Computer History Museum

Interview of Robert "Bob" Dobkin

Interviewed by:
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David Laws: Good morning. My name is David Laws. I am semiconductor curator here at the Computer History Museum in Mountain View. We're meeting this morning with Robert "Bob" Dobkin -- Chief Technical Officer at Linear Technology to pick up on an interview that we started back in March, when we did an oral history of the founding of Linear Technology Corporation. We'd like to add more information on the aspects of the design engineer and the role that he plays or she plays—[there are] very few, unfortunately, she's in the business -- in the development of products for a company like Linear Technology.

When we did the last interview, we covered quite a bit of Bob's educational and other background, so we won't repeat that today. And if anyone is interested in finding that out, then they can refer to the March 31st, 2014 oral history on the founding of Linear Technology. [http://www.computerhistory.org/collections/catalog/102746888] So without further ado, Bob, I think it would be very useful if you could describe the process that an analog design engineer would go through in creating an analog circuit. In what ways does that differ from the digital design engineer?

Robert "Bob" Dobkin: Well, let's start with maybe defining analog and digital.

Laws: Good point.

Dobkin: Analog is voltage. It's a real world parameter. Digital is a number. It doesn't matter whether the number is in beads on a string or in electrons or in waveforms. It's a number. So when you operate on something that's digital, or the circuitry that operates on digital, what you're doing is you're manipulating numbers. And it doesn't matter whether the output comes out as 20 volts or 1/10 of a volt as long as the number's right. It also doesn't matter which way you got to it. Yeah, there may be some speed differences, but as long as the output number is right, you've manipulated the digital information correctly.

Analog is a real world parameter, so there's a lot of things that touch the analog signal. There's noise. There's distortion. There's amplitude. There's power. There's how much power supply current it draws. So the analog circuit has a lot of paths between the input and the output. And what those paths are makes a difference in what the output signal is. So the analog designer has to be able to thread a path through many different kinds of circuits to get to an optimized path of circuitry to manipulate its analog information.

In that way the analog designer has a kind of more difficult job. And there are much fewer analog designers than there are digital designers. I think that the people who end up doing analog design want to be there. I look at doing analog design like learning another language. When you start out learning a language, you start working with the dictionary and a set of rules or grammar. And as you're learning the language and you're, say, translating a piece of information from one language to another, you keep looking back at the dictionary to learn what things do. You should look at the rules of grammar to figure out how it's put together.

When you're doing a circuit and you're fresh out of college, you've got a set of tools, a set of parameters that you work with. You do your node equations. You do your circuit analysis, piece by piece, and after a while, you figure out what the circuit's doing. When you're doing a translation, you put it together piece by piece; at the end you know what it says. By the time you're doing analog design for five years to 10 years, you've picked up the vocabulary of analog design, and you know what pieces of circuits do all by themselves. You don't have to do any more equations. You just look at that piece of circuit. Oh, I know that's a differential amplifier, and I know what the input and the output's going to do.

So you have all these pieces of vocabulary on analog design that you know and you know how they work, even down on an intuitive level. A good analog designer can take a big schematic and just look through it for a minute and understand what the circuit is doing. It just takes experience, and it takes learning the language. So an analog designer has to be in the business for a period of time before they pick that up. And then the analog designer has all the tools, and he can start writing his own circuits.

Laws: So as opposed to digital design, there's much more a craft to it in terms of all the different kinds of tools that I have to use and how you put them together?

Dobkin: Today the simulation tools which are used to do the analog circuitry are not complete and able to simulate all the affects that you find in an analog circuit. The simulation tools will give you a pretty good overview and pretty detailed response on a lot of things, but noise simulation isn't perfect. Interactions between different transistors in the circuit aren't perfect.

Thermal simulation, that's one big area with power devices where there's no simulator to simulate what happens when you put 50 watts into a chip. And that all takes experience from the designer. The next thing that can happen on an analog chip, it can be that chip can be affected by the packaging. The stress on the silicon chip changes the characteristics of the transistors in the chip. So what you see in the simulator may be different than what you see in the package.

And since the stress isn't always the same--

Laws: Is it physical stress?

Dobkin: Physical stress. You may see a lot of circuits that have a wide distribution of parameters you didn't expect because stress on the silicon is changing the parameters of the transistors. So simulation doesn't show everything, whereas with digital when you're working with numbers, numbers in numbers out, you're pretty much assured that the digital is working like you expected if you simulate it.

Laws: This difference in the kind of skill that's required to develop analog circuit versus a digital, and it doesn't sound like something you can easily learn in college. How do you go about teaching an analog circuit designer to be productive and effective?

Dobkin: The people who went into analog design, they've taken analog design courses in college. They've done some projects in college. If they get towards a Ph.D, they design some circuits, and they work with that. And then they come into Linear, and they're assigned a senior design engineer to work with them. A senior design engineer has maybe 10 years or more experience. And the junior engineer works with the senior engineer.

A junior engineer gets to design something on almost a daily basis. It gets critiqued. It gets worked over. It gets suggestions, so the junior engineer gets to look at what the senior engineer is doing. Plus, there's a repository of finished analog designs at Linear, and looking at what other people have done is a good way of learning how to do analog design yourself because you get a chance to look at what many people have done to make a good analog circuit.

Laws: You must have gone through this process yourself at some point. I believe you went to National [Semiconductor]. You worked for Bob Widlar. Did he teach you in this manner, or was it sink or swim for Bob Dobkin?

Dobkin: With Bob Widlar, it was sink or swim. But I was able to look at what had been done in the past.

Laws: Sure. By a master.

Dobkin: And I was able to look at what other people had done. And it was still pretty early then. I mean when Bob Widlar started, there was zero. And as time progressed, there was a history. So I only had to catch up on five years of ICs maybe.

Laws: Instead of 40 years the people coming in now have to do.. So recognizing that there is a special set of skills and probably a specific kind of personality that enjoys working with this, how would you go about putting together an engineering department to be productive and effective?

Dobkin: OK, we're a start up. We don't have any revenue. The main important thing for us is we have to get products out. We've got to start selling stuff before the money runs out. So as a start up, we hired experienced engineers. We couldn't afford to take a guy right out of school and wait five years for them. Now, I will say there are people coming right out of school that are really good. They can start designing right away. But most of the people need a training session or training for a few years to get up to speed.

You have to learn the process and all the tools and things like that now. So we hired experienced engineers. Back when we started, there were no simulators on personal computers. We did bread boards.

Laws: And the time period? It was 1981 when the company was founded, to put a perspective on this.

Dobkin: Yes, 1981.

Laws: The PC wasn't even announced by IBM.

Dobkin: No. No PCs. If you were doing simulations, and there were some, it was done on a mainframe, very expensive. Sometimes, you had to do it. But the circuitry was designed by pencil and paper, and then you would build it out of parts that came from ICs. You would solder it together, and then you would test it. We'd test it in the oven over temperature. Then, you would lay it out. You would turn the schematic diagram into pieces, into parts, on a chip. Then, you would make the chip.

Then, the chip would come out, and you would look at the chip and see what's working, what's not working, and make changes. Sometimes, these chips had to go around three or four times before all the bugs were worked out.

Laws: So if you had to start out by hiring experienced engineers, you bring in some of these very talented people--I think you called a number of them "Gurus" at the time in terms of promoting the skills of the company. They must have had very strong personalities. How do you go about managing a group like this?

Dobkin: First of all, they did have strong personalities. And you don't manage them, OK? You just hire them in, and you say, we're here to make money. OK, go do it. You don't hire people that need a lot of management. You just need people who have the same vision or the same direction as you do. And you just let them go. You make the environment as conducive to manufacturing, as conducive to designing and inventing as you can.

So these people came in. We put together some rough product plans. And just let them go do it. You don't need to oversee them really carefully. My job, as the leader of the development design group, I looked at what everybody was doing. If I saw better ways to do it, I'd suggest it to them. I'd help them if I could. Sometimes, I was helpful. Sometimes, there was nothing I could do. They're as good as I am.

And you put together an environment where people feel comfortable doing their own innovation. I was very careful when I put it together that if we had a group of people that were really talented designers, I took no credit for their circuits. They're very proud of what they did. If I made it a little bit better, that's great. They can take the circuit, and we'll all make money out of it afterwards because we were a business.

So you can't stifle people. You have to give them enough room to grow, enough room to develop their talents. And you can't try to take away any credit from them because they're very proud of what they did, and they really should be. I've seen environments where the boss tries to take the credit for all the people working for them. That doesn't work with really talented engineers.

And so we put together that group. And one of the other things that we did as we were growing is the design engineers would go out and visit customers. That did two things. That promoted the products we had. This is a couple years after the company started, maybe mid '80s. And it also gave us ideas for new products.

Customers would show us their problems. And for the most part, these few engineers that we had at Linear were some of the best in the industry. They could look at these problems. They would come up with their own solution to them. We'd go to look at customers that had similar problems. And after we saw enough of them, we know we can make a solution that will fit all these customers.

And I can do it on a small chip because I know what I can put in a chip, and I know what I can't. So I'm not going to try to put everything in there. I'm going to put in what makes an efficient chip, what works well. And I'll make a chip that handles all this-- this whole group of customers. And this one piece over here, yeah, they'd like to have it in a chip, but it's not worth it. It's going to make it too expensive for them. So we make a very efficient chip. One that we could make, that we could make money on, that would solve multiple customer problems.

And it was done because we sent the engineers out to go look at the problems, not ask the customer what you wanted, but we look at the problem and come up with their own solution to it. And the engineers liked that. They got to see the guys who were designing what they already made, and they got to see what's needed and become great engineers. They wanted to solve problems, so they were solving problems. It went over very well within the company.

Laws: Now, this would have been after doing business for a few years and having established some validity as a competent company. How did you go about choosing the very first products? Did you choose the products, or did you choose the engineers and see which products they could design most efficiently?

Dobkin: When you're starting a company, you need to get revenue. Having been in analog for a long time, I knew that it takes years to get sales in a product. You come out with a product. Six to 12 months, later you get the information out to the engineering community. They start designing it into their products. Takes them a year to finish their product. Sometime in the third year, you'll start to get sales.

That's what makes consumer items and custom chips attractive to some companies because you get that revenue sooner. But there's problems with that. So the first thing that we did was we came out with second source products. These are products that already had a base in the industry that we were selling into many different areas. But if what we just came out with was the same thing that everybody else had, we could only sell on price if it was exactly the same.

So I instituted within Linear, and within our test systems, the ability to trim critical parameters on these parts during the manufacturing step. This was a new innovation. Analog Devices [Inc.] was doing some trimming with lasers. We implemented a different type of trimming on these parts.

Laws: What kind of trimming was that?

Dobkin: We put fuses on the parts so it could blow the fuse and that would change the parameter. Or, what we call Zener zapped, which would provide a short circuit between two points. And right from the get-go, we built a whole portion of our test system to be able to drive those. Now we could take the parts that were industry standard and make them 10 to 20 times better on critical parameters than the parts that were out in the marketplace.

Laws: So this was because you can control the precision value of a resister, for example, that might have had a widespread [value with] just with a regular diffusion.

Dobkin: That's right. We could take the spread of the parts that we've got and narrow that to very narrow distribution right at the critical parameters that people buy these parts for. So an op amp that might have millivolts of offset voltage, we could take that down from millivolts to microvolts, sometimes 100 to 1,000 times better.

Now, the customer gets a benefit. They don't have to trim their system. I gave them better specs. They don't have to trim their system. They have a reason to buy my part now.

Laws: And they're prepared to pay a little more for it.

Dobkin: They're prepared to pay a little more because it saves them money, and it also brings the business to us. So by implementing that, we were able to make parts that fit in existing sockets out in the field and get our sales earlier because we had better parts out there.

The second piece was there's some existing sockets in the industry that have certain configurations, like an operational amplifier has a certain number of pins. They are always in a certain order. And the function of an operational amplifier is to amplify and be able to precisely control the parameters with external resistors. So we made some new operational amplifiers that fit into an existing pinout with better performance.

We did that with some regulators too. And that was an early strategy for getting sales fairly quickly. But we gave people a reason to buy our parts other than price.

Laws: Are there two or three part types that really made the difference in the early days that you can recall?

Dobkin: Yeah, back in the early days, one of the part types that got a lot of interest was the LT1013, and it was a precision op amp with very low offset, very precise. It also worked really well on a 5 volt supply. And a 5 volt supply, power supply, was what most digital circuits ran on. So we could sell this to people who had digital systems that needed some analog. And that got to be a very popular part.

There was another part, the LT1085. It was a low dropout regulator for the day. It was a 5 amp regulator. It got used in many, many of the PCs that were being manufactured then because the PC needed 3.3 volts for the processor and the power supplies were 5 volts. So this was able to regulate the 3.3 volts off a 5 volt power supply.

Laws: And those kinds of products will go into a whole vast array of different kinds of end systems. So you're not just chasing a particular computer [model] or a particular customer's device with it.

Dobkin: No, we tried to make parts that went into many, many systems. So if we lost one order, we'd pick up another one. Another part that we made back then was LT1070, which was a switching regulator, a new 5 pin configuration for switching regulators. It ended up in many, many disk drives.

And these are all general purpose parts. They're all selling today.

Laws: You are still selling those same part numbers?

Dobkin: A good general purpose part will sell for a long time. I've made parts that I introduced in the early '70s that are still selling in high volume today. Good general purpose parts, as far as I can see, they have an unlimited lifetime. If you do it as good as you can, and nobody's going to make a better one, it's going to sell for a long time.

Laws: So a couple products there - voltage regulators, operational amplifiers - was there another product category in the early days that was important to you?

Dobkin: We did some interface circuits at the time, RS232, RS485. About the time in the mid '80s, Maxim came out with an RS232 circuit. It generated its own supplies. They did it in CMOS. I did it in bipolar. At the time that I did mine, mine was more rugged and immune to latch up. We did the first low power RS485 circuit. 485 circuits were pretty power hungry and made on a bipolar process. We did ours on CMOS. We tried to pick places where we get our parts and give our parts an advantage that would be attractive to designers. And if we did an attractive part, we got sales in it. And they're selling today. They're still selling today.

Laws: That's incredible compared with the digital business. The process you mentioned, bipolar, was the standard high volume process at the time throughout digital and analog businesses. So you started out with a bipolar process?

Dobkin: We started with a bipolar process. CMOS was also in high volume production for digital. It was much denser for digital products, but most of the analog circuitry that was existing was bipolar, and bipolar circuitry ran over a wider voltage range up to 100 volts in some applications. The CMOS ICs did not at that time.

So we were going after existing sockets or existing-- not existing sockets, but existing applications which were intended to be higher voltage. And for that we needed to have bipolar.

Laws: And as opposed to many other companies that were starting at that time and using third party manufacturers, foundries they were called, Linear built their own bipolar fab [fabrication facility]. Why is that?

Dobkin: We felt if we were going to be a high volume linear company, we needed a bipolar fab. There were no bipolar foundries for the types of circuits that we wanted, so it was imperative that we-- and we built our own fab for performance. We had to control the transistors, the noise, for reliability, and for control over our own destiny, we needed a bipolar fab. So we started with a bipolar fab.

Laws: And that was built here in Silicon Valley?

Dobkin: Yeah, we got our first wafers out of our own fab 14 months after we were founded. Built the fab from scratch, outfitted it, came up with a process, debugged it, got first working wafers in 14 months.

Laws: Fascinating! You couldn't get a building permit these days in that time.

Dobkin: That's probably true. Actually, when we built it, we built in Milpitas because Milpitas was much more friendly to semiconductor companies at the time, than Sunnyvale or Mountain View or San Jose.

Laws: Interesting. And so you stuck with bipolar predominantly for the first five years or so. At some point, you did start, as you mentioned, to build some CMOS products.

Dobkin: Yes. Bipolar is good for a lot of things, but CMOS has its advantages. CMOS is a perfect switch. You can turn on and off the CMOS transistor, and it's virtually a perfect switch. That's what makes it good for digital logic. It's also very dense for digital logic. But for analog purposes, having a perfect switch is also really useful.

There's a lot of circuitry that we would call sample data circuitry where the analog information is sampled or you need a switch somewhere in the circuit. Analog to digital converters need these switches. Chopper amplifiers need these switches. Multiplexers need these switches. So there are a lot of circuits where having MOS available makes a big difference in whether you can do that circuit.

And we could see that coming for a lot of the circuitry, so we needed an MOS process. We built our own MOS process.

Laws: OK. So you built your own MOS fab as well?

Dobkin: We made our fab versatile enough that we could make MOS and bipolar in the fab.

Laws: I see. OK. Did that require bringing much new skill into the company or was the engineering department capable of building their own CMOS process?

Dobkin: The engineering department was pretty much cable of building their own CMOS process without bringing in additional people. But we were growing, so we were bringing people in at the same time.

Laws: Sure. So now you've got your company. You've got second source-- improved second source products out. You're starting to get feedback from the customer in terms of what additional products

they'd like to see. What was the process of interacting [with them]? Did the design engineers always go out or did you build an applications department that interfaced with the customers.

Dobkin: We had an applications department, and this was to help the customer. We had a lot of application engineers in the field to help customers. And these are not salespeople. They can't even give a price to a customer. They're out there specifically to help designs. And we did not ask the customer what he wanted. We came up with our designs on our own. We went out, and we looked at the problems and came up with solutions.

I think that's a big difference from what some of the other companies have done in the past. They would have their marketing departments go survey the customers, see what the customers want, put together specifications on what the product is the customer wants. By having the design engineer go out there, he knows the silicon, he knows circuitry, he can understand the problems, he can partition it better. He can partition a more efficient chip. And he knows after he's talked to the customers which specs are most important.

They would be able to make the trade off in the design that this non-important spec, I can let that go or I can let that be lost. These are the most important, critical ones. I have to make sure I do those properly. If you're just handed a spec to design to, then you don't know what's important, what's not, and what can be changed or what can't be changed. So by giving the engineer the freedom to come up with what he wanted to solve the problem, we got better products out.

Laws: And presumably, those better products were harder to design than some other products. They would require you to be on the leading edge of design. How do you develop those skills?

Dobkin: Very good people. This company was built on very good people, and it's really important that when you're building a company, you build it with good people, and you know that they're not interchangeable. And you treat them well. You treat them like they're important because they are. They are really important to your company.

Laws: And a lot of them hang around for a long time, I understand, at Linear.

Dobkin: Linear keeps its people happy. I mean the environment is a good engineering environment. People who come to Linear rarely leave.

Laws: How do you define a good engineering environment? What is it about an environment that causes an engineer to want to say around?

Dobkin: Very low politics. Many engineers that they work with are smart, I can work with them, I understand what they're doing. Having management that understands the problems that occur. And being able to work with the engineers to solve those problems, being able to see your part in the field, talk to customers, and get feedback from customers. I really love your part. It's working great. I'm going to buy a million of them.

That's a nice ego boost for somebody who's worked on a part. We have schedules, but we understand schedules are our own. Since we're making parts that are innovative and haven't existed before, our schedules are our own to get those parts out. We're not making a custom part at a customer's schedule. So if the schedule slips we don't like it but it happens and nobody gets dinged for it.

So we've got an engineering environment where engineers can do their engineering. They get appreciated for it. And we make it an easy place for them to work to do engineering.

Laws: So it seems like we've covered three important aspects of the engineering. There's the analog design engineer. There's process engineering, which is important. And there's the applications engineering role within the company. How do they work together? What drives decisions between the relative roles of these different departments?

Dobkin: I tend to think it's more design centric. The design engineers also do many of the applications for their circuit because they know their circuit better by the time it's out than anybody else. The applications engineers work with the finished ICs and solve bigger problems, system problems that show up. They work with the customers and help solve the customer problem on the customer end.

Although back when we were very small, we didn't have a lot of applications people. The design engineers talked to customers and helped them solve their problems as well. Process is a separate group, and there are things that you can manipulate in the process for your circuitry. We would work with the process engineers. And there are parameters that we can manipulate. We can manipulate some of the transistor parameters, some of the spacings, depending on the voltage breakdown that we need.

There are some things that we can't manipulate. We can't manipulate lithography. They say I can make this size, that's the size you make it. So we work with the process engineers, tell them which parameters we think are important. They would come back and tell us what we do, and we'd end up with a process where we were pretty happy with the transistors. They were pretty happy with the producibility. And after everything was characterized, we'd start to build designs with it.

Laws: Were the designers able to design their own transistor at that point?

Dobkin: Not only did they design their own transistor geometries, they sometimes modified the process to optimize the product. And there's some things that you can be modify to get better performance. And we do that in the fab. Because the fab was computer operated, we have a different recipe for different products.

So if you're in the analog IC business, you can't be where everything's vanilla. We have our own process changes that we make to optimize what we're doing. And the transistor geometries, in some cases with foundries, you get a geometry, you can't change it. In our process, transistors are changed all the time, go on different sizes, different shapes, and different ways.

Laws: Very different from the digital design that I lived with for so many years.

Dobkin: When it comes to digital design, you design it on a computer in a language - Verilog. Then, you go through some steps and that Verilog [file] ends up turned into transistors. And if I'm a digital engineer, I don't necessarily know what each transistor does. In fact, I don't even know what groups of transistors do because all I was working with is the logic, not the circuit.

Laws: You had a very high profile applications engineer at Linear for many years, Jim Williams. How aware were customers of the role of applications played at Linear? Or, was it the design gurus that got all the notoriety?

Dobkin: Jim was a special case, I think. He had a long history of doing consulting. So he had a long history of doing analog circuitry, which is what he liked to do. He came to Linear to do analog circuitry. He also liked to be a teacher, and he was very good at writing. So the kind of things that Jim would do is write tutorial analog articles for teaching customers how to do design work, how to measure certain parameters, and the circuitry he would use would emphasize some of the linear ICs that Linear made.

They were really educational application notes. They were not sales pieces. And yes, they had linear ICs in them. They came from us. But it established a solution for a lot of customers and sold some ICs on the side.

So Jim was very prolific at writing, and his writing was carried by one of the major electronics magazines for 30 years. They loved to have his articles because they were highly read. They were appreciated. They were very fine electronic articles down to the transistor and design level that didn't exist in other places. The customers liked them. The editors liked them. And we liked them. And he was very unique in that respect.

Laws: And helped present Linear as a company that provided solutions perhaps rather than products.

Dobkin: Very much so. Plus, he was a good friend.

Laws: He was an interesting guy. I enjoyed meeting him. Are their some other names in the early days at Linear that the public was aware of.

Dobkin: Some of them. Carl Nelson, great designer. George Erdi, well known for doing precision circuits. Tom Redfern, he did our first MOS circuits. Nello Sevastopoulos, he was our filter guru. Doing those filters took lots of mathematics and Nello was very good at that.

Laws: Are there any stories about any of these people that got around that gave the company personality?

Dobkin: Actually, pretty much in the early days, we worked well together. If it works, it works. If it doesn't work, it doesn't work. It's black and white. So we got to do our circuits, and if something didn't work, people knew it. And then when it did work, they also knew it. So I think I was very lucky having such a wonderful group of people to work with.

Laws: You certainly had a unique crew there to work with. How has the process of analog designed changed over the years. When you started out there were no personal computers. You used kit parts to build devices and check them out. Has it changed a lot?

Dobkin: Immensely.

Laws: --or is it still fundamentally the same process?

Dobkin: I remember when we bought our first personal computer to do circuit simulation on. It was 1986. And it was the first time you could do simulation on your desk rather than on a terminal. We had to be worried about how many seconds of CPU time we were using. And during the '80s, there was a big transition.

At the end of the '80s, all circuits were being designed on computer. It got rid of a lot of the problems that you had in trying to breadboard it. In a computer, all transistors match really well, and they're all the same temperature because that's a number in the computer. It's really important in what you're doing. So the design transitioned from breadboard to computer.

Then, as time went on, the circuits got more and more complex. In the early '80s and '70s, circuits had 50 to 100 transistors in it. MOS circuits had more. And then by the end of the '80s, we're at several hundred transistors. And then it just moved up from there.

The CMOS circuits that we do now have processors in them. They'll have thousands of transistors doing either random logic or processor type logic. So today's circuits, maybe some of them are 20% analog and 80% digital, but it's the analog part that differentiates them from other circuits that are out there. Because the analog part takes a skilled analog engineer to make it.

One of our circuits, a 20-bit A/D converter, it's got a lot of digital in it, but it's 1 ppm linear. That's more linear than resistors, and it takes a skilled analog engineer to be able to do that. Takes a skilled analog engineer to be able to use it too.

Laws: When an engineer began to have access to a workstation, or personal computer of their own now to work with, this changed the process of circuit design. Were there any particular tools that were favored for simulation and design of analog circuits? And did you develop those or were they provided by third parties?

Dobkin: We started off using readily available commercial SPICE simulators and graphic viewers. SPICE is a program that simulates a circuit. It solves matrices. SPICE will bring any computer to its knees no matter how fast it is. We have circuits that'll take a week to simulate one cycle of, so yes, we used SPICE.

We have our own SPICE circuit. It's called LTspice™, and it's a simulator, schematic entry, and graphic viewer. It's free. It's an unrestricted SPICE. The only thing that makes it Linear Technology is we put models of our own products with it and that's how we distribute it. But customers are free to use it with anything else that they want without restriction.

It's the world's most popular SPICE. There's probably a million copies of it out there. That was a decision to make. Should we make it restricted or should we just make it available to everybody?

Laws: Why would a customer want to know what's going on inside a circuit?

Dobkin: Well, they would take out models of our chips and use it to build their system.

Laws: Got it. So they would embed that in their system design process.

Dobkin: Yes. They would simulate it, and that's how they would see how their system works. I know there's one major aircraft manufacturer [that] has made it the standard simulator with their company. And we use it to make ICs. It's a very fast SPICE. There's a lot of optimization that was done to increase the speed of it. [But] it still takes days to simulate some circuits.

So we use SPICE. For other applications, we use HSPICE, which is another company's SPICE. We'll use Cadence Spectre, which is another simulator. It depends on the particular problem we'll have to solve or what we have to interface it to. And there's some RF simulators that we use as well.

Laws: Are there particular pieces of hardware that design engineers like to use when they're debugging their circuits or trying to understand it. There's always the famous Tektronix scope, of course, from the old days. How did that side of the design process evolve?

Dobkin: Well, all of the circuit design and development is debugged on the SPICE simulator. And the fastest computer isn't fast enough, but that's what we got. When it comes down to debugging the IC, it gets more difficult. You put measurement points inside the IC so you can measure it. If you have multiple layers of metal and you want to go in and probe a piece of metal and see what the signal is on it, it's difficult if it's very far down on the bottom of multiple layers.

So we put points where we bring metal out so we can measure it. We'll make test masks where we cut things apart, bring out a section of the circuit. We have probes that will go in, and we can touch a metal line and measure the signal on it. We have a laser that we can cut metal lines, or we have a fab where we can cut metal lines and rewire a portion of the circuit on the chip just test different things.

So we have tools, but the best tool, I think, is understanding what the circuit's doing and what it should do and what the difference is. Scientific method still applies.

Laws: This is a very hands-on process.

Dobkin: It is.

Laws: Which again would appeal to a certain kind of personality and style, the kind of people who used to be radio hands perhaps in the old days.

Dobkin: It may take weeks or months to debug a circuit. There are still new things we are finding about why silicon doesn't react like a simulation. And we're learning on it.

Laws: So which technology was most important from the mid '90s, on CMOS or bipolar, in terms of the growth of the company? You talked about circuits becoming that much more complex. There's a lot more digital to analog and analog to digital kinds of design going on in the chips. Does that make CMOS the predominant process today?

Dobkin: CMOS is probably 60% today, but bipolar is still growing. I mean having both of them is important. We have certain areas that we've decided we're going to make products in, and there's a process that does a better job going into one area compared to the other. So for a lot of the precision work, you need to have bipolar. For a lot of the switching regulator work for products that need sample data, CMOS is important. If you need microprocessor control, CMOS is important. But they're both important.

I think one of the ways we were able to grow stably was by having both processes available. And it's not a matter of people saying oh this is better or worse. It's a matter of what's the right tool to do the job. The right tool is whatever will get the job done the best. If it's CMOS, it's the one. If it's bipolar-- and we have BiCMOS too, so it can be a bipolar CMOS combination.

Laws: One of the items you mentioned early on was the role of the package and the impact that can have on the operation of the circuit. And there are other aspects such as long term stability of voltage references that can be impacted by the package. Where does that skill will come from, just a matter of knowing what happened in the past and how to tweak it? Are there particular skills in the company that allow you to make better decisions in that area?

Dobkin: Packaging is a necessary evil. The chip itself is strain sensitive, so any flexing or pressure affects the transistors. So when we put it in a package, there's two places that get stressed. One is from the back of it, the back of the chip. And the other is when the plastic comes down on the top.

There are, after long periods of experimentation, there are places on the chip where there's more stress or less stress. And it's not always the same because the molding compound doesn't harden the same at all times, but we try to put critical transistors in areas of low stress. It's still not a perfect science. Or, maybe it's a perfect science, but the answers are still pretty random.

So we have some skill in it just from experience, but that's it. And the packaging changes, the parameters change with time because the plastic hardens slowly over months. Temperature cycling changes it. Packages absorb water, and you can watch a parameter or a chip change as the package is put into a humid environment.

So things are not easy to do in a lot of these packages. Hermetic packages, which are too expensive for most commercial use now, are much better. And they're used for really precision items or military stuff or satellite stuff.

Laws: And they tend to be a larger package, and there's such pressure today to use the smallest possible package that will fit.

Dobkin: Yes, the military one's bigger. Their main order process is called Rad Hard because the satellites are in a radiation zone.

Laws: Do you do much design specifically with that in mind?

Dobkin: We modified one of our processes to make it much more radiation tolerant for space level. And we sell products that are space level qualified which have that modified process. And those have to go into a hermetic package because it won't be as reliable as needed in a plastic package.

Laws: So what are the future challenges that you expect to face in the analog industry? Certainly, wanting more and more analog to digital conversion, and back to analog again. How are you preparing to tackle those? Are you personally involved in these decisions these days?

Dobkin: I'm involved in everything. But I don't run it all anymore, which is a pleasure. So we're still pushing the limits in a lot of things that we're doing. Power circuits, switching regulators are a big piece of Linear's business. We make some very sophisticated switching regulators that run at high frequency, megahertz, that do clean switching at high efficiency power conversion. And we're going to push in the same direction, higher power, higher current and higher frequency. Makes them smaller, makes them easier for the customer.

Data converters, it's obvious which direction you can do. You make them faster, and you make them have more bits. And we've got some industry leading parts out there. We've got 20-bit converters. We've got hundreds of megahertz at 16-bits. Going for more and in both directions. And of course, you get analog parameters with the data converter. What's their linearity? What's their noise? What's their SFDR?

Laws: SFDR is what?

Dobkin: It's various frequencies that show up as you're doing the analog to digital conversion. RF parts, how linear they are, how good they are at frequency conversion. But the push is for smaller and faster

and higher power. Also, some of our amplifier devices, the push is still in the direction of precision and speed and stability with time. We haven't run out of things to do yet.

Laws: Still plenty of challenges, especially the demands on less and less power usage in systems today. Which circuits presented the biggest challenges for you over the years in terms of getting it to do what you wanted it to do? Are there any particular areas that come to mind that you struggled with for a long time?

Dobkin: They're all hard. They really are all hard. I mean data converters are probably the hardest. Although some of the switching regulators are high frequencies, being able to switch amps on a chip and not disturb the low level circuitry that's running on microamps and not couple to them is difficult. It's a real design and layout exercise. We have a device that has the switches in megahertz and runs on three microamps of quiescent current.

And we've got these transistors switching amps out of megahertz, and it's not allowed to change the reference.

Laws: Is that a whole class of circuits?

Dobkin: Some of our latest switching regulators are designed that way. They're really appreciated by the automotive industry, which is putting more electronics into cars, but they'd like to have some of the stuff stay alive when the car's off. But you can't draw much power because you don't want to discharge the battery, so getting the quiescent current down to a few microamps means they don't have to worry about it anymore.

Laws: Are there some favorite circuits that you've designed over the years?

Dobkin: I started to design back at National. I wanted to design a three terminal regulator that was adjustable down to zero. The process technology components were not available at the time. I tried a couple of mask sets. Didn't work well. I defaulted to a design which came out as the LM317, which is a three terminal adjustable regulator, but it can only go down to 1.2 volts, not zero.

At Linear, I designed, 30 years later plus, a circuit that is adjustable down to zero with a single resistor, makes it easy to adjust. You can parallel them. Has low dropout. And that's one of the ones I was happy I was able to make because I had the idea so long ago and wasn't unable to make it at the time.

The process technology gave me the parts I needed. And 30 years more experience gave me the circuit design experience I needed.

Laws: Are there other circuits that come to mind that you really felt good about accomplishing the design.

Dobkin: That was one of my personal favorites. But you work on these circuits for a long time. I mean you work on them for a year, two years, or three years. And when they come out, they're all an accomplishment. And I think that the other engineers feel that way too.

Laws: Are there a couple other circuits, perhaps within Linear's portfolio, designed by one of the other gurus that you can look at and say, "That was a real accomplishment for them to do that."

Dobkin: Our 24-bit A/D converter. They were the first of the kind that are single shot delta sigma converters. They were a great advance in that area, copied at other places. We have a 20-bit converter there. We have two high current switching regulators that we started with in the '80s that have grown into a whole line of parts. Really nice, clean designs that are as easy to use as possible considering they've got high currents and high voltages flying around, and you do need a good layout on it to make it work right.

But I think that we've got many circuits that really push the state of the art that I'm really happy with. And I talk a little bit about standards circuits. It's interesting that standard circuits, when they're done well, will sell for 20 years plus in high volume. We've got circuits that we came out with when we first started that are still selling in really high volume 30 years plus later.

Laws: Linear is still building and supplying?

Dobkin: What?

Laws: They are still in the Linear catalog?

Dobkin: There's very few products that we've obsoleted. Some are our very early products, like the 1013 I mentioned, are still very high volume products today.

Laws: Other people haven't tried to copy that.

Dobkin: Some people have tried to copy it, yeah, as their own version. Some of our other products, the LT1085, the regulator that I mentioned that was used with some of the Intel processors, that was copied by several other companies. I think the mark of a really good general purpose product is people try to copy it.

Every portable computer in the world that has a sleep mode uses a patent that Linear had. The patent's now expired. We called it Burst Mode. It's a way of making a switching regulator that has high efficiency when it's running, and it has high efficiency when it's in a quiescent state, like the three microamps I mentioned.

That's used in every portable computer as the power supply circuit because you take your computer and you close it up. And it goes to sleep, and you open it up, and it comes back. During that sleep time, the power supply circuit is going into a mode that we call Burst Mode that we invented, where it maintains high efficiency at really low power, so you can get long battery life with your computer sleeping. And that was a development that Linear did.

Laws: Have patents played a very important role in the company?

Dobkin: They've kept our attorneys very wealthy over the time period. We have collected on some of the patents. We've paid on some other company's patents. Patents are important to protect your technology. They are also important for defense against other companies. I think the patent system needs radical revision. If you have a circuit, you're selling maybe half a million dollars worth a year. That's a reasonable circuit. It's not a blockbuster. But then somebody else copies it. Is it worth spending $5 to $10 million to defend that patent?

Laws: Probably not.

Dobkin: The patent system requires attorneys, and attorneys are expensive. And the minimum you can do in a patent suit is couple million dollars, so it makes it hard to make decisions.

Laws:, That's the minimum that it would cost to defend a patent?

Dobkin: Yes. Yeah, defending a patent it is an expensive proposition.

Laws: As well as consuming a lot of time and energy within a company.

Dobkin: It does.

Laws: How do you get your engineers to think about patenting a circuit? Is there a reward system of some kind?

Dobkin: There's a small reward for patenting, but they're part of the company. They know what's important. Their boss knows what's important. And we always do the trade-off. Is it worthwhile patenting it? We don't patent everything. Some companies do because they want to take and say your portfolio of patents is this high, mine is this high, so pay me some money.

We just look at patents and look at their value, and if we think they're going to be valuable, we'll patent them. And usually it's patents that we think we might spend the money on to defend. So we do put together patents. We are also conscious of other people's patents. We don't want to infringe them. We want to design around them, which is something that we did extensively in our A/D and D/A converter area.

Laws: Design around patents?

Dobkin: Yes. Do it differently-- do it in a different way.

Laws: Is that usually fairly straightforward because the other patents are so specific or is it--

Dobkin: Well, we have to read them. You have to read them. You have to work with an attorney. We don't want to infringe patents, so we work very hard around them. And we do protect our intellectual property but we protect it in more ways than patents.

The circuitry is difficult, difficult to understand. It's made on our own process for a good portion of our circuitry, so without our process, you can't duplicate it. Some things use foundry, but you know, when you're doing a circuit with tens or hundreds of thousands of transistors, you can't just copy it. You have to really design it yourself to know how it's working. So just the complexity of the circuit keeps competitors from making it. It's easier to design from scratch.

Laws: Back to the question about foundries. How much of Linear's production is made in foundries these days?

Dobkin: Maybe, maybe 5%.

Laws: As small as that?

Dobkin: We make it internally because we get to control it and we invest in it. It comes to some products where it's very small line width. We don't have that capability in-house, so we have to go to our foundry. And in a lot of cases, it's not worth trying to put in these very small feature-sized digital processes in-house. They're very expensive to get amortized over many millions of wafers of digital circuitry, and we wouldn't have nearly that volume. So we put the processes in well after digital had started to abandon them.

And then there are fine line processes for analog. The equipment has come down in cost. And it becomes more economical for us to put it in-house, but at the leading edge, we'll use a foundry.

Laws: And you have wafer fabrication area here in Silicon Valley. Do you have one somewhere else in the US?

Dobkin: We have another wafer fabrication in Camas, Washington.

Laws: Washington.

Dobkin: And that's a large wafer fab.

Laws: And on to the topic of moving outside of Silicon Valley, one thing that Linear has been fairly aggressive at is setting up design centers outside of the Valley. You have 14 or so now, I understand, around the world.

Dobkin: Yes, we have them all around the world. We go to where there are groups of good analog engineers. Not everybody can move to Silicon Valley now. It's very expensive here. And not everybody wants to, so we'll put together a design center in areas that are attractive to engineers and families, both from a cost point of view, an education point of view. We'll set up a design center there.

We have lots of interaction between the design center and the Milpitas design center. We fly engineers back and forth all the time. And so we end up with engineers working in a Linear environment in other parts of the country. A lot of times the manager has worked at Linear and moved away to run the design center.

Laws: And certainly in setting up activities outside of the area, it's very important to try to maintain the culture of the company so that people share the same goals and the same aspirations. One method of doing that, you said, is that you take people who have worked here at Linear and have them set up somewhere else. Are there other ways you try to maintain the Linear presence?

Dobkin: We have good communication between the design centers. We set them up the same way we're set up here in Milpitas, where our major design center is. And all the people that are hired, they talk to the managers both in the local area and in Milpitas, and they have to get approved both on technical skills and maybe personality because we want to set up a good working environment. We've got a very stable working environment and working personnel. And that continuity helps us. We'd like to keep that, and we have in the design centers.

Laws: Do you send people out from the factory to the design centers regularly? I think you did quite a bit of traveling or do quite a bit of traveling.

Dobkin: I did. We have a company plane. And several times a year, a group of us will go visit all the design centers.

So we keep lots of communication up, and people feel like they're part of the same company.

Laws: How else do you keep the communication going other than going personally?

Dobkin: We have weekly conference calls. We know what they're doing. I'll call people in design centers. They'll call me. They'll call their boss. We're very open in terms of having the ability to talk to the vice president of the group. We're an open door company with lots of communication.

Laws: Must have very different styles in different parts of the country, in different parts of the world. How do you manage a Japanese design group versus a Greek design group?

Dobkin: Well, we only have a few design groups outside the country. We have one in Germany, one in Singapore, and one in China.

Laws: Now there's two big differences, China and Germany.

Dobkin: We have our sales center in Germany. And we set up a design group there. And the person who set it up with, started it, was from Milpitas originally. So he set it up with the culture. We now have a local manager. They know all the people back in Milpitas. Singapore design center is where our Singapore factory is, so they get lots of communication between Milpitas and Singapore. And they're a productive group too. Back when we started [in Singapore], there were lots of design groups at other companies. I think ours was one of the most productive, and it's one of the longest lasting ones too. They're still there. They're growing. They're making products for US. China, there were some Chinese engineers that

worked for Linear who, for personal reasons, wanted to move back to China to the rest of their families, and they started up their design group there.

Laws: Where is the group in China?

Dobkin: Hangzhou.

Laws: And in Singapore, that's a test facility-- a packaging and test facility?

Dobkin: Singapore is mostly test and design center. We have our assembly in Penang, Malaysia.

Laws: Are there any other international operations for Linear that you've been involved with?

Dobkin: We have sales centers all around the globe, but those are the manufacturing design areas.

Laws: Do you get different demands in terms of application support from different parts of the world? Are people's expectations different?

Dobkin: No, our products are all industrial, general purpose products, so we're always selling into the industrial, general purpose market.

Laws: One area I'd like to discuss a little more, Bob, that has obviously played a tremendously important role in the success of Linear, is this elevation of the analog designer onto a pedestal.

Dobkin: Maybe that's a little bit of me because I'm an analog designer, but it really is a team effort. And I think one of the things that I could say is Bob Swanson kept the whole company marching in the same direction. He was a businessperson. The direction he set us in is make products and make money and keep a focused eye on what our business is. So he kept the whole company aimed at being a successful, entrepreneurial company.

And within that, we have designers, and the designers are involved in picking the product, making the product, applications for the product, working with marketing to sell the product, and visiting customers. And we expose the designers to the whole process. They get exposed to pricing the product, the cost of the product, and how to sell it.

I think we can do that, compared to some other companies, because our designers are experienced. They work with customers. They've been out in the field. They're not secluded, so they are entrepreneur by themselves. Their entrepreneurship is in making a business out of their product, and they like that. And we like that too, but you can't do it alone.

During the years before we started Linear, I had many offers to go to other companies. But it's a combination of you have to have a good business guy in charge. You have to have good processing. You have to have assembly. You have to test. You have to have all the pieces working together to make a good product, and without it, you don't have a good company. So it's a matter of having engineers that are interested in all aspects and exposing them to all aspects.

Laws: This is not something that the average public would think of as the skill of an engineer. Engineers tend to be thought of as being very skilled in a particular narrow set of disciplines. But here, you're saying that your engineers are entrepreneurs. They enjoy meeting people. They mix well socially. They can present themselves well. And they're also great designers. Are these people born, and you just find them. Or, do you make them?

Dobkin: I think that some of them are born. They get put into an environment where they have a chance to grow in all kinds of directions, and we let them. So they grow there. And the ones that work well end up running their own group and teaching their own new group on how the company has made products. I think it comes from me in that when I started at National, I worked with customers. I answered the application phone calls. I make the engineers do that at some point. Keeps them from being overly optimistic on how customers treat their parts.

They make sure the customer can get the part to work. We call it the theory of minimum phone calls. When you make a million parts that don't work right, you get a million phone calls. So I did that. I talked to customers. I thought it was interesting and all the aspects were interesting. I let the engineers, and I encourage the engineers at Linear to do that. And I think it's worked out well.

I know other companies, they write specs. They pass the specs to engineers. The engineers design to the spec, and don't see what the product is or what good [design] is. I think that that's the typical vision of an engineer. But I think they can help in all kinds of areas in making a company successful.

Laws: Linear has certainly distinguished itself in that area. How much was Swanson's role in this? Did he deliberately step back and let you and your team stand out?

Dobkin: I didn't try to do Swanson's job, and he didn't try to do my job. Where we did mix was we had a weekly meeting on selection of new products where we looked at the product. We looked at the business case for it, what it's going to cost to make it, what we think we can sell it for, what the volumes are, so we

can come up and make a business case this product will make the company money. And that was one of the areas that Bob Swanson was [involved] in.

The other area was in pricing the product. We have costs. We have certain aspects of the marketing of it, what's the competition. Where do we have to price the product properly to sell? We want to make the most amount of money, but we don't want to overprice it or we won't sell any. And Bob Swanson's a part of that.

But in terms of how I ran the engineering group and how we picked products to present at those meetings, that was mine.

Laws: Any conflicts about product areas that you felt were good from an engineering perspective, but it didn't make sense economically?

Dobkin: I knew what the parameters were on making products. So if I had a great product, but it would sell for $0.15, it never got presented. I had parameters on the cost and on the die sizes and the economics of the product, so we targeted our product to fit into the company business model.

Laws: The products that are coming out of the design groups are determined by the design groups? Do they come up with a product idea or do the product ideas come from someplace else and get given to them?

Dobkin: They come up with it from the product group.

Laws: There must have been some disappointments or disagreements when you have all those groups out there, right?

Dobkin: Yeah. I mean there's no disagreement per se. There's disappointments. We thought this product would sell, and it's not selling very well. But by the time a product is presented and we're making it, there's no disagreement as to whether we should make it or not.

Laws: Because you've gone through a long process to get to that point?

Dobkin: We've gone through some internal processes. We don't have formal processes. The managers, in each group, are experienced in picking products. There are some people that are good at picking products. Some people aren't. We have people that are good at picking products, and they're the ones that suggest the product for their group.

And some of the products come from our business with customers. Some of our products come from we think this will be a good product. Let's make it and see. And most of those turn out to be a very good products, and we make money off of it. A few of them bomb, but you can't be 100%.

Laws: In the digital business, certainly 80% of your sales come from about 20% of your products. Is that a similar ratio in analog?

Dobkin: I'd say I don't think it's quite that radical. But maybe 40% of our products are really good sellers. And some of them are good sellers, and they've dropped off after 20 years. We don't have the same kind of problems that consumer products companies do. You go from zero to a really high volume, say 50 million product sales for a year and a half, and then it goes back to zero.

Laws: The model gets changed, and the product gets dropped along with it.

Dobkin: That whipsaws the company, whipsaws the engineering department, and whipsaws the stock price.

Laws: Sure. With such a beautiful model to copy, why haven't other people been able to emulate what Linear's done?

Dobkin: It's very hard. This is a model that requires many talented people. It requires recognizing talented people and working with these talented people in an environment that they want to work in. It's a hard model to duplicate without experienced people to at least go get it started.

You can get, from school, some pretty good engineers with a Ph.D. in design circuits, but unless they've been out in industry, they don't know what to design. So you go ask the marketing department. The marketing department goes out and asks the customer. And the customer doesn't know what the silicon can do, so he wants everything in one chip. So that's when you come back and you tell your engineers what to make. But that doesn't actually make the most efficient product.

It makes a product that has all the specs in it. Maybe one or two specs could be left out, and it would make the product much smaller, and much cheaper. And the people who were defining it, the customers, don't know that. And the people who are designing it just got a spec, so they don't know that either. I think you have to be involved in all sections of the development process. Plus, you have to have a large group of engineers, like we have now, that are experienced in many different areas.

Laws: Have there been any successful spinouts from Linear?

Dobkin: No.

Laws: Why is that?

Dobkin: People are happy.

Laws: People are happy. There's a Japanese book written about that we talked about last time [in the oral history on the founding of Linear].

Dobkin: It's a book that says "the company nobody leaves." Back when I was at National, if they had made it a fun place to work, or they made the pay really good, we might not have left. But it was matrix management. The pay was good, but not great. It was enough to make people want to go do something on their own. Because what we saw when we left was we had a really good department doing analog, well-known as the best analog company in the world at the time, yet overall we were not able to influence the overall National company.

So we would say if we just had an analog company that did what we did at National and do it better, we'd have a great company. And we were right.

Laws: Anything you'd have done differently along the way?

Dobkin: We've done so many right things because we're still in business. I know what products not to make now. I mean that some of them were wasted effort at the time.

Laws: Because you didn't understand the market?

Dobkin: Or they weren't targeted exactly right. But we had enough experience to make some things and do well with them. We had enough people that understood applications [well enough] to design general purpose products for those applications. I don't know how to run a company that says I'm going to make the next modem or the next RF chip for Wi-Fi. Huge market, difficult product to do, but everybody's going to be in that market and everybody's going to copy it.

And we don't have those people within the company. That's not the kind of business that we are or we're looking for. We're looking for really high performance products in our areas that we want to sell in the industry. And most of the markets that we go after are not really visible.

Laws: There are some interesting things going on right now with the Maker movement, the hobbyists are getting into it. Have you seen much interest in your products from that area?

Dobkin: No, we haven't. But they use a lot of our products.

Laws: I would imagine so.

Dobkin: I mean power supply products are general purpose products. Anybody that's making some electronics needs a power supply to power it, so that makes a good area for us.

Laws:. How about other technologies, things in non-silicon semiconductors Have you ever looked at gallium arsenide or silicon carbide?

Dobkin: We've looked at gallium arsenide. Silicon carbide is a good area. One of the things that's been part of our business philosophy is: Do what you're good at. We don't know anybody in the gallium arsenide area. We don't know anybody in the silicon carbide area. We know companies that have made it in that business, but there's no reason to think that we can get into that business, provide our products with an advantage, and go and make a good business out of it.

We do look at things. I mean we looked at micro machine sensors. You can buy an accelerometer at Digi-Key in quantities of one for $0.60. I don't know that I could make an accelerometer that's that much better that I could sell for a higher price at lower volume that you can compete with that.

Laws: And there's not a lot of analog stuff you could stick around it and put it on a chip and have it make sense?

Dobkin: They've already done that.

Laws: That's been done for $0.60?

Dobkin: For $0.60, and that's a low value price.

Laws: How about graphene and some of these other new materials?

Dobkin: When it shows up to be useful to us, we'll go after it. Those straight research areas are too far away from commercialization for us to look at them. We look at all new areas. We look at graphene. We

look at silicon carbide. We look at: Do we want to try to make it or do we want to use it in our applications? And we'll use it in our applications. It takes a while for us to decide, hey that would be a good process to put in our stable to go forward.

We did do a step change at one time when we decided we're going to go from making ICs to making modules where we took our ICs, we hooked them up with resistors, capacitors, and transformers, or whatever we needed, to make a 1 inch by 1 inch by less than a quarter inch thick encapsulated module to make it easier for customers to put these parts down. They were able to buy a fairly complex function with guaranteed operating parameters. They knew they could put it down on their board and have it work. They didn't have to do any design. And we're selling those modules, which is a new assembly technique for us. New for us in that we have to buy a lot of components outside.

Laws: How long have you been doing that? Several years now?

Dobkin: Yeah, it's probably 10 years now.

Laws: Oh, 10 years. OK. And it's obviously-- you wouldn't have kept at it for 10 years if it wasn't providing some value to the company.

Dobkin: Maybe it's seven years.

Laws: Do you think Linear is a product company, a solutions company, or a service company?

[INTERPOSING VOICES]

Dobkin: I think it is all the above. It's a product company. It's a service company. We know where we make our money. It comes from customers. We have to service those customers. It's really important to understand that the customers are really important to everybody at Linear. I mean we're not 100% perfect, but we understand that the customers are important to us.

And we try to keep them happy. We try to work with them. We try to provide solutions for them. Things don't always work right. We try to fix it. So I think some of the bigger companies understand that, but maybe the lower levels within the company just don't see it because they're working so isolated from their customers.

Laws: OK Bob, is there any last comment you'd like to make? What are you doing with your life now, and are you going to stay at Linear forever?

Dobkin: I'm working full time. Everybody I've seen that retires gets old fast. And I like making products.

Laws: So you are still coming up with new product ideas and designing.

Dobkin: I do. And I get called in to solve problems when problems show up. I'm still enjoying the technology.

Laws: Well, that's great.

Dobkin: Thank you for this opportunity.

END OF INTERVIEW