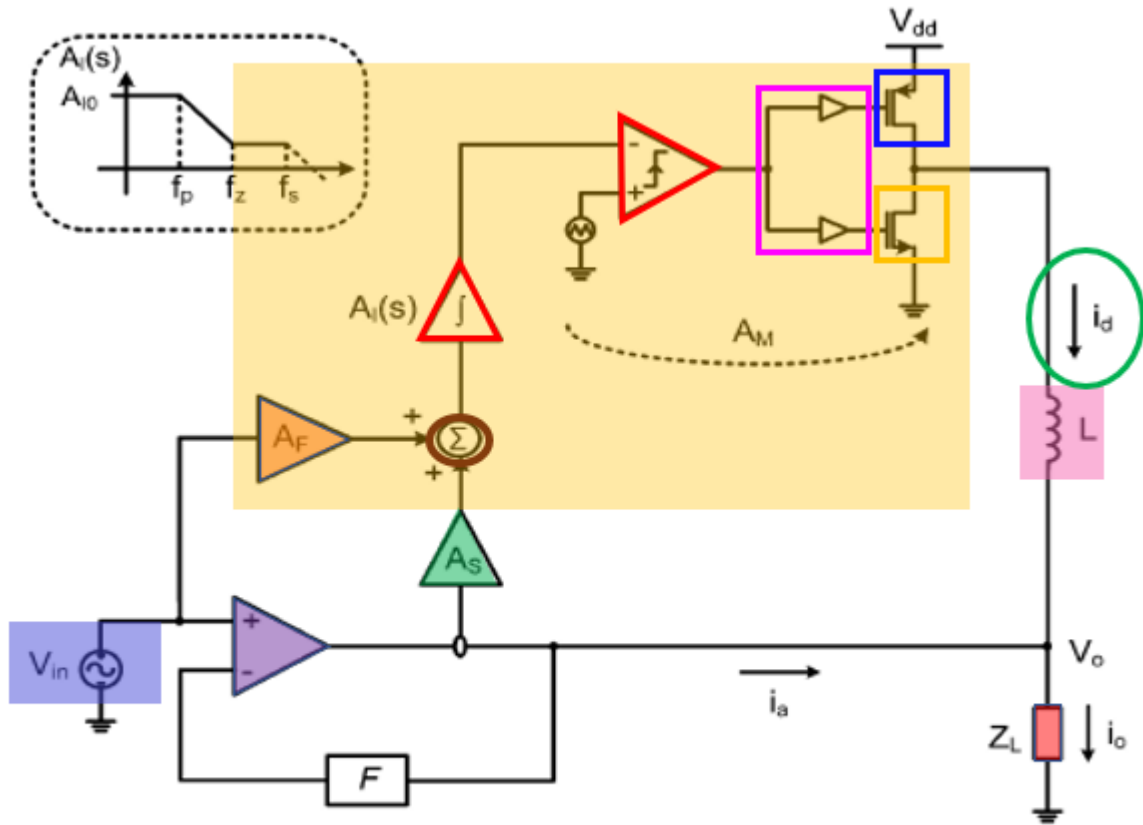


Fig. 5. Hybrid switching amplifier with the feedforward path.

Kwak – Figure 5

Ex. 1211 at 2666 (“[O]ur proposed CMOS hybrid switching amplifier achieves both high speed and high efficiency through the combination of a wideband linear amplifier with a very efficient switching amplifier.”); *id.* (“As shown in Fig. 2(a), the hybrid switching amplifier has a master–slave structure consisting of a wideband linear amplifier as a voltage source and a switching amplifier as a current-controlled current source. The wideband linear amplifier accurately controls the output voltage with good linearity, and the switching amplifier

efficiently supplies most of the output current by sensing and amplifying the output current of the former.”); *id.* at 2668-69 (“If we add a feedforward path, like the one shown in Fig. 5, the input signal can directly control the switching amplifier. Such a path is faster than the feedback current path formed by sensing the output current of the linear amplifier.”). The envelope amplifier receives an envelope signal V_{in} (highlighted in blue) and, based on that signal, provides a second supply current (i_a) to the PA. Ex. 1203 at ¶¶118-119.

(b) “wherein a total supply current comprises the supply current from the switcher and the second supply current from the envelope amplifier.”

Kwak discloses this limitation. The supply current to the PA (i_o) comes from two sources: the envelope amplifier and the switcher. The total supply current (i_o) therefore comprises the sum of the switcher’s supply current (i_d) and the second supply current from the amplifier (i_a). *See* Ex. 1211 at 2666 (“[T]he switching amplifier supplies most of the output current through the relation of $i_o = i_a + i_d = (1 + \beta) \cdot i_a$. In reality, however, as shown in Fig. 2(b), the output current of the switching amplifier (i_d) is slower and less than the output current (i_o) because of the finite loop gain β .”); *id.* (“the required output current of the linear amplifier i_a ”). Ex. 1203 at ¶120.

4. Claim 20

Claim 20 is anticipated by Kwak, as explained below. Ex. 1203 at ¶¶121, 124.

- (a) **“The apparatus of claim 15, further comprising: a power amplifier operative to receive the supply current from the inductor and to receive and amplify an input radio frequency (RF) signal and provide an output RF signal.”**

Kwak discloses this limitation. As explained above regarding claim 15, Kwak discloses the apparatus of claim 15. Kwak also discloses a power amplifier, highlighted below in red.

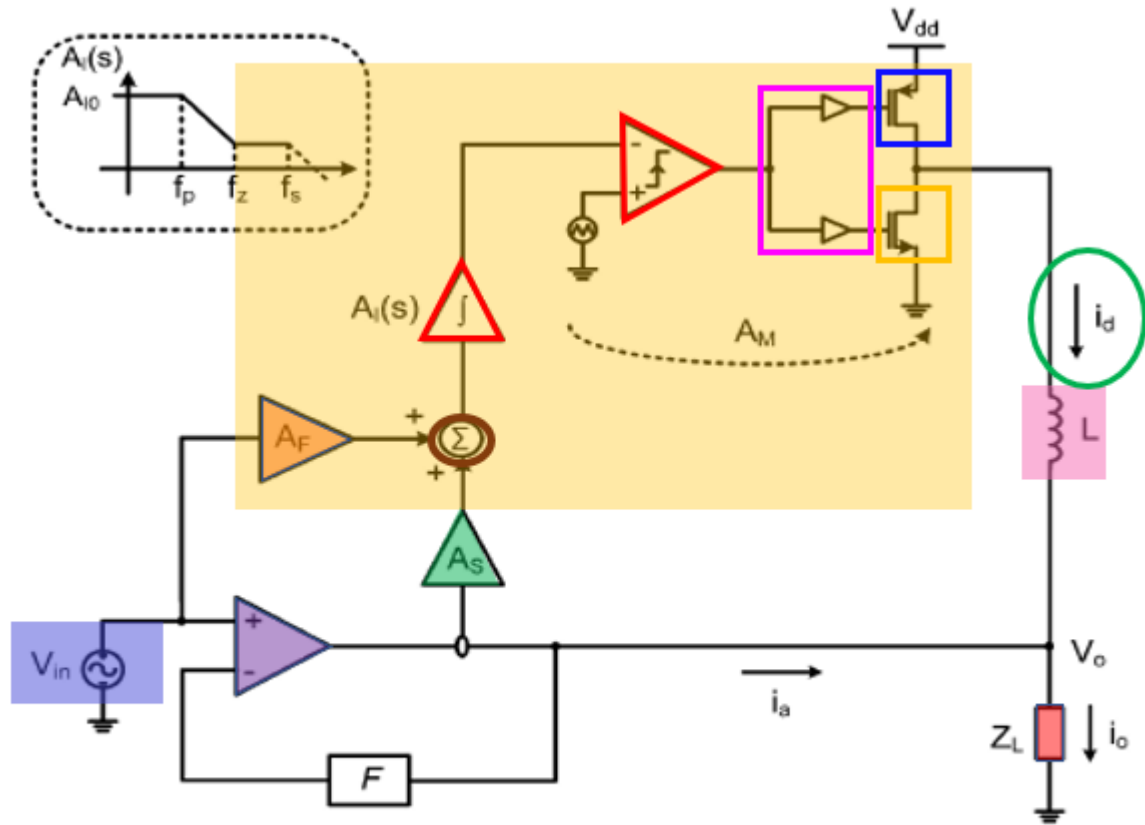


Fig. 5. Hybrid switching amplifier with the feedforward path.

Kwak – Figure 5

Ex. 1211 at Figure 5, Abstract (“This paper presents a hybrid switching amplitude modulator for class-E2 EDGE polar transmitters.”). Ex. 1203 at ¶122.

The power amplifier receives the supply current from the inductor. Moreover, the power amplifier is described as receiving and amplifying an input RF signal and providing an output RF signal. Ex. 1211 at Abstract (“It can drive an RF power amplifier with an equivalent impedance of 4 Ω up to a maximum output power of 2.25 W with a maximum efficiency of 88.3%.”); *id.* at 2670 (“By

assuming the phase-modulated signal of $\cos(\omega_c t + \Theta(t))$ is applied at the input of the RF power amplifier, we can express the output of the power amplifier $s'_c(t)$ by the amplitude modulation of $a'(t)$ and $\cos(\omega_c t + \Theta(t))$ as follows”). Ex. 1203 at ¶123.

B. Ground II: Claim 16 is obvious in view of Kwak

1. Claim 16

Claim 16 is obvious based on Kwak, as explained below. Ex. 1203 at ¶¶125, 129.

- (a) “The apparatus of claim 15, wherein the switcher operates based on a first supply voltage, and wherein the offset is determined based on the first supply voltage.”**

Kwak discloses this limitation.

As explained above, Kwak anticipates claim 15. Ex. 1203 at ¶126.

As shown in Figure 5 above, Kwak also discloses a first supply voltage V_{dd} coupled to the top terminal of the transistor outlined in blue. Kwak’s switcher operates based on this first supply voltage because, as discussed above regarding limitation 17(b), Kwak’s switcher uses V_{dd} to generate the switching signal for the inductor L. Ex. 1203 at ¶127.

It would have been obvious to determine the offset (as discussed above regarding limitation 15(c)) based on the first supply voltage V_{dd} . The offset is

provided by the A_F block, which is depicted in Figure 5 with a triangle symbol typically used for amplifiers, and Kwak describes the A_F block as having gain, suggesting amplification. Ex. 1211 at 2669 (“[T]he gain of the feedforward path is given as”). See Section X.A.1(c). As explained further by Dr. Apsel in her accompanying declaration, it would have been obvious for a POSA to implement this block with an active component, such as a driver or amplifier, such as a two-stage transconductance amplifier as disclosed in a well-known standard textbook regarding the design of analog circuits (Ex. 1224 (Fig. 8.13(c))). This would have been particularly obvious in an implementation such as Kwak where the feedforward path needs to provide high gain to improve (i.e., speed up) the response of the switcher to changes in the envelope signal. It also would have been obvious to use the available V_{dd} (the first supply voltage) for that power supply. Ex. 1203 at ¶128.

In this obvious implementation, the transfer function of the amplifier (i.e., the relationship of the output versus the inputs) would depend on the V_{dd} supply voltage. As Dr. Apsel explains, the gain of each stage of the amplifier device will depend on the drain current of each stage, which in turn depends on the drain-to-source voltage (V_{DS}) and the supply voltage (V_{dd}). See Ex. 1224 at 22 (equation 2.20). For example, if V_{dd} increases, the output current of the amplifier would increase. As a result, the offset current from the A_F block would be determined

based on, among other things, the first supply voltage (as well as on the input voltage V_{in}), and Kwak therefore discloses this limitation. Ex. 1203 at ¶128.

C. Ground III: Claim 19 is obvious in view of Kwak combined with Choi 2010

1. Claim 19

Claim 19 is obvious in view of Kwak combined with Choi 2010, as explained below. Ex. 1203 at ¶¶130, 140.

- (a) “The apparatus of claim 18, further comprising: a boost converter operative to receive the first supply voltage and provide a boosted supply voltage having a higher voltage than the first supply voltage,”**

Kwak combined with Choi 2010 renders this limitation obvious. As explained above, Kwak anticipates claim 18. Ex. 1203 at ¶131.

Choi 2010 discloses the remaining elements of this limitation, and it would have been obvious to a POSA to modify Kwak so that it generates a boosted supply voltage that is higher than the first supply voltage. As shown below, Choi 2010 (like Kwak) discloses a supply generator (“supply modulator”) for a PA, and Choi 2010’s supply generator (like Kwak’s) includes an envelope amplifier (highlighted in purple) that receives an envelope signal Env:

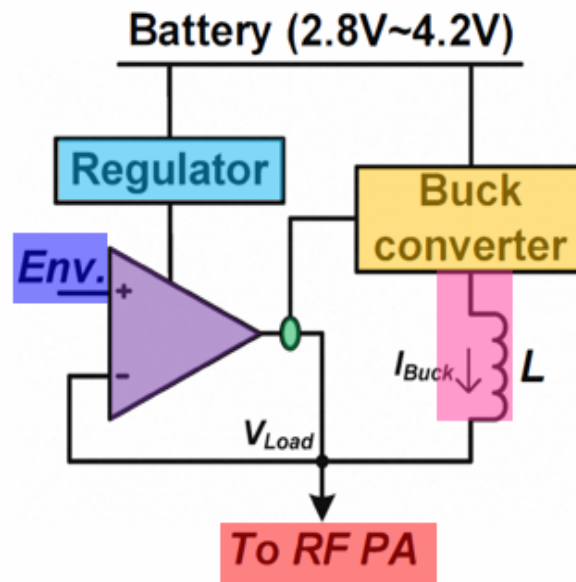


Fig. 5. Battery-to-5V boosting PA supply modulator.

Choi 2010 – Figure 5

The Choi 2010 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 higher than the first supply voltage. Ex. 1207 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 (“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, whose input range is from 2.8V to 4.2V, 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. ... 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. 1203 at ¶¶132-133.

(i) Motivation to Combine Kwak and Choi 2010

It would have been obvious to modify Kwak’s supply modulator to incorporate the boost converter of Choi 2010. Both Kwak and Choi 2010 are from the same field of endeavor—each discloses a supply modulator for a PA. Choi 2010 even cites Kwak as prior art that the Choi 2010 apparatus builds upon. Ex. 1207 at 1074, 1077 (reference [5]). Ex. 1203 at ¶134.

Moreover, a POSA would have been motivated to use Choi 2010’s boost converter in Kwak to prevent distortion as the battery becomes depleted and the voltage provided by the battery falls. Specifically, it would have been desirable to operate Kwak’s linear amplifier with a boosted voltage so that (1) when the battery voltage starts depleting, Kwak’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, 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 Kwak accordingly. Ex. 1207 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, while that of the buck converter is still coupled to the battery in the HSA, 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. 1203 at ¶135.

The Maehara patent, for example, taught using a boost converter (“step-up converter”) in an amplifying circuit to prevent distortion. *See* Ex. 1218 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.***”).³

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.

³ All emphasis has been added, except where otherwise noted.

1215 [Maxim Integrated Products, Inc., *MAX9738 –16VP-P Class G Amplifier with Inverting Boost Converter*, Datasheet 19-3700, Rev. 0 (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 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. 1203 at ¶136.

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, and thus further confirm the motivation for this modification. Because adding a boost converter had been used to improve numerous similar devices, a POSA would have recognized that this same technique would also improve the Chu’s supply modulator. References such as Maehara and Maxim show that the results of incorporating a boost converter such as Choi 2010’s boost converter into Chu’s supply modulator were entirely

predictable, and in line with the results to be expected from the express teaching of Choi 2010. Ex. 1203 at ¶136.

It was also well known in the art that the voltage output of a battery declines over time with use. In particular, it was known that, in operation, a battery will start at a fully charged voltage output level, but that the voltage level output by the battery will decline over time as the battery becomes depleted. A person of ordinary skill in the art would understand that the output of a battery is not binary (i.e., not either fully on or fully off) but instead will decay over time until the battery's voltage output reaches zero. Given this state of battery technology in the prior art, it was obvious to use a boost converter to boost a falling battery voltage and provide the boosted voltage to circuit components, such as Chu's envelope amplifier, to maintain operation and minimize distortion as battery voltages drop. Ex. 1203 at ¶137.

Finally, adding the Choi 2010 boost converter to Kwak's supply generator would have yielded only expected, predictable results. Combining the teachings of Choi 2010 with Kwak would have been: (a) a combination of prior-art elements according to known methods to yield predictable results, because a POSA would understand, 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) to improve a similar device (Kwak'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 (Kwak'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. 1203 at ¶138.

(b) “wherein the envelope amplifier operates based on the first supply voltage or the boosted supply voltage.”

Choi 2010 discloses this limitation. As discussed above in connection with limitation 19(a), the boost converter in Choi (the Regulator) is coupled to the envelope amplifier, such that the envelope amplifier operates based on the boosted supply voltage. See Section X.C.1(a). It would have been obvious to modify Kwak to incorporate the boost converter of Choi 2010 for the reasons stated above regarding 19(a). Ex. 1203 at ¶139.

XI. CONCLUSION

Based on the foregoing, claims 15-20 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
1201	U.S. Patent No. 8,698,558
1202	File History for U.S. Patent No. 8,698,558
1203	Declaration of Dr. Alyssa B. Apsel
1204	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”)
1205	Declaration of IEEE regarding Chu, Kwak, Kim, and Blanken (“IEEE Chu Decl.”)
1206	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”)
1207	Declaration of IEEE regarding Choi 2010 (“IEEE Choi Decl.”)
1208	Declaration of Debabani Choudhury (“Choudhury Decl.”)
1209	Declaration of Jinsung Choi (“Choi Decl.”)
1210	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”)
1211	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”)
1212	U.S. Patent No. 5,929,702, “Method and Apparatus for High Efficiency High Dynamic Range Power Amplification,” to Myers et al. (“Myers”)
1213	Kim, D. et al., “High efficiency and wideband envelope tracking power amplifier with sweet spot tracking.” <i>Radio Frequency Integrated Circuits Symposium (RFIC):</i> 255-258 (2010) (“Kim”)

1214	U.S. Patent No. 6,300,826, “Apparatus and Method for Efficiently Amplifying Wideband Envelope Signals” (filed May 5, 2000) (“Mathe ’826”)
1215	Maxim Integrated Products, Inc., <i>MAX9738 –16VP-P Class G Amplifier with Inverting Boost Converter</i> , Datasheet 19-3700, Rev. 0 (March 2008) (“Maxim”)
1216	Ertl, H. et al., “Basic considerations and topologies of switched-mode assisted linear power amplifiers,” <i>IEEE Transactions on industrial electronics</i> 44.1 (1997): 116-123 (“Ertl”)
1217	Kang, D. et al., “A multimode/multiband power amplifier with a boosted supply modulator” <i>IEEE Transactions on Microwave Theory and Techniques</i> 58.10 (2010): 2598-2608 (“Kang”)
1218	U.S. Patent No. 5,834,977, “Amplifying Circuit with Power Supply Switching Circuit” (filed October 30, 1996 and issued November 10, 1998) (“Maehara”)
1219	U.S. Patent No. 5,870,340, “Multiplexer” (filed July 8, 1997 and issued February 9, 1999) (“Ohsawa”)
1220	U.S. Patent No. 6,566,935, “Power Supply Circuit With a Voltage Selector” (filed August 28, 2000 and issued May 20, 2003) (“Renous”)
1221	Certificate of Correction for U.S. Patent No. 8,698,558 (“558 COC”)
1222	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”)
1223	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”)
1224	Razavi, <i>Design of Analog CMOS Integrated Circuits</i> (2001) (“Razavi”) (excerpts)

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 1201-1224
- 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 11,355 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 28, 2018

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