

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

APPLE, INC.,

Petitioner,

v.

RESONANT SYSTEMS, INC.,

Patent Owner.

Case No. IPR2024-00983
U.S. Patent No. 11,152,882

REMOTE DEPOSITION OF BLAKE HANNAFORD, Ph.D.

FRIDAY, JUNE 27, 2025, 9:31 A.M.

CONDUCTED REMOTELY

HELD REMOTELY VIA VIDEOCONFERENCE

STENOGRAPHICALLY REPORTED BY:

Tami L. Le, CSR No. 8716, RPR

Job No. 114850

1 UNITED STATES PATENT AND TRADEMARK OFFICE

2

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5 APPLE, INC.,

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9 Patent Owner.

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11 Case No. IPR2024-00983
12 U.S. Patent No. 11,152,882

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18 REMOTE DEPOSITION of BLAKE HANNAFORD, Ph.D.,

19 taken on behalf of the Patent Owner, with all

20 participants appearing remotely via Zoom

21 videoconference, commencing at 9:31 a.m., on Friday,

22 June 27, 2025, before Tami L. Le, Certified Shorthand

23 Reporter 8716, in and for the State of California.

24

25

1 REMOTE APPEARANCES:

2

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1	I N D E X	
2	WITNESS: BLAKE HANNAFORD, Ph.D.	
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8	PREVIOUSLY MARKED EXHIBITS (NOT ATTACHED):	
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1 FRIDAY, JUNE 27, 2025, 9:31 A.M.
2 HELD REMOTELY VIA VIDEOCONFERENCE
3 oOo

4 THE STENOGRAPHER: My name is Tami Le. I am
5 a California Certified Shorthand Reporter,
6 License No. 8716.
7

8 BLAKE HANNAFORD, Ph.D.,
9 having been first duly sworn, was
10 examined and testified as follows:
11

12 EXAMINATION

13 BY MR. RUBIN:

14 Q Good morning, Dr. Hannaford.

15 A Good morning, Mr. Rubin.

16 Q So you've been deposed twice this week in
17 other IPRs between Apple and Resonant Systems; is that
18 right?

19 A That's correct.

20 Q And you're familiar with the deposition
21 process?

22 A Yes.

23 Q So I won't go over the ground rules again
24 unless you have any questions.

25 Do you have any questions about the rules

1 governing today's deposition?

2 **A I have no questions.**

3 Q Are you -- withdrawn.

4 Is there any reason you can't give complete
5 and accurate testimony here today?

6 **A No.**

7 Q Are you currently suffering from any illness
8 or taking any medication that would affect your memory
9 or your ability to understand and answer questions?

10 **A I am not.**

11 Q So today we're here in IPR2024-00983 brought
12 by Apple, Inc. against Resonant Systems, Inc. And you
13 submitted a declaration in that IPR with a date of
14 June 3rd of this year; is that right?

15 **A I -- that's approximately right in my -- I**
16 **can't remember the exact date, but I did submit a**
17 **declaration around that time.**

18 Q And that was the second declaration you
19 submitted in that IPR; is that right?

20 **A There is a supplemental declaration, yes.**

21 Q Do you have any printed materials with you
22 here today?

23 **A No.**

24 Q Do you have any materials in electronic form
25 for your use during the deposition?

1 **A No, I don't.**

2 MR. RUBIN: I've just uploaded in the Zoom
3 chat Exhibit 1018 in this IPR.

4 (Document published on the screen.)

5 BY MR. RUBIN:

6 Q Are you able to download that?

7 **A Give me one moment. Successfully downloaded,**
8 **Exhibit 1018.**

9 Q Does this appear to be a copy of the
10 declaration that you signed that was submitted in
11 IPR2024-00983?

12 **A Yes. And it has my signature on the last**
13 **page and date. As you stated, June 3.**

14 Q Sitting here today, are you aware of any
15 errors in this declaration or things that you'd like
16 to correct?

17 **A No.**

18 Q I'd like to turn to Paragraph 16 of your
19 declaration on Page 11. And here you produce a quote
20 from the patent owner's response, which reads in part:

21 "Alexander is not about resonant
22 motors at all."

23 Do you see that?

24 **A I see that quotation, yes.**

25 Q Now, I understand that you disagree with the

1 statement that "Alexander is not about resonant motors
2 at all"; is that right?

3 MR. DEUTSCH: Objection; form.

4 BY MR. RUBIN:

5 Q And maybe I should restate that because there
6 are a few layers of negation in there.

7 So the portion of the quoted statement that
8 says "Alexander is not about resonant motors at all,"
9 you disagree with that portion of the quoted
10 statement; correct?

11 A I don't recall, sitting here now, that
12 Alexander discloses a resonant motor.

13 Q And you don't offer any opinions in this
14 declaration that Alexander discloses a resonant motor;
15 correct?

16 A Well, I -- I -- I still have the opinion that
17 they -- that Alexander -- that they don't accurately
18 summarize Alexander in Cosper or how a POSITA would
19 interpret those references, but I don't recall a
20 statement anywhere in my declaration that Alexander
21 discloses resonant motors.

22 Q Did you offer any opinion in your declaration
23 that Alexander discloses anything about resonance at
24 all?

25 A Not that I recall, sitting here today, other

1 **than a system that can be adapted to have resonance.**

2 MR. RUBIN: I've just uploaded, using the
3 chat function, Exhibit 1006, which is a U.S. patent
4 application publication to Cosper, et al.

5 (Document published on the screen.)

6 BY MR. RUBIN:

7 Q Are you able to download that?

8 A **Yes, sorry. Just one second. Yes, I have**
9 **it.**

10 Q You offer some opinions about Figure 1 of
11 Cosper.

12 Do you recognize that figure?

13 A **I do.**

14 Q Would you agree this figure is a schematic
15 drawing?

16 A **Sorry. I'm fiddling with the orientation on**
17 **my copy, and now it matches what I see on your screen.**
18 **Yes.**

19 Q And would you agree that a schematic drawing
20 shows connections between components but not
21 necessarily their physical appearance, layout, or
22 directions of motion?

23 MR. DEUTSCH: Objection; form.

24 THE DEPONENT: That sounds like a common
25 definition of schematic drawing, yes.

1 BY MR. RUBIN:

2 Q Going back to your supplemental declaration.
3 In Paragraph 15, you quote from Cosper saying it
4 describes, quote:

5 "Systems and methods for control of
6 a mass and bias (e.g. elastomeric
7 members) subassembly, including
8 oscillating mechanical systems, that
9 operate in an oscillatory mode at or
10 near their mechanical resonant
11 frequency."

12 Do you see that?

13 A Yes, I see that quote in Paragraph 15.

14 Q So do you believe that a POSITA would have
15 been motivated to create a combination of Alexander
16 and Cosper that included elastomeric members?

17 MR. DEUTSCH: Objection; form.

18 THE DEPONENT: I interpret -- I think a
19 POSITA would interpret that quote, in particular the
20 term "bias," to be a spring which can be, for
21 example -- and the letters "e.g." are known to stand
22 for that in Latin -- an elastomeric member can be a
23 spring.

24 BY MR. RUBIN:

25 Q Would you agree that an elastomer --

1 withdrawn.

2 Would you agree that the term "elastomer"
3 generally refers to a class of polymers?

4 MR. DEUTSCH: Objection; scope.

5 THE DEPONENT: Polymers with elastic
6 properties is what -- is how I think a POSITA would
7 interpret that in this context.

8 BY MR. RUBIN:

9 Q So when you say -- withdrawn.

10 So when you said a moment ago that an
11 elastomeric member can be a spring, were you saying
12 that a spring could be used that is made out of a
13 polymer with elastic properties?

14 A You know, reading that quote as a whole,
15 they're clearly talking about operation at or near a
16 mechanical resonant frequency, and that requires a
17 mass and an elastic element. A spring is an elastic
18 element, and an elastomer is also an elastic element.

19 And their use -- their more generic term is
20 "bias," which I -- I would feel is an unusual term for
21 a spring or an -- unusual term for an elastic element,
22 but I believe it's clarified to a POSITA by the full
23 sentence which includes operating in an oscillatory
24 mode at or near their mechanical resonant frequency.

25 Q Let's turn to Paragraph 35 in your

1 declaration.

2 **A I'm there.**

3 Q In the first sentence, you refer to:

4 "Advantages associated with
5 derivation of velocity including the
6 sharper peak associated with velocity
7 or acceleration (dv/dt)."

8 Do you see that?

9 **A Yes.**

10 Q What is the sharper peak you're referring to?

11 **A It refers to a POSITA being familiar with the**
12 **idea that if you were to make a graph of velocity**
13 **versus frequency, it would have a peak at the resonant**
14 **frequency and it would be a larger peak than the peak**
15 **in a graph of displacement or position versus**
16 **frequency.**

17 Q Would you agree that for a device operating
18 at or near resonance, both the -- withdrawn.

19 Would you agree that for a device operating
20 at or near resonance, each of the graphs of position
21 versus time, velocity versus time, and acceleration
22 versus time will be approximately sinusoids?

23 MR. DEUTSCH: Objection.

24 THE DEPONENT: Yeah, in the -- sorry.

25 In the abstract, mathematically speaking,

1 yes, I agree with that.

2 BY MR. RUBIN:

3 Q Would you agree that for a given frequency,
4 each of those graphs of position, velocity,
5 acceleration will have the same period?

6 A All waves that have the same frequency also
7 have the same period, so yes.

8 Q So if the graphs of position, of velocity,
9 and of acceleration are each sinusoids with the same
10 period, in what sense does the graph of velocity or of
11 acceleration have a sharper peak than the graph of
12 position?

13 A Your two previous questions have referred to
14 a graph of position, velocity, or acceleration versus
15 time. But the graph I described, if you go back and
16 check what I said, is a graph of amplitude or strength
17 of the signal versus frequency. So those are just
18 different graphs.

19 Q At any given frequency, would you agree that
20 the amplitude of the velocity versus time graph is
21 equal to the amplitude of the position versus time
22 graph times the frequency?

23 MR. DEUTSCH: Objection; scope.

24 THE DEPONENT: I might want to review that
25 math, but sitting here right now, I agree with what

1 you said.

2 BY MR. RUBIN:

3 Q Suppose that the position is defined by a
4 function $A \sin(\omega T)$ or where A is the amplitude
5 and ω is the frequency, then velocity would be
6 something, like, $A \omega \cos(\omega T)$; right?

7 A That sounds right to me sitting here now.

8 MR. DEUTSCH: Objection; scope on the
9 question.

10 BY MR. RUBIN:

11 Q And amplitude would be minus ω^2 --
12 I'm sorry, minus $A \omega^2 \sin(\omega T)$

13 A Could you reask that question. I'm sorry. I
14 couldn't quite hear.

15 Q I'm sorry. I misstated the question. Let's
16 start over.

17 The acceleration as a function of time would
18 then be minus $A \omega^2 \sin(\omega T)$

19 MR. DEUTSCH: Objection; form and scope.

20 THE DEPONENT: Again, sitting here right now,
21 that sounds correct for a general sinusoid.

22 BY MR. RUBIN:

23 Q So -- withdrawn.

24 So if we imagine the graph of the amplitude
25 in position as a function of velocity -- I'm sorry.

1 If we imagine the graph of amplitude in
2 position as a function of frequency, we'll have some
3 peak near the resonant frequency, and it will fall
4 off, that is, the amplitude will fall off as the
5 frequency moves away from the resonant frequency; is
6 that right?

7 MR. DEUTSCH: Objection; form and scope.

8 THE DEPONENT: It's a -- it's -- it's correct
9 to the extent that the system is resonant. So if the
10 system is less resonant, it turns out the peak is
11 slightly different than -- the peak moves relative to
12 a highly resonant frequency, but these are fine
13 details. At a -- at a sort of a coarser level of
14 analysis, what you said is correct.

15 BY MR. RUBIN:

16 Q Okay. So to go from that graph of position
17 amplitude versus frequency to a graph of velocity
18 amplitude versus frequency, you'd take that graph and
19 you'd multiply each value on the graph by the
20 frequency; right?

21 MR. DEUTSCH: Objection; form.

22 THE DEPONENT: Yeah, I mean, you're asking
23 sort of mathematical questions based on a verbal
24 description. I'd like to see your math. But I -- it
25 sounds -- to the extent that I can answer it

1 accurately, it sounds approximately right.

2 BY MR. RUBIN:

3 Q Now, would you agree that the peak in that
4 graph will be shifted somewhat from the peak in the
5 position versus -- position amplitude versus frequency
6 graph?

7 MR. DEUTSCH: Objection; form.

8 THE DEPONENT: It will be shifted to a higher
9 peak.

10 BY MR. RUBIN:

11 Q Why would it be shifted to -- well,
12 withdrawn.

13 Would you agree that it will be shifted to a
14 different position, that is, a different value of the
15 frequency?

16 MR. DEUTSCH: Objection; form.

17 THE DEPONENT: No.

18 BY MR. RUBIN:

19 Q Why do you say the peak would be sharper?

20 A **It's multiplied by omega relative to the**
21 **amplitude of position.**

22 Q Imagine that omega, that resonance is less
23 than 1. In that instance, would the peak be sharper
24 or not?

25 MR. DEUTSCH: Objection; form and scope.

1 THE DEPONENT: I'd have to work out that
2 math.

3 BY MR. RUBIN:

4 Q So when you say that the peak would be
5 sharper, your reason for saying that is that there's
6 multiplication by a factor of omega? That is, when
7 you say that the peak would be sharper in the velocity
8 versus -- withdrawn.

9 When you say that the peak would be sharper
10 in the velocity amplitude versus frequency curve than
11 in the position amplitude versus frequency curve, your
12 reason for saying that is that there's a factor of
13 omega appearing as a multiplicative factor in the
14 velocity amplitude?

15 MR. DEUTSCH: Objection; form.

16 THE DEPONENT: Among other reasons, yes.

17 BY MR. RUBIN:

18 Q What other reasons?

19 A As we go into later, a velocity computation
20 could drive -- could be used for -- for example, in a
21 band-pass filter, which would potentially increase the
22 amplitude of the measurement or reduce -- sharpen the
23 peak actually, reduce the noise in other frequencies.

24 So I -- I think, you know, it's -- there are
25 a lot of reasons to compute the velocity of the signal

1 that would improve the ability of the system to track
2 the resonant frequency.

3 Q You refer to -- withdrawn.

4 In the middle of Paragraph 35, you refer to
5 using velocity as inputs to a band-pass filter or
6 Kalman filter.

7 Do you see that?

8 A Yes.

9 Q And am I pronouncing Kalman correctly? Do
10 you know?

11 A Yeah.

12 Q Kalman. All right.

13 So the band-pass filter you're referring to,
14 what would its inputs be and what would its outputs
15 be?

16 MR. DEUTSCH: Objection; form.

17 THE DEPONENT: If -- what I think a POSITA
18 would understand from Gregorio is that you would
19 measure, for example, a position from a sensor, and
20 POSITAs are well aware that many times sensor
21 measurements also contain noise in addition to the
22 signal that is of interest.

23 So frequently a filter is applied to the raw
24 information or raw signal that comes out of --
25 otherwise, lets -- by "raw," I mean, otherwise

1 unprocessed signal that comes out of a sensor. And
2 one such filter is a band-pass filter which excludes
3 frequencies below and above -- or let's say
4 predominantly excludes frequencies below a band and
5 above a band. And the band would be the range of
6 frequencies that the POSITA would expect the system to
7 operate at.

8 BY MR. RUBIN:

9 Q What would be the inputs of the band-pass
10 filter that you believe a POSITA would have recognized
11 would have been used in Gregorio and what do you
12 believe the outputs of that band-pass filter would be?

13 MR. DEUTSCH: Objection; form and scope.

14 THE DEPONENT: The input would be the signal
15 from a position sensor. The output would be a signal
16 used to determine velocity, for example, by dv/dx
17 (Pdt).

18 BY MR. RUBIN:

19 Q And P there is the position?

20 A Yes. So the output would be a position
21 signal with the frequencies below a band-pass and
22 above a band-pass filtered or attenuated.

23 Q You also refer to a Kalman filter. What is a
24 Kalman filter?

25 A It's a more sophisticated, mathematically

1 defined filter which requires various -- you know, it
2 requires a predictor and a corrector. It balances a
3 model prediction with a noisy signal. So -- but it --
4 in computing it, you -- among -- you have to compute
5 terms which are equivalent to a derivative.

6 Q So when you say you have to compute terms
7 that are equivalent to a derivative, you have to
8 compute the difference between consecutive values of
9 position?

10 A That's one way to do it, yes.

11 Q So would the Kalman filter you're describing
12 here take as inputs a sequence of position
13 measurements and based upon those inputs, estimate the
14 position and rate of change of position and then
15 update those estimates as new position measurements
16 that are received?

17 MR. DEUTSCH: Objection; form.

18 THE DEPONENT: That's a reasonable high-level
19 explanation. It creates an optimal trade-off between
20 using a model of the system and using the measurement.
21 So it -- it eliminates noise in a proveably optimal
22 way.

23 But I -- I don't mean -- I don't offer any
24 opinion about a detailed implementation for a Kalman
25 filter because I wasn't asked to. I'm just giving it

1 as an example of a thing that POSITAs would
2 understand. It may or may not be an overcomplex
3 filter for this kind of application, but it is one
4 that is relevant and would benefit from a derivative.
5 BY MR. RUBIN:

6 Q I'd like to turn to Paragraph 36.

7 In the second-to-last sentence you say that
8 calculating dv/dt is expressly mentioned in Gregorio
9 to calculating "how far the mass will rise above the
10 zero crossing in determining the resonant frequency."

11 Do you see that?

12 A I do.

13 Q So as you understand Gregorio, how is
14 calculating dv/dt used in order to determine how far
15 the mass will rise above the zero crossing? What's
16 the relationship between dv/dt and how far the mass
17 will rise above the zero crossing?

18 MR. DEUTSCH: Objection.

19 THE DEPONENT: You kind of -- oh, sorry.

20 Go ahead, Craig.

21 MR. DEUTSCH: Objection; form.

22 THE DEPONENT: You kind of combined a couple
23 questions there, so I was going to ask you to split it
24 up.

25 ///

1 BY MR. RUBIN:

2 Q As you understand Gregorio, how is
3 calculating dv/dt used in order to determine how far
4 the mass will rise above the zero crossing?

5 A The amount the mass rises above the zero
6 crossing, as I interpret it, as I think a POSITA would
7 interpret it, is another way to say the amplitude.
8 And calculating the amplitude is -- is -- as we went
9 over, can come from the acceleration signal dv/dt , and
10 it's a known effect of option for tracking the
11 resonance.

12 Q So in order to determine how far the mass
13 will rise above the zero crossing in Gregorio, is the
14 system calculating dv/dt once? Is it calculating it
15 at a sequence of points in time?

16 What's the actual procedure that Gregorio
17 would use to determine the -- how far the mass will
18 rise above the zero crossing?

19 MR. DEUTSCH: Objection; form and scope.

20 THE DEPONENT: I think a POSITA would
21 understand various options. One would be first
22 compute V by measuring the differential or the change
23 in position divided by the change in time, ΔT ,
24 and then, in turn, computing dv/dt the same way.
25 ///

1 BY MR. RUBIN:

2 Q And then what would happen next in order to
3 determine how far the mass will rise above the zero
4 crossing?

5 MR. DEUTSCH: Objection; form.

6 THE DEPONENT: The amplitude will be inferred
7 from the acceleration as we discussed.

8 BY MR. RUBIN:

9 Q So will it be inferred from the value of
10 acceleration at a single point in time? At a sequence
11 of different points in time?

12 A There are many ways --

13 MR. DEUTSCH: Objection -- objection; form
14 and scope. Sorry.

15 THE DEPONENT: Sorry.

16 There's many ways known to a POSITA to do
17 that and it's -- you know, another interpretation of
18 this zero crossing quote is that the value of dv/dt
19 taken at the time of the zero crossing would be useful
20 in determining the resonant frequency.

21 MR. RUBIN: Pass the witness.

22 THE DEPONENT: I'm sorry. I heard a very
23 partial word.

24 MR. RUBIN: All right. Sorry. I said I'll
25 pass the witness, so...

1 THE DEPONENT: Okay.

2 MR. RUBIN: If Mr. Deutsch has any questions,
3 he can ask them now.

4 MR. DEUTSCH: Yeah, just a couple questions,
5 Dr. Hannaford.

6 THE DEPONENT: Okay.

7

8 EXAMINATION

9 BY MR. DEUTSCH:

10 Q If we could turn to Exhibit 1006, briefly.
11 And do you recall discussing Figure 1?

12 A Sorry. I'm needing to pull that up. I have
13 it, yes.

14 Q Would you agree that even though, you know, a
15 figure like Figure 1 can be described as schematic,
16 that it -- that a POSITA can still discern various
17 things about the components and the relationships of
18 the components?

19 MR. RUBIN: Objection; scope. Objection;
20 leading exception. Objection; form.

21 THE DEPONENT: I believe this schematic
22 diagram fully conveys a resonant system having a mass
23 and a spring and other components in such a way that a
24 POSITA would understand both the physics of how it
25 works and also enhancements like a sensor and feedback

1 and also would understand ways to build such a
2 resonant system.

3 MR. DEUTSCH: Thank you. No further
4 questions.

5 MR. RUBIN: All right. No further questions
6 for me. So I think we can go off the record.

7 THE STENOGRAPHER: Do you need a copy of the
8 transcript?

9 MR. DEUTSCH: Yes, please. We don't need any
10 rush time frame or anything like that.

11 THE STENOGRAPHER: Do either of you need a
12 rough draft?

13 MR. RUBIN: I'll take a rough.

14 MR. DEUTSCH: Yes, please.

15 (The deposition concluded at 10:23 a.m.)
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1 REPORTER'S CERTIFICATE

2 I, TAMI L. LE CSR # 8716 do hereby certify that
3 the foregoing deposition of BLAKE HANNAFORD, Ph.D.,
4 was taken on JUNE 27, 2025 via zoom videoconference before
5 me at 9:31 A.M. for the purpose in the caption stated; that
6 the Witness was first duly sworn to tell the truth, the
7 whole truth, and nothing but the truth; that the deposition
8 was taken before me stenographically and afterwards

9 transcribed under my direction; that the foregoing is a
10 full, true, and correct transcript of the said deposition
11 so given; that counsel for all parties were present at
12 the time of the deposition; that there was not a request
13 for the witness to read and sign the transcript.

14 I further certify that i am neither of counsel nor
15 of kin to any of the parties to this action, and am in
16 no way interested in the outcome of said action.

17

18

19 Witness My Signature on July 14, 2025.

20

21

22

23

24

25


TAMI L. LE
CSR # 8716

1 STATE OF CALIFORNIA)
2 COUNTY OF ORANGE) ss.

3

4 I, Tami L. Le, Certified Shorthand Reporter,
5 Certificate No. 8716, for the State of California,
6 RPR, hereby certify:

7 I am the deposition officer that
8 stenographically recorded the testimony in the
9 foregoing deposition;

10 Written notice pursuant to Code of Civil
11 Procedure, Section 2025.520(a) having been sent to the
12 deponent, the deponent:

13 () In person made the changes set forth in
14 the foregoing transcript;

15 () Approved the transcript by signing it;

16 () Failed or refused to approve the
17 transcript by not signing it;

18 () By signed letter attached hereto, made
19 the changes set forth therein and
20 approved, or refused to approve, the
21 transcript;

22 () Failed to contact the deposition
23 officer within the allotted time
24 period.

25 Dated: July 12, 2025.

26 _____/s/_____
27 TAMI L. LE
28 Certified Shorthand Reporter No. 8716, RPR

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