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# Transcript of Andrew Wolfe, Ph.D.

**Date:** January 23, 2026

**Case:** Shenzhen Tuozhu Technology Co., Ltd. -v- Stratasy, Inc. (PTAB)

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Transcript of Andrew Wolfe, Ph.D.  
Conducted on January 23, 2026

<p>1 UNITED STATES PATENT AND TRADEMARK OFFICE 2 ----- 3 BEFORE THE PATENT TRIAL AND APPEAL BOARD 4 ----- 5 SHENZHEN TUOZHU TECHNOLOGY CO., LTD., 6 Petitioner, 7 v. 8 STRATASYS, INC., 9 Patent Owner. 10 ----- 11 Case IPR2025-00531 12 U.S. Patent No. 9,168,698 13 Case IPR2025-00532 14 U.S. Patent No. 10,556,381 15 ----- 16 17 REMOTE DEPOSITION OF 18 ANDREW WOLFE, PH.D. 19 January 23, 2026 20 21 Reported by: Susan S. Klinger, RMR-CRR, CSR 22 Job No. 616852</p>	<p>1 A P P E A R A N C E S: 2 3 Attorneys for Petitioner: 4 Joshua A. Griswold, Esquire 5 FISH &amp; RICHARDSON 6 1717 Main Street, Suite 5000 7 Dallas, Texas 75201 8 214.747.5070 9 10 Attorneys for Patent Owner: 11 Aashish Kapadia, Esquire 12 McDERMOTT WILL &amp; SCHULTE 13 300 Colorado Street, Suite 2200 14 Austin, Texas 78701 15 512.726.2600 16 17 18 19 20 21 22</p>
<p>1 January 23, 2026 2 10:03 a.m. 3 4 5 6 Remote Deposition of ANDREW WOLFE, PH.D., held 7 before Susan S. Klinger, a Registered Merit 8 Reporter and Certified Realtime Reporter of the 9 State of Texas. 10 11 12 13 14 15 16 17 18 19 20 21 22</p>	<p>1 I N D E X 2 3 WITNESS PAGE 4 ANDREW WOLFE, PH.D. 5 EXAMINATION BY MR. KAPADIA 5 6 7 E X H I B I T S 8 (Not attached.) 9 10 No. Description Page 11 Exhibit 1003 Wolfe declaration, '698 10 12 Exhibit 1003 Wolfe declaration, '381 10 13 Exhibit 1004 Warren reference 74 14 15 16 17 18 19 20 21 22</p>

<p>5</p> <p>1 PROCEEDINGS 2 ANDREW WOLFE, PH.D., 3 having been first duly sworn testified as follows: 4 EXAMINATION 5 BY MR. KAPADIA: 6 Q Dr. Wolfe, can you please state your full 7 name? 8 <b>A Andrew Wolfe.</b> 9 Q Because we're conducting a remote 10 deposition today, you and I are not in the same 11 room, and so I'm going to ask you a few questions 12 about your environment. I think we have been 13 through this before. 14 First thing, do you have any materials, 15 whether written or electronic, with you today? 16 <b>A Yes.</b> 17 Q Okay. And what do you have with you? 18 <b>A So I have printed out a number of</b> 19 <b>documents. My declarations for each of the IPR</b> 20 <b>matters, both of which are labeled Exhibit 1003,</b> 21 <b>the '698 and '381 patents, and then the Warren and</b> 22 <b>Calderon references. My copies all came from the</b></p>	<p>7</p> <p>1 Q How about on your phone, do you have any 2 chat or messaging applications running on your 3 phone? 4 <b>A My phone is in the next room.</b> 5 Q Okay. How about email, do you have access 6 to email or do you have email applications open? 7 <b>A They're not open.</b> 8 Q Okay. 9 <b>A I don't have any notifications.</b> 10 Q Okay. All right. Is there anyone else in 11 the room with you? 12 <b>A No.</b> 13 Q Okay. During the deposition today, if 14 anyone else does enter the room, will you let us 15 know? 16 <b>A I will.</b> 17 Q Okay. All right. Dr. Wolfe, you have 18 been deposed before, right? 19 <b>A Yes, I think I've been deposed by you</b> 20 <b>before.</b> 21 Q Yes. Do you know how many times you have 22 been deposed?</p>
<p>6</p> <p>1 <b>PTAB website.</b> 2 <b>And then I'm sitting at my computer. It</b> 3 <b>has got millions of documents on it, but none of</b> 4 <b>them are open.</b> 5 Q Okay. Anything else? 6 <b>A No.</b> 7 Q Okay. You mentioned you have millions of 8 documents on your computer. Do you intend to open 9 any of those materials today during the 10 deposition? 11 <b>A No. If you ask me to I will, but that</b> 12 <b>would be the only exception.</b> 13 Q Okay. And if you want to open any 14 materials that are accessible to you, just let us 15 know so that we can mark them and keep the record 16 of this deposition clean; is that okay? 17 <b>A Okay.</b> 18 Q Okay. On your computer do you have access 19 to any chat or messaging applications besides this 20 Zoom application that we're using today? 21 <b>A As far as I know, nothing else is</b> 22 <b>currently running.</b></p>	<p>8</p> <p>1 <b>A No, certainly more than 100.</b> 2 Q Yeah. All right. Well, you know, as 3 usual I will ask questions. You're under oath to 4 answer. Your counsel may object, you still have 5 to answer; is that okay? 6 <b>A I understand.</b> 7 Q Okay. After I ask you a question, just, 8 you know, please answer that question that I've 9 asked you and not anything else. Does that make 10 sense? 11 <b>A I will do my best.</b> 12 Q Okay. As usual, I will take a break when 13 needed. I will certainly ask if we want to take a 14 break periodically. All I ask is that if anyone 15 wants to take a break, we just finish your 16 response to any pending question before we take 17 that break; is that okay? 18 <b>A I understand.</b> 19 Q All right. Is there any reason that you 20 cannot testify truthfully today? 21 <b>A Not that I'm aware of.</b> 22 Q Okay. And you mentioned that you have a</p>

<p>9</p> <p>1 pair of declarations in front of you, correct? 2 <b>A Yes.</b> 3 Q Okay. Those declarations are in support 4 of, I believe, two petitions for inter partes 5 review. The first one is IPR2025-00531 for U.S. 6 Patent Number 9,168,698, and then the other one is 7 for IPR2025-00532 for U.S. Patent Number 8 10,556,381. Does that sound right to you? 9 <b>A It does. Unfortunately the copies that I</b> 10 <b>have don't have the -- the proceeding number on</b> 11 <b>them, but they do have the patent numbers, so...</b> 12 Q Okay. And do those patent numbers 13 match -- 14 <b>A They do.</b> 15 Q -- the patent numbers that I've mentioned? 16 <b>A Yes.</b> 17 Q For those inter partes reviews, do you 18 know if the petitioner is Shenzhen Tuozhu 19 Technology Company, Limited? 20 <b>A They are labeled Shenzhen Tuozhu 1003, so</b> 21 <b>I assume so.</b> 22 Q Okay. And I -- I think you had done this</p>	<p>11</p> <p>1 <b>them. This is the '698 patent.</b> 2 Q Yes. 3 <b>A Okay. I have them.</b> 4 Q Okay. So and do you have it open as well? 5 <b>A Yes.</b> 6 Q Okay. Excellent. So is the one that you 7 have open that I mentioned for the '698, that is 8 -- Exhibit 1003, is that a copy of your 9 declaration for the IPR for the '698 patent? 10 <b>A It appears to be, yeah.</b> 11 Q Okay. And so that we can keep everything 12 straight, but also simple, is it all right if I 13 refer to this as your '698 declaration today? 14 <b>A Yes.</b> 15 Q Okay. And if you open up the second 16 document that I uploaded, that is for the '381 17 patent, correct? 18 <b>A Right.</b> 19 Q Okay. If I refer to that declaration 20 today as the '381 declaration, would that be okay? 21 <b>A Yes.</b> 22 Q Okay. And from time to time I might refer</p>
<p>10</p> <p>1 earlier, but whenever I refer to U.S. Patent 2 Number 9,168,698 I might just say the '698 patent; 3 is that okay? 4 <b>A Yes.</b> 5 Q Then for U.S. Patent Number 10,556,381, I 6 might just say the '381 patent; is that okay? 7 <b>A Yes.</b> 8 Q Okay. Let me start out by introducing a 9 couple of exhibits into the chat and we will do -- 10 <b>A Okay. And then those are exhibits I</b> 11 <b>should download?</b> 12 (Exhibits 1003 discussed.) 13 Q Yes. Here is one. Let me give it a 14 second. So the first exhibit that I dropped into 15 the chat -- they're both exhibit -- in respective 16 proceedings they're Exhibit 1003. The first one 17 is for proceeding IPR2025-00531 and then the 18 second one is for IPR2025-00532. 19 Let me know when you have received those 20 two and you can go ahead and just open up the -- 21 the first one, the one for the IPR2025-00531? 22 <b>A Again, they don't have the IPR numbers on</b></p>	<p>12</p> <p>1 to "your declarations," meaning both the '698 and 2 the '381 declaration. Would that be okay? 3 <b>A It is going to depend on the question. I</b> 4 <b>may need clarification.</b> 5 Q Okay, sure. If you need clarification, 6 you will let me know though, right? 7 <b>A Yes.</b> 8 Q Okay. Let's talk about your declarations, 9 Dr. Wolfe. Was anyone else involved in creating 10 them? 11 <b>A Yes.</b> 12 Q Who else was involved? 13 <b>A I worked with counsel. I -- I developed</b> 14 <b>my opinions and discussed my opinions with counsel</b> 15 <b>and then they worked with me to -- to write</b> 16 <b>portions of it. But I had the final say over</b> 17 <b>everything that went into the declaration.</b> 18 Q Okay. Anyone else? 19 <b>A No.</b> 20 Q And do you recall which counsel you worked 21 with? 22 <b>A I recall working with Mr. Griswold and</b></p>

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1 **Mr. Gupta, but there may have been others as well.**  
2 Q Okay. Besides counsel, did anyone else  
3 contribute to your declaration?  
4 **A I cite documents written by other people,**  
5 **but I prepared all the opinions in the matter that**  
6 **I -- that I explained before.**  
7 Q Okay. For each of your declarations, I  
8 think there are two page numbers at the bottom of  
9 each page. And so to keep things simple, I'm  
10 going to refer to the bottommost of those two page  
11 numbers, I believe that starts with page 1 and  
12 then goes to the last page of whatever the  
13 document is. Would that be okay?  
14 **A That is fine.**  
15 Q So that should correspond to the page  
16 number -- if you have the PDF viewer up, the page  
17 number of the PDF viewer?  
18 **A It appears to, yes.**  
19 Q All right. Do you recall how many hours  
20 you spent in preparing your declarations?  
21 **A No.**  
22 Q Was it approximately 10 hours?

14

1 **A I think it was probably more than that,**  
2 **but I don't recall.**  
3 Q Okay. Let's -- let's talk a little bit in  
4 relation to these declarations, your declarations.  
5 I would like to discuss your background. So the  
6 first question I have for you is what sort of  
7 industry experience do you have related to 3D  
8 printing?  
9 **A In the 1980s, I started working with**  
10 **additive manufacturing techniques and subtractive**  
11 **manufacturing techniques and building factory**  
12 **equipment or modifying factory equipment to make**  
13 **products using those techniques, using a variety**  
14 **of materials. I continued to do that through the**  
15 **mid '90s or so.**  
16 **I also worked in and taught in areas**  
17 **related to automation, what we typically refer to**  
18 **as megatronics. So electronically controlled**  
19 **moving systems primarily, again, for factories.**  
20 **When I was at Princeton in the '90s, I worked with**  
21 **General Motors and other companies on -- on both**  
22 **control and sensing for manufacturing equipment.**

15

1 **And then I started becoming familiar with**  
2 **3D printers in the early 2010s, and then again,**  
3 **started teaching megatronics classes, I believe,**  
4 **in 2014. And at that point I started actually**  
5 **using and teaching students to use and maintain**  
6 **consumer grade 3D printers. So I've been teaching**  
7 **about them and using them since 2014 and I still**  
8 **do today.**  
9 Q Okay. So you mentioned that you started  
10 becoming familiar specifically with 3D printers in  
11 the early 2010s; is that right?  
12 **A Yeah, yeah. The first one I used was the**  
13 **MakerBot, but I was familiar with other ones that**  
14 **were being developed in the industry as well.**  
15 Q Okay. You mentioned in the 1980s you  
16 started working with additive manufacturing  
17 techniques. What types of additive manufacturing  
18 techniques were you working with back then?  
19 **A So primarily material deposition in layers**  
20 **to manufacture displays and touch sensors. So**  
21 **these were various techniques for -- for applying**  
22 **layers of materials generally or removing portions**

16

1 **of layers of materials with masks.**  
2 **So we would use stencils, we would use**  
3 **thick film materials, pastes, gels, inks, we would**  
4 **put through them. We would use thin film**  
5 **materials that would be deposited in vacuum**  
6 **chambers using plasma deposition and sputtering.**  
7 **We would use adhesives, which would be extruded**  
8 **using machines that would be designed to extrude**  
9 **them in particular patterns, all those things.**  
10 **And of course, my training included**  
11 **training in semiconductor manufacturing, which**  
12 **although it happens on a much smaller scale, also**  
13 **is -- tends to be additive and subtractive**  
14 **manufacturing.**  
15 Q Okay. So you mentioned it was -- that  
16 sort of additive manufacturing was for displays  
17 and touch sensors. Was there anything else that  
18 it was used for?  
19 **A We might have done something else, because**  
20 **we had all the equipment. We made night lights,**  
21 **but it was mostly focused around displays and --**  
22 **and touch sensors.**

<p>17</p> <p>1 Q Okay. So that is additive manufacturing 2 techniques. How about subtract -- I think you 3 said subtractive manufacturing techniques? 4 <b>A Right. So there you would typically do 5 something like put down a layer of material, then 6 put down a photo mask on top of it or a stencil on 7 top of it. And then use water or acid or 8 something to remove the portions that -- that 9 didn't belong there.</b> 10 Q Okay. So those were for manufacturing of 11 similar products to, was it touch sensors? 12 <b>A Yeah. And of course, you know, we also 13 did die cutting, which is a very simple 14 subtractive manufacturing technique where you just 15 cut a piece out.</b> 16 Q And die cutting, are you referring to 17 semiconductor dies? 18 <b>A No, no. I don't know why they're called 19 dies, but they're -- they're basically very 20 heavy-duty cookie cutters that you press down on 21 the material and it cuts a piece out.</b> 22 Q Okay.</p>	<p>19</p> <p><b>1 printing and a couple of them have built 3D 2 printers or 3D scanners.</b> 3 Q Okay. Let's -- let's talk a little bit, 4 you mentioned that you -- some of your work 5 related to, I think touch -- was it touch sensors; 6 is that right? 7 <b>A Yes.</b> 8 Q What were those touch sensing -- I don't 9 know if that is the right term, touch sensors or 10 touch sensing devices? 11 <b>A Well, I primarily worked on components and 12 integration. In the earliest days when I started 13 doing it around '83, they would have been 14 information kiosks. We put one in Logan Airport, 15 a bunch in Macy's and Neiman Marcus, some in 16 tourist destinations. Later in Epcot Center where 17 you would walk up and you would touch the CRT 18 screen and get some kind of information, you know, 19 like -- like -- like -- the wares, the store at 20 the mall kind of display.</b> 21 <b>Later on we did a lot of the early 22 handheld products. I did the first prototype for</b></p>
<p>18</p> <p><b>1 A Tool and die manufacturer is the way we 2 think of it traditionally.</b> 3 Q Okay. So let's -- that is industry 4 experience, how about research experience. Have 5 you had research experience related to 3D 6 printing? 7 <b>A No. I had a little bit, again, related to 8 additive manufacturing for displays and touch 9 sensors, but my direct 3D printing experience has 10 been teaching about what is known in the industry, 11 not inventing it myself.</b> 12 Q Okay. And you mentioned that you teach a 13 course, I think, was it in mechatronics? 14 <b>A Yes. I also teach a -- I also teach an 15 electronic prototyping class as well, that also 16 some years uses 3D printing and always uses 17 printed circuit board manufacturing.</b> 18 Q Okay. And besides those classes, do you 19 have any other teaching experience related to 3D 20 printing? 21 <b>A Yes. I've supervised over 70 senior 22 thesis projects, and a number of them have used 3D</b></p>	<p>20</p> <p><b>1 the Apple Newton, the first prototype for the IBM, 2 the first smartphone, Motorola's first smart PDA. 3 I did the first tablet computer and also what we 4 call point of sale or signature capture devices 5 where, you know, you would sign for your credit 6 card receipt. We did one for Sears, one for 7 McDonald's. So those were kind of the flavor of 8 the things that we were typically working on.</b> 9 Q Okay. Were any of those devices that you 10 mentioned were they used as part of like a 3D 11 printer? 12 <b>A Probably not. That was probably too early 13 for anybody to be really using the term 3D 14 printer, but they were often used to control 15 factory equipment, manufacturing equipment.</b> 16 Q Okay. So let's -- let's talk about some 17 of those devices. You had mentioned that there 18 was a device used in the information kiosk like in 19 Logan Airport, for instance. 20 What did that device -- you mentioned a 21 CRT, what else did that device do? You know, what 22 was its functionality?</p>

21

1 **A I believe it had a telephone modem and an**  
2 **old Apple II inside the kiosk. And it was**  
3 **operated by Fidelity Investments and it would tell**  
4 **you why you should invest in mutual funds.**  
5 **Q Really interesting. So a user walks up to**  
6 **the CRT, I suppose, and then they touch the -- the**  
7 **glass screen of the CRT. Is that how it would**  
8 **work?**  
9 **A Yeah, there were different kinds, but that**  
10 **particular one had a glass screen. It wasn't a**  
11 **glass screen of the CRT. We put another piece of**  
12 **glass in front of it, and that was one selectively**  
13 **coated with what we call indium tin oxide, a -- a**  
14 **thin film transparent conductor that would measure**  
15 **the capacitance of your skin.**  
16 **Q So -- so it measures the capacitance of**  
17 **your skin and then what does it -- what does it do**  
18 **with that?**  
19 **A That particular one actually just had, I**  
20 **think, 32 different locations on the screen. And**  
21 **it would tell the Apple computer which one you**  
22 **were touching, and then in that particular case I**

22

1 **actually wrote all the software too. So then that**  
2 **would go and -- you know, if you picked tell me**  
3 **about mutual funds, it would bring up a little**  
4 **script to tell you about mutual funds.**  
5 **Q Okay. And so the -- was it that thin film**  
6 **layer would -- it would detect a -- is it a**  
7 **capacitance of the finger, how did that work**  
8 **exactly?**  
9 **A There was a circuit that measured the**  
10 **capacitance of that piece of metal. And when you**  
11 **touched it, your capacitance added to that piece**  
12 **of metal. In that particular case there is what**  
13 **was called an RC oscillator. And when you added**  
14 **capacitance it would slow down. And I -- I had a**  
15 **circuit that was counting the pulses, and when it**  
16 **slowed down we would know you were touching that**  
17 **spot.**  
18 **Q Okay. And does that -- that same basic**  
19 **functionality, does that apply to the kiosk that**  
20 **went into, say, Macy's and Neiman Marcus?**  
21 **A I don't remember. We made a number of**  
22 **different technologies including ones that had**

23

1 **multiple resistive films. And later ones that had**  
2 **a continuous capacitive surface that could**  
3 **triangulate where you were touching. I don't**  
4 **actually remember which one we put into Macy's and**  
5 **Neiman Marcus.**  
6 **Q Okay. Let's -- let's talk about the you**  
7 **said dual resistive layers; is that right?**  
8 **A Uh-huh.**  
9 **Q How does that work?**  
10 **A Again, there were a variety of ways, but**  
11 **typically you would send a DC voltage across the**  
12 **lower layer. You would use the top layer as a**  
13 **probe. There would be -- again, through this**  
14 **additive manufacturing, we would add a bunch of**  
15 **little, very, very tiny insulator dots onto the**  
16 **lower layer of the plastic that would hold the top**  
17 **layer up. But when you touched it, you would**  
18 **press it down and compress those dots and make**  
19 **contact and probe the lower surface. And then we**  
20 **would flip the circuits around and you would use**  
21 **the lower surface to probe the upper surface.**  
22 **We had other designs where we could**

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1 **actually get the electricity to run in both**  
2 **directions on the lower surface linearly and you**  
3 **would always use the upper surface as a probe. So**  
4 **again, we would -- we would manufacture these**  
5 **different layers additively, the -- the -- take**  
6 **the substrate, we would just buy, just plastic**  
7 **film, deposit the conductor on it sometimes in a**  
8 **patterned way. Sometimes deposit silver or carbon**  
9 **inks to change the resistivity on top of that and**  
10 **then deposit a UV curable plastic gel that we got**  
11 **from 3M that would create the separator dots and**  
12 **then another conductive layer on another substrate**  
13 **on top. And then we would typically die cut kind**  
14 **of a ring of adhesive to go around the outside**  
15 **that would hold all the pieces together.**  
16 **Q On the outside of the display?**  
17 **A Yeah.**  
18 **Q Okay. Would any of these displays be able**  
19 **to distinguish between, you know, like maybe**  
20 **someone who is more experienced with the touch**  
21 **display and barely touches the display versus,**  
22 **like, a child who smashes on it with their thumb**

25  
1 or something like that?  
2 **A Some of them could, some of them could**  
3 **not.**  
4 Q Which ones could kind of just make that  
5 distinguish?  
6 **A You know, we had different software or**  
7 **different firmware for different ones. And if**  
8 **people wanted that kind of touch distinguishing,**  
9 **you know, the strength of the touch or the, you**  
10 **know, the size of the user, there are ways we**  
11 **could measure that. I didn't have any – it was**  
12 **on a – almost everything was designed for an**  
13 **individual customer, customized for an individual**  
14 **customer. So you know there were – there were**  
15 **hundreds or thousands of individual products.**  
16 Q So would you take, say, one physical  
17 product and then adjust the -- you mentioned, I  
18 think, firmware or software for the particular  
19 customer or would you custom design the entire  
20 system?  
21 **A Both. Oftentimes every display was a**  
22 **different size, so we would have to do a custom**

26  
1 **design for every customer at that point.**  
2 Q Okay. Were there any designs for the  
3 display itself where you would have to make design  
4 changes in order to accommodate a customer request  
5 to distinguish between, let's say, one customer  
6 who is pushing on a display very hard versus a  
7 customer who is just barely touching the surface?  
8 **A We did that. I mean, you know, there were**  
9 **– there were cases where people would want to**  
10 **touch it, drag it around and push harder to click.**  
11 **So – so there were instances of that, yes.**  
12 Q So for that example where a customer, you  
13 know, touches a display, drags around their finger  
14 and pushes even harder to click, would you have to  
15 make design changes to the display?  
16 **A Not to display, but to the touch sensor**  
17 **software –**  
18 Q Okay.  
19 **A – and that firmware.**  
20 Q So what sort of changes -- help me  
21 understand what sort of changes would you make to  
22 the touch sensor software?

27  
1 **A It has been 30 plus years. Generally we**  
2 **didn't measure the touch force on most of those**  
3 **products, but we had the capability to measure it.**  
4 **And we would only measure it – again, we're**  
5 **talking a long time ago. So in those days, we**  
6 **didn't want to use our CPU time to measure it if**  
7 **the customer didn't care, so we would only turn on**  
8 **the – that particular measurement phase. Again,**  
9 **we're talking the '80s now, if the customer needed**  
10 **that information, but we knew how to do it.**  
11 Q Okay. So you mentioned that that was in  
12 the '80s. Did you work on similar types of  
13 systems in the '90s?  
14 **A Yeah, through about the mid '90s, yeah, up**  
15 **until I moved to California.**  
16 Q Okay. And -- and was the same sort of  
17 focus was that in play in the '90s where you  
18 didn't want to use the CPU time to measure it if  
19 the customer didn't care to, I guess, perform a  
20 particular measurement?  
21 **A I think that was generally true for air**  
22 **products. You know there were all kinds of – you**

28  
1 **know, there were competitors that all kinds of**  
2 **force sensing technology and it was very**  
3 **well-known, but wasn't the bulk of the market at**  
4 **that point.**  
5 Q Okay. You mentioned tablet computers as  
6 well, you have experience with tablet computers?  
7 **A I do.**  
8 Q Do those tablet computers accept input  
9 from a pen, for instance?  
10 **A From a stylus, yeah.**  
11 Q Stylus?  
12 **A The – the first one I did was – was –**  
13 **always used a stylus, the later ones could use a**  
14 **stylus or a finger.**  
15 Q Okay. What kinds of sensors were used on  
16 those systems so that you could accept input from  
17 a stylus?  
18 **A In those particular systems, ones I worked**  
19 **on, again they were either capacitive touch**  
20 **sensors or resistive touch sensors.**  
21 Q So did they use similar sorts of sensors  
22 to what you had described earlier with films,

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1 whether it be one or more layers?  
2 **A The ones I worked on did.**  
3 Q And for those systems where you would have  
4 a stylus as an input, do you recall if those  
5 systems would distinguish between, for instance, a  
6 stylus that has just touched the screen or maybe a  
7 harder press that might correspond to a click?  
8 **A I don't recall that being part of any of**  
9 **the commercial systems, the actual systems that I**  
10 **worked on. I mean, again, they were known in the**  
11 **industry, but not the ones that I worked on.**  
12 Q Okay. So aside from the stylus input or a  
13 touch input from a human finger, did you work on  
14 other sorts of touch systems for a touchscreen?  
15 **A I'm not sure I understand the question. I**  
16 **worked on things that would detect a stylus and**  
17 **things that would detect a finger.**  
18 Q Okay. But not -- those two objects,  
19 nothing else?  
20 **A They might have responded to other things,**  
21 **but that wasn't the normal usage --**  
22 Q Okay.

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1 **A -- matter.**  
2 Q Okay. I think you --  
3 **A I mean the resis -- the resistive**  
4 **touchscreens, if you -- if you put a brick on**  
5 **them, that would count as a touch as long as you**  
6 **had enough pressure to overcome the -- the**  
7 **separators.**  
8 Q So you mentioned just now if you had  
9 enough pressure you had also mentioned that there  
10 were force sensing. So is there -- is that  
11 basically the same thing, like, having enough  
12 pressure and the force sensing capability of these  
13 systems or is that a different capability?  
14 **A In the touchscreen world, we would use the**  
15 **term "force sensing" when we were measuring it,**  
16 **but we might have had a force threshold even if we**  
17 **weren't measuring the force. Just was it enough**  
18 **to turn it on or not enough, right.**  
19 **So again, it takes a certain amount of**  
20 **force to turn on the ordinary light switch in my**  
21 **office, right, but nobody calls a light switch a**  
22 **force sensor even though it requires a certain**

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1 **amount of force to turn it on.**  
2 Q Okay. So you have used the term force  
3 sensor a few times. It sounds like you're  
4 familiar with it. What -- in your view what is a  
5 force sensor?  
6 **A Again, it varies among industries and**  
7 **context, and it varies over time. But generally a**  
8 **force sensor is a device that can be used as part**  
9 **of a system to measure a force.**  
10 Q Can you give me an example of a force  
11 sensor?  
12 **A A strain gauge is one that is commonly**  
13 **used, something called a load cell. It can be a**  
14 **variable resistor within -- with a spring. It can**  
15 **be -- we have what we call capacitive force**  
16 **sensors where we press two plates together and**  
17 **measure the capacitance. There are piezoelectric**  
18 **force sensors where we call them force sensors.**  
19 **They don't literally measure force, they actually**  
20 **measure changes in force. Accelerometers and**  
21 **gyroscopes can be force sensors. They can measure**  
22 **force depending on how you hook them up and how**

32

1 **you use them.**  
2 Q Any other examples come to mind?  
3 **A I'm sure there is others. We just used**  
4 **something called a force sensing resistor. It was**  
5 **an actual, like, a thick film material that would**  
6 **respond to force. There may be other kinds of**  
7 **force sensors out there. It is a pretty**  
8 **well-known and rich field.**  
9 Q Let's -- let's talk about some of those  
10 sensors you mentioned. I think the first one you  
11 mentioned was a strain gauge?  
12 **A Yes.**  
13 Q How does a strain gauge work?  
14 **A I don't know all the material science**  
15 **involved, but I can tell you just as a -- as a**  
16 **person who would typically use a strain gauge, I**  
17 **believe that it has two thin pieces of metal. And**  
18 **when you put a force on it, one or both of them**  
19 **bend and the resistance of the metal changes when**  
20 **it is deformed.**  
21 Q So is -- is a strain gauge measuring  
22 resistance of the metal or a change in resistance?

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1 **A It is measuring force. It is used to**  
2 **measure force, but the mechanism for measuring the**  
3 **force is by measuring the change in the resistance**  
4 **to metal. And -- and again, you can't directly**  
5 **measure resistance, I don't think. So what you do**  
6 **is you measure the response to a current or a**  
7 **voltage. That is how we measure resistance.**  
8 Q Okay. So you -- so the strain gauge will  
9 measure a response to a current or a voltage and  
10 then by understanding that change corresponding to  
11 resistance it will then be able to measure a  
12 force; is that right?  
13 **A Correct, that is the way it is typically**  
14 **used. It is a standard kind of a force sensor.**  
15 Q Okay. I think you had also mentioned  
16 capacitive sensor?  
17 **A Yes.**  
18 Q How does a capacitive sensor work? Is  
19 that the same way as a strain gauge?  
20 **A No. Capacitive sensors typically have two**  
21 **metal plates that are separated by some**  
22 **insulation. That insulation can be air or vacuum**

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1 **or it can be some other material. And typically**  
2 **the force that is being measured will -- will push**  
3 **them closer together. And when you push metal**  
4 **plates closer together, the capacitance between**  
5 **them changes and that can be, again, measured with**  
6 **a simple circuit.**  
7 Q Okay. And so when the capacitance  
8 changes -- so you measure, I guess, a change in  
9 the capacitance, does that -- so the sensor just  
10 measures capacitance, it doesn't measure force?  
11 **A The sensor measures force and then**  
12 **represents that force in the form of a**  
13 **capacitance. And then the user measures the**  
14 **capacitance as a representation of the force.**  
15 Q Okay. And for, like, a capacitive sensor,  
16 how would you know like if I -- I'm going to make  
17 up a capacitance, I don't know, 10 -- 10  
18 nanofarads, how would you know what 10 nanofarads  
19 means?  
20 **A Either you would be provided that**  
21 **information by the manufacturer or you would**  
22 **characterize it by applying a variety of different**

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1 **forces and making measurements and -- and -- and**  
2 **graphing it yourself, so that you know the**  
3 **response. The response isn't going to change over**  
4 **time.**  
5 Q Okay. So does the -- are there any --  
6 what variables go into that response? Is it just  
7 a simple I measure different capacitance values  
8 and then I know the force from it?  
9 **A You would measure capacitance in known**  
10 **forces.**  
11 Q Okay.  
12 **A You know, you would -- you would draw a**  
13 **curve, same as any other sensor.**  
14 Q Okay. And so earlier I think you had  
15 mentioned that for some touchscreens you would  
16 use, say, a finger, for instance. Would it matter  
17 whether you are using a finger to apply the force  
18 or something else?  
19 **A In the capacitive touchscreens it would.**  
20 **But in -- for a -- for a capacitive force sensor,**  
21 **generally not.**  
22 Q Okay. What is the distinction between a

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1 capacitive touchscreen and a capacitive force  
2 sensor?  
3 **A A capacitive touchscreen is measuring the**  
4 **capacitance of the person, which will vary as a**  
5 **function of force as a side effect of the fact**  
6 **that -- that your finger is deformable and that it**  
7 **is made up of a complex set of liquids and solids.**  
8 **So it is not -- not -- it is different for each**  
9 **person. And it could only be measured with a very**  
10 **general level of accuracy.**  
11 **The capacitive force sensors are much more**  
12 **precise and they're not tied to the capacitance of**  
13 **the body or any of the other material properties**  
14 **of the body. The force acts on some type of a**  
15 **spring, usually one that doesn't look like what we**  
16 **think of as a spring, but -- but is simply part of**  
17 **the -- of the natural materials of the sensor.**  
18 **And that causes the distance between the sensor**  
19 **plates to vary and that is much more predictable**  
20 **and much more reliable.**  
21 Q Could someone use a capacitive force  
22 sensor with their finger, I guess?

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1 A It depends on the range of the sensor,  
2 right? I mean, if the sensor was designed to -- I  
3 mean, yes, you could, right. The question is  
4 whether or not you could apply enough force with  
5 your finger to trigger that particular sensor.  
6 For some sensors you could, for some sensors you  
7 could not.

8 Q Could -- what if -- what if I have -- I  
9 don't know, an older person who has very squishy  
10 fingers. You mentioned earlier fingers -- your  
11 finger can deform if you touch something. Is that  
12 a reason why maybe you can't apply enough force  
13 for a capacitive force sensor for a particular  
14 capacitive force?

15 A No, no. There -- there are capacitive  
16 force sensors at very different ranges, right. So  
17 there might be one to -- to measure the force of a  
18 suspension of a truck, right. If you try to apply  
19 that much force with your finger you would just  
20 shatter the bones, right? We're not talking about  
21 subtleties here, right?

22 You can build -- you can buy capacitive

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1 force sensors over, you know, three, four orders  
2 of magnitude. And some of them are suitable for  
3 interaction with a person and some of them are  
4 suitable for interaction with -- with, you know, a  
5 locomotive.

6 Q And when the -- so for the ones that are  
7 suitable for interaction with a person, would it  
8 matter how much the person's finger, for instance,  
9 deforms when they use the sensor?

10 A Not significantly for most applications,  
11 right. Certainly not -- not, you know, not to two  
12 decimal places or something like that. It would  
13 not -- not in a way that -- that any application I  
14 have ever seen would care.

15 Q Okay. So -- and so you mentioned two  
16 decimal places. Help me understand what is the  
17 distinction here between the deformation of the  
18 finger and -- and what you care about?

19 A Well, it might be that the deformation of  
20 the finger could -- could change the amount of  
21 force that is being applied. I mean, all that  
22 matters is the amount of force.

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1 Now, if it wasn't applied uniformly could  
2 there be a difference in measurements of .001  
3 percent, I don't know, because it is so irrelevant  
4 to any application I have ever seen that I've  
5 never seen anybody measure that.

6 Q Okay. So we've talked about strain gauges  
7 and capacitive sensors. Have you ever -- I think  
8 you also mentioned piezoelectric sensors; is that  
9 right?

10 A Yes.

11 Q How do those work?

12 A Piezoelectric materials generally are  
13 crystals. One of the properties of them is that  
14 if you apply a change in force to the crystal, it  
15 will generate a voltage that corresponds to the  
16 change in force. So for example, sometimes  
17 they're used in microphones to measure the  
18 difference in air pressure.

19 Q Okay. So again, you're -- you're  
20 measuring a change in voltage; is that right?

21 A Not so much you're measuring. You're  
22 measuring the change in force, but it gets

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1 represented in the signal as a voltage.

2 Q So the signal from the piezoelectric  
3 sensor is a change in voltage?

4 A Yes. I mean, you can't put a force on  
5 a -- you can't represent a force electrically on a  
6 wire, right? So the whole point of a sensor -- of  
7 a force sensor is to turn the force into some type  
8 of an electrical signal.

9 Q Okay.

10 A That is why we use electronic force  
11 sensors is to perform that translation. We call  
12 them transducers. They -- they -- they take in  
13 one form of energy and output a different form of  
14 energy.

15 Q Okay. And so you're -- you're saying  
16 that, so your output to signal is a different form  
17 of energy than the force, but you then use --

18 A Right.

19 Q -- that signal to perform a measurement?

20 A That would be a typical thing to do,  
21 right? I mean, if -- if you didn't need to  
22 transform it, you wouldn't need a sensor, right?

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1 **So that is why we use sensors is to -- is to take**  
2 **one type of energy or one type of other physical**  
3 **phenomenon and transform it into another.**  
4 Q And -- and how would you know, for  
5 instance, what sort of signal corresponds to a  
6 given force?  
7 A **Typically when you buy the sensor, it just**  
8 **tells you in the instructions. But if you didn't**  
9 **have that, you would perform a simple experiment**  
10 **with it to -- to characterize it.**  
11 Q Okay. Let's talk about some other --  
12 other types of sensors, I think you might have  
13 heard of these before.  
14 Are you familiar with optical sensors  
15 being used as a force sensor?  
16 A **There are lots of different kinds of**  
17 **optical sensors. Optical sensors can be used to**  
18 **determine if something is being deformed, that can**  
19 **be a force sensor. They can be used to measure**  
20 **distance. If you know the correspondence between**  
21 **distance and force, that can -- that can work.**  
22 **There are probably other kinds of optical**

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1 **force sensors as well, but I haven't used any**  
2 **other ones.**  
3 Q Okay. So I think the two things you  
4 mentioned is that the optical sensors are used to  
5 determine if something is deformed and to  
6 understand or to measure distance; is that right?  
7 A **Those are the two that I mentioned.**  
8 Q Okay. And for the -- for the first one  
9 where you are looking at or trying to determine if  
10 something is deformed, how does the optical sensor  
11 do that?  
12 A **Again, I don't know -- you know, to use**  
13 **these sensors you don't necessarily have to know**  
14 **how they work all the time, right, because they**  
15 **come in instructions. So that has been my -- you**  
16 **know, that would be my normal way of interacting**  
17 **with them. But I do know from some of the work**  
18 **that I've done at the university that one way to**  
19 **do that is -- is that you basically look at**  
20 **something and see whether or not its shape has**  
21 **changed.**  
22 Q Okay. So you're just looking for a change

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1 in shape in this optical system?  
2 A **In some of them, you are looking to see if**  
3 **something bends. But again, there are other ones**  
4 **as well that will actually, you know, measure**  
5 **distance with time of flight or use some kind of**  
6 **interference pattern between lights. You know,**  
7 **there are a variety of different ways to do this,**  
8 **but again, these are -- these are simple**  
9 **components.**  
10 **Generally you just go buy one. It gives**  
11 **you a chart that says, you know, here is how the**  
12 **signal represents the force. And it gives you**  
13 **instructions on how to connect it up and that is**  
14 **what you do.**  
15 Q Okay. And how would an optical sensor --  
16 so you have a certain amount of deformation. How  
17 would you know, let's say, 1 millimeter of  
18 deformation, how -- how do you translate that to  
19 force?  
20 A **It depends on the materials involved, but**  
21 **again, you know, the deformation of -- of**  
22 **materials is well-known. It can be described by**

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1 **spring constants, it can be -- in some cases just**  
2 **read off of charts, and other cases you can run it**  
3 **through a tool, a finite element analysis tool**  
4 **what, you know, what would be an ordinary CAD**  
5 **tool. So it depends on the circumstances, but**  
6 **again, people who build things out of materials**  
7 **understand how to characterize the deformation as**  
8 **a function of the force. And that is only one way**  
9 **to do it.**  
10 Q Okay. How about have you heard of a  
11 potentiometric sensor?  
12 A **Yes, I had mentioned that before when we**  
13 **were talking about the variety of sensors.**  
14 Q And how does a potentiometric sensor work?  
15 A **So a potentiometric refers to something**  
16 **using a potentiometer. A potentiometer is a word**  
17 **for a variable resistor. Generally, I mean there**  
18 **are lots the different kinds of sensors like that,**  
19 **but if you want it to be a force sensor, generally**  
20 **you would combine the potentiometer with a spring.**  
21 **The length of the -- sorry. The length of the**  
22 **spring would vary as a function of the applied**

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1 force.  
2 The potentiometer would be adjusted to  
3 match the length of the string -- of the spring,  
4 right. So essentially, there are potentiometers  
5 that you push and pull on them, right.  
6 And then the potentiometer's length would  
7 correspond to the spring length, which would  
8 correspond to the force. And you can measure the  
9 resistance of the potentiometer as a function of  
10 its length. It could also be done rotationally as  
11 well.  
12 Q And earlier I think you had mentioned that  
13 you don't measure resistance directly. Does that  
14 apply in this circumstance as well?  
15 A I think that is right. You always measure  
16 -- you know, resistance, current and voltage are  
17 always in a fixed relationship according to Ohm's  
18 Law. So what you do is you -- to measure one, you  
19 use the other two. So if you want to measure  
20 resistance, you look at the relationship between  
21 voltage and current.  
22 Q Okay. And so for a potentiometric sensor

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1 you are looking at, let's say, a measurement of  
2 the resistance and that corresponds to a change in  
3 the length of a -- of a spring; is that right?  
4 A In a common one. Again, they can be built  
5 differently, it can be based on torque. I'm sure  
6 there are lots of different configurations, but  
7 that is the common one that I'm -- that I'm used  
8 to.  
9 Q Okay. So in that circumstance, then, is a  
10 potentiometric sensor a force sensor?  
11 A Yes, it is measuring force.  
12 Q So -- so help me, maybe I'm  
13 misunderstanding something. I thought we just  
14 said that it was measuring the length of a spring?  
15 A Right. But a spring, according to Hooke's  
16 Law, the length is going to be a function of the  
17 applied force, right. I mean, that -- that is the  
18 nature of measurement, right. You measure things  
19 by -- by -- by understanding the physical  
20 relationships and taking advantage of those  
21 relationships, right.  
22 Your -- your -- your bathroom scale

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1 doesn't measure your weight, right. It doesn't  
2 measure -- it measures the deformation of either a  
3 potentiometric sensor or a capacitive sensor that  
4 correspond to the force of gravity on your body.  
5 We still think of a scale as measuring weight in  
6 normal usage.  
7 Q Okay. Okay. I see what you are saying.  
8 How about an acoustical sensor, can that  
9 be a force sensor?  
10 A It could. I've seen it in the literature.  
11 Again, I think it is primarily measuring  
12 deformation or distance, but there could be other  
13 kinds as well. Again, you know, as a person of  
14 ordinary skill in the art, we don't have to  
15 understand the underlying physics of every sensor,  
16 because you just buy them with documentation on  
17 how to use them, anymore than somebody has to  
18 understand how their TV works to watch TV.  
19 Q Have you ever -- so for all the sensors  
20 that you have used in your experience, do they all  
21 have the documentation that you need in order to  
22 understand how to use them for, say, a force

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1 sensor?  
2 A Not always, but that is always a option.  
3 If you need a force sensor, you can always get one  
4 when it comes documentation.  
5 Q Yes.  
6 A Some -- some people just buy surplus or,  
7 you know, things that are just, you know, have --  
8 come in bins. But typically if you go to a  
9 manufacturer, either -- either it comes with  
10 documentation or they will work with you to  
11 generate the documentation.  
12 Q Okay. So aside from having the  
13 documentation or working with the manufacturer  
14 to -- to generate it upon request, what else would  
15 someone do if you get it from -- something from a  
16 parts bin, what would someone do to understand how  
17 that sensor works?  
18 A It is what we call characterizing a  
19 sensor. So today is Friday. On Tuesday, my  
20 students built their own sensors, right, they were  
21 distance sensors. They built them themselves. I  
22 didn't really tell them much about the parts, so

<p style="text-align: right;">49</p> <p>1 they had to characterize them.</p> <p>2 So they did a very simple experiment.</p> <p>3 Took them about 45 minutes where they placed the</p> <p>4 sensor 5 centimeters, 10 centimeters, 15</p> <p>5 centimeters, 20 centimeters from the wall and they</p> <p>6 measured its output. And then they drew a graph</p> <p>7 and now they knew what the transfer function was</p> <p>8 of that sensor. A very elementary kind of a thing</p> <p>9 to do.</p> <p>10 Q Okay. So that was measuring -- was that a</p> <p>11 sensor that was measuring distance?</p> <p>12 A That was a distance sensor.</p> <p>13 Q Okay. And --</p> <p>14 A And an optical distance sensor in that</p> <p>15 case.</p> <p>16 Q Okay. And -- and so let's say you have</p> <p>17 the readings from the sensor for this optical</p> <p>18 distance sensor and now you know what distance</p> <p>19 that corresponds to, right?</p> <p>20 A Right.</p> <p>21 Q Do you refer to that as a transfer</p> <p>22 function, I believe?</p>	<p style="text-align: right;">51</p> <p>1 other type of, say, electrical metric directly?</p> <p>2 A No, they measure what they're intended to</p> <p>3 measure. It could be a force, it could be a</p> <p>4 distance. It could be a person's capacitance.</p> <p>5 And again, they're transducers. That is what</p> <p>6 sensors generally are. So they then output some</p> <p>7 signal. In today's world, it could be a digital</p> <p>8 signal, but traditionally it would be a voltage or</p> <p>9 a current or a frequency or a resistance or a</p> <p>10 capacitance. Some electrical parameter that is</p> <p>11 well-known and that any electrical engineering</p> <p>12 student would know how to measure.</p> <p>13 Q Okay. So you had mentioned a couple of</p> <p>14 things that I understood in terms of capacitance,</p> <p>15 voltage, current, but then you also mentioned</p> <p>16 things like frequency. How does frequency work</p> <p>17 into a measurement for an electrical parameter?</p> <p>18 A There is -- there are circuits that will</p> <p>19 oscillate at a frequency that is reflective of the</p> <p>20 resistance capacitance and/or inductance of the</p> <p>21 circuit. So for example, that very first</p> <p>22 capacitive touchscreen that I use -- that I sold</p>
<p style="text-align: right;">50</p> <p>1 A Yes.</p> <p>2 Q Would that transfer function be used to</p> <p>3 tell you what sort of force, for instance, was</p> <p>4 used to -- to have that sort of distance?</p> <p>5 A No. In this case this was a distance</p> <p>6 sensor so it just measured distance. This was not</p> <p>7 a force sensor in this case, but you would do the</p> <p>8 same process with a force sensor. Instead of</p> <p>9 making measurements at known distances you would</p> <p>10 make measurements at known forces.</p> <p>11 Q Okay. So you would apply a particular</p> <p>12 force and then what would you measure?</p> <p>13 A Whatever the output of that particular</p> <p>14 sensor is. Again, in electronics it is usually a</p> <p>15 voltage or a current, but it could be a frequency</p> <p>16 or something else. You know, we have -- there</p> <p>17 are -- there are a dozen or more very, very common</p> <p>18 techniques. Sensors have been around for hundreds</p> <p>19 and hundreds of years.</p> <p>20 Q And so are all these types of sensors</p> <p>21 we've been talking about essentially just</p> <p>22 measuring a voltage or a current or some sort of</p>	<p style="text-align: right;">52</p> <p>1 that I told you about in Logan Airport I had a</p> <p>2 circuit that would vary its oscillation frequency</p> <p>3 as a function of the person's capacitance that was</p> <p>4 touching it.</p> <p>5 And it would get slower when a person</p> <p>6 touched it because the RC delay -- the resistive</p> <p>7 capacitance product that impacted the timing of</p> <p>8 the oscillation would increase. So I would simply</p> <p>9 count the number of oscillations for a 10th of a</p> <p>10 second or something. And if there were more</p> <p>11 oscillations then I knew it was not being touched.</p> <p>12 If there were fewer oscillations, then I would</p> <p>13 know the frequency had gone down and it had been</p> <p>14 touched.</p> <p>15 Q So you were looking for a change in</p> <p>16 frequency over time?</p> <p>17 A In that case. Well, no, I was -- I was</p> <p>18 looking for what is the current oscillation</p> <p>19 frequency right now, because in that particular</p> <p>20 case, that would tell me the current capacitance</p> <p>21 on the circuit.</p> <p>22 Q Okay.</p>

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1 **A But for example, if I had a capacitive**  
2 **force sensor that might be the way that I would**  
3 **interface with it, is that I would connect it to a**  
4 **oscillator and as its capacitance would change, my**  
5 **oscillation rate would change.**  
6 Q Okay. So you might measure the -- the  
7 frequency of the oscillation and then from there  
8 determine what the capacitance is?  
9 **A Correct.**  
10 Q And then --  
11 **A And again --**  
12 Q -- how would it go --  
13 **A -- I would know from the documentation or**  
14 **from my characterization how the capacitance**  
15 **describes the applied force.**  
16 Q Okay. Okay. So -- so you get the  
17 frequency, then you get the capacitance, and then  
18 you looked at the documentation to understand what  
19 applied force corresponds to a particular  
20 capacitance?  
21 **A Yes. And again, that has just been a**  
22 **normal way to use sensors of all kinds for**

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1 **hundreds of years.**  
2 Q Okay. When you are dealing with a  
3 touchscreen, is that -- is that relationship  
4 uniform across the entire screen?  
5 **A It depends what kind of touchscreen it is.**  
6 Q Well, what -- what are the different types  
7 of touchscreens?  
8 **A There are many. There are probably more**  
9 **than 20 that I've worked with. But there are**  
10 **touchscreens called zone capacitive touchscreens**  
11 **where you just break the screen into regions.**  
12 **There is some that we used to call analog**  
13 **capacitive touchscreens, where the capacitive**  
14 **response varies across the screen, and you have to**  
15 **triangulate it by making measurements from various**  
16 **edges. And there are what we primarily use today**  
17 **on our phones, which are called projective**  
18 **capacitive touchscreens, where there are rows and**  
19 **columns and we interpolate the signals between the**  
20 **rows and columns.**  
21 Q Okay. So for the screens that I think  
22 most of use today, those are capacitive

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1 touchscreens?  
2 **A The ones we use on phones, yes. Cars**  
3 **sometimes are still resistive. Other kinds of,**  
4 **you know, cheaper devices may be resistive, but --**  
5 **low-end tablets, but most of our phones are what**  
6 **we call projective capacitive touchscreens, which**  
7 **were, you know, they were -- they were made**  
8 **popular by the iPhone.**  
9 Q What does projective mean in this context?  
10 **A It has to do with the fact that there is a**  
11 **-- an electric field that is actually jumping from**  
12 **one strip of conductor to another. And it --**  
13 **it -- it goes out into the space above the flat**  
14 **touchscreen. So they think of the electric field**  
15 **as being projected up into the area where your**  
16 **finger would be.**  
17 Q So what does it measure? Is it still  
18 measuring capacitance?  
19 **A It is. It is measuring what is called**  
20 **mutual capacitance. And it is very complicated,**  
21 **because depending on the circuit parameters it is**  
22 **measuring both the ability of your finger to**

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1 **couple -- again, these are AC signals, between the**  
2 **stripes, but also the ability for you to take the**  
3 **signals and absorb them, and, you know, bring them**  
4 **down to the ground through your feet. And**  
5 **different manufacturers emphasize different**  
6 **combinations of those two capabilities.**  
7 Q So then is it possible to detect when  
8 someone is, I guess, close to the screen instead  
9 of actually smashing their finger on to it?  
10 **A It is. In various -- we call that**  
11 **hovering usually in the business. And most --**  
12 **most phone manufacturers try to avoid responding**  
13 **to that, because it is very hard to control your**  
14 **finger when it is not touching something, but --**  
15 **but it is certainly possible to measure in that**  
16 **kind of a phone.**  
17 Q Okay. I think another type -- I don't  
18 think we have discussed this today, but are you  
19 familiar with Hall effect sensors?  
20 **A Yes.**  
21 Q What are those?  
22 **A Boy, again, I can't get too much into**

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1 physics, because it is way down in the quantum  
2 world. But a Hall effect sensor is a  
3 semiconductor device whose conductivity will  
4 change in the presence of a magnetic field.  
5 Q So let's break that down, because I don't  
6 know if I follow everything you said.  
7 So you have a magnetic field. What is  
8 generating the magnetic field?  
9 A Usually a magnet.  
10 Q Okay. So you have a separate magnet that  
11 generates the magnetic field and then -- and then  
12 you have the Hall effect sensor to -- to, I guess,  
13 detect changes?  
14 A Yes. Now, oftentimes a Hall effect sensor  
15 is integrated with a switch, so it will actually  
16 make a switch happen at a certain threshold. But  
17 let me give you some examples of where they're  
18 used today.  
19 When I open and close the windows in my  
20 house, there are Hall effect sensors to  
21 communicate with the alarm system, right. So the  
22 window frame has a magnet on it. When I close the

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1 window, that magnet is in front of the Hall effect  
2 sensor, and it tells the alarm that the window is  
3 closed.  
4 If you were to buy a very high end gaming  
5 keyboard or joystick, a Hall effect sensor would  
6 be used to measure the -- the keypresses, because  
7 they don't wear. We use them in my lab. My  
8 students we use them as motor encoders. We put  
9 the magnets around the shaft of the motor. We use  
10 two Hall effect sensors. As the motor spins, the  
11 magnet will pass by the Hall effect sensor and  
12 create a pulse. We can determine how fast the  
13 motor is running.  
14 Q Okay.  
15 A But there are other kinds as well. You  
16 could combine a Hall effect sensor with a spring  
17 and produce a force sensor.  
18 Q So is that what is done in these, like,  
19 the keyboards you mentioned?  
20 A Yes. In fact, when we -- when we go to  
21 purchase a Hall effect key from a key  
22 manufacturer, again, that one has got a built-in

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1 switch, but we will specify literally how many  
2 newtons of force we want to have as being the --  
3 the threshold for when we treat the switches being  
4 pressed.  
5 Q Okay. So the spring -- help me understand  
6 that, where the spring comes into play?  
7 A The spring naturally responds to force  
8 with distance, right. So the position of a spring  
9 is a function of the force that is applied on it.  
10 Hall effect sensors can measure the  
11 position of a magnet. So if you connect the  
12 magnet to a spring, the position of the magnet  
13 will be a function of the applied force on the  
14 spring, which we can then measure with a Hall  
15 effect sensor.  
16 Q Okay. So it is a combination of -- of, I  
17 guess, distance, the spring moving the magnet, but  
18 then also you're not measuring the distance. You  
19 are measuring -- what did you say earlier, the  
20 magnetic --  
21 A Position.  
22 Q Okay.

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1 A Oh, you are measuring the position of the  
2 magnet by measuring the magnetic field.  
3 Q Okay.  
4 A Again, you know, all modern transducers,  
5 all modern sensors use a combination of effects.  
6 Q Okay. Okay. So in that sort of  
7 configuration, the Hall effect sensor is a force  
8 sensor?  
9 A It would be a component of a force sensor.  
10 The whole thing is the force sensor. The  
11 combination of the spring, the magnet and the Hall  
12 effect sensor.  
13 Q Okay. How about have you heard of an  
14 electromagnetic Eddy current sensor?  
15 A I have. I actually do not know the  
16 physics of how they work, but I know that you can  
17 use them to measure variations in Eddy currents in  
18 materials that vary as a function of force. It is  
19 somewhat -- it is very similar to a string gauge  
20 in that the material itself changes its properties  
21 as a function of force.  
22 Q Okay. You mentioned Eddy currents and I

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1 know I used the term, too, but I don't -- I don't  
2 actually know what the term means. Do you know  
3 what an Eddy current is?  
4 **A You know, I use it in certain contexts,**  
5 **but I don't know if I know the formal definition.**  
6 **I think an Eddy current is basically a current**  
7 **that is just kind of going in whatever creation it**  
8 **wants as opposed to directly between the two**  
9 **points so that -- that you are concerned about.**  
10 Q Okay. And so that -- that goes back to  
11 what you were saying earlier about current, was it  
12 current voltage and resistance have a  
13 relationship?  
14 **A Yes.**  
15 Q Okay. And is that why you think Eddy  
16 current sensors are similar to string gauges?  
17 **A In both cases you have got a situation**  
18 **where in circuit the current varies as a function**  
19 **of the force, because of the material properties**  
20 **vary. Again, this is beyond my real expertise,**  
21 **but I believe it just has to do with -- with the**  
22 **molecules being pressed closer together and**

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1 **further apart.**  
2 Q Okay. We've been going for a little over  
3 an hour now, if you want to take a short break and  
4 then we can resume.  
5 **A Sure.**  
6 (Recess, 11:09 to 11:18 a.m.)  
7 Q All right, Dr. Wolfe, welcome back.  
8 During the break we just had, did you  
9 speak to anybody?  
10 **A No.**  
11 Q Did you receive any chats or messages?  
12 **A I don't know, I didn't check.**  
13 Q Okay. And did you open any materials?  
14 **A No.**  
15 Q Okay. I'm going to drop into the chat the  
16 patents. We're going to start with -- we will do  
17 one at a time. Let me know when you have  
18 downloaded this one.  
19 **A Okay. That is the '698 patent.**  
20 Q Okay. And let me then drop in the other  
21 one. This way we keep them separate, this is  
22 another patent. Let me know when you have that

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1 one downloaded and opened?  
2 **A That is the '381 patent.**  
3 Q I guess, the first thing I have a question  
4 about is you have reviewed both the '698 and '381  
5 patents before, right?  
6 **A Yes.**  
7 Q Do those two patents have the same  
8 figures?  
9 **A As far as I can tell, yes.**  
10 Q Okay. Let's start with the '698 patent.  
11 I'm going to use the page numbers again at the  
12 bottom of the page to direct you to various pages.  
13 So on the second page of the '698 patent you  
14 should see figure 1. Do you see figure 1?  
15 **A Yeah, give me a chance to rotate it here.**  
16 Q Yeah, you may need to rotate it.  
17 **A Okay.**  
18 Q Figure 1 is a block diagram of a 3D  
19 printer, right?  
20 **A Yes.**  
21 Q Okay. I wanted to ask you about some  
22 parts of figure 1. Which -- which portion of

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1 figure 1 -- are you familiar with the term  
2 "extruder"?  
3 **A In various contexts, yes.**  
4 Q Which portion of figure 1 is the extruder?  
5 **A I believe the patent refers to 106 as the**  
6 **extruder.**  
7 Q And what are all of those things kind of  
8 around the extruder? What does an extruder of a  
9 3D printer include?  
10 **A It is going to vary from printer to**  
11 **printer.**  
12 Q How about here in figure 1?  
13 **A The patent language is all permissive. It**  
14 **all says what it may include. It talks about**  
15 **chamber 122 and extrusion tip 124 and a heater 126**  
16 **and a motor 128. But it neither limits it to**  
17 **those things nor says that it must include those**  
18 **things.**  
19 Q So if you look at figure 1, how would you  
20 -- how does -- help me understand how does the  
21 extruder work. It has -- it shows these various  
22 elements that you just described, but what is it

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1 doing?  
2 **A Well, the patent doesn't necessarily tell**  
3 **us in detail what it is doing, but it tells us**  
4 **some aspects of what it might be doing. It talks**  
5 **about a whole bunch of different ways they can do**  
6 **it, but -- but generally, it is being fed some**  
7 **type of -- again, in the art, it would be fed some**  
8 **type of a thermal plastic type material.**  
9 **The patent mentions ABS, which was a**  
10 **horrible to use plastic that was popular at the**  
11 **time. HDPL, which is high density polyethylene,**  
12 **which I think is basically cutting boards. And**  
13 **PLA, polylactic acid, which is a corn derived**  
14 **plastic that has become very, very popular since**  
15 **that time.**  
16 **And again, this particular one is not**  
17 **specific. Ordinarily, it does talk about being**  
18 **fed in as a -- from a spool as a filament. The**  
19 **other way to do it would be as a -- as pellets.**  
20 **And then the heater would ordinarily melt it down**  
21 **to -- the patent calls it a liquid, you might also**  
22 **refer to it more as a paste. It is kind of a**

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1 **viscus liquid. And then the motor, again,**  
2 **depending on design, the motor can either be used**  
3 **to keep feeding more filament in or it can be used**  
4 **to create pressure for the -- for the liquid.**  
5 **And then the extruder tip is usually more**  
6 **of kind of a nozzle. And again, depending on the**  
7 **design it may be controlled or it may be**  
8 **uncontrolled and I don't think the patent limits**  
9 **it either way.**  
10 **Q Okay. And so you had mentioned that the,**  
11 **I guess, the plastic is melted down. Is it with**  
12 **the heater; is that right?**  
13 **A That is the way it is typically done. And**  
14 **that is one of the embodiments that is at least**  
15 **somewhat described in the spec.**  
16 **Q Okay. And then does -- does the paste or**  
17 **liquid, the viscose material, does that come out**  
18 **of the nozzle?**  
19 **A The extruder tip 124.**  
20 **Q Okay. The extruder tip?**  
21 **A Yes, and selectively if you want to be**  
22 **able to build anything.**

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1 **Q Okay. So you put that down selectively,**  
2 **because you want to build something. And how does**  
3 **-- so you just have a bunch of, like, I guess to**  
4 **use one of your terms, a bunch of paste that goes**  
5 **down. Is that -- is that -- you are just putting**  
6 **one --**  
7 **A Yeah, again --**  
8 **Q -- paste that --**  
9 **A -- I'm not a material science person, but**  
10 **yeah, I would characterize it as -- as kind of a**  
11 **paste or a very viscose fluid at that point. And**  
12 **it is just -- it is like squirting toothpaste out**  
13 **of a tube and trying to draw something on the**  
14 **table, right, by moving it around. And typically,**  
15 **it is hot enough that when you put one layer on**  
16 **top of another layer they will -- they will fuse**  
17 **to each other.**  
18 **Q Okay. How does it -- I mean, if I put a**  
19 **bunch of toothpaste down, I haven't done this**  
20 **since I was kid, but I'm pretty sure it just like**  
21 **-- it just forms some sort of like mush. How do**  
22 **you actually create, like, you mentioned you put**

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1 **it in a powder and make an object. It seems like**  
2 **if it is all paste it would be a bunch of junk at**  
3 **the end of the day.**  
4 **A Well, I've actually done it. I mean not**  
5 **with paste, but I've built 3D printers that use**  
6 **clay or -- or -- or plaster. The idea is that you**  
7 **want to get some kind of a phase change soon after**  
8 **deposition.**  
9 **So in these particular printers typically**  
10 **what you will do is you will heat it just to the**  
11 **liquefaction point. The idea is that when you put**  
12 **it down it cools and it becomes solid again. So**  
13 **that way by the time you go and try to put**  
14 **something else on top, it is pretty solid.**  
15 **Q So in the printers that you have used,**  
16 **what is that typically, the cooling rate, what is**  
17 **that typically? Is that -- are you talking about**  
18 **milliseconds or how long does it take?**  
19 **A I don't know. Typically you don't -- you**  
20 **do one layer at a time in these deposition**  
21 **printers. So it is not unusual for it to take a**  
22 **minute to an hour before you come back. So I've**

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1 never tried to figure out what the cooling time  
2 is. But PLA -- see if I remember the number here,  
3 PLA I think would typically deposit at about 200  
4 to 230 degrees Celsius. And my guess is that by  
5 the time it would cool by 10 percent, it would  
6 kind of harden.  
7 Q Okay.  
8 A I don't know how long that takes. I am  
9 sure it has to do with airflow and -- and again,  
10 oftentimes the build platform is heated so there  
11 is a lot of factors in there. But it is -- it  
12 is -- you know, been a solved problem for a lot of  
13 time, how to extrude things.  
14 Q If you are heating the build platform,  
15 what sort of temperature is -- is that typically  
16 heated to?  
17 A Again, for PLA I typically use 60 C. For  
18 polycarbonate, which was the other thing I've  
19 printed recently, I think it was 110 C. I think  
20 for PETG, which is another common material today,  
21 we typically use 85 C. And that is to prevent  
22 warping, so that when it cools it doesn't warp.

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1 Q Okay. You had also mentioned I think what  
2 you said is a horrible material, ABS; is that  
3 right?  
4 A Yes.  
5 Q What is the sort -- does it have the same  
6 sort of temperatures ABS the --  
7 A I believe that the polycarbonates were a  
8 substitute for ABS. I think they were about the  
9 same temperature. I think they -- the platform  
10 would have been up in -- well -- well, I mean part  
11 of the problem is a lot of the ABS work that was  
12 done 10, 15 years ago didn't use heated platforms  
13 so it did all warp, which was part of the problem.  
14 But ABS temperatures, again, I think you  
15 deposit them up around 250, 260 C and you try to  
16 keep the bed temperature up in the 85 to 100  
17 range. But again, I'm not a materials person, so  
18 I don't -- you just -- you buy it and it is -- it  
19 is printed on the box.  
20 Q Yeah. Okay. And you mentioned the bed.  
21 So before you -- when you first start printing, is  
22 that -- is that first layer of material that you

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1 are printing if you want to do a pattern, is that  
2 printed onto the bed?  
3 A Normally.  
4 Q And so is the bed usually the same thing  
5 as this -- like, so we mentioned different types  
6 of plastics, PLA, ABS, polycarbonate, is the bed  
7 usually the same thing as those?  
8 A No, my experience is the bed is steel or  
9 aluminum.  
10 Q Okay. Do you ever -- have you ever  
11 printed metals, 3D printed metals?  
12 A I have not.  
13 Q Okay. When -- so you mentioned that you  
14 do a layer and then your experience is when you  
15 come back around to do the next layer that the  
16 previous layer has sufficiently cooled, right?  
17 When -- when plastics --  
18 A Or hardened, right. With thermoplastics  
19 it is cooled, with other materials sometimes it is  
20 evaporative hardening or UV hardening or catalytic  
21 hardening.  
22 Q Okay. Does the shape of the material

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1 change at all from when you first put it down to  
2 when it hardens or cools?  
3 A I'm sure it does, but it is kind of on a  
4 microscopic level that an ordinary user generally  
5 doesn't concern themselves with, but a 3D printer  
6 designer probably is aware of that.  
7 Q Okay. So -- so you don't know if it does  
8 cool, if it does change you don't know by how  
9 much, for instance?  
10 A Right. I would expect there to be some  
11 change, but I don't know by how much and I think  
12 it is -- it is very complicated.  
13 Q Okay. Are you familiar with the -- the  
14 term "Young's modulus"?  
15 A Yes, but I have no idea what it is.  
16 Q So you have heard -- you have heard of the  
17 term before?  
18 A Yes. As I said, I've worked on -- on --  
19 on 3D printer designs before, and I know that that  
20 was an important issue, but I was able to send the  
21 students off to talk to a mechanical engineering  
22 specialist to figure it out. So I actually don't

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1 **know what the -- what the definition of a Young's**  
2 **modulus is.**  
3 Q Okay. So you don't know what a Young's  
4 modulus might pertain to?  
5 **A Not really. I think it has something to**  
6 **do with deformation or -- or -- or**  
7 **compressibility, but I don't -- it is not**  
8 **something I really understand.**  
9 Q Okay. So for -- if it does pertain to  
10 deformation, do you know the relationship between  
11 Young's modulus and deformation?  
12 **A No.**  
13 Q If it pertains to compressibility, do you  
14 know the relationship between Young's modulus and  
15 compressibility?  
16 **A No.**  
17 Q Okay. I'm going to drop into the chat  
18 another reference, give me a second. Let me know  
19 when you have downloaded and opened this one.  
20 **A I have it.**  
21 Q So in your declarations I believe you  
22 express opinions regarding a reference named

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1 Warren; is that right?  
2 **A Yes, I believe in each of the**  
3 **declarations.**  
4 (Exhibit 1004 discussed.)  
5 Q Do you recognize the exhibit I dropped in  
6 the chat, Exhibit 1004?  
7 **A That appears to be the Warren reference as**  
8 **it was presented to the PTAB.**  
9 Q Okay. And do you know if the same Warren  
10 reference was used in both of your declarations?  
11 **A I believe it was.**  
12 Q Okay. I'm going to use the page numbers  
13 again at the bottom of the page, so that should  
14 correspond to the -- the PDF viewer page. If you  
15 could turn to page 18 of Warren, please?  
16 **A Okay.**  
17 Q And specifically I want to draw your  
18 attention to figure 21 at the bottom of page 18.  
19 Do you see figure 21?  
20 **A Yes.**  
21 Q What does the number 1 in figure 21 show?  
22 **A So let's -- let's start by putting figure**

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1 **21 in context. Figure 1 doesn't generally get**  
2 **discussed in the spec. It is described as a**  
3 **figure, but in the context of what is discussed in**  
4 **the spec, a reader, a POSITA would have been able**  
5 **to understand figure 21.**  
6 **Figure 21 is showing the relationship**  
7 **between a vibration signal amplitude on the**  
8 **material deposition tip and frequency, because**  
9 **Warren teaches that you can use the vibration**  
10 **signal amplitude at one or more selected**  
11 **frequencies as a force measurement signal. So in**  
12 **that vein, that sensing mechanism has been**  
13 **characterized here for one example, very similar**  
14 **to the way that I told you before.**  
15 **So what they have done is with no**  
16 **additional force from contact with the underlying**  
17 **substrate or -- or object, they have looked at the**  
18 **vibration signal amplitude at a variety of**  
19 **frequencies and they've grafted it, and that is**  
20 **what element number 1 is.**  
21 Q And then how about element number 2 in  
22 figure 21, what is that?

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1 **A Element number 2 appears to be a**  
2 **measurement after contact.**  
3 Q Okay. And you had mentioned, I think,  
4 that this figure 21 has both X and Y axes to it,  
5 right?  
6 **A I don't think I mentioned that, but it**  
7 **does.**  
8 Q Okay. And for the -- for the Y axes, you  
9 mentioned vibration signal amplitude, I believe?  
10 **A Correct.**  
11 Q And what are the units for vibration  
12 signal amplitude?  
13 **A Here there are no units. It just says you**  
14 **can use arbitrary units, but typically you could**  
15 **pick whatever units you wanted and it would really**  
16 **depend on how you're measuring the vibration**  
17 **signal. But typically by the time you were to**  
18 **characterize it, it would be in, you know,**  
19 **millivolts or something like that, because it is a**  
20 **signal.**  
21 Q And then for the X axes you said  
22 frequency. What are the units for the X axes?

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1 **A Again, the SI unit, the typical metric**  
2 **unit would be hertz cycles per second, but, you**  
3 **know, could be megahertz or kilohertz. It doesn't**  
4 **really matter.**  
5 Q Okay. And so we talked about element 1  
6 and element 2 of figure 21. What is element 3 of  
7 figure 21?  
8 **A It says it is the change of the signal**  
9 **after the contact X30, so it seems to be a**  
10 **differential. It does not seem to be the**  
11 **difference between 1 and 2. It seems to be after**  
12 **a different contact.**  
13 Q Okay. So help me understand that, the  
14 difference between 1 and 2 is not what element 3  
15 represents?  
16 **A It doesn't appear to be, if you just look**  
17 **at it visually. And it doesn't say just change of**  
18 **signal after contact. It says after the contact**  
19 **X30. So I think it is a different contact that**  
20 **was measured in figure 2.**  
21 Q Okay. And -- and do you know what X30  
22 means?

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1 **A Not off the top of my head.**  
2 Q Okay.  
3 **A But, again the whole process is described**  
4 **in the text. So you know, figure 21 is really**  
5 **just an illustration of what is being taught**  
6 **elsewhere in the specification.**  
7 Q Okay. And across the frequencies, if you  
8 will, what -- what sort of amplitude is shown in  
9 figure 21?  
10 **A Vibration signal amplitude.**  
11 Q So there is not -- there is not a  
12 particular number or units associated with that  
13 amplitude?  
14 **A There would always be a unit in practice,**  
15 **but -- but -- but the teachings aren't tied to a**  
16 **particular unit. It could be millivolts, it could**  
17 **be tens of millivolts.**  
18 Q So would you say that, say, element 1 of  
19 figure 21 is 10 millivolts?  
20 **A It would be implementation dependent. I**  
21 **mean, it doesn't matter, right? I mean, people**  
22 **have been dealing with sensor signal amplitudes of**

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1 **various ranges for 3, 400 years, so, you know,**  
2 **pick your favorite implementation and measure the**  
3 **signal amplitude. That is what you --**  
4 Q So if someone asked you can you tell me  
5 what the amplitude of signal or element 1 is, how  
6 would you go about determining that?  
7 **A Well, from the figure, I would just simply**  
8 **say, you know, it is up as high as approximately**  
9 **30 units. But if I were to replicate this process**  
10 **the way it is taught, I would put an instrument on**  
11 **it and I would use the units that the instrument**  
12 **measures, for example, millivolts.**  
13 Q Okay. Okay. And so you -- you had  
14 mentioned that, you know, it is as high as  
15 approximately 30 units, so it is not 30 units  
16 across -- I guess, you were talking about the Y  
17 axes, it is not 30 units across the entire X axes?  
18 **A No. And again, the teaching of the patent**  
19 **is not that you have to measure it every**  
20 **frequency. It is that you pick one or more**  
21 **frequencies and do your measurements at that**  
22 **frequency, and then it might be helpful to do a**

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1 **graph like this to help to choose a good**  
2 **frequency.**  
3 Q So in the example in figure 21, what  
4 frequency would -- would you choose?  
5 **A I would probably choose something around**  
6 **the extremities of figure 3. So either where**  
7 **figure 3 goes very low showing a big negative**  
8 **difference in the signal after contact of X30 or**  
9 **one of the top peaks.**  
10 Q Okay. And you said figure 3, are you --  
11 **A I'm sorry, signal 3.**  
12 Q Signal 3, okay.  
13 So you would pick either a trough or a  
14 peak of signal 3?  
15 **A Yes. Although it would work fine if I**  
16 **picked many other -- I mean, I wouldn't want to**  
17 **pick something where it is a zero crossing, but**  
18 **there were many frequencies where -- where it**  
19 **would work fine. But -- but the best ones would**  
20 **probably be the ones that show the biggest change.**  
21 Q Okay. And earlier you had mentioned that  
22 it appears that signal 3 or element 3 is a

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1 different type of contact than what is shown  
2 between, I think you were referring to elements 1  
3 and 2 or signals 1 and 2?  
4 **A Not necessarily a different type of**  
5 **contact, but a different -- a different degree of**  
6 **contact.**  
7 Q Okay. So you would -- you would look to,  
8 like, a different degree of contact. And the --  
9 the amplitudes for that contact as a signal 3 to  
10 figure out which frequencies to use for a  
11 particular amplitude?  
12 **A So again, just the text tells me that it**  
13 **is going to work at pretty much any frequency that**  
14 **I choose and that I can use a combination of**  
15 **frequencies, right, and it is almost certainly**  
16 **going to work.**  
17 **But if I wanted to optimize it, I would**  
18 **perform the kinds of contacts that I want to**  
19 **distinguish, and I would find the largest changes**  
20 **in response to those contacts.**  
21 Q So why wouldn't you pick the frequency --  
22 if you look at figure 21 on the, say, the

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1 left-hand side of figure 21, why wouldn't you pick  
2 one of those sorts of frequencies?  
3 **A Well, the one where the number 3 is**  
4 **pointing would be a perfectly fine frequency to**  
5 **pick.**  
6 Q Okay. Anything to the left of that?  
7 **A I wouldn't want to pick the one that gave**  
8 **me a zero difference, right, but those are few and**  
9 **far between, right. If I picked something halfway**  
10 **between the -- the point where the 3 is pointing**  
11 **and the zero, I think it would still work fine.**  
12 Q Okay.  
13 **A I mean, you don't have to get it perfect,**  
14 **you know, you just have to be able to detect the**  
15 **contact.**  
16 Q So let's say -- let's say, you're looking  
17 at -- do you see the part of figure 21 where it is  
18 to the left of the number 3 and the -- the line,  
19 if you will, ends? Do you see that point?  
20 **A The line ends.**  
21 Q Or you might think of it as the line  
22 beginning?

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1 **A Okay. I think that is just the first**  
2 **measurement point.**  
3 Q Yes. So if you look at that measurement  
4 point, would that be one of the examples of the  
5 points where you think it would -- you could pick  
6 that frequency and it would -- it would give you  
7 the information you need?  
8 **A If I needed to detect contacts like X30, I**  
9 **think I could derive the -- the information from**  
10 **that, right? In other words, I would measure that**  
11 **difference. That difference is maybe 3 in the**  
12 **measured arbitrary units. And yeah, I think a**  
13 **person of ordinary skill could build a system that**  
14 **would then be able to detect and respond to**  
15 **that -- to that type of contact.**  
16 Q Okay. And if you look at lines 1 and 2 or  
17 signals 1 and 2 at that same point, what is the  
18 sort of difference between those -- those two  
19 lines or signals?  
20 **A There it is not noticeable from this**  
21 **graph. So if I wanted to measure -- to be able it**  
22 **distinguish the contact shown in signal 2, I**

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1 **wouldn't choose that point. I would choose a**  
2 **different point.**  
3 Q Okay.  
4 **A And again, the teachings allow me to**  
5 **choose multiple points. So I could measure**  
6 **multiple kinds of contacts although claims don't**  
7 **require that.**  
8 Q And if I look at these signals we could  
9 pick, let's say, signal 1 as an example, is the  
10 frequency proportionate to the amplitude?  
11 **A No.**  
12 Q Is it -- is it the same answer for signal  
13 2, is the frequency proportionate to the  
14 amplitude?  
15 **A Yeah, I don't think the frequency is ever**  
16 **proportional to the amplitude.**  
17 Q Okay. Okay. Why don't we turn to --  
18 we've been looking at figure 21. If you could  
19 turn to page 21 of Warren.  
20 **A Okay.**  
21 Q I believe for this one you may need to  
22 rotate it as well.

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1 **A Let me do that.**  
2 Q Do you see figures, I think, 23A and 23B  
3 and 23C?  
4 **A Okay.**  
5 Q What is -- do you see the number 100 in  
6 figures 23A and 23C?  
7 **A Yes.**  
8 Q What is 100 referring to generally?  
9 **A I don't recall off the top of my head. Is**  
10 **it something I discussed in my declaration?**  
11 Q Well, I think you discussed Warren so I'm  
12 asking you about this figure in Warren?  
13 **A Again, I don't think -- I don't recall**  
14 **relying on this in my declaration, but I can look**  
15 **and see what Warren says about it. I think in**  
16 **general Warren just refers to any material**  
17 **dispenser as 100.**  
18 Q Okay. And so if I -- if I follow, let's  
19 say, figure 23A, as an example, there are one,  
20 two, three, four material dispensers?  
21 **A In that particular embodiment, yes.**  
22 Q Okay. And do you know if Warren describes

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1 using them -- I mean, to use one at a time, use  
2 them all together, do both?  
3 **A It certainly describes being able to use**  
4 **them individually. I don't remember whether or**  
5 **not he described using them simultaneously.**  
6 Q Okay. So if I look at the right -- the  
7 three dispensers on the right-hand side, they kind  
8 of look similar, right, in figure 23A?  
9 **A In the figure they do.**  
10 Q And if those three dispensers are at the  
11 same -- sort of the bottom of the dispensers at  
12 the same level, how would you -- how would you be  
13 able to use one, you know, while another one is  
14 not being used? Wouldn't that, like, touch the  
15 material that you already -- like the pattern of  
16 material that you have already put down?  
17 **A Not necessarily. Again, you know, this is**  
18 **only one of his embodiments. And it would depend**  
19 **on maybe the shape you are doing and whether or**  
20 **not it is oriented along that line. But also, he**  
21 **describes various embodiments in a variety of**  
22 **materials.**

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1 **Even -- so -- so with thermoplastics, the**  
2 **most common way to do it today is to apply some**  
3 **pressure on the material that you are dispensing**  
4 **so that it will bond well with the layer below,**  
5 **but not necessarily actually applying pressure on**  
6 **the previous layer, right?**  
7 **So I believe there are even systems that**  
8 **are somewhat like this that are out there**  
9 **commercially today with thermoplastics. And the**  
10 **idea is that since only one of them is extruding,**  
11 **the actual material deposition happens a few**  
12 **fractions -- a fraction of a millimeter below the**  
13 **nozzle.**  
14 **So that if you really are -- are**  
15 **depositing material with the appropriate**  
16 **precision, other nozzles of the same height**  
17 **wouldn't interfere. But of course, you know, big**  
18 **picture Warren also doesn't require that you have**  
19 **multiple nozzles. He also describes embodiments**  
20 **that don't have multiple nozzles.**  
21 Q Okay. And you had mentioned some, I  
22 guess, thermoplastic printers today where you

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1 apply pressure. Do you know how the pressure is  
2 applied?  
3 **A I believe just by extruding under**  
4 **pressure.**  
5 Q Okay. So the -- the extruder -- the  
6 output from it, the materials under pressure, is  
7 that what you mean?  
8 **A Yes. I don't know where that pressure**  
9 **comes from in modern devices, whether it is just**  
10 **the weight of the material above it or the force**  
11 **of the filament motor. But it is my understanding**  
12 **that in most modern devices there -- in other**  
13 **words, the material is not just dripping out. It**  
14 **is being pushed out, again, kind of like**  
15 **toothpaste.**  
16 Q Okay. All right. Let's go to the next  
17 page of Warren, page 22. And this time at the top  
18 of the page, do you see figure 24?  
19 **A I do. Again, I don't think this is**  
20 **something I relied on, but I see it.**  
21 Q And do you see where it says, cells  
22 deposited right above the label figure 24?

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1 **A Yes.**  
2 Q What sort of industry experience do you  
3 have with deposition of cells?  
4 **A None.**  
5 Q Do you have research experience related to  
6 depositing cells?  
7 **A I don't, but Warren again, talks about a**  
8 **lot more than that including deposition of**  
9 **inorganic materials and specifically the**  
10 **deposition of polymers.**  
11 Q How about a teaching experience? Do you  
12 have teaching experience related to depositing  
13 cells?  
14 **A No. I mean, not – not human – not**  
15 **biological cells, no.**  
16 Q Okay. What non-biological cells do you  
17 have experience with deposition on?  
18 **A That – just that word might be used to**  
19 **describe other materials. But again, I don't have**  
20 **any – I don't have any experience in depositing**  
21 **biological materials.**  
22 Q Okay. Okay. All right. I think with

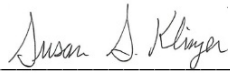
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1 that I don't have any further questions.  
2 MR. KAPADIA: Josh, the witness is yours.  
3 MR. GRISWOLD: I don't have any questions,  
4 thank you.  
5 (Deposition adjourned at 11:52 a.m.)  
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1 CERTIFICATE OF SHORTHAND REPORTER  
2  
3 I, Susan S. Klinger, Certified Reporter  
4 before whom the foregoing deposition was taken, do  
5 hereby certify:  
6 That ANDREW WOLFE, PH.D., the witness  
7 whose deposition is hereinbefore set forth, was  
8 duly sworn by me before the commencement of such  
9 deposition, and that such deposition was taken  
10 before me and is a true record of the testimony  
11 given by such witness, that said testimony was  
12 taken by me stenographically and thereafter  
13 reduced to typewriting under my direction.  
14 I further certify that the adverse party,  
15 Shenzhen Tuozhu represented by counsel at the  
16 deposition.  
17 I further certify that the deposition of  
18 ANDREW WOLFE, PH.D., occurred remotely on the  
19 23rd, January 2026, commencing at 10:03 to 11:52.  
20 TIME USED:  
21 Mr. Kapadia: 01:40  
22 Mr. Griswold: 00:00

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1 I further certify that reading and signing  
2 was not discussed.  
3 I further certify that I am not related to  
4 any of the parties to this action by blood or  
5 marriage, I am not employed by or an attorney to  
6 any of the parties to this action, and that I am  
7 in no way interested, financially or otherwise, in  
8 the outcome of this matter.  
9 IN WITNESS WHEREOF, I have herunto set my  
10 hand on the 25th of January, 2026.  
11  
12  
13   
14 Susan S. Klinger, RMR-CRR, CSR  
15 Texas CSR 6531, Exp: 10/31/27  
16 California CSR 14487, Exp: 11/30/26  
17  
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19  
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