

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

XILINX, INC. AND XILINX ASIA PACIFIC PTE. LTD.,
Petitioner,

v.

ANALOG DEVICES, INC.,
Patent Owner.

IPR2020-01484
Patent 6,900,750 B1

Before JEFFREY S. SMITH, SCOTT A. DANIELS, and
GEORGIANNA W. BRADEN, *Administrative Patent Judges*.

SMITH, *Administrative Patent Judge*.

JUDGMENT
Final Written Decision
Determining All Challenged Claims Unpatentable
35 U.S.C. § 318(a)

On August 17, 2020, Xilinx, Inc. and Xilinx Asia Pacific Pte. Ltd. (collectively “Petitioner”) filed a Petition requesting an *inter partes* review of claims 10, 11, 13–32, and 35–43 of U.S. Patent No. 6,900,750 B1, issued on May 31, 2005 (Ex. 1101, “the ’750 patent”). Paper 1. Petitioner filed a corrected Petition on October 29, 2020, to correct typographical errors. Paper 7 (“Pet.”). Analog Devices, Inc. (“Patent Owner”) filed a Response. Paper 17 (“PO Resp.”). Petitioner filed a Reply, and Patent Owner filed a Sur-Reply (“PO Sur-Reply”). Papers 23, 25. A hearing was held on December 10, 2021. Paper 29.

We have jurisdiction under 35 U.S.C. § 6. This Final Written Decision is entered pursuant to 35 U.S.C. § 318(a). We determine that claims 10, 11, 13–32, and 35–43 are unpatentable.

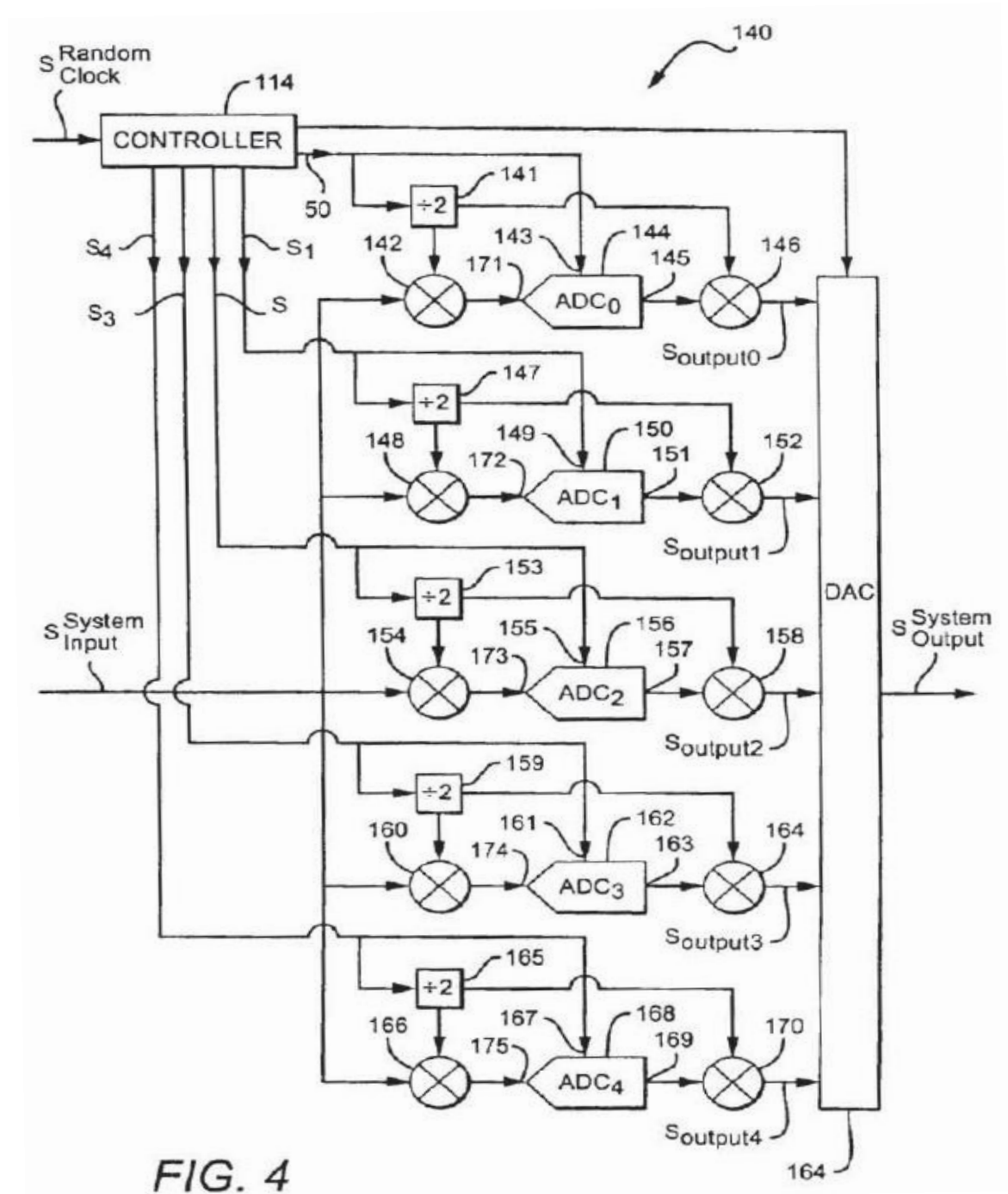
I. BACKGROUND

A. *The ’750 Patent (Ex. 1101)*

The ’750 patent relates to adjusting gain and offset mismatches in a signal conditioning system having interleaved analog-to-digital converters (ADCs). Ex. 1101, 1:9–14, 5:28–29, 6:63–66. Interleaving multiple ADCs provides the advantage of increasing the sampling rate proportionally to the number of ADCs. *Id.* at 6:63–7:4. For example, if the clock frequency of each ADC is f_c and the number of interleaved ADCs is M , then the sampling rate of the system is $f_s = M \cdot f_c$. *Id.* The interleaved ADCs often have mismatches in offset and gain, however, which affect the Signal-to-Noise and Distortion ratio. *Id.* at 1:26–37. To correct the offset mismatches of the interleaved ADCs, the system includes an offset sensor coupled with the ADCs to sense and adjust an offset signal difference. *Id.* at codes (54), (57), 3:41–47, 7:5–21, Figs. 1–4. To correct the gain mismatches, the system includes a gain sensor coupled with the ADCs to sense a gain difference, and

a gain corrector coupled with the gain sensor to adjust the gain difference.
Id. at codes (54), (57), 3:41–47, 10:12–21, 10:40–65, 11:26–52, Figs. 6–8.

Figure 4 below shows a block diagram illustrating a signal conditioning system 140 including interleaved ADCs. Ex. 1101, 3:44–46, 8:16–23.



As shown in Figure 4 above, signal conditioning system 140 includes interleaved ADCs 144, 150, 156, 162, and 168. Ex. 1101, 8:24–25. Each of the ADCs is a zero offset ADC, in which the offset signal is subtracted from an analog input signal to condition a digital output signal. *Id.* at 9:7–13; see *id.* at 5:17–45, Fig. 1. Controller 114 provides a random select or clock signal to each ADC through respective ADC select terminals. *Id.* at 8:51–54. For example, controller 114 provides random clock signal S_0 to ADC 144 through ADC select terminal 143. *Id.*

Each ADC has a modulator coupled to its input and a demodulator coupled to its output. Ex. 1101, 8:25–48. For example, modulator 142 is coupled to input 171 of ADC 144, and demodulator 146 is coupled to output 145 of ADC 144. *Id.* at 8:25–27. The modulators and demodulators are coupled to the controller through a respective divider. *Id.* at 8:25–48. For example, controller 114 is connected to modulator 142 and demodulator 146 through divider 141. *Id.* at 8:27–29.

Inputs of the modulators are configured to randomly receive the system input signal. Ex. 1101, 8:58–60. Each modulator multiplies the system input signal by the divided random clock prior to being converted by the corresponding ADC, and each demodulator multiplies the output of the corresponding ADC by the divided random clock to form each output signal $S_{\text{output}0}$ to $S_{\text{output}4}$. *Id.* at 8:41–67. The outputs of the demodulators are coupled to digital-to-analog converter (DAC) 164, which converts the digitized output into an analog signal. *Id.* at 9:1–6.

B. Illustrative Claim

As noted above, Petitioner challenges claims 10, 11, 13–32, and 35–43, of which claims 10, 19, 25, 32, and 41 are independent. Claim 10 is reproduced below.

10. An integrated circuit that converts between an analog signal and a corresponding digital code with a system sampling rate f_s , said circuit comprising:

a plurality of converter circuits clocked by a random clock, at least one converter circuit in said plurality of converter circuits sampling the analog signal at least every $1/f_s$ seconds; and

an offset sensing circuit configured to sense signal offsets and/or signal offset differentials between the outputs of said plurality of converter circuits.

Ex. 1101, 14:38–48.

C. Related Proceedings

Petitioner and Patent Owner identify the following related litigation asserting the '750 patent: *Analog Devices, Inc. v. Xilinx, Inc. and Xilinx Asia Pacific Pte. Ltd.*, C.A. No. 19-cv-02225-RGA (D. Del.). Pet. 84; Paper 4, 2. Patent Owner also states that “Petitioner[] filed petitions for *Inter Partes* Review of U.S. Patent No. 10,250,250 (Case No. IPR2020-01210), U.S. Patent No. 8,487,659 (Case No. IPR2020-01219), U.S. Patent No. 7,012,463 (Case No. IPR2020-01336), U.S. Patent No. 7,286,075 (Case No. IPR2020-01559), U.S. Patent No. 7,719,452 (Case No. IPR2020-01561), and U.S. Patent No. 6,900,750 (Case Nos. IPR2020-01483, IPR2020-01564, and the present case), which are also at issue in the above litigation.” Paper 4, 2.

D. References

Petitioner relies on the following references:

1. “Eklund” (U.S. Patent No. 6,392,575 B1, issued May 21, 2002) (Ex. 1106);
2. “Jamal” (A 10-b 120-Msample/s time-interleaved analog-to-digital converter with digital background calibration, IEEE Journal of

Solid-State Circuits, vol. 37, no. 12, pp. 1618–27, Dec. 2002) (Ex. 1105);

3. “Ferragina” (Gain and offset mismatch calibration in multi-path sigma-delta modulators, Proceedings of the 2003 International Symposium on Circuits and Systems, 2003) (Ex. 1107).

4. “Agazzi” (U.S. Patent No. 7,245,638 B2, issued July 17, 2007) (Ex. 1115).

E. Asserted Challenges to Patentability

Petitioner asserts that claims 10, 11, 13–32, and 35–43 are unpatentable on the following challenges:

Ground	Claim(s) Challenged	35 U.S.C. §	Reference(s)/Basis
1	10, 11, 13, 14, 16, 17, 19, 20, 23–30, 32, 35–43	103	Eklund, Jamal
2	15, 18, 21, 22	103	Eklund, Jamal, Ferragina
3	27, 28, 31, 37, 40, 42	103	Eklund, Jamal, Agazzi

Petitioner also relies on testimony from Dr. Douglas Holberg (Ex. 1102, “Holberg Decl.”). Patent Owner relies on the testimony of Dr. Arigit Raychowdhury (Ex. 2106), “Raychowdhury Decl.”).

II. ANALYSIS

A. Legal Principles

“In an [*inter partes* review], the petitioner has the burden from the onset to show with particularity why the patent it challenges is unpatentable.” *Harmonic Inc. v. Avid Tech., Inc.*, 815 F.3d 1356, 1363 (Fed. Cir. 2016) (citing 35 U.S.C. § 312(a)(3) (requiring *inter partes* review petitions to identify “with particularity . . . the evidence that supports the grounds for the challenge to each claim”)); *see also* 37 C.F.R. § 42.104(b) (requiring a petition for *inter partes* review to identify how the challenged

claim is to be construed and where each element of the claim is found in the prior art patents or printed publications relied upon).

A claim is unpatentable under 35 U.S.C. § 103(a) if “the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains.” *KSR Int’l Co. v. Teleflex Inc.*, 550 U.S. 398, 406 (2007). The question of obviousness is resolved on the basis of underlying factual determinations, including: (1) the scope and content of the prior art; (2) any differences between the claimed subject matter and the prior art; (3) the level of skill in the art; and (4) when in evidence, objective evidence of obviousness or nonobviousness, i.e., secondary considerations. See *Graham v. John Deere Co.*, 383 U.S. 1, 17–18 (1966). An obviousness analysis “need not seek out precise teachings directed to the specific subject matter of the challenged claim, for a court can take account of the inferences and creative steps that a person of ordinary skill in the art would employ.” *KSR*, 550 U.S. at 418.

Additionally, the obviousness inquiry typically requires an analysis of “whether there was an apparent reason to combine the known elements in the fashion claimed by the patent at issue.” *KSR*, 550 U.S. at 418 (citing *In re Kahn*, 441 F.3d 977, 988 (Fed. Cir. 2016) (requiring “articulated reasoning with some rational underpinning to support the legal conclusion of obviousness”)). Furthermore, Petitioner does not satisfy its burden of proving obviousness by employing “mere conclusory statements,” but “must instead articulate specific reasoning, based on evidence of record, to support the legal conclusion of obviousness.” *In re Magnum Oil Tools Int’l, Ltd.*, 829 F.3d 1364, 1380 (Fed. Cir. 2016).

B. Level of Ordinary Skill in the Art

In determining whether an invention would have been obvious at the time it was made, we consider the level of ordinary skill in the pertinent art at the time of the invention. *Graham*, 383 U.S. at 17. Petitioner asserts a person of ordinary skill in the art (“POSITA”) at the time of the invention “would have at least a Master’s Degree in Electrical Engineering or equivalent field, including studies in designing data converters, and two to five years of relevant experience; or a Ph.D. degree in Electrical Engineering or equivalent field.” Pet. 23 (citing Ex. 1102 ¶ 17). Patent Owner does not address the level of ordinary skill in the art in its Response. *See generally* PO Resp.

For purposes of this decision, we adopt Petitioner’s formulation because it is consistent with the ’750 patent and the asserted prior art.

C. Claim Construction

We interpret claims in the same manner used in a civil action under 35 U.S.C. § 282(b) “including construing the claim in accordance with the ordinary and customary meaning of such claim as understood by one of ordinary skill in the art and the prosecution history pertaining to the patent.” *See* Changes to the Claim Construction Standard for Interpreting Claims in Trial Proceedings Before the Patent Trial and Appeal Board, 83 Fed. Reg. 51,340, 51,358 (Oct. 11, 2018) (amending 37 C.F.R. §42.100(b) effective November 13, 2018) (now codified at 37 C.F.R. § 42.100(b) (2019)). Only terms that are in controversy need to be construed, and then only to the extent necessary to resolve the controversy. *Nidec Motor Corp. v. Zhongshan Broad Ocean Motor Co.*, 868 F.3d 1013, 1017 (Fed. Cir. 2017).

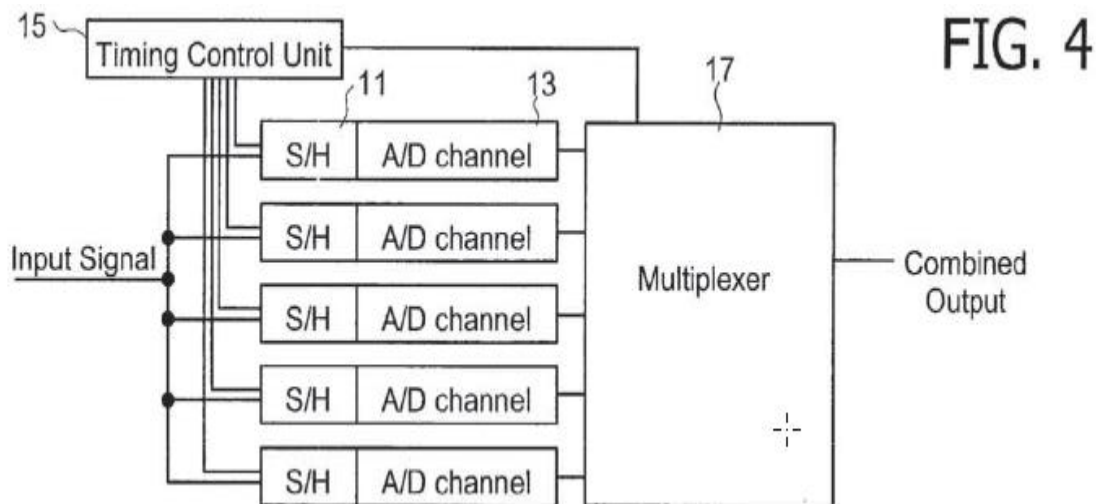
Patent Owner contends that “random clock,” “offset sensing circuit,” and “sensing” a gain or offset signal need to be construed. PO Resp. 16–21.

Petitioner disagrees. Reply 1. Patent Owner's contentions were addressed in our Final Written Decision for IPR2020-01483, which was mailed on the same day as this Decision. We agree with Petitioner and decline to construe these terms for the reasons given in our claim construction analysis in the Final Written Decision for IPR2020-01483. We find there is no need to explicitly construe any claim terms.

D. Asserted Obviousness Over Eklund and Jamal

1. Overview of Eklund (Ex. 1106)

Eklund discloses a parallel analog-to-digital converter having random conversion sequencing. Ex. 1106, code (54). Figure 4 of Eklund shows a block diagram of a parallel ADC converter and is reproduced below. *Id.* at 3:13–14.



As shown in Figure 4 above, input analog signal V_s is sampled by sample and hold circuits 11, as controlled by clock signals from timing control unit 15. *Id.* at 3:30–35. The timing control unit can use a random number generator to control which circuit receives the clock signal. *Id.* at 4:20–34. The clock signals are generated at a uniform rate to sample the analog input signal at periodically occurring times. *Id.* at 3:36–37. A/D

channel 13 connected to a corresponding sample and hold circuit compares the sampled value to reference values, and delivers an output to multiplexer 17. *Id.* at 3:38–45.

2. Overview of Jamal (Ex. 1105)

Jamal discloses a time-interleaved ADC that uses digital-background calibration to overcome offset, gain, and sample-time errors between channels. Ex. 1105, 7.¹ Figure 1 of Jamal is reproduced below.

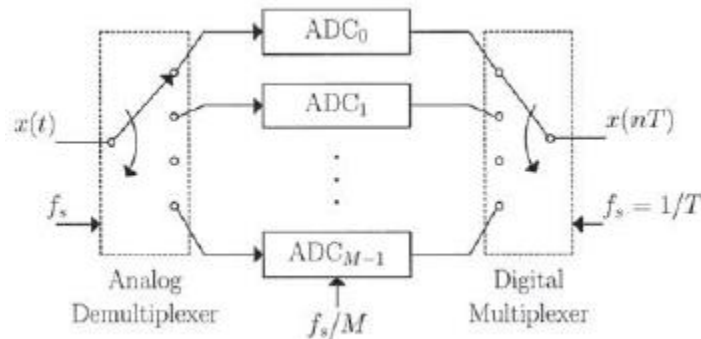
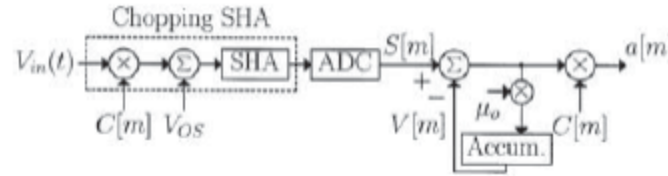


Figure 1 above shows a block diagram of a time-interleaved ADC including M ADCs in parallel, an analog demultiplexer at the input, and a digital multiplexer at the output. Ex. 1105, 7–8. During operation, the analog demultiplexer selects each channel in turn to process the analog input signal. *Id.* at 7. The digital multiplexer selects the digital output of the selected channel to form a high-speed ADC, where the overall sampling rate increases by a factor of M . *Id.* The performance of the interleaved ADCs, however, is sensitive to mismatches among the channels. *Id.*

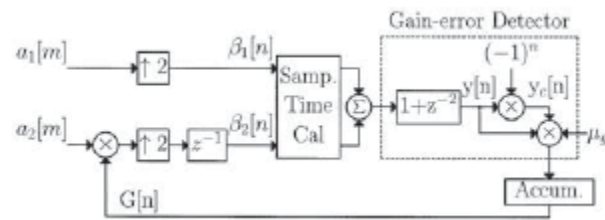
Figure 3 of Jamal shows a block diagram of a signal channel that uses chopper-based offset calibration to correct the offset at the output of each ADC and is reproduced below. Ex. 1105, 8.

¹ We cite to the page numbers inserted by Petitioner at the bottom of each page of Exhibit 1105.



As shown in Figure 3 above, a chopping SHA (sample and hold amplifier) multiplies the analog input signal $V_{in}(t)$ by a pseudorandom binary signal $C[m]$, where m is a discrete time index. Ex. 1105, 8. $C[m]$ is white, has zero mean, and is uncorrelated with the input signal. *Id.* Together with V_{os} , the chopped analog signal is sampled and digitized by the ADC, producing signal $S[m]$. *Id.* The accumulator produces a variable offset $V[m]$ that is subtracted from the output $S[m]$ of the ADC, and the result is multiplied again by $C[m]$ to produce the channel output $a[m]$. *Id.* The combination of the accumulator and the summer forms a feedback loop that forces the average of the accumulator input to be zero, which results in canceling the offset of the channel. *Id.*

Jamal also discloses correcting gain mismatch between ADC channels using a gain calibration method shown in Figure 5, which is reproduced below. Ex. 1105, 8–9.



As shown in Figure 5 above, a gain-error detector and an accumulator produce a gain correction signal $G[n]$ based on signals $a_1[m]$ and $a_2[m]$ that represent the outputs of two ADC channels after offset calibration. *Id.* Gain correction signal $G[n]$ adjusts to be the ratio of G_1 to G_2 , which are the gains of two interleaved ADC channels, respectively. *Id.* The gain mismatch is

corrected by multiplying the offset calibrated output signal $a_2[m]$ by gain correction signal $G[n]$, which makes the gain of each channel equal to G_1 .
Id.

3. *Analysis*

Petitioner contends claims 10, 11, 13, 14, 16, 17, 19, 20, 23–30, 32, 35–43 are unpatentable over Eklund and Jamal. Pet. 23–70.

Claim 10

The preamble of claim 10 recites “[a]n integrated circuit that converts between an analog signal and a corresponding digital code with a system sampling rate f_s .” Petitioner contends, to the extent the preamble is limiting, the combination of Eklund and Jamal teaches this limitation because “Eklund discloses that the parallel ADC system is disposed on an integrated circuit,” and Jamal discloses implementing time interleaved ADCs and an offset calibration system on an integrated circuit. Pet. 24–26 (citing Ex. 1106, Figs. 1, 4, 1:11–15, 3:25–46; Ex. 1105, 7–8, 13, Fig. 12).

Petitioner contends that implementing Eklund’s ADC system on an integrated circuit as disclosed by Jamal is the combination of familiar elements according to known methods that does no more than yield predictable results, uses a known technique to improve similar devices in the same way, and applies a known technique to a known device ready for improvement to yield predictable results. Pet. 27 (citing Ex. 1102 ¶¶ 143–60). Petitioner further contends that a person of ordinary skill in the art would have implemented Eklund’s interleaved ADC system on an integrated circuit for the benefit of making the overhead small enough to use the calibration algorithms in products as taught by Jamal. Pet. 27–28 (citing Ex. 1105, 13; Ex. 1102 ¶¶ 145–49, 158–60).

Claim 10 recites “a plurality of converter circuits clocked by a random clock.” Petitioner contends that Eklund discloses this limitation because Eklund discloses a plurality of converter circuits, each of which is randomly clocked by a random clock. Pet. 28–30 (citing Ex. 1106, Figs. 4, 5, 3:29–36, 3:63–4:9; Ex. 1102 ¶¶ 203–07).

Claim 10 recites “at least one converter circuit in said plurality of converter circuits sampling the analog signal at least every $1/f_s$ seconds.” Petitioner contends that Eklund discloses this limitation because Eklund discloses at least one converter circuit that samples the analog signal at least every $1/f_s$ seconds. Pet. 30–31 (citing Ex. 1106, 3:25–4:5; Ex. 1102 ¶¶ 208–11).

Claim 10 recites “an offset sensing circuit configured to sense offsets and/or signal offset differentials between the outputs of said plurality of converter circuits.” Petitioner contends that Jamal discloses an offset sensing circuit configured to sense signal offsets at the output of each ADC. Pet. 31–32 (citing Ex. 1105, 8, Fig. 3).

Petitioner contends that using Jamal’s offset correction circuit in Eklund’s interleaved ADC system is the combination of familiar elements according to known methods that yields the predictable benefit of reducing gain and offset mismatch in an interleaved ADC system, resulting in an improved signal-to-noise-and-distortion ratio (SNDR). Pet. 32–38 (citing Ex. 1102 ¶¶ 161–93).

Whether Petitioner has shown a reason to combine Eklund and Jamal

Patent Owner contends that a person of ordinary skill in the art would not have been motivated to combine the teachings of Eklund and Jamal because (a) Eklund teaches that gain and offset mismatch can be effectively addressed using random interleaving alone, (b) incorporating Jamal’s

teachings would result in a larger, more complex circuit without providing any additional benefit, (c) the proposed combination would render the prior art unsatisfactory for its intended purpose and changes its principles of operation, and (d) Jamal expressly criticizes configurations which use extra ADCs, like Eklund's configuration. PO Resp. 21–22. We address each contention below.

(a) whether Eklund teaches that gain and offset mismatch can be effectively addressed using random interleaving alone

Patent Owner contends that Eklund teaches that offset and gain mismatch can be effectively addressed using random interleaving alone. PO Resp. 32. Patent Owner contends that there is no credible motivation to modify Eklund with Jamal to address offset and gain mismatch that Eklund teaches can be effectively addressed using random interleaving alone. *Id.* at 35; PO Sur-Reply 8–13. In particular, Patent Owner contends that Eklund discloses that “[i]n some cases the noise can be lower than the quantification noise and has then practically disappeared.” PO Sur-Reply 12 (quoting Ex. 1106, 5:42–44.) (alteration in original, emphasis omitted). We disagree with Patent Owner's contention.

Dr. Holberg, in addressing the portion of Eklund quoted by Patent Owner, testifies that

Jamal discloses that offset and gain calibration improves the SNDR of the system. Ex. 1105, section V, pp. 1624-1625. According Figures 14 and 15 of Jamal, gain and offset calibration improves the SNDR by about 18 dB for small inputs. Ex. 1105, Figures 14 and 15, section V, pp. 1624-1625. Therefore, one of ordinary skill in the art would have been motivated to modify Eklund to incorporate Jamal's gain and/or offset mismatch correction system in order to improve the signal-to-noise-and-distortion ratio (SNDR) of the interleaved ADC system. Even though the random interleaving disclosed by Eklund reduces the

effect of undesired tones, this improvement occurs because “signal distortion is transformed to noise.” Ex. 1106, 5:34-39. Eklund admits, “The total energy of the error is still approximately the same but the characteristics thereof have been totally changed. The error is [now] distributed in the frequency domain and is not collected at some peaks. *In some cases* the noise can be lower than the [quantization] noise and has then practically disappeared.” Ex. 1106, 5:39-44. In other words, Eklund’s random interleaving reduces the peak distortion caused by errors, but does not improve the SNDR of the system. It follows that *error mismatch degrades the performance of Eklund’s system when the noise caused by mismatch error is greater than the quantization noise of the ADC.*

Ex. 1102 ¶ 162 (emphasis added). We agree with Dr. Holberg, that Eklund’s random interleaving reduces the peak distortion caused by errors, but does not improve the SNDR of the system. We also agree with Dr. Holberg, that error mismatch degrades the performance of Eklund’s system when the noise caused by mismatch error is greater than the quantization noise of the ADC. We agree with Dr. Holberg, that a person of ordinary skill in the art would have appreciated the ability of Jamal’s gain and offset correction circuit to improve the SNDR of an interleaved ADC system. *Id.* ¶ 163. We also agree with Dr. Holberg, that a person of ordinary skill in the art would have applied Jamal’s gain and offset correction circuits to Eklund’s interleaved ADC system to yield the predictable benefit of “improv[ing] the SNDR of the system under conditions in which the noise energy caused by offset mismatch exceeds the quantization noise of the system.” *Id.* Thus, contrary to Patent Owner’s contention, the Petition and Dr. Holberg identify a deficiency in Eklund, as well as a benefit that Jamal provides when combined with Eklund.

Dr. Holberg testifies that Jamal provides an express motivation to combine its teachings with those of Eklund. Ex. 1002 ¶ 192. Dr. Holberg

testifies that Jamal teaches performing a random chopper-based offset calibration scheme to remove offset mismatches to “eliminate the notches in the ADC output spectrum.” *Id.* (quoting Ex. 1105, 8). Dr. Holberg testifies that a person of ordinary skill would have understood that the random chopper-based offset correction of Jamal removes the offset of the sample and hold amplifier (SHA) and ADC, but preserves the offset present in the input signal. *Id.* Dr. Holberg testifies that an ADC that uses random-chopping can be used to convert signals that have useful information at dc and low frequencies. *Id.* Dr. Holberg testifies that a person of ordinary skill in the art would have applied Jamal’s random-chopper based offset calibration to Eklund’s randomly interleaved ADC system for the benefits of removing offset mismatch and eliminating “notches in the ADC output spectrum,” thereby enabling Eklund’s interleaved ADC system to both reduce the effect of offset mismatch between individual converters, and to convert analog signals at dc and low frequencies in the digital domain. *Id.* ¶ 188; *see id.* ¶¶ 181–87, 189–93. We agree with Dr. Holberg, that Jamal provides an express motivation to combine its teachings with those of Eklund.

(b) whether incorporating Jamal’s teachings would result in a larger, more complex circuit without providing any additional benefit

Patent Owner contends that combining Eklund and Jamal would result in a larger, more complex circuit with increased power consumption, without providing any identified additional benefit. PO Resp. 36–38. The Federal Circuit has stated that “a given course of action often has simultaneous advantages and disadvantages, and this does not necessarily obviate motivation to combine.” *Medichem, S.A. v. Rolabo, S.L.*, 437 F.3d

1157, 1165 (Fed. Cir. 2006). “Instead, the benefits, both lost and gained, should be weighed against one another.” *Id.*

Here, Petitioner and Dr. Holberg have identified a benefit that Jamal’s offset and gain correction circuitry provides to the interleaved ADC system of Eklund, which is improving the SNDR of the system under conditions in which the noise energy caused by offset mismatch exceeds the quantization noise of the system. Ex. 1102 ¶¶ 162–63. The Petition and Dr. Holberg have also identified Jamal’s benefits of removing offset mismatch and eliminating notches in the ADC output spectrum, thereby enabling Eklund’s interleaved ADC system to both reduce the effect of offset mismatch between individual converters, and to convert analog signals at dc and low frequencies in the digital domain. *Id.* ¶ 188; *see id.* ¶¶ 181–87, 189–93.

Further, Petitioner and Dr. Holberg identify benefits of Eklund’s interleaved ADC system that are not provided by Jamal’s offset and gain correction circuitry. Ex. 1102 ¶¶ 164–67. For example, Dr. Holberg testifies that mismatches in bandwidth between individual ADCs degrades the spurious free dynamic range (SFDR) of the interleaved ADC system. *Id.* ¶ 164 (citing Ex. 1114, 266–69). Dr. Holberg testifies that Jamal’s offset and gain mismatch circuitry would not address such mismatches in bandwidth, but the random interleaving of Eklund would, resulting in an SFDR improvement. *Id.* (citing Ex. 1106, 5:28–42). Dr. Holberg also testifies that mismatches in differential nonlinearity (DNL) and integral nonlinearity (INL) result in noise floors that peak at frequency spurs. *Id.* ¶ 165. Dr. Holberg testifies that Jamal’s offset and gain mismatch correction circuitry would not address mismatches in DNL and INL, but the random interleaving of Eklund would, resulting in an SFDR improvement. *Id.*

We are persuaded by Dr. Holberg's testimony, that the benefits provided by the combined teachings of Eklund and Jamal outweigh the alleged increases in complexity, cost, and size.

(c) whether the proposed combination would render the prior art unsatisfactory for its intended purpose and changes its principles of operation

Patent Owner contends that combining Jamal's teachings regarding random-chopping in a sequentially time interleaved ADC system with Eklund's randomly interleaved ADC system would induce gain errors, making the combination unsatisfactory for its intended purpose. PO Resp. 38–40. Patent Owner contends that because Jamal relies on sequential interleaving, and Eklund relies on random interleaving, the proposed combination requires changing Jamal's principle of operation. *Id.* at 40. Patent Owner contends that Jamal does not teach how to sense or correct offset or gain mismatch in a randomly interleaved system. *Id.* at 41.

Petitioner contends that Patent Owner has not provided a reason why combining Jamal's offset control circuit would change the principle of operation of Jamal's offset control circuit, or would render Jamal's offset control circuit unsuitable for its intended purpose. Reply 9. Petitioner contends that Jamal's offset correction circuit still works when included in Eklund's randomly interleaved system, because Jamal's offset correction scheme operates on one channel individually in the context of an interleaved ADC, thus, the proposed combination would not change the function of Jamal's choppers, summing block, or accumulator. *Id.*

Petitioner contends that Jamal's sequential interleaving is not a "principle of operation," but rather, is a specific example of an ADC system that uses Jamal's gain correction scheme. Reply 10. Petitioner contends

that Jamal's principle of operation is using the relationship between the input at f_0 and the image at f_i to correct for gain mismatch. *Id.* at 10–11 (citing Ex. 1105, 8–9). Petitioner contends that random interleaving does not change Jamal's expressly stated gain correction principle of operation. *Id.* at 11 (citing Ex. 1123 ¶¶ 10–16 (Holberg reply declaration)). Petitioner contends that the data sequencing function of Jamal does not perform gain error detection or gain correction. *Id.* at 13. Petitioner contends that the gain correction system shown in Figure 5 of Jamal includes an interface configured to accept an alternating sequential data format. *Id.* at 14. Dr. Holberg testifies that adapting Jamal's interface to accommodate a randomly sequenced data format would have been within the level of ordinary skill. Ex. 1123 ¶¶ 23–24.

Patent Owner contends that the adaptation discussed by Dr. Holberg was not mentioned in the Petition, and that the adaptation is beyond what *KSR* permits. PO Sur-Reply 15–16. Patent Owner contends that even if the combined teachings of Eklund and Jamal were made operable, a person of ordinary skill would have appreciated that Eklund obliterates the spikes, so that there would have been no need to add Jamal. *Id.* at 16.

We disagree with Patent Owner's contention that because Eklund obliterates spikes caused by offset and gain mismatches, there would have been no need or motivation to add Jamal. When the spikes are "obliterated," as alleged by Patent Owner, the total energy of the signal distortion is still approximately the same, but distributed in the frequency domain. Ex. 1106, 5:34–44. Thus, random interleaving decreases distortion, but does not improve the SNDR of the system. Ex. 1102 ¶ 162. As we discussed above, we credit Dr. Holberg's testimony in finding that error mismatch degrades

the performance of Eklund's system when the noise caused by mismatch error is greater than the quantization noise of the ADC. *Id.*

We agree with Petitioner and Dr. Holberg, that when applying Jamal's principle of operation to a randomly sampled ADC, the result does not change Jamal's expressly stated gain correction principle of operation. Reply 11; Ex. 1123 ¶¶ 10–16. We agree with Dr. Holberg, that it “would be well within one of ordinary skill in the art to adapt a data interface to accommodate the different timing of a randomly sequenced ADC.” Ex. 1123 ¶ 22.

We disagree with Patent Owner's contention that adaptating Jamal's interface to accommodate a randomly sequenced data format is beyond what *KSR* permits. The mere fact that Jamal's gain correction system that includes an interface configured to accept an alternating sequential data format may not be physically combinable with Eklund's randomly sequenced data format does not undermine a showing of obviousness. See *Facebook, Inc. v. Windy City Innovations*, 973 F.3d 1321, 1343 (Fed. Cir. 2020) (“[T]he test for obviousness is not whether the features of a secondary reference may be bodily incorporated into the structure of the primary reference.”) (quoting *In re Keller*, 642 F.2d 413, 425 (CCPA 1981)); *In re Keller*, 642 F.2d at 425 (“Rather, the test is what the combined teachings of the references would have suggested to those of ordinary skill in the art.”). The Supreme Court has held that “[a] person of ordinary skill is also a person of ordinary creativity, not an automaton,” and that the obviousness analysis “need not seek out precise teachings directed to the specific subject matter of the challenged claim, for a court can take account of the inferences and creative steps that a person of ordinary skill would employ.” *KSR*, 550 U.S. at 421, 418.

Dr. Holberg provides persuasive testimony that “the operation of data sequencers that sequence incoming parallel data and to provide a serial stream are well known in the art,” and that it “would be well within one of ordinary skill in the art to adapt a data interface to accommodate the different timing of a randomly sequenced ADC.” Ex. 1123 ¶ 22. Dr. Holberg testifies that “all it requires is following Jamal’s expressly disclosed two-step gain-error detection principle of operation (chopping at a sample frequency followed by a multiplication), accumulating the detected error, multiplying the gain of one channel by the accumulated error, and serializing the data provided by the interleaved ADC to a data stream compatible with the particular implementation of the gain correction algorithm.” *Id.* ¶ 23 (citing Ex. 1105, 9); see Ex. 1102 ¶¶ 57–73, 105–11 (describing operation of Jamal’s gain error corrector as chopping at a sample frequency followed by a multiplication, accumulating the detected error, and multiplying the gain of one channel by the accumulated error), 136–42). We credit Dr. Holberg’s testimony in determining that modifying the data interface of Jamal’s offset and gain correction circuitry to accommodate Eklund’s timing was not “uniquely challenging or difficult for one of ordinary skill in the art.” *Leapfrog Enters., Inc. v. Fisher-Price, Inc.*, 485 F.3d 1157, 1162 (Fed. Cir. 2007) (citing *KSR*, 550 U.S. at 419). We agree with Dr. Holberg, that modifying the data interface of Jamal’s offset and gain correction circuitry to accommodate the timing of Eklund’s randomly sequenced ADCs would have been within the level of ordinary skill. *Facebook, Inc.*, 973 F.3d at 1343.

We are persuaded by Dr. Holberg’s testimony that “[s]imilar to Jamal’s example system adapted to operate with a fixed, sequential interleaving, adapting Jamal’s system to operate with a randomly interleaved

ADC would still perform the functions of sequencing incoming data, measuring a gain difference between channels, and adjusting the gain of one channel based on the measured gain difference in a closed loop manner.”

Ex. 1123 ¶ 23. We agree with Petitioner and Dr. Holberg, that Jamal’s gain correction circuit would maintain its principle of operation and would be suitable for its intended purpose of sensing and correcting gain mismatch when combined with Eklund’s randomly interleaved ADC system. Ex. 1102 ¶ 110; Ex. 1123 ¶¶ 9–24. We also agree with Petitioner and Dr. Holberg that combining Jamal’s offset control circuit with Eklund’s randomly interleaved ADCs would not change the principle of operation of Jamal’s offset control circuit, nor would it render Jamal’s offset control circuit unsuitable for its intended purpose. Ex. 1123 ¶¶ 5–8.

We find that Dr. Holberg’s Reply testimony “follow[s] from contentions raised in the Petition” and “properly responds to arguments raised in Patent Owner’s Response.” See *Ericsson Inc. v Intellectual Ventures I LLC*, 901 F.3d 1374, 1379–1381 (Fed. Cir. 2018). Here, unlike in *Ariosa*, Dr. Holberg “does not identify a previously unidentified piece of prior art to make a meaningfully distinct contention, but instead expands the same argument made in the Petition,” that combining Jamal’s offset circuit with Eklund’s randomly interleaved ADCs would have been obvious. *Id.* at 1381 (citing *Ariosa Diagnostics v. Verinata Health, Inc.*, 805 F.3d 1359 (Fed. Cir. 2015). “Nor does [Dr. Holberg’s testimony] constitute an entirely new rationale worthy of being excluded.” *Id.* (citing *Intelligent Bio-Systems, Inc. v. Illumina Cambridge Ltd.*, 821 F.3d 1359, 1370 (Fed. Cir. 2016)). Here, unlike in *Intelligent Bio-Systems*, Dr. Holberg “cites no new evidence and merely expands on a previously argued rationale as to why” the

combination of the prior art disclosures was within the level of ordinary skill. *Id.*

(d) whether Jamal expressly criticizes configurations which use extra ADCs, like Eklund's configuration

Patent Owner contends that Jamal expressly criticizes systems which use extra sub-ADCs, such as Eklund's system. PO Resp. 42. In particular, Patent Owner contends that Jamal identifies a paper by Dyer as an example of analog calibration circuits that are not easily portable to evolving scaled technologies, where the Dyer paper describes a time-interleaved ADC system that uses adaptive calibration to overcome gain and offset mismatches by interleaving a number of high speed ADCs with an additional reference ADC. *Id.* (citing Ex. 1105, 7; Ex. 2109, 1913). Patent Owner contends that Eklund includes an extra ADC in order to achieve randomization. *Id.* at 42–43 (citing Ex. 1106, 3:26–29). Patent Owner contends that Jamal's statement and reference to Dyer's additional reference ADC is a criticism of all $M + 1$ architectures as not easily portable, and teaches away from combination with any $M + 1$ architecture, such as Eklund's. *Id.* at 42–44; PO Sur-Reply 16–17.

Petitioner, relying on the testimony of Patent Owner's expert, Dr. Raychowdhury, contends that Jamal is not criticizing all $M + 1$ architectures, but only those that use extra calibration ADCs. Reply 15–17 (citing Ex. 1124, 266–267). Petitioner contends that Eklund does not include a calibration ADC. *Id.* at 17 (citing Ex. 1124, 268). Petitioner also contends that Jamal's criticism of circuits that are not easily portable to evolving scaled technologies refers to analog calibration circuits, not to digital calibration circuits used by Eklund and Jamal. *Id.* (citing Ex. 1124, 269).

We agree with Petitioner. Dr. Raychowdhury, when asked “it’s your understanding that Jamal criticizes adding additional calibration ADCs; is that correct,” answered “Yes, that’s right.” Ex. 1124, 267:7–10. Dr. Raychowdhury testified that “Eklund’s patent . . . [does] not talk about any calibration [T]he whole principle here is . . . to avoid calibration by randomly interleaving the different channels of the ADC So this method is – is not connected to the calibration – of any kind of calibration.” *Id.* at 268:9–20. Dr. Raychowdhury testified that “as we go to smaller and smaller technology nodes, it becomes harder and harder to design analog circuits. It’s easier to design digital circuits because they are more scaling friendly. That’s what I suspect Jamal is saying when he mentions that the required analog calibration circuits are not easily portable to evolving scaled technologies.” *Id.* at 269:14–22. We rely on Dr. Raychowdhury’s testimony in determining that Jamal is criticizing analog circuits that use extra calibration ADCs, not all $M + 1$ architectures, and that Eklund does not describe an analog circuit that uses extra calibration ADCs. Therefore, Jamal does not teach away from the invention.

We also disagree with Patent Owner’s contention that even if Jamal does not expressly teach away, Jamal’s alleged preference against combining its teachings with any $M + 1$ architecture shows that a skilled artisan would not be motivated to combine Eklund and Jamal. PO Resp. 43–44 (citing *Polaris Indus., Inc. v. Arctic Cat, Inc.*, 882 F.3d 1056, 1069 (Fed. Cir. 2018)). Even were we to accept Patent Owner’s contention that Jamal criticizes all $M + 1$ architectures, including “digital circuits [that] are more scaling friendly” (Ex. 1124, 269:14–22) such as Eklund’s, Patent Owner does not consider the advantages of Eklund’s $M + 1$ architecture, namely, improving SFDR by addressing mismatches in bandwidth and mismatches

in DNL and INL. Ex. 1102 ¶¶ 164–165. The Federal Circuit has stated that “a given course of action often has simultaneous advantages and disadvantages, and this does not necessarily obviate motivation to combine.” *Medichem, S.A.*, 437 F.3d at 1165. “Instead, the benefits, both lost and gained, should be weighed against one another.” *Id.* We are not persuaded that Jamal’s alleged preference against all $M + 1$ architectures outweighs the advantages of decreasing the impact of errors due to mismatches in bandwidth, DNL, and INL provided by Eklund’s $M + 1$ architecture.

Further, “[i]t’s not necessary to show that a combination is the best option, only that it is a suitable option.” *Intel Corp. v. Qualcomm Inc.*, 21 F.4th 784, 800 (Fed. Cir. 2021); see *In re Mouttet*, 688 F.3d 1322, 1334 (Fed. Cir. 2012) (finding no teaching away where nothing in the prior art device suggested that the invention was unlikely to work). “And if a technique has been used to improve one device, and a person of ordinary skill would recognize that it would improve similar devices in the same way, using the technique is obvious unless its actual application is beyond his or her skill.” *Intel Corp.*, 21 F.4th at 800 (citing *KSR*, 550 U.S. at 417). We agree with Dr. Holberg, that we have that here. Ex. 1102 ¶¶ 152–53, 171–73, 187–89.

Conclusion

For the reasons set forth by Petitioner and explained above, we are persuaded that Eklund and Jamal teach all of the limitations of claim 10, and that a person of ordinary skill would have combined the teachings of the references to achieve the integrated circuit recited in the claim and would have had a reasonable expectation of success in doing so. Dr. Holberg’s testimony provides sufficient evidence of reasons that a person of ordinary skill would have used the teachings of Jamal within the interleaved ADC system of Eklund, and would have had a reasonable expectation of success

in doing so. Petitioner has proven by a preponderance of the evidence that claim 10 would have been obvious over Eklund and Jamal.

Claims 11, 13, 14, 16, 17, 19, 20, 23–30, 32, and 35–43

Claim 11 depends from claim 10 and recites “said offset sensing circuit includes a plurality of offset sensing sub-circuits, each offset sensing sub-circuit in said plurality of sub-circuits being configured to adjust the signal offset differential and/or signal offsets between respective pairs of converter circuits. Petitioner contends that Jamal teaches this limitation in disclosing that the offset sensing circuit of a single channel includes sub-circuits such as an accumulator and a summer. Pet. 38–39.

Claim 13 depends from claim 10 and recites “a controller circuit configured to detect instances when available converter circuits in said plurality of converter circuits are available to process an upcoming one of said random samples.” Petitioner contends that Eklund teaches this limitation in disclosing a controller circuit configured to detect instances when available converter circuits are available. Pet. 39–42.

Claim 14 depends from claim 10 and recites “said plurality of converter circuits are interleaved.” Petitioner contends that Eklund teaches this limitation in disclosing a plurality of interleaved A/D channels. Pet. 42.

Claim 16 depends from claim 10 and recites “each offset sensing circuit includes at least one of a filter and an amplifier.” Petitioner contends that Jamal teaches a filter as an accumulator and a summer, and teaches an amplifier as scaling the output of the summer. Pet. 42–43.

Claim 17 depends from claim 10 and recites “each converter circuit in said plurality of converter circuits is corrected to one of a zero offset and another desired offset value.” Petitioner contends that Jamal teaches this

limitation in disclosing introducing a notch at dc, as well as setting the accumulator input to be zero, which results in a zero offset. Pet. 43–44.

The preamble of independent claim 19 recites a “method of adjusting an offset signal in a signal conditioning system.” Petitioner contends that Eklund teaches the preamble in disclosing conditioning an output signal of a converter with an offset signal. Pet. 44.

Claim 19 recites “clocking a first converter with a random clock.” Petitioner contends that Eklund teaches this limitation in disclosing a plurality of converter circuits clocked by a random clock. Pet. 45.

Claim 19 recites “sensing a first offset signal of said first converter.” Petitioner contends that the combination of Eklund and Jamal teaches this limitation for the reasons given in Petitioner’s analysis of claim 10. Pet. 45.

Claim 19 recites “conditioning one of an input signal and an output signal of said first converter with said first offset signal.” Petitioner contends that Jamal teaches this limitation in disclosing conditioning an output signal of a first converter with an offset signal. Pet. 45–46.

Claim 20 depends from claim 19 and recites “a step of sensing a second offset signal of a second converter, said second converter being clocked with said random clock.” Petitioner contends the combination of Eklund and Jamal teach this limitation for the reasons given in Petitioner’s analysis of claim 19. Pet. 46–47.

Claim 23 depends from claim 20 and recites “a step of sampling an input signal to said first and second converters with said random clock.” Petitioner contends that Eklund teaches this limitation in disclosing signals generated by a time control unit select the active channel in a random way. Pet. 47.

Claim 24 depends from claim 23 and recites “a step of selecting said first and second converters in a random sequence correlated to said random clock.” Petitioner contends that Eklund teaches this limitation in disclosing a time control unit that includes an output selector that activates an A/D channel corresponding to a randomly selected channel. Pet. 47–48.

The preamble of independent claim 25 recites a “signal conditioning system.” Petitioner contends that Eklund teaches the preamble in disclosing a system that conditions analog input values to provide digital output values. Pet. 48–49.

Claim 25 recites “a first converter with a first gain and a second converter with a second gain, said first and second converters being clocked in a random sequence.” Petitioner contends that Eklund teaches this limitation in disclosing that each ADC has a gain error, where the gain is different for the individual ADCs, and are clocked in a random sequence. Pet. 49–50.

Claim 25 recites “a gain corrector configured to adjust a difference between said first and second gains.” Petitioner contends that Jamal teaches this limitation in disclosing offset and gain correction circuitry, and that a person of ordinary skill would have applied Jamal’s circuitry to the interleaved ADC of Eklund for the predictable benefit of improving the SNDR of the system under conditions in which the noise energy caused by offset mismatch exceeds the quantization noise of the system. Pet. 50–54.

Claim 26 depends from claim 25 and recites “at least one of a random clock generator, a pseudorandom clock generator, and an aperiodic clock generator to provide said random sequence.” Petitioner contends that Eklund teaches this limitation in disclosing a generator that randomly selects the active channel using a random number generator. Pet. 54–56.

Claim 27 depends from claim 25 and recites “said gain corrector provides a difference between said first and second gains.” Petitioner contends that Jamal teaches a gain-error detector that provides a difference between first and second gains. Pet. 56–57.

Claim 28 depends from claim 27 and recites “said difference provides a gain correction signal to adjust said gain difference between said first and second converters.” Petitioner contends that Jamal teaches this limitation in disclosing a gain-error detector that adjusts a gain of one ADC channel to have the same gain as another ADC channel. Pet. 58.

Claim 29 depends from claim 25 and recites “said gain corrector provides a gain correction signal proportional to a ratio between said first and second gains.” Petitioner contends that Jamal teaches this limitation in disclosing a gain correction signal that adjusts the ratio of the gains of two interleaved ADC channels. Pet. 59.

Claim 30 depends from claim 25 and recites “said gain sensor forms one of a feedback loop and a feedforward loop.” Petitioner contends that Jamal teaches a feedback loop that controls the gain. Pet. 59–60.

The preamble of independent claim 32 recites an “integrated circuit that converts between an analog signal and a corresponding digital code at a clock rate f_s .” Petitioner contends that the combination of Eklund and Jamal teaches the preamble for the reasons given in Petitioner’s analysis of claim 10. Pet. 60.

Claim 32 recites “a plurality of converter circuits clocked by a random clock.” Petitioner contends that Eklund teaches this limitation for the reasons given in Petitioner’s analysis of claim 10. Pet. 61.

Claim 32 recites “a gain sensor coupled to each converter circuit in said plurality of converter circuits, said gain sensor circuit sensing a gain

from said corresponding converter circuit, each gain sensor circuit being coupled to one of said plurality of converter circuits.” Petitioner contends that Jamal teaches this limitation in disclosing a gain sensor circuit that produces a gain correction signal based on signals that represent the outputs of two ADC channels after offset calibration. Pet. 61–62.

Claim 32 recites “a controller circuit configured to select said plurality of converter circuits in a random sequence.” Petitioner contends that Eklund teaches this limitation in disclosing a time control unit. Pet. 62.

Claim 35 depends from claim 32 and recites “said plurality of converter circuits are interleaved.” Petitioner contends that Eklund teaches this limitation for the reasons given in Petitioner’s analysis of claim 14. Pet. 63.

Claim 36 depends from claim 32 and recites “an input signal provided to said plurality of converter circuits includes a zero-offset signal.” Petitioner contends that Jamal teaches this limitation in disclosing the technique of random-chopping in conjunction with offset mismatch correction to equalize the offset between parallel channels of an interleaved ADC. Pet. 63.

Claim 37 depends from claim 32 and recites “said gain sensor circuit provides a gain correction signal proportional to a difference between said gain of said corresponding converter circuit and a reference gain of one other correction circuit.” Petitioner contends that Jamal teaches this limitation in disclosing a gain-error detector that outputs a signal having a dc component proportional to the gain mismatch of two interleaved channels. Pet. 63–64.

Claim 38 depends from claim 32 and recites “said gain sensor provides a gain correction signal proportional to a ratio between a gain of

said corresponding converter circuit and a reference gain of one other corrector circuit.” Petitioner contends that Jamal teaches this limitation for the reasons given in Petitioner’s analysis of claim 29. Pet. 64–65.

Claim 39 depends from claim 32 and recites “said gain sensor circuit forms one of a feedback loop and a feedforward loop.” Petitioner contends that Jamal teaches this limitation for the reasons given in Petitioner’s analysis of claim 30. Pet. 65.

Claim 40 depends from claim 32 and recites “said gain sensor circuit includes at least one of a filter circuit and a rectifier circuit.” Petitioner contends that Eklund teaches this limitation for the reasons given in Petitioner’s analysis of claim 31. Pet. 65.

The preamble of independent claim 41 recites a “method of adjusting a gain mismatch in a signal conditioning system.” Petitioner contends that Eklund teaches the preamble in disclosing an ADC that converts analog input signals to a digital output signals in parallel. Pet. 66.

Claim 41 recites “sensing a first gain of a first converter, sensing a gain of a second converter.” Petitioner contends that Jamal teaches this limitation for the reasons given in Petitioner’s analysis of claim 32. Pet. 66–67.

Claim 41 recites “said first and second converters being clocked with a random clock.” Petitioner contends that Eklund teaches this limitation for the reasons given in Petitioner’s analysis of claim 25. Pet. 67.

Claim 41 recites “adjusting at least one of said first and second gains to adjust said gain mismatch between said first and second converters.” Petitioner contends that the combination of Eklund and Jamal teaches this limitation for the reasons given in Petitioner’s analysis of claim 25. Pet. 67–69.

Claim 42 depends from claim 41 and recites “the step of adjusting at least one of said first and second gains includes a step of sensing a difference between said first and second gains.” Petitioner contends that the combination of Eklund and Jamal teaches this limitation for the reasons given in Petitioner’s analysis of claim 27. Pet. 69.

Claim 43 depends from claim 41 and recites “the step of adjusting at least one of said first and second gains includes a step of sensing a ratio between said first and second gains.” Petitioner contends that the combination of Eklund and Jamal teaches this limitation for the reasons given in Petitioner’s analysis of claim 29. Pet. 70.

Patent Owner does not argue separately claims 11, 13, 14, 16, 17, 19, 20, 23–30, 32, and 35–43, but instead relies on arguments presented for claim 10, with which we disagree as discussed in our analysis of claim 10. *See generally* PO Resp. 21–44. Petitioner’s analysis for claims 11, 13, 14, 16, 17, 19, 20, 23–30, 32, and 35–43, supported by the testimony of Dr. Holberg (Ex. 1102 ¶¶ 217–335), which we credit, is persuasive that claims 11, 13, 14, 16, 17, 19, 20, 23–30, 32, and 35–43 would have been obvious over Eklund and Jamal.

E. Asserted Obviousness over Eklund, Jamal, and Ferragina

1. Overview of Ferragina (Ex. 1107)

Ferragina discloses correcting offset mismatch in time interleaved ADCs. Ex. 1107, 6.² Ferragina discloses that “[t]he difference between the digital outputs of the path under calibration and the reference path is

² We cite to the page numbers inserted by Petitioner at the bottom of each page of Exhibit 1107.

integrated over the calibration time slot NT_{CK} .” *Id.* at 7–8. “The result is a digital word proportional to the difference between the offsets of the two paths.” *Id.* Thus, when the offset “is added to the output of the path under calibration, its overall offset becomes equal to the offset of the reference path.” *Id.* at 8. According to Ferragina, “[t]his procedure is repeated for the M paths” so that “all the M paths have the same overall offset of the reference path, thus avoiding spurious tones.” *Id.*

2. Analysis

Petitioner contends claims 15, 18, 21, and 22 are unpatentable as obvious over Eklund, Jamal, and Ferragina. Pet. 70–75.

Claim 15 depends from independent claim 10 and further recites “wherein said offset signal is subtracted from one of said input signal through a feedback loop circuit and said corresponding output signal through a feedforward loop circuit.” Petitioner contends that Ferragina teaches this limitation in disclosing that an offset signal is subtracted from a corresponding output signal through a feedforward loop circuit that includes an averaging block and adder. Pet. 71 (citing Ex. 1107, 7–8, Fig. 3; Ex. 1102 ¶¶ 339, 359–60). Petitioner contends that a person of ordinary skill in the art would have reduced offset mismatch in the ADCs of Eklund and Jamal by setting the offset of each channel to a reference ADC as taught by Ferragina for the predictable benefit of avoiding spurious tones caused by offset mismatches between parallel channels as taught by Ferragina. Pet. 72–73 (citing Ex. 1102 ¶¶ 340–55).

Patent Owner contends that the sigma-delta converter implementation of Ferragina is incompatible with the Nyquist-rate converter implementation of Eklund. PO Resp. 45–48. In its Reply, Petitioner contends that the Petition does not propose bodily incorporating the specific implementation

of Ferragina's offset and gain control system in the system of Eklund and Jamal. Reply 18. Petitioner contends that the Petition suggests incorporating Ferragina's teaching of setting the offset of a first channel to match the offset of another channel. *Id.* at 18–19. In the Petition, Petitioner contends that a person of ordinary skill would have recognized that Ferragina's technique of setting the offset of each ADC channel to the offset of a selected ADC channel is substitutable with the ADC system taught by Eklund and Jamal that sets the offset of each ADC channel to zero individually, and yields the predictable result of reducing offset mismatch between channels. Pet. 72. In its Sur-Reply, Patent Owner contends that Petitioner's Reply makes a new argument, which ignores the sigma-delta implementation of Ferragina's system. PO Sur-Reply 17–18.

We agree with Petitioner. Ferragina discloses that when the offset “is added to the output of the path under calibration, its overall offset becomes equal to the offset of the reference path.” Ex. 1107, 8. Ferragina discloses that this procedure is repeated for each channel, so that all paths “have the same offset of the reference path, thus avoiding spurious tones.” *Id.* Dr. Holberg testifies that “setting the offset of each ADC channel to a selected ADC channel is . . . substitutable with the ADC system taught by Eklund and Jamal that sets of each ADC channel to zero individually, and yields the predictable result of reducing offset mismatch between channels, thereby decreasing the amplitude of spurs and distortions caused by such offset mismatch.” Ex. 1102 ¶ 343; *see id.* ¶¶ 340–42, 344–55.

We agree with Petitioner and Dr. Holberg, that the Petition does not propose bodily incorporating the specific implementation of Ferragina into the combined system of Eklund and Jamal, but rather, suggests setting the offset of each ADC channel to a selected ADC channel as taught by

Ferragina, instead of to zero as taught by Eklund and Jamal, for the benefit of reducing or eliminating offset mismatch between channels, thereby decreasing the amplitude of spurs and distortion caused by such offset mismatch. *See* Pet. 72 (citing Ex. 1102 ¶¶ 350–55). We credit Dr. Holberg’s testimony in determining that setting the offset of each ADC channel to a selected ADC channel as taught by Ferragina instead of to zero as taught by Eklund and Jamal was not “uniquely challenging or difficult for one of ordinary skill in the art.” *Leapfrog Enters.*, 485 F.3d at 1162.

Patent Owner contends that Jamal explicitly criticizes using the $M + 1$ ADC architecture utilized in Ferragina. PO Resp. 48–49. Petitioner contends that Jamal’s criticism of analog calibration circuits does not apply to Ferragina’s digital calibration. Reply 19. We agree with Petitioner, that Jamal does not criticize digital calibration circuits, for the reasons given in our analysis of claim 10.

Patent Owner contends that if Jamal’s random-chopping technique is applied to Ferragina, Ferragina’s gain calibration can no longer work. PO Resp. 49–51. Petitioner contends that the Petition incorporates Ferragina’s teaching of setting the offset of a first channel to match the offset of another channel, but does not suggest combining Ferragina’s gain control system with Eklund and Jamal, and that claims 15, 18, 21, and 22 do not require gain correction. Reply 19 (citing Ex. 1125, 281–284). We agree with Petitioner, that claims 15, 18, 21, and 22 do not require gain correction. We determine that Patent Owner’s arguments regarding combining the gain correction of Ferragina with Eklund and Jamal do not address the proposed combination in the Petition and are not commensurate with the scope of claims 15, 18, 21, and 22.

Patent Owner contends that combining the teachings of Ferragina with those of Eklund and Jamal would add additional cost and complexity with no identified benefit. PO Resp. 51. Patent Owner has not shown how setting the offset of a first channel to match the offset of another channel instead of setting the offset to zero would increase cost or complexity. Further, according to Dr. Holberg, Ferragina itself teaches the benefit of setting the offset to a first channel is that all paths “have the same offset of the reference path, thus avoiding spurious tones.” Ex. 1107, 8; Ex. 1102 ¶¶ 339–355.

For the reasons set forth by Petitioner and explained above, we are persuaded that Eklund, Jamal, and Ferragina teach all of the limitations of claim 15, and that a person of ordinary skill would have combined the teachings of the references to achieve the integrated circuit recited in the claim and would have had a reasonable expectation of success in doing so. Dr. Holberg’s testimony provides sufficient evidence of reasons that a person of ordinary skill would have used the teachings of Ferragina within the interleaved ADC system taught by Eklund and Jamal, and would have had a reasonable expectation of success in doing so. Petitioner has proven by a preponderance of the evidence that claim 15 would have been obvious over Eklund, Jamal, and Ferragina.

Claim 18 depends from independent claim 10 and further recites “wherein each converter circuit in said plurality of converter circuits is corrected to said offset signal of one converter circuit in said plurality of converter circuits.” Petitioner contends that Ferragina teaches this limitation in disclosing calibrating all ADCs so that all the M paths have the same overall offset of the reference path. Pet. 73–74.

Claim 21 depends from claim 20 and recites “a step of sensing a difference between said first and second offset signals.” Petitioner contends that Ferragina teaches this limitation in disclosing integrating the difference between the digital outputs of the path under calibration and the reference path. Pet. 74–75.

Claim 22 depends from claim 21 and recites “a step of adjusting said difference between said first and second offset signals.” Petitioner contends that Ferragina teaches this limitation in disclosing that as the offset is added to the output of the path under calibration, the difference between the offset of the reference path and the offset of the path under calibration is also adjusted. Pet. 75.

Patent Owner does not argue separately claims 18, 21 and 22, but instead relies on arguments presented for claim 15, which we find unpersuasive as discussed in our analysis of claim 15. *See generally* PO Resp. 44–51. Petitioner’s analysis for claims 18, 21 and 22, supported by the testimony of Dr. Holberg (Ex. 1102 ¶¶ 363–74), which we credit, is persuasive that claims 18, 21 and 22 would have been obvious over Eklund, Jamal, and Ferragina.

F. Asserted Obviousness over Eklund, Jamal, and Agazzi

1. Overview of Agazzi (Ex. 1115)

Agazzi discloses a multi-path parallel receiver in which an ADC is implemented with parallel paths that operate at lower rates than the received data signal. Ex. 1115, 2:20–24. The parallel ADC paths are operated in an interleaved fashion. *Id.* at 2:28–29. Gain errors in the interleaved ADC paths are compensated for on a path by path basis, using path specific automatic gain control (AGC) circuits. *Id.* at 15:35–41. Figure 7 shows an

example of a path-specific AGC implementation that can be used to reduce gain errors in the interleaved paths, and is reproduced below. *Id.*

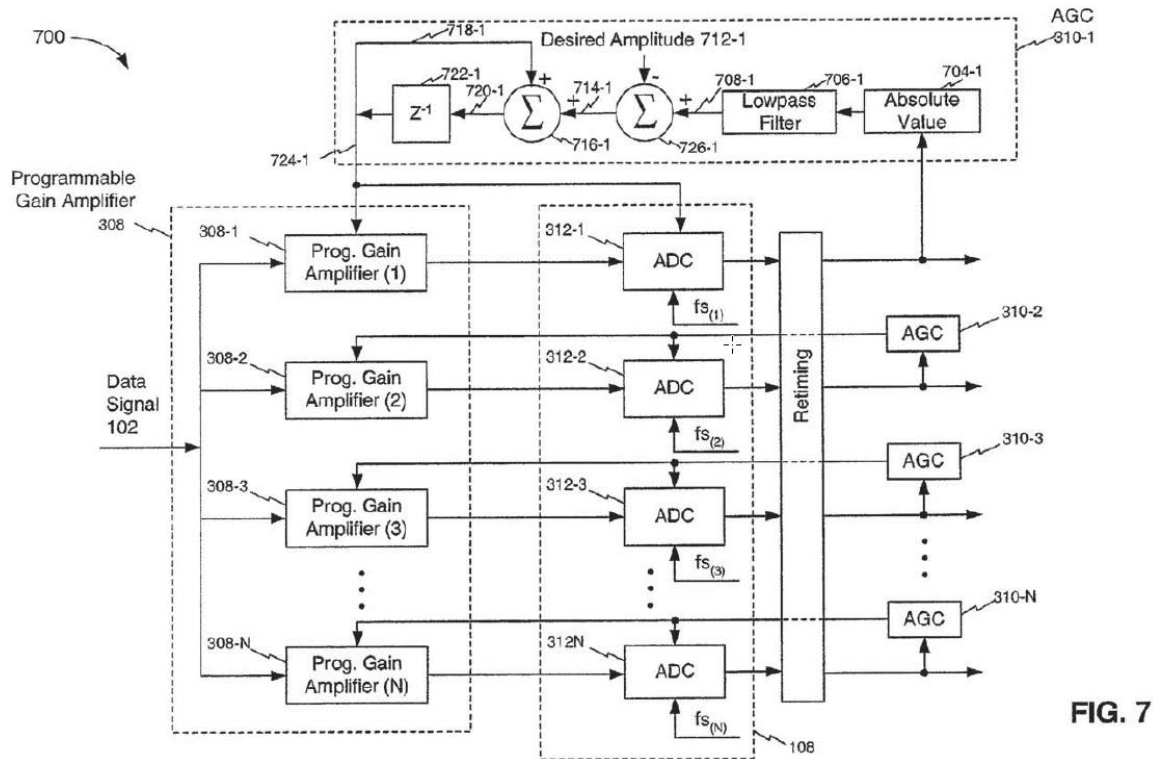


FIG. 7

Figure 7 above shows path specific AGC 310-1 including absolute value module 704-1 and lowpass filter 706-1 that provides measured amplitude 708-1 to differencer 726-1. *Ex. 1115, 15:53–58.* The differencer subtracts desired amplitude 712-1 from measured amplitude 708-1 and outputs difference value 714-1 to adder 718-1. *Id. at 15:58–60.* The adder and accumulator 722-1 constitute a digital integrator, which integrates the difference value and outputs programmable gain amplifier (PGA) control value 724-1 to PGA 308-1. *Id. at 15:60–64.* The PGA control value can be provided to ADC 312-1 to adjust a reference voltage. *Id. at 15:64–66.* Because the gain error is measured in the digital domain, any gain errors introduced by ADCs 312-1 through 312-N will be driven to approximately zero by the AGC circuitry. *Id. at 16:1–7.*

2. *Analysis*

Petitioner contends that claims 27, 28, 31, 37, 40, and 42 are unpatentable over Eklund, Jamal, and Agazzi. Pet. 75–83.

Claim 27 depends from independent claim 25 and further recites “said gain corrector provides a difference between said first and second gains.” Petitioner contends that Agazzi teaches this limitation in disclosing a differencer that subtracts a desired gain from a measured gain. Pet. 75–76 (citing Ex. 1115, Fig. 7, 15:34–16:29; Ex. 1102 ¶¶ 396–98). Petitioner contends that modifying the interleaved ADC system of Eklund and Jamal by substituting the known AGC shown in Figure 7 of Agazzi for the known gain mismatch correction circuitry shown in Figure 5 of Jamal yields the predictable result of reducing gain mismatch in an interleaved ADC system. Pet. 76–79 (citing Ex. 1115, Fig. 7, 15:34–16:29; Ex. 1105, 13–15; Ex. 1102 ¶¶ 383–98).

Claim 28 depends from claim 27 and recites “said difference provides a gain correction signal to adjust said gain difference between said first and second converters.” Petitioner contends that Agazzi teaches this limitation in disclosing adjusting the gain difference between the converters as the gain of each ADC channel is adjusted. Pet. 80.

Claim 31 depends from claim 25 and recites “said gain sensor includes at least one of a filter and a rectifier.” Petitioner contends that Agazzi teaches this limitation in describing an AGC circuit that includes a filter and a rectifier. Pet. 80–81.

Claim 37 depends from claim 32 and recites “said gain sensor circuit provides a gain correction signal proportional to a difference between said gain of said corresponding converter circuit and a reference gain of one other corrector circuit.” Petitioner contends that Agazzi teaches this

limitation in describing an AGC circuit that provides a difference between a measured amplitude of a reference ADC channel and a measured amplitude of a channel being corrected. Pet. 81–82.

Claim 40 depends from claim 32 and recites “said gain sensor circuit includes at least one of a rectifier circuit and a filter.” Petitioner contends that Agazzi teaches this limitation in describing an AGC circuit that includes a filter and a rectifier. Pet. 82.

Claim 42 depends from claim 41 and recites “the step of adjusting at least one of said first and second gains includes a step of sensing a ratio between said first and second gains.” Petitioner contends that Agazzi teaches this limitation in describing an AGC circuit that provides a difference between a measured amplitude of a reference ADC channel and a measured amplitude of the ADC channel being corrected. Pet. 83.

Patent Owner does not argue separately claims 27, 28, 31, 37, 40, and 42, but instead relies on arguments presented for claim 10, which we find unpersuasive as discussed in our analysis of claim 15. See PO Resp. 51. Petitioner’s analysis for claims 27, 28, 31, 37, 40, and 42, supported by the testimony of Dr. Holberg (Ex. 1102 ¶¶ 363–74), which we credit, is persuasive that claims 27, 28, 31, 37, 40, and 42 would have been obvious over Eklund, Jamal, and Agazzi.

III. CONCLUSION

As summarized in the table below, the Petition and supporting evidence has shown by a preponderance of the evidence that claims 10, 11, 13–32, and 35–43 of the '659 patent are unpatentable.³

Claims	35 U.S.C. §	Reference(s)/Basis	Claims Shown Unpatentable	Claims Not Shown Unpatentable
10, 11, 13, 14, 16, 17, 19, 20, 23–30, 32, 35–43	103	Eklund, Jamal	10, 11, 13, 14, 16, 17, 19, 20, 23–30, 32, 35–43	
15, 18, 21, 22	103	Eklund, Jamal, Ferragina	15, 18, 21, 22	
27, 28, 31, 37, 40, 42	103	Eklund, Jamal, Agazzi	27, 28, 31, 37, 40, 42	
Overall Outcome			10, 11, 13–32, 35–43	

³ Should Patent Owner wish to pursue amendment of the challenged claims in a reissue or reexamination proceeding subsequent to the issuance of this decision, we draw Patent Owner's attention to the April 2019 Notice Regarding Options for Amendments by Patent Owner Through Reissue or Reexamination During a Pending AIA Trial Proceeding. *See* 84 Fed. Reg. 16,654 (Apr. 22, 2019). If Patent Owner chooses to file a reissue application or a request for reexamination of the challenged patent, we remind Patent Owner of its continuing obligation to notify the Board of any such related matters in updated mandatory notices. *See* 37 C.F.R. § 42.8(a)(3), (b)(2).

IV. ORDER

Accordingly, it is:

ORDERED that pursuant to 35 U.S.C. § 314(a), an *inter partes* review is hereby instituted as to claims 10, 11, 13–32, and 35–43 of the '750 patent on the grounds set forth in the Petition; and

FURTHER ORDERED that pursuant to 35 U.S.C. § 314(c) and 37 C.F.R. § 42.4, notice is hereby given of the institution of a trial; the trial will commence on the entry date of this decision.

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Patent 6,900,750 B1

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