

誰もやめない会社

The
Company
That
No One
Leaves

Kyoko Katase and Hiroki Yomogita

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Contents

Preface	vii
Foreword	ix
Introduction	xi
1 There is an Amazing Company in Silicon Valley	1
Support for the 2,000 LED Lights on the Tokyo Sky Tree	1
Successful Realization of a Profit Ratio of Approximately 40% for Ten Straight Years	3
Dedicated Analog Semiconductor Manufacturers	5
No Acquisitions or Mergers in 30 Years	9
Products from 30 Years Ago Are Still Being Sold Today	10
Revolutionary Concept 1: Analog, Not Digital	11
Revolutionary Concept 2: Defocus from Consumer Product Marketplace	12
Revolutionary Concept 3: Senior, Experienced Members of Staff Provide Mentoring to Bring About Innovation	14
Voice Mail Was Not Used	16
This is an Engineer's Paradise	17
"This is What Dobkin Said"	20
Charismatic Founder Who Spearheads This Unique Company	22
This is the Path for Japanese Manufacturers	25
2 Why Go with Analog Technology in the Golden Age of Digital Technology?	27
The 1980s, the Golden Age of Digital Technology	27

	Swanson, the Founder	29
	Setting the Stage for a New Company	31
	“What Have These Linear Design Gurus Been Up To?”	33
	Capital for the Manufacturing Plant Acquired from a Long-Distance Bus Company Subsidiary	36
	Reason for Not Acquiring DSP	38
	Interview with Robert Swanson, the Founder of Linear Technology	42
3	Defocus from Consumer Market	47
	Linear Technology Faces One of Its Biggest Challenges Since Its Founding	47
	Times of Slow Transition and Hard Struggles	51
	Sales Merits and Demerits	55
	One Step Toward Defocusing from Consumer Markets	57
4	Senior Engineers Bring About Innovation	61
	It Takes 10 Years to Become a Full Fledged Engineer	61
	Wednesday 3:00 and Friday Meetings	62
	All Product Ideas Are Born on the Shop Floor	64
	Ability and Passion the Criteria for Hiring Engineers	68
	The “Home of Analog Gurus” Lives On	70
	Message from Bob Dobkin to Young Engineers: “Ardent Desire Is the Mother of Invention”	71
	The Words of Jim Williams	73
5	Die Bank System That Has Attracted Attention Around the World	75
	The Third Strength of Linear Technology	75
	Waiting List of People Wishing to View the Company’s Inventory Management System	76
	Maintaining a Four to Six Month Inventory	76
	Undaunted Even by the Floods in Thailand	78

Aiming to Manufacture the Best Products in the World	79
Reason for Focus on Long-Term Stable Supply	81
Backbone Supporting Infrastructure Companies	81
The First Company Acquired in 30 Years	82
Expansion of Scope to Include M2M	83
Next Areas of Focus: Automobiles and Communication Infrastructure	86
Anticipation of Battery Monitoring IC Market Growth	87
Targeting the Electric Powered Vehicle Market	89
Bright Outlook for Analog ICs	90
Power Supply ICs for Environmental Power Generation	90
Applying Strengths in Other Fields	91
Interview with CEO Lothar Maier About the Company's Future, Vision, Products and Employees	92
6 Linear Technology's Next Target: Environmental Power Generation	97
Harvesting Small Amounts of Energy in Our Immediate Environment	97
Changes in Peripheral Components	99
Interview with Robert Swanson on His Expectations for Environmental Power Generation	100

Preface

This book, published in Japanese by the premier Japanese publisher, Nikkei, first appeared in 2012. It has been sold both online and in the business book sections of bookstores in Tokyo and throughout Japan. *The Company That No One Leaves*, as the title translates into English, is a case study of Linear Technology Corporation.

The book was conceived by Nikkei editor Hiroki Yomogita, who visited Linear several times, and for two years served as a Nikkei Electronics editor based in Silicon Valley. Mr. Yomogita researched this book via visits to Linear Technology and other sources, and co-authored the book with Kyoko Katase. The authors chose Linear Technology as a case study, as it presents a unique business model that they felt would interest the business community in Japan. Linear Technology, a high performance analog semiconductor company, has been in business for over three decades, and was started as a venture-funded Silicon Valley company—a model that interests many in the Japan technology community.

According to Linear Technology Co-founder and Executive Chairman Bob Swanson, “After reading the English translation of the book, I find that some aspects of the book are accurate depictions and some are fiction—but it’s good fiction. I thought it would be of interest to some people in the Linear community and beyond to see how our business model is depicted by Japanese writers. Enjoy.”

Foreword

Linear Technology Corporation is a company based in Silicon Valley that specializes in developing and designing analog semiconductors. Over the 30 years since it was established, it has continued on a strong growth trajectory.

To people familiar with the industry and industry insiders, this company is well respected for its high quality products. However, those outside of the industry have probably never heard of the company, so I would like to introduce the company to them and others like them as follows:

Linear Technology Corporation hires talented employees and lets them grow at the company through their work, resulting in a company that no one wants to leave.

If business is good, then workers receive good remuneration. And, if remuneration is good, there's no reason why anyone would want to leave.

It's easy to generalize the reasons that people do not leave the company with such a short and simple statement. However, is that really the case? Perhaps it's not completely accurate. The remuneration at Linear Technology is not significantly higher than that of other companies in the same business, and there are other reasons that most employees have for leaving a company. In fact, the reason Robert Swanson had for leaving a large semiconductor manufacturer and going on to found Linear Technology Corporation was not related to money.

So, in a word, what is it about Linear Technology Corporation that attracts highly talented engineers? That is the question I wanted to answer, and so I proceeded to investigate.

I discovered that Linear Technology has in place some company policies that at first appear odd, but make a lot of sense if you listen closely. Let me give you some examples:

- Do not replace old products with newer ones
- Withdraw from markets where the numbers are predictable
- Keep a large inventory, where most say less is best
- Do not focus production at one factory to improve efficiency

These policies express what makes Linear Technology Corporation unique. In order to reinforce the “DNA” of the company, they sometimes had to look past immediate cost and short-term efficiency. It’s evident that this is not so simple. Many companies have said, “If only we hadn’t stumbled by being fooled into focusing only on the short-term.”

So how has Linear Technology been able to grow steadily over 30 years? I have set out to answer this question.

— Kyoko Katase

Introduction

I set out to interview the people at Linear Technology Corporation at their U.S. headquarters in late January 2012. It was still very cold in Tokyo.

On Monday, after finishing my daily work, I headed home to pack my clothes, and flew out of Haneda Airport on a late night flight. After two days of interviews, I left San Francisco on Thursday afternoon, and by Friday afternoon, I was back at Narita Airport. You could say it was quite a “whirlwind tour.”

John Hamburger, Director of Marketing Communications at Linear Technology, was the one who kindly set up all the meetings at their headquarters. He gave me a full tour of the campus, from the analog semiconductor design floor to a cafe where the employees enjoy a pleasant, casual lunch. He invited a co-worker of the late Jim Williams to come by and talk, and took me to the Computer History Museum (located in Silicon Valley) where they had Mr. Williams’ circuit board-filled desk on display. He even asked the museum to stay open later to accommodate us—he really went out of his way for us.

I had only planned to interview the Executive Chairman and the CEO, but I wanted to learn more about the DNA of Linear Technology Corporation. Assuming I’d be turned down, I asked John Hamburger, “Is it okay if I come tomorrow as well?” I was delighted when he responded, “Of course! Please ask me anything.” The next day I visited and it just so happened that legendary analog guru Bob Dobkin (CTO) was there that day, so I was able to meet and speak with him. Although my visit was short, thanks to their open and inviting spirit, I was able to understand the atmosphere of Linear Technology Corporation.

Actually, more than the word “atmosphere,” I would call it an “air of intrigue that is unlike any other company in Silicon Valley.” When it comes to the West Coast of America, there is a strong image of people changing jobs regularly in order to advance their careers. The idea of working at a single company until you retire is a very Japanese concept, so I was surprised to find that most employees at Linear Technology Corporation indeed work there until they retire. There were other things that made it feel less like a Silicon Valley company and more like a Japanese small factory, such as how they don’t use voice mail and, until recently, orders were placed by fax, not by email.

I think it’s wonderful that a company that is “unlike any other company” also has one of the highest profit margins in the world. Being a person who loves to go against the flow, I find it incredibly appealing that, while everyone is moving toward digital, there is a company that walks their own path toward analog, and their contrarian business style has allowed them to remain highly profitable, in both good and bad times.

I would like to extend my deepest gratitude to Robert Swanson (Executive Chairman of Linear Technology Corporation), Lothar Maier (CEO), Bob Dobkin (CTO), John Hamburger, Yasushi Mochizuki (Sales Director of Japan for Linear Technology), and the Linear Technology Japan office for their incredible support and advice in the creation of this publication.

I find Linear Technology to be a fascinating company. As I have written in this publication, I believe that Japanese companies can learn a lot from them. I am looking forward to what they do next.

— Hiroki Yomogita
Deputy Editor
Nikkei Electronics

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There is an Amazing Company in Silicon Valley

Support for the 2,000 LED Lights on the Tokyo Sky Tree

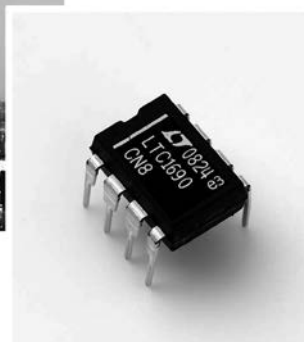
The towering Tokyo Sky Tree thrusts up into the Japanese sky. The beautiful lights that adorn this edifice, the highest radio tower in the world at 634 meters, glitter and sparkle in the night sky. As many as 2,000 energy-saving LED lights are used to produce this lighting effect. Incidentally, did you know that the special components essential to the stable operation of these LED lights were supplied by a manufacturer in the United States? These are extremely important components that monitor LED light illumination status remotely and enable reliable control over a span of many years (Figure 1.1a).

The LED lights on the Tokyo Sky Tree are but one example of the use of these components. Components produced by this manufacturer are used in all kinds of well-known structures and industrial equipment, as well as the hybrid car, Prius—the pride and joy of Toyota Motor Corporation around the world—and NASA space missions, including the Mars Curiosity rover and the spacecraft that delivered it to Mars. Among the other products manufactured by this company are many components that only this manufacturer can

produce, and components for which the company owns greater than 90% share.



(a)



(b)

1.1: Tokyo Sky Tree (a) and the Analog IC Used (b)

Linear Technology Corporation's analog ICs are used to ensure the stable operation of the approximately 2,000 LEDs mounted on the Tokyo Sky Tree.

Tokyo Sky Tree photo courtesy: Flownage Photos/Flickr/Getty Image

The company that supplies these components is an outstanding American semiconductor manufacturer. Semiconductors are black devices that look something like multi-legged centipedes and are referred to by terms such as LSI and IC (Integrated Circuit).

The Japanese semiconductor industry has been recently resounding with talk of economic downturn, as demonstrated by cases such as the much-discussed business failures of Elpida Memory Inc. and Renesas Electronics Corporation, which cut its workforce by one

third. However, the company that supplied components for the Tokyo Sky Tree couldn't be doing better and recorded its highest level of profits ever in 2011.

Why has this company been prospering so well when Japanese semiconductor manufacturers are struggling to survive? Why are the products of this company used in all kinds of well-known structures and products? Closer scrutiny of this puzzle will reveal not only the reasons for the Japanese semiconductor industry's descent into a state of crisis but also issues confronting production industries and important hints for the future growth of Japanese companies. This company has faced and overcome all the problems currently facing Japanese companies including employment, innovation and advancing into overseas markets head-on.

The company in question is located in Silicon Valley in the state of California, United States of America. When you think of well-known companies in this area characterized by dry climate and expansive lush orchards, names like Facebook, Google or Apple may come to mind, but the company we're talking about is not one of these.

The name of this company is Linear Technology Corporation. Many people have probably never heard this name before, but the successes of this company make up an abundance of elements from which we must learn, especially now.

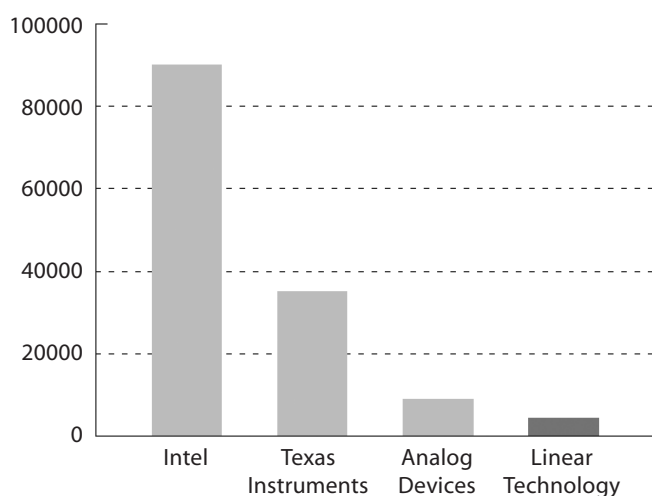
Successful Realization of a Profit Ratio of Approximately 40% for Ten Straight Years

Linear Technology is a semiconductor manufacturer established in Milpitas in the state of California in 1981. Positioned in the center of the area known as Silicon Valley, the city of San Jose is located approximately 70 kilometers south of San Francisco, a metropolis located in northern California.

Linear Technology employs a workforce of approximately 4,400 personnel, a small number compared to other companies in the same industry such as Intel, which has a workforce of roughly 90,000 and Texas Instruments Incorporated, with about 35,000 (Figure 1.2).

This company maintains its headquarters at the same location where the company was originally established. Highway 101 passes through the San Jose belt and extends as far as Los Angeles. Linear Technology Corporation is located approximately 20 minutes north of the San Jose turnoff on 101. Like other companies in Silicon Valley, the office building is low but wide with expansive white walls, and its staff including engineers, marketing supervisors and the CEO (Chief Executive Officer), as well as other lower-level executives, work side by side here. At a glance, the company looks very much like other companies in Silicon Valley.

One point worthy of special mention is the high profit margin of this company. The company recorded a sales volume of 1.48 billion U.S. dollars in FY2011 (July 2010 – June 2011), of which the operating profit was 767 million U.S. dollars, more than 50% of the sales volume.



1.2: Workforce Size of Major Semiconductor Manufacturers

We compared the workforce size of Linear Technology Corporation with those of other semiconductor manufacturers. For example, Intel Corporation, the top microprocessor manufacturer, employs a workforce of approximately 90,000. Looking at rival analog semiconductor manufacturers, Analog Devices Inc. has a workforce of approximately 8,900. Linear Technology Corporation employs a workforce of approximately 4,400 (figures derived from documentation of each of the companies cited).

It is not only the current fiscal term during which the company has realized high income. Over the last ten years, Linear Technology Corporation has realized an average profit ratio (ratio of net profit of the sales volume) of 36.8%. At its highest, the company has achieved a profit ratio of 43.9% and the figure averaged over 4 quarters has often approached 50%. From these figures alone, Linear Technology Corporation can be regarded as a truly outstanding company.

Even Intel Corporation, the world's leading manufacturer of the microprocessors that act as the "brains" of computers, has achieved no more than a profit ratio of about 20% to 40% (operating profit ratio). The operating profit ratio of Qualcomm, the world's leading manufacturer of microprocessors for smartphones, is around the 30% mark, on a par with or in excess of levels of other companies in the same industry. Low profit ratios of approximately 1% to 3% that are causing Japanese semiconductor manufacturers so much grief do not bear comparison with these figures.

Moreover, Linear Technology Corporation has consistently maintained this extremely high profit margin for almost twenty years. This company has weathered events such as the financial crisis (the so-called "Lehman Shock") that hit in 2008, the economic crisis brought about by 9/11, and the collapse of the dotcom bubble. It continues to maintain a healthy track record.

Dedicated Analog Semiconductor Manufacturers

Although Linear Technology Corporation is a semiconductor manufacturer, it differs slightly from companies such as Intel, the well-known microprocessor manufacturer. Rather than semiconductors such as microprocessors that handle digital signals, Linear Technology produces analog semiconductors (analog ICs).

So, what do we mean by "analog"? No doubt, a lot of people would ask the same question. The term "analog semiconductor" used here refers to almost all products except for semiconductors that handle digital signals.

In Japan, many people probably have the impression that analog technology is old or outdated. Taking landline phones in homes as an

example, phones on which the number is dialed by turning the dial on the phone are analog types, while pushbutton phones where the number is input using buttons on the phone emitting a small bleep when pressed are digital types. However, the word “analog” appearing in this book is not used as synonymous with “old.” Here, it refers to signals handled by devices.

Analog ICs handle signals that are different from those handled by digital ICs. Digital ICs are devices that handle digital signals “0” or “1,” while analog ICs handle constantly fluctuating elements such as current and voltage values. Taking the smartphone as an example, the core semiconductor that shoulders the burden of all kinds of digital signal processing is called a microprocessor (also known as an application processor), while devices that store data are memories such as DRAMs and flash memories. Because these semiconductors all handle digital signals, they are known as “digital semiconductors.” Digital semiconductors feature several thousand to several tens of thousands of elements that register only the two statuses of “0” and “1,” enabling advanced logical operation processing in an extremely short period of time.

On the other hand, the same smartphones also contain components such as “signal amplifiers” (amps) used to enlarge the output of transmitted signals when radio waves are transmitted from antennas; “wireless ICs,” which perform functions such as conversion and facilitation of reading of frequencies to make signals received from antennas easier to handle internally; and “power supply control ICs” that perform adjustments to make power from internally mounted batteries easy to handle by the various internal circuits. Because they handle analog signals, these are known as “analog semiconductors,” “analog components” or “analog-digital mixed signal semiconductors.”

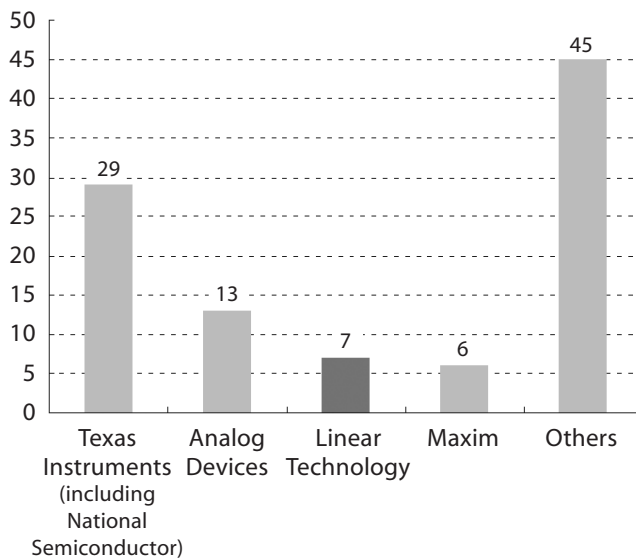
Digital semiconductors such as microprocessors specialize in the receipt and high-speed processing of “0” or “1” information. In the natural world, information never takes the form of “0” or “1.” For this reason, continuous streams of information in the natural world (analog information) need to be converted into digital signals so that

they can be readily processed by digital semiconductors. Continuous streams of information from the natural world (e.g., current and voltage values) are converted into noncontinuous “0” or “1” information. In other words, Linear Technology Corporation manufactures components such as amps, power supply ICs, data conversion ICs and wireless ICs for the processing of continuous streams of information.

Linear Technology Corporation monopolizes one corner of the field of major manufacturers who design, produce and sell these analog ICs. From the time of its establishment, the company has supplied high-performance analog semiconductors used, for example, on telephone lines and in signal processing circuits. ICs manufactured by Linear Technology Corporation are used mainly in industrial devices and large industrial facilities, in automotive electronics and in mobile telephone network base stations. For reference, analog IC manufacturers in competition with Linear Technology Corporation include Analog Devices Inc., with its headquarters in Boston, Massachusetts in the United States (workforce: approximately 8,900, sales volume: approximately 2.8 billion U.S. dollars); Texas Instruments Incorporated (TI) with its headquarters in the state of Texas, United States (workforce: approximately 35,000, sales volume: approximately 13 billion U.S. dollars); and Maxim Integrated Products Inc., a company that, like Linear Technology Corporation, was born in Silicon Valley (workforce: approximately 9,300, sales volume: approximately 2.5 billion U.S. dollars) (Figure 1.3).

The largest of these enterprises is Texas Instruments, a company that produces not only analog ICs, but also digital semiconductors. Texas Instruments was the company where Jack St. Clair Kilby, known as the inventor of the integrated circuit (IC), worked. For a long time now, this company has manifested its prowess over a range of products—from ICs for electronic calculators to audio and digital control devices. In addition, repeated acquisitions of analog component manufacturers have resulted in the expansive analog semiconductor portfolio that characterizes this company.

In addition to owning an extremely high share of the market for A/D converter and D/A converter devices, which perform functions such as conversion of analog signals into digital signals and vice versa, Analog Devices is a company that is also engaged in digital semiconductors known as DSP (digital signal processors). Meanwhile, like Linear Technology, Maxim Integrated Products is a company whose forte lies in its analog semiconductor portfolio. Incidentally, although there are also analog IC manufacturers in Japan, there are none on the scale of enterprises such as Linear Technology or Analog Devices. Of all the countries in the world, the United States is the place where large numbers of analog semiconductor companies have emerged. Linear Technology has realized continuous growth through a process



1.3: Analog Product Market Share (General-Purpose Analog Products in 2010)

This figure shows an analysis of general-purpose analog products for 2010 (including products such as analog ICs) conducted by the American market research company Databeans, Inc. The total combined shares belonging to Texas Instruments (TI) and National Semiconductor Corporation (NS), a company acquired by TI, occupy the top place. TI announced its acquisition of NS in April 2011. According to this share analysis, Linear Technology occupies third place overall with a 7% share.

of improvement through rivalry with its competitors. The high profit ratio achieved by Linear Technology in such a competitive market is undoubtedly worthy of special note.

No Acquisitions or Mergers in 30 Years

Since its establishment, Linear Technology Corporation has engaged in almost no corporate buyouts or mergers, an extremely rare phenomenon among Silicon Valley companies. Dust Networks, Inc., a wireless sensor network-related company acquired in December 2011, is the only company that Linear Technology Corporation has acquired in the 30 years since its inauguration.

Companies born in Silicon Valley operate through financing for operations and capital investments from sources such as venture capital investors. This is why investors expect consistently high long-term growth. Sales volume and earnings are constantly under scrutiny.

Corporate buyouts are sometimes a good way to realize high growth at an early stage. In many cases, investors actively promote corporate buyouts. Active pursuit of corporate buyouts is also a normal practice to achieve goals such as the launch of new businesses or further reinforcement of strong business fields. Probably less than 0.5% of companies established in Silicon Valley have survived for more than 30 years without engaging in corporate buyouts or mergers. In the tough, “dog eat dog” world of IT and semiconductor industries especially characterized by rapid changes of fortune, such cases are almost nonexistent. Linear Technology Corporation is the only exception to the rule.

In common with many other enterprises, Linear Technology Corporation also had plans for the acquisition of a digital signal processing manufacturer with the aim of launching digital-related business. However, the acquisition was abandoned after Linear’s management determined that it is not possible to develop strengths in areas outside the company’s expertise. We will be looking at the philosophy of Linear Technology Corporation on acquisitions later.

Products from 30 Years Ago Are Still Being Sold Today

High profits are not the only aspect of this company that is intriguing. The company's product strategy is also truly unique. One aspect of this that is surprising is the company's basic policy of not discontinuing a product once it has been put on the market. Even now, products that were being sold at the time of the company's establishment 30 years ago are still selling steadily. "It is our policy not to discontinue a product once it has been launched on the market unless special circumstances arise, such as the necessary raw materials becoming unavailable" (Linear Technology Corporation). For example, the IC, LT1001, that was launched on the market by Linear Technology Corporation in 1983 can still be purchased on websites almost 30 years later.

A look at other companies engaged in the semiconductor business reveals that companies adopting this kind of policy are extremely rare. In particular, the circuit line width used in the design of digital ICs that handle digital signals is becoming finer and finer with the passage of time (process refinement), making it possible to produce ever smaller ICs capable of the same functions. In digital ICs, the finer the line width of the circuit, the smaller the circuit that can be fabricated for the same function. This ability to miniaturize is an extremely important point. This is because semiconductor circuits are produced from chips cut from a single circular plate approximately 300 millimeters in diameter called a wafer, and a small circuit line width and chip size make it possible to produce a high yield of chips from a single wafer. In other words, the finer the circuit line width, the greater the chip yield from a single wafer, enabling reduction in the production cost per chip. Because of this, new digital semiconductor products featuring fine circuit line widths are appearing one after the other, with the result that existing products are constantly disappearing from product catalogs.

Rather than this kind of digital IC, Linear Technology Corporation produces analog ICs. This is why it is not possible, for example,

to downsize ICs simply because of process refinement or to reduce prices. The company produces difficult to fabricate, extremely high-precision ICs that remain unrivalled by other commercialized products even after 30 years.

There is one more aspect that stands out amid the uniqueness of Linear Technology Corporation: once recruited, almost no one on the staff of this company has resigned. The reason for 95% of the cases of personnel resigning from the company is retirement upon reaching retirement age. There have been almost no incidents of personnel leaving the company to move to other companies, for example.

In particular, circuit designers (design engineers) who design analog ICs almost never leave the company, with the exception of cases of personnel reaching retirement age. Why is the job turnover at Linear Technology Corporation so low? We will be examining this issue in greater detail later.

Revolutionary Concept 1: Analog, Not Digital

The reason for the maintenance of a high profit ratio by this unique company, Linear Technology Corporation, is that it has taken on concepts that are contrary to those of many other companies. This company has adopted a managerial approach that might be called “contrarian management.”

Broadly speaking, Linear Technology Corporation embraces the following three revolutionary concepts.

- (1) Focus on analog rather than digital
- (2) Defocus from the consumer electronics marketplace
- (3) Focus on experience and mentoring

In 1981, the year when Linear Technology Corporation was established, the world was buzzing with the digital revolution. Companies that produced semiconductors such as memories and microprocessors using digital technology emerged one after another

and new devices and media that used these products were making their appearance.

In Silicon Valley, too, this was a time when enterprises focused on digital technology were constantly emerging. In the midst of all this, Linear Technology Corporation boldly chose to go with analog devices. Robert Swanson, the founder of Linear Technology Corporation, recalling the era, said, "No one was interested in analog technology in those days. When I approached investors, I was met with responses such as, 'This is the digital era. The analog era is over. What on earth are you thinking?'"

However, it is fair to say it was the fact that Linear Technology did not go down the same path as other companies that has led to its present day success. If, like other companies, the company had set up venture management with the focus on digital technology, it is likely that it would have had no hope of achieving such a high profit ratio and would probably not have survived for as long as 30 years. This is borne out by the fact that almost all the countless digital IC manufacturers that appeared in those days have disappeared.

Unwavering commitment to the revolutionary concept of choosing analog during the golden age of digital technology is surely why the company has survived for 30 years and is undoubtedly the driving force behind realization of high profits envied by other enterprises.

Revolutionary Concept 2: Defocus from Consumer Product Marketplace

Another of the intriguing revolutionary concepts of Linear Technology is its policy of not focusing on semiconductor products for consumer devices. In other words, the company does not focus on general-purpose components for consumer products that many other manufacturers are frenziedly pursuing, such as smartphones, televisions and PCs.

At a glance, markets for these types of consumer products would seem to have great appeal. Products for the mobile phone device market, where almost 1 billion units are shipped each year, offer the prospect of high shipment volumes. Even if used in only one type

of device, the volume of products shipped would probably be in excess of several tens of thousands of units. According to the head of a certain analog semiconductor manufacturer, "Consumer markets are very important to us." In media such as newspapers and magazines, the main focus in the field of electronics is consumer products such as smartphones and televisions, and this is also apparent in "star products" in certain types of electronics fields. It might seem as if the decision not to handle such star products would result in a niche path.

However, Linear Technology Corporation has adopted a policy of distancing itself from these consumer markets. The reason for this is clear. The final consumer device product is subject to tough price competition and this means that component and materials manufacturers cannot increase their profits. When discussing reasons for defocusing from the consumer market, Robert Swanson, the founder of Linear Technology Corporation, put it this way: "At the end of the day, customers for consumer products make very stringent price demands. In these markets, the demand is for steady decreases in prices. There is no way that we are going to expend our invaluable engineering resources on such low-profit markets."

In the past, Linear Technology Corporation produced semiconductor products for devices in the consumer market. However, because such products yielded low profits compared to products in other markets such as industrial and medical, in 2005 the company made a major change in direction by adopting a policy of defocusing from such products. The price of the components for consumer applications can be expected to drop by half in a matter of a few months. This is why it is difficult for a components manufacturer like Linear Technology Corporation to realize stable profits. No doubt, it is because Robert Swanson, a powerful and charismatic manager, was on the scene that the company succeeded in achieving this immense change in strategy of defocusing from the consumer market.

Linear Technology Corporation made the decision to defocus from consumer markets at an early stage. This change in manage-

ment strategy has been an obvious success. While many semiconductor manufacturers that fabricate semiconductors for devices such as smartphones and televisions are struggling with low profits, Linear Technology Corporation is enjoying a profit margin of 40% or more. No doubt, to Japanese semiconductor manufacturers, the magnificent transformation of Linear Technology Corporation is seen as a truly dazzling achievement.

In adopting the strategy of distancing itself from consumer markets, the company braced itself for difficulties and some employees also found themselves in a predicament. We will discuss the experiences of the company at that time in more detail later.

Revolutionary Concept 3: Senior, Experienced Members of Staff Provide Mentoring to Bring About Innovation

The third revolutionary concept of Linear Technology Corporation is the value it places on mentoring by its senior engineers. According to Lothar Maier, the CEO, "Technical innovation is extremely important for Linear Technology Corporation. It is our senior engineers with their extensive understanding of elements such as technology, customers and markets, who bring about such innovations. This is something that inexperienced personnel cannot imitate. Personnel probably need ten years of experience and mentoring before they will be acknowledged as senior engineers by Linear Technology Corporation."

While understanding the importance of its young engineers, Linear Technology is even more respectful of its senior engineers. It takes time to get to know customers and markets. It is because of their extensive experience that senior engineers are able to create products with high added value that will gain market acceptance unrivalled by other companies. Almost all personnel in management have technical backgrounds and this is why they have a good understanding of this concept.

This both illustrates the company's stance of placing the focus on its senior engineers and also explains why such personnel stay with the company. The only explanation for personnel pledging long-term allegiance to Linear Technology Corporation, much as in the Japanese system of employment for life, and continuing to bring about innovations is that the company has a corporate culture that values engineers.

When you enter the headquarters of Linear Technology Corporation, you will see electronics-dedicated magazines that feature the successes of the engineers of Linear Technology Corporation on display along the corridors, as if the company is displaying the prowess of its senior engineers. (Figure 1.4)



1.4: Display of Framed Magazine Covers

Corridors are lined with framed covers of magazines in which the company has been featured.

Photograph: Koichiro Hayashi

Voice Mail Was Not Used

In relating the corporate culture of Linear Technology Corporation, there is one more aspect of interest worth mentioning and that is the extreme value the company places on direct communication, both between employees and between employees and customers.

As John Hamburger, Director of Marketing Communications, says, "Meeting people in person and talking directly: this is the most basic and important thing."

For example, when taking phone inquiries from persons such as customers, unless it is absolutely unavoidable, voice mail is not used by the company. If the supervisor concerned is not available, a colleague takes the call and passes on the message to the supervisor. Needless to say, the person taking the message does not use voice mail to pass on the message to the supervisor concerned.

The same applies even when holding small meetings. First, the organizer of the meeting calls the other persons involved and, if they are unavailable, leaves a message with their colleagues to have the people concerned call back. The approach of leaving messages on voice mail is avoided as much as possible. It seems that the company has an extreme prejudice against voice mail.

Well-known engineers at Linear Technology Corporation have business cards of customers from all kinds of major electronics companies lined up on their desks so that they can call them whenever necessary. It seems that, even today, there is a strong feeling in the company that direct communication by phone is superior to e-mail.

And that's not all. Linear Technology Corporation adopted e-mail long after other companies. Even though many other companies introduced e-mail systems in the early years of the 21st century, Linear Technology Corporation did not make much use of such systems. For this reason, companies doing business with Linear Technology Corporation placed and received orders mainly by fax rather than e-mail. According to a supervisor at a certain components manufacturer that does business with Linear Technology Corporation, "The persistent use of faxes gave the impression that Linear Technology Corporation

was an extremely unique company. It occurred to me that the company's 'analog-like' approach of placing emphasis on orders by fax, a media that everyone had grown accustomed to over the years, was typical of Linear Technology in a good sense."

The company's late introduction of voice and e-mail systems, for example, can be traced to the thinking of the company's founder, Robert Swanson. As Robert Swanson may have said, "I won't jump to a new system without a deep-rooted understanding that its adoption will be really meaningful. What's wrong with using faxes instead of e-mail? What's the difference?" One can picture Robert Swanson barking comments like this as he turned down repeated proposals at management meetings to introduce the use of e-mail. Linear Technology has fermented a unique corporate culture that, while imbued with frankness typical of Silicon Valley, is extremely conservative when it comes to introducing new systems. This is also an episode that reveals one aspect of the company's culture.

However, it would be wrong to interpret this as the "fixation of someone passionate about analog." Swanson saw through the fear of digitization. While it's no easy task to steal confidential information covering countless sheets of paper, the same information in digitized form can be removed from the premises or copied with ease.

This is an Engineer's Paradise

It was mentioned earlier that the design engineers engaged in the design of semiconductor products at Linear Technology Corporation almost never resign. Let's think about the reasons for this.

Broadly speaking, there are three reasons.

- (1) Engineers can expect high remuneration;
- (2) Engineers have a high degree of freedom when it comes to product planning and development; and,
- (3) Engineers have the opportunity to work with analog designers (analog gurus) widely known and highly respected around the world.

First, the total cash compensation of engineers at Linear Technology Corporation is high, even compared to those offered by other companies in the same industry. Although the company does not release exact figures, it is probable that the average annual income is in excess of \$150,000. Since the company has consistently realized a high profit ratio, employees can receive proportionate performance-based bonuses every year. At the high point, all personnel were awarded profit sharing equivalent to more than 50% of their annual incomes. Stock options are another perk that employees look forward to. Improved company performance results in increases in the value of its shares and consequent increases in profits when stock options are exercised.



1.5: Engineer at Linear Technology Corporation

Engineers at Linear Technology Corporation are responsible for the entire process from planning, development and manufacture of new products to sales and marketing. Meeting with customers directly to investigate needs and proposing product planning is also part of the engineer's job.

Second, the high degree of freedom engineers enjoy when it comes to product planning and development arises from the fact that the entire new product process at Linear Technology Corporation, from product planning, development and production to sales and marketing, is entrusted to engineers. Engineers at Linear Technology Corporation initially visit customer companies to investigate needs. Based on the results, they plan products they then propose to the company. The next step is development and engineers are then involved at all the subsequent stages of manufacture of the developed product, cost price management, construction of supplier chains, worldwide marketing and handling of after-sales inquiries from customers. This approach of leaving all these tasks in the hands of a mere engineer resembles a venture company with only a few employees (Figure 1.5). "Engineers at our company are very different from those you will find elsewhere," stated Steve Pietkiewicz, VP and General Manager, S Power Products at Linear Technology Corporation. "All our employees have a grasp of elements ranging from market requirements to cost management and costs relating to marketing. An engineer is involved at all stages of a product he has planned right up to the business launch phase."

It is surely only at Linear Technology Corporation that an engineer can, not only be involved in product design, but can also be in touch with so many diverse aspects of business. Engineers also travel overseas on business quite often, enabling them to learn about global markets. The development of outstanding products is impossible without knowledge of markets and customers.

Needless to say, compared with engineers at other companies who need only design products, engineers at Linear Technology Corporation are confronted with many aspects to which they are unaccustomed and have to overcome numerous challenges, but they undoubtedly enjoy an elevated sense of freedom that comes from being able to achieve a wide range of undertakings in their own way.

When an engineer has an idea for a certain product that he thinks is necessary, he makes a proposal to his superior. In such cases, almost without exception, the superior concerned will give the engineer the go ahead. "At Linear Technology Corporation you won't find silly instances where it takes a superior three months to give their approval. All managers give designers their full support," remarked Steve Pietkiewicz.

"This is What Dobkin Said"

The third reason that engineers do not leave Linear Technology Corporation is that they have the chance to work alongside famous analog gurus.

Analog IC circuit design is said to be "a kind of art" and belongs in a world close to that of the art of craftsmen. An IC circuit consists of arrays of several tens to several hundreds of millions of circuit elements, such as transistors and capacitors of microscopic dimensions. Factors such as how wiring is laid out to connect these elements, and where to accumulate an electrical charge are all dependent on the creativity of the designer. This is why the designer can produce creative circuit designs much in the same way an artist produces an oil painting. Given 100 engineers, it would be possible to create one hundred, or rather 10,000 different circuit designs. This is why analog IC design is called "art." (Figure 1.6)

In this world of analog IC design, there exist engineers who are revered as "masters." This handful of outstanding analog circuit designers are referred to as "analog gurus" (analog masters). These are the masters or teachers of circuit design.

Bob Dobkin, a super engineer acknowledged as an analog guru, is co-founder and Chief Technical Officer of Linear Technology. Jim Williams was another super engineer and analog guru that Linear Technology Corporation was proud of, and reports of his sudden death in 2011 sent shock waves throughout the industry. The existence

Charismatic Founder Who Spearheads This Unique Company

Linear Technology Corporation is a company that maintains a high level of morale with its employees while, at the same time, consistently producing a good business track record. The driving force behind this excellent company is its founder, Robert Swanson. It is fair to say that Swanson's intense individuality has forged this unique company and maintained its unique culture.

Before he established Linear Technology Corporation, Swanson worked at National Semiconductor Corporation, a company also in the semiconductor industry. There, his duties included responsibility for European market operations and manufacturing plant control.

National Semiconductor Corporation, established in the state of Connecticut in the United States in 1959, was initially a transistor company, and later became an early pioneer in analog IC design. Subsequently, however, the company became increasingly diversified and, as well as semiconductors, started handling products such as electronic calculators and office systems, going on to components such as digital semiconductors and microprocessors. After relocating the company's headquarters to Santa Clara in the state of California in 1967, the company established its prominence as a Silicon Valley semiconductor manufacturer.

As its business expanded, the importance and share of analog IC business within the company diminished. Swanson strenuously opposed the neglect of the company's analog IC division and the shift to digital business, and this prompted him to establish his own analog semiconductor company, along with Bob Dobkin, a noted designer at National.

Even after Swanson had established Linear Technology Corporation, National Semiconductor Corporation continued to diversify and grow. In 1987, National Semiconductor Corporation began promoting expansion of the scale of its business through both analog and digital IC strategies by taking steps such as the acquisition of Fairchild Semiconductor, a company belonging to the same industry. However, factors such as the worsening of its financial performance led to

a slowdown in the growth of National Semiconductor Corporation, resulting finally in the company being bought out by Texas Instruments, another player in the same industry, in 2011 for approximately 6.5 billion U.S. dollars.

Meanwhile, regardless of the digital-oriented trend of the times, Swanson maintained his preference for analog technology at the other end of the scale, and subsequently parted ways with National Semiconductor Corporation. The growth of Linear Technology Corporation, through its specialization in analog ICs spanning the long 30 years since its founding, is due to Swanson's strong resolve "not to pursue both analog and digital technologies as if chasing after two hares."

As this illustrates, Swanson is brimming with rebellious spirit. As Swanson always says, "Linear Technology will never pursue fads." It is because the company did not pursue short-lived fads that it now stands at the very forefront of the trend for "renewed awareness of analog."

The movement toward renewed awareness of analog technology has been gradually growing over the last 10 years. Back in the early 1980s, many companies changed direction to adopt the digital technology that was just emerging at the time, resulting in diminished analog development. Many semiconductor companies in Japan, too, cut back their analog divisions and cut down on development proposals. This was a time when many analog engineers transferred to digital divisions or lost their jobs.

But now, we are seeing a reversal taking place. Companies no longer capable of realizing product differentiation due to advancing digitization are desperately seeking ways to achieve differentiation, and analog technology has become a significant candidate for consideration. Analog technology that cannot be easily imitated is resistant to obsolescence and, moreover, readily lends itself to the accommodation of differentiating elements.

Even if a semiconductor manufacturer that has abandoned the analog business wishes to change course and go back to analog, the

necessary human resources are no longer available. This is why a worldwide movement has arisen to seek out outstanding analog engineers. Skilled analog engineers can secure high salaries, especially in a region like Silicon Valley, where semiconductor manufacturers are concentrated and engineers are in great demand.

It is no exaggeration to say that Swanson, who was the subject of derision for his singular preference for analog technology in the past, is now standing at the helm of this movement toward a renewed awareness of analog technology. This development is exactly as Swanson had foreseen.

There is also a different aspect to renewed awareness of analog technology that has arisen, and that is that analog technology is essential to current global trends such as “expectations of new forms of energy” and “energy-saving technologies.”

An example of this is photovoltaic power generation, which has been attracting attention as a new energy technology. This technology involves the use of solar-cell panels to generate power from sunlight. Highly efficient power supply circuits are essential to related processes, such as the accumulation of generated power in storage batteries and usage of power applied to some kind of load. Poor efficiency in distribution and use of generated power results in wasted power. It is analog technology and analog semiconductors that determine the degree of efficiency for these processes.

This also holds true for energy saving. Often, the quality of analog semiconductors represents the determining factor when it is necessary, for example, to reduce power consumption by 10% or 20%. For instance, a situation could arise in which “although the power consumption of power supply ICs at Company-A is 1 W, the outstanding circuit design of power supply ICs at Company-B enables reduction in power consumption to 0.9 W.” In other words, when energy reduction is required, companies with expertise in analog technology have an opportunity to differentiate themselves from other companies. It is as if Swanson foresaw the advent of such an era and unreservedly invested his company’s in-house resources

into the development of analog technology, achieving subsequent steady growth.

Almost all employees at Linear Technology Corporation respect Swanson and, at the same time, stand in awe of him. This is because employees, either directly or indirectly, hear Swanson's frightening angry voice that booms out, for example, at product definition meetings. However, the general consensus of opinion in the company is that "Swanson is very strict and demands high standards, but he's always right in the end." Although feared as if he were a demon, the results he achieves also earn him the respect due a five-star manager. This is Swanson.

At 73 years old, Swanson relinquished the position of CEO to Lothar Maier in 2005, and now acts as executive chairman and advisor to the CEO. However, they say that he still puts in an appearance at weekly product planning meetings where he shoots out questions like a machine gun. Whispered comments can be heard from employees to the effect that "Swanson has calmed down to a great extent, but still hasn't reached the totally mellow stage."

This is the Path for Japanese Manufacturers

While training the spotlight on the style and thinking of this charismatic manager, Robert Swanson, this book also sheds light on the state of the extremely unique company, Linear Technology Corporation. This is because the diverse policies undertaken by this company are, without exception, models that would prove enlightening to Japanese companies. Needless to say, this is because Linear Technology Corporation has implemented differentiation strategies that are meaningful not only to companies such as semiconductor manufacturers that are currently in the midst of a crisis, or home appliance manufacturers struggling with reduced demand whose core products are items such as televisions, but to all manufacturers. How can a company recruit and hold on to outstanding human resources in the long term? What are the important factors in maintaining a high profit margin of 30% to

40%? And, how did Linear Technology Corporation manifest the contrarian concept of “going with analog technology during the golden age of digital technology” in its corporate decision-making? These are all questions to which Japanese companies are so earnestly seeking the answers.

If we trace the past and future of Linear Technology Corporation, we will probably find an abundance of hints that apply to the future business of Japanese companies. “I won’t walk down the same path as others. I won’t go along with the flow and take the easy approach of doing something just because others are doing it.” No doubt, readers will find many such examples of Swanson’s philosophy scattered throughout the pages of this book.

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Why Go with Analog Technology in the Golden Age of Digital Technology?

The 1980s, the Golden Age of Digital Technology

From the latter half of the 1970s into the 1980s, humanity was witnessing the diverse possibilities of digital technology.

Apple Computer (present day Apple Inc.) was established in 1977. The IBM PC, IBM's first personal computer, went on sale in 1981. The CPU (microprocessor) used in this computer was the 8088, produced by Intel Corporation in the United States, and it was this development that spurred Intel's rapid growth.

1982 saw the beginning of production of music CDs, accompanied by the launch of CD players onto the market. This was also the year in which NEC's personal computer, the PC 98 Series, made its debut in Japan.

Nintendo's family computer became available in 1983, followed in 1986 by the first "Dragon Quest" from Square Enix, as digital technology began permeating ordinary households.

In 1985, Microsoft's Windows was launched in the United States and this heralded the beginning of commercial use of the Internet in 1988. Four years later, 1989 saw the appearance on the market of Motorola's first mobile phone, the MicroTAC.

This was a time when products that had never existed before appeared one after another, bringing digital technology, something that seemed akin to magic, onto center stage.

Digital technology regards everything as noncontiguous data. Rather than a simple evaluation to distinguish between high and low volume, strength and weakness, or high and low density, digital technology handles data on a strictly “1” or “0” basis to find the target it seeks. Conclusions are reached by repeated selections of these “1” or “0” values. For a human being, the task of repeating the selection of these two values to distinguish between high and low volumes, strength and weakness, or high and low density, is a time-consuming and troublesome process, but for machines that specialize in simple tasks, this is an easy approach.

Analog phenomena in our world can be converted into digital format by a process called “sampling.” Sampling is a process that maps contiguous analog signals as noncontiguous numerical values.

This digitized data features a number of characteristics that cannot be found in analog technology.

First of all, digitized data is resistant to degradation. Data that has been reduced to values of “0” and “1” are easy to record in memory. This data is highly retentive. Although memory is vulnerable to elements such as static electricity or water, such exposure can be prevented as long as they are suitably coated, and, unlike videotapes, they cannot be severed or become entangled in reproducing heads.

A good example is image data taken by a digital camera. Unlike film or printouts, such data cannot be damaged by sunlight, torn or burned. Once shredded, important documents printed on paper completely cease to exist, but if digitized, such data can be printed out over and over again.

In addition, the media on which data is collected can be downsized. The content of countless video tapes can be accommodated on a single Blu-ray disk. Pieces of music from any number of analog records can be stored on a small iPod.

And it’s not only the media on which data is saved that can be downsized. Devices such as music players that read data from such

media and convert it into a form that can be perceived by human beings can also be downsized.

The changeover from vacuum tubes to transistors in radios not only resulted in enhanced sound, but also had a major impact in terms of downsizing. The brown tube television with its bulky depth was replaced by smart liquid crystal units thanks to the development of digital technology.

The streamlining of the environment for the handling of digital data was a process that began in the 1980s. Astonishing advances in semiconductor processes led to improved performance in processors that handle digital signals and expansion of memory capacity, enabling processing of large volumes of data at unprecedented speeds.

It was in the midst of this golden age of digital technology that, in 1981, Robert Swanson and Bob Dobkin established Linear Technology Corporation, a company specializing in analog technology.

Swanson, the Founder

Robert Swanson, the first CEO of Linear Technology Corporation, was born in 1938 in Boston, Massachusetts. Swanson graduated in Industrial Engineering Science from Northeastern University in the United States and chose Transitron as his first place of employment.

Although, at the time, Transitron was a leading company in the semiconductor industry alongside Texas Instruments, a later business failure prompted Swanson to move to Fairchild Semiconductor. Although Robert Noyce, Gordon Moore and Andrew Grove, who were later to establish Intel, were also with Fairchild Semiconductor, the company stalled in the latter half of the 1960's. At this point in time, Swanson moved to National Semiconductor Corporation. This was in 1968.

After joining the company, Swanson was put in charge of analog electronic circuits.* For his first five years in the company, he relocated to Germany and Scotland, where he acted as the driving force of the business in Europe. After returning to the United States, as vice president, he continued to drive the analog IC business for which he had won high acclaim.

* Correction, Swanson only became involved in National Semiconductor's analog business after returning from his European assignment.

National Semiconductor was originally a company that produced analog ICs, particularly operational amplifiers used for signal amplification. Operational amplifiers are essential for electronic devices that handle media in which audio, video and other data is accommodated. Without operational amplifiers, it would be impossible to adjust volume, for example. This meant that Swanson found himself in a starring position.

However, National Semiconductor was beginning to change tack toward digital technology. Witnessing Intel's rapid growth in the field of processors and the efforts Japanese companies were putting into digital technology, the company felt it needed to catch up. There was a sense of unrest in the company, arising from a fear of being left behind unless it made efforts in this direction. The company started work on processors, the focus of attention at the time, and directed its efforts toward integrated circuits called MSI and SSI, which were the precursors of LSI. The company was determined to achieve success even in digital technology.

Finding himself in the midst of this major upheaval, Swanson felt that achieving this change of direction would not be such a simple matter. He believed that catching up with the leading companies in the digital field would not be easy.

Digital products are the result of a condensation of diverse technologies. From this standpoint alone, the realization of a single product requires the involvement of many experts and takes a great deal of time. It was unimaginable that a late-starting manufacturer could easily acquire such technologies and stamina. From another viewpoint, in the world of digital technology, a manufacturer can achieve dominance with relative ease if it adopts human resource tactics.

On the other hand, Swanson also felt that the analog technology with which he had become so familiar over the years was being neglected. The sole subject of debate in the company was how to achieve growth in the field of digital technology. Swanson came to realize that analog technology was becoming a postscript. Years went by during which no new analog product appeared. The company's product

lineup of almost 100 products now included only a few that could be called purely analog devices.*

It wasn't long before Swanson's growing frustration with the company where he had worked for 14 years made him decide to resign.

Setting the Stage for a New Company

At this stage, it was inevitable that Swanson would set his sights on analog technology for his new company. Swanson was an analog expert. Just as he couldn't make cars or clocks, neither could he make digital circuits. He believed that if he was going to resign from a major company and take a chance, the only path for him to follow was to put his money on his own field of expertise. Moreover, he foresaw that, even if the world was going with the digital flow, analog technology would survive. As he saw it, "The more the digital revolution progresses, the greater will be the demand for outstanding analog products to support digital technology. I understood that the world was analog. I also understood that the analog world was eternal. I therefore believed that there would always be a place for analog technology."

In concrete terms, this is true. No matter how much digital technology may advance, the interface that enables human beings to use this technology cannot be anything but analog. This is because analog information is easier for human beings to understand. Indeed, one could say that human beings can only understand analog information.

People who can look at row after row of data in "0" and "1" format and understand the words, colors or music that such data expresses are extremely rare. Therefore, even if the data stored on media and sent through cables is digital, the conversion of such data from digital to analog format is essential if it is to have any meaning understandable by human beings. Conversely, to efficiently transmit and store information that human beings understand, such information must be converted from analog to digital format. Failure to realize effective digital-to-analog and analog-to-digital conversion would result in speech that sounds distorted, colors that appear drab and musical

* Correction, National Semiconductor's analog group consistently put out large numbers of leading edge products.

melodies that sound off-pitch. This is why everything cannot be digital. Analog technology must remain.

However, convinced that the golden era of analog technology was over, people and companies drawn by the appeal of digital technology were gradually withdrawing from analog technology. To Swanson, this represented a chance.

News of Swanson going independent spread within National Semiconductor and there were not many people who welcomed this. One could even go as far as to say that many people thought Swanson was being “stupid” or “reckless.”

But there were others who felt the same as Swanson. There were other entities moving toward establishing an analog company; companies such as Maxim, founded later in 1983, and Burr-Brown which later was acquired by Texas Instruments in 2000. Both these companies had been established in the belief that advances in digitization at the time would increase the number of opportunities for the use of analog technology. There were others who shared Swanson’s beliefs. Swanson was not alone.



2.1: The Founders of Linear Technology

The co-founders at the start of construction of the headquarters office building in 1982. Robert Swanson is second from the right, Bob Dobkin is second from the left, and Brian Hollins is at the right.

There was another aspect that spurred Swanson's determination to go independent, and that was the fact that it required only a small number of engineers to design an analog circuit.

To start up a digital business would require several hundred or several thousand engineers and, additionally, massive capital investment. On the other hand, Swanson knew from his experience that it was possible to realize a high sales volume with only a few outstanding analog circuit engineers. These circumstances were well suited to setting up a venture.

In 1981, the year the IBM PC appeared on the market, Swanson, Bob Dobkin and three other co-founders established Linear Technology Corporation (Figure 2.1). This was three years before National Semiconductor would launch sales of the first 32-bit processor.

"What Have These Linear Design Gurus Been Up To?"

Swanson going independent was big news in the semiconductor industry. In those days, job-hopping in the semiconductor industry was not unusual. However, the movements of the vice president of National Semiconductor, a major corporation, attracted an exceptional degree of attention. "I've heard that he's going to leave National Semiconductor and set up his own business."

It was said that Swanson's phone was ringing off the hook with calls from analog engineers who had heard this rumor. Many of these callers were analog engineers working in the companies that had begun to move toward digital technology and who were looking for jobs with Linear Technology. They, too, were experiencing the same kind of frustration as Swanson.

This encouraged Swanson. However, at the start-up stage, the company did not have the constitution to hire all those who wished to change jobs. In the end, three of the co-founders worked as engineers. These were Bob Dobkin, Bob Widlar and George Erdi.

Bob Dobkin used to work in the Analog Circuit Division at National Semiconductor with Bob Swanson. Before changing jobs, he was Chief Design Manager of the Advanced Linear Group.

Bob Widlar was the person who designed the first analog IC at Fairchild. His high level of skill earned him the nickname “god of the operational amplifier.”

George Erdi was widely known as the designer of the high-precision operational amplifier. At PMI, he was in charge of development of staple products such as the OP07 and REF01.

All three of these engineers were charismatic figures known in the industry as “Analog Gurus.”

Swanson used likenesses of these three charismatic characters in an ad for his company (Figure 2.2).

The ad included the catch phrase, “What have these linear design gurus been up to?” The answer to this question was the destination of these gurus—Linear Technology.

This ad captured the hearts of many analog circuit designers who hadn’t known what Swanson had been up to, as well as those who did know but had not taken action. There was no shortage of engineers who wanted to work with these much admired gurus and the number of people wanting to work at Linear Technology was on the increase.

WHAT HAVE THESE LINEAR DESIGN GURUS BEEN UP TO?

PLENTY.

These five designers used to have only one thing in common. They were responsible for the design of the industry standard linear IC's that are the underpinnings of the growing \$1 billion linear market. Now, they have something else in common. A company named Linear Technology.

In the linear world, a small band of pioneering linear designers have made most of the significant contributions to the industry. And now they've joined forces as a group to be reckoned with.

Linear Technology's vision of the state of linear designers will be seen introducing the next generation of design concepts and circuit technology.

We were founded in late 1983. Here, after a period of diligent preparation, we're ready to announce the next generation of linear circuits in the areas of precision, high speed, low power, and more. And we have an extremely modern fabrication facility, the process engineers, and the process to support our designers' concepts.

Linear Technology. For that name is the lack of your names here. And we'll fill this space in the next issue for the first in a series of new product announcements.

Linear. Our name may not be familiar. But the facts and reputations of our design team certainly are.

☐ I'd Like To Be Kept Current on Linear's Products

Name _____

Address _____

City _____ State _____ Zip _____

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2.2: The Ad Using Photos of the “Analog Gurus”

Ad that used photographs of the gurus, charismatic design engineers revered as “masters” in the analog IC industry. This ad carried the headline, “What have these linear design gurus been up to?”

This ad subsequently continued to be an icon that attracted engineers with a wealth of experience to Linear Technology.

The presence of these gurus proved to be an effective tool not only for recruitment, but also for sales.

This was because, once they heard the names of these gurus, Jim Williams, and others who had joined the company shortly after its inauguration, even those who hadn't heard of the newly emergent Linear Technology would say, "Ah, you mean the company where *they* work," and would need no further explanation.

There was only one impediment to setting up a workforce, and that was lawsuits. Not only Swanson, but also other founding members, as well as engineers who subsequently joined Linear Technology were originally from National Semiconductor. Although they themselves wished to change jobs to join Linear Technology in search of a more appealing workplace, from the standpoint of National Semiconductor, this represented a drain on engineers who knew corporate secrets. Countless lawsuits were filed over a period of seven years by National Semiconductor, accusing Linear Technology of headhunting its engineers with the goal of acquiring its corporate secrets.

Had National Semiconductor seen Linear Technology as a worthless venture, they undoubtedly would not have gone as far as they did. It could be said that the lawsuits that followed one after the other were testament to the fact that National Semiconductor itself acknowledged the technical skills of both Swanson and the others who had left the company.

Still, it is perhaps not surprising that this irritated this major company, since the other two co-founders were Brent Welling of Marketing and Brian Hollins of Manufacturing, both originally from National Semiconductor.

National Semiconductor claimed that, when Swanson left, "He even took the doorknobs with him."

Capital for the Manufacturing Plant Acquired from a Long-Distance Bus Company Subsidiary

From the early days of the startup of Swanson's company, venture capitalists in the United States already knew of the existence of Linear Technology and, compared to other venture businesses, this marked an auspicious beginning. However, the misunderstanding that analog technology was becoming outdated was rampant.

When approaching any venture capitalist, Swanson and his colleagues first had to assure them that, "Certainly the digital revolution is genuine, but for it to survive and become firmly established, outstanding analog technology is required."

At the beginning of the 1980s, it wasn't that difficult to put together venture capital. This is because the revision to U.S. tax laws in 1978 resulted in a reduction by half of tax levied on capital gains from approximately 40% to 20%. The amount of venture capital available continued to increase at a dramatic rate.

However, Swanson was unwilling to procure all the funding required for development, design and manufacturing from venture capital. This was because venture capitalists require shares as compensation for expenditure. The greater the degree of dependence on venture capitalists, the lower the ratio of shares owned by the founders.

In the end, Swanson stopped at a total of five million U.S. dollars procured from six venture capitalists. Since the dollar was worth approximately 250 yen at the time, this was equivalent to about 1.3 billion yen. This was the absolute minimum required for the start-up.

There are a number of customs relating to ventures and venture capital. One of these is the "closing dinner." Once the agreement has been successfully concluded, the closing dinner is held in an atmosphere of great reverence and respect. This is an event that celebrates the start of the venture capitalists on the venture.

On the afternoon of the day in question, Swanson had only just obtained the check for five million dollars. After taking the check to the Bank of America that he had contacted beforehand, he set out in high spirits for a well-known French restaurant in Los Altos in

Silicon Valley. It was here that he handed over the business plan to the venture capitalists involved. The venture capitalists had made the decision to invest with no real concrete understanding of what Linear Technology wished to achieve. In other words, Swanson had received their approval for 1.3 billion yen without explaining in detail what it was that he expected to achieve. Although Swanson said, "I think I am the first person ever to have done that," it later became apparent that he was wrong. There had already been a previous episode in which Intel had submitted business plans after the agreement had been signed.

At any rate, Swanson had at least acquired the minimum capital he needed.

The next challenge for Swanson was to procure the necessary capital to support analog IC manufacturing. For this, he would need to build a facility for approximately 7 million dollars, or about 1.75 billion yen, and would need manufacturing equipment of approximately \$10 million, or about 2.5 billion yen. This time, he approached banks rather than venture capitalists.

Every bank knew of Linear Technology and the high standards of technical skills of its members. Swanson was met with encouraging comments such as, "You certainly have a wonderful team," and all the banks he approached expressed willingness to provide financing with the proviso that he would put up collateral in the same amount. Needless to say, a venture that has just started up and is taking its first steps cannot raise such collateral. It seemed that he would have to rely on venture capitalists after all.

As Swanson was pondering this, he first found a builder who agreed to build Linear's manufacturing building at a cost of \$7 million with no requirement for Linear to put any money down. Second, a company from the Greyhound Group, famous for its long-distance buses, came to his rescue. This was a financing company called Greyhound Financial.

This company agreed to put up the \$10 million required for Linear's manufacturing equipment, with no collateral deposit from Linear. As

part of the deal, Greyhound invested \$2 million in the young company, providing the capital needed to get its manufacturing plant up and running.

Reason for Not Acquiring DSP

In 1983, Linear Technology launched sales of its first product, the LT1001, a high-precision operational amplifier that was to subsequently become an industry standard. At this point in time, the company still only employed only a few hundred personnel. This small kernel of personnel gave the world a product that is still selling 30 years later.

Next came the linear regulator. This is a device essential for the stable operation of power supply circuits indispensable in all kinds of electronic devices. Devices such as analog-to-digital and digital-to-analog conversion circuits were also launched. These devices serve to translate data from machine language into forms decipherable by people and vice versa. The company also produced switching regulators, devices that stabilize power supply. This lineup was further extended by DC-DC converters that convert direct current voltage into different direct current voltages.

Linear Technology's products operated without waste and provided high efficiency. Even in a small electronic circuit, operating the circuit by current flow or voltage produces loss. This is the same situation as with a car: No matter how flat the road, the car's tires will inevitably be exposed to friction and wear, and if you want to use the engine only to move forward, this will certainly involve the generation of heat. So, it becomes a matter of how you go about designing the tire and how the engine should be structured. This is where the skills of the designer come into play. The same applies to analog circuits. How do you design an efficient circuit?

Naturally, relevant theories can be found in text books. An analog circuit can be designed following these theories, but improving efficiency presents difficulties. Which components should be separated from each other to avoid interference? What is the best cable length to

connect point A and point B? These things cannot be learned without building up experience. This is similar to the difference between being able to drive a car and being able to drive a car well.

Furthermore, such design capabilities cannot easily be refined simply by practice. Only designers with qualities that can be described by words like sense and intuition can design circuits that feature extremely high efficiency.

The analog gurus are so-called because they have these qualities. They have an instinctive ability to design the best circuits possible.

Needless to say, even if the design is successful, there's no point unless the result can be manufactured. The designer needs to have the ability to foresee problems. For example, if the designer specifies that a component should be mounted on the other side of a certain component, a problem may be encountered where a 1mm² component cannot be passed through a 0.5mm gap.

So, given these skills and abilities, what kind of products should be produced? The answer is general-purpose products. You do not manufacture specialized products that can only be used in a certain product manufactured by a specific company. If you want to provide specialized functions, you propose a combination of general-purpose components.

In addition, you do not manufacture products that will end up being sold at low prices. All products must be given unique added value, which must be properly reflected in the price. Linear Technology pegged its products at a premium for their improved functional value. Linear Technology is a company that manufactures not mere, ordinary analog products, but high performance analog products. This policy, however, was slightly amended at a later date. Even though Linear Technology manufactured groundbreaking products that won high acclaim in technical journals, for example, there were cases where they actually failed to sell well because their excessively high performance resulted in prices that were too high.

Still, no matter how extensive the range of products, they were still limited to the field of analog technology. This was entirely due to the fact that Swanson and his colleagues “were analog experts and knew nothing else.” It was also because of their expertise that there were no companies that they considered for acquisition. There was not a single company in existence that possessed the analog technology that Linear Technology did and, even if there were, they would have headhunted outstanding engineers from such companies individually.

One exception to this was the near acquisition in 1996 of a company engaged in digital signal processing. This was because Swanson had begun to believe that, “If, as an analog company, we don’t have digital signal processing technology, we will hit a ceiling.” Analog and digital technologies share a close relationship. Nothing can be achieved using either of these technologies alone. This is why there are two trains of thought: The need to keep the two as separate industries and the need to possess both technologies. This was a point in time when Linear Technology, a company that had always embraced the former concept, began leaning toward the latter.

At the end of the day, however, Linear Technology did not go through with acquisition of the company concerned. This was because Swanson and other members of the management team could not fully assess the value of this company. In the first place, they could not determine whether Linear Technology, an analog company, needed the infusion of digital technology.

In addition, they did not know whether the technology of the company they were considering was superior to that of other companies in the same industry. This was because engineers at Linear Technology were stumped for an answer when asked, “Are the products of this company superior to those of, say, Motorola, Analog Devices or AT&T?” At this point, realizing that they did not know whether the company under consideration had digital gurus in its

employ, and even if it did, that they had no basis for making a meaningful decision themselves, Swanson and his colleagues abandoned the acquisition.

Had they gone ahead with the acquisition, it is conceivable that Linear Technology would have made a half-baked attempt to incorporate digital technology—and in doing so, failed in both digital and analog fields, with the end result that Linear would not have reached its present day prominence.

Abandoning this attempt to take on digital technology boosted Linear Technology's analog strengths and led to its present day success.

Interview with Robert Swanson, the Founder of Linear Technology

Amidst the drive toward digitization, Swanson chose conversely to commit to the field of analog ICs. To discover the real intentions behind this choice, we interviewed him and asked some pretty tough questions (Figure 2.3).

Why did you go with analog IC business in the midst of the golden age of digital technology?

We knew nothing about digital technology. That's why going down that path was not the result of choice. What we knew was analog, not digital. Analog was the field where we had outstanding staff and experts. That's all there is to it. What else? Let me see; we knew that competition in the field of digital business was very tough. That might also have had something to do with our decision.

There was no doubt that those were times when the direction was toward digital technology. Of course, a great many other companies and people were pursuing digital technology as if it were the obvious thing to do. But I went against the grain. I believed that it was because this was the digital age, because the digital revolution had started, that there would be a great demand for high-performance analog products to support and expand digital products and to create bigger markets. That's why, full of the spirit of "Let's go!" we started making moves toward setting up a venture in the field of analog, not digital technology.

Before establishing Linear Technology, you worked at National Semiconductor. At that time, National Semiconductor was making inroads into all kinds of fields of business and was in the process of growth. Why did you decide to bail out of this company?

I worked for National Semiconductor for 14 years. During that time, among other things, I spent some time stationed in Germany overseeing business in Europe and also supervised business in the



2.3: Robert Swanson, the Founder

United States. It was in the midst of all this that I encountered an extremely interesting business. I'm referring to the analog IC business. In the 1970s, National Semiconductor had a very sizable share of the analog IC market and its products were well known.

You ask why I quit National Semiconductor. To put it in a nutshell, the main reason was "frustration." When I say frustration, to put it simply, I mean that I wasn't happy.

The frustration I felt while I was with National Semiconductor was due to the fact that the company's most important strategy at that time was "how to succeed in the digital business." Needless to say, at the time we're talking about, National Semiconductor was the number-one analog IC company. But let me tell you what they believed. Because the world was moving toward digitization, they believed that the only way to become a bigger company was to succeed in the field of digital technology. This is why semiconductor products that used digital technology came to occupy the mainstream position at National Semiconductor.

For me, this was very frustrating, because I didn't believe there were many chances to succeed in the digital market segment. Digital-related semiconductors in those days meant memory or microprocessors. At the time in question Japanese manufacturers were unstintingly pouring all their efforts into the memory business with devices such as DRAMs, and came to take the lead in the field of memory. Meanwhile, Intel was trying to establish a wonderful position for itself with microprocessors. Amid all this, I didn't believe that it would be possible for National Semiconductor to succeed in any way.

I have been asked questions like this before: "What has most surprised you during these 30 years?" Here's how I responded: "What most surprised me was that many really big companies showed an interest in digital technology to the exclusion of all else." To me, this movement toward digital technology by all these companies was baffling.

I knew, of course, that the analog IC market was much smaller than the digital IC market. And I was also aware that, with the beginning of the digital revolution and the digitization of all kinds of items, this current trend would probably result in the rapid growth of the digital-related semiconductor market. But there was something else that Bob Dobkin and I knew, and that was that the world is made of analog technology. Although we had no idea how big the analog IC market would become, we absolutely knew that it would never disappear.

That sums up all we knew. We only did what we knew. (Figure 2.4).

We had to decide which products to concentrate on—areas where we could build products superior to the competition. We determined that we could design better precision op amps and better voltage regulators than anyone else. When it came to certain specific analog ICs, we could create better products than anyone else. We had the best guys right there in our company to do this. Two products that especially exemplified our company's strengths were amplifiers and linear regulators. As far as these are concerned, I believe that we were unrivalled then and still remain so today.



2.4: Linear Technology's First Management Team

Seated left to right: Robert C. Dobkin, Vice President of Engineering; Robert H. Swanson, President; Brent C. Welling, Vice President, Marketing and Sales; Standing left to right: Brian E. Hollins, Vice President of Operations; R. Michael O'Malley, Vice President of Finance; Clive B. Davies, Vice President, Quality and Reliability.

To express it a little differently, it's like this: "Today we are a manufacturer that supplies products of unrivaled high performance right across the analog A to Z board." This is our strategy and our goal.

When you first thought of committing to analog ICs 30 years ago, did you think that you would realize such a great success?

The answer to that is "No."

When we established the company 30 years ago, the global analog IC market was worth about US\$ 2 billion. Now, though, the global analog IC market has expanded to US\$ 42 billion. Thirty years ago, the analog business of National Semiconductor was on a scale of around US\$ 250 million a year. At Linear Technology, we achieve a larger sales volume than that each quarter.

One unique feature of the analog IC business is that one company can achieve decisive differentiation over other companies with a single superior design. This is completely different from the field

of digital technology. The world of digital technology is fettered by Moore's Law. To put it another way, everyone is capable of doing the same thing. It's all about using as large a silicon wafer as possible and downsizing the initial processing dimensions to reduce the cost per transistor. It's advances in process technology and software tools that make that possible. But analog technology is different. You can come up with IC design contrivances to improve performance and realize completely different added values.

Were you involved with analog technology before you became engaged in the industry? For example, did you study analog circuit design at university?

I only became acquainted with analog technology while I was with National Semiconductor, where I was in charge of the analog business for eight years. During these eight years, I became an analog fan in my own right.

As a result, I have become a person who knows only analog technology. I also believed that analog technology had a future. However, looking back over the last 30 years, analog technology became a bigger and more important market than even I imagined at the time.

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Defocus from Consumer Market

Linear Technology Faces One of Its Biggest Challenges Since Its Founding

Armed with the unrivalled analog technological prowess of its analog gurus and the outstanding engineers that had been entranced and attracted by these masters, Linear Technology enhanced its presence by creating compact products featuring high efficiency that no one else could produce. Everybody in industrial or communications device manufacturing was familiar with the name Linear Technology. The company had become the top entity in the field of analog technology both in name and in fact.

Moreover, as Swanson had foreseen and hoped, the existence of digital technology was becoming firmly established, resulting in a consequent increase in demand for analog technology. Eventually, Linear Technology's products also came to be used in consumer products including mobile music players, game machines, mobile phones, PCs, digital cameras and car navigation systems.

The main reason Linear Technology became seriously involved in consumer markets in which it had almost no involvement up to this

point was the increasing downsizing of consumer products. Countless devices have to be squeezed into a small package. Downsizing is impossible without the necessary technical prowess.

The result of supplying products requested by customers was that products for consumer markets accounted for almost 30% of Linear Technology's sales volume in 2005. This was something that was certainly not intended at the time the company was established. Circuits that placed an emphasis on performance rather than cost were almost never used for consumer markets.

Based on this thinking, it could be said that the few years during which digital products suddenly flooded consumer markets were an exception. The presence of technical prowess, which had been the primary weapon in Linear Technology's arsenal, gradually began to wane in consumer markets where it had once flourished. In many cases, the demand for components used in consumer products, which were enjoying a growth period, was more for products that could be manufactured quickly and cheaply in large volumes rather than on performance. There were also other manufacturers capable of meeting this demand. Such manufacturers included companies that had been involved in analog technology in the past, such as National Semiconductor, the company to which the founder of Linear Technology himself had once belonged. In addition to this, companies that had previously employed Linear Technology engineers also represented rivals. If one disregards their scale, such companies were almost countless.

It also became apparent that these were markets in which Linear Technology could not engage in business as it did for industrial or communications devices, for example. First class products were not in demand. Thus, in these markets alone, competitors were able to manufacture products capable of directly competing with the products of Linear Technology. However, the process of imitation takes two or three years, and this gave Linear Technology the breathing space it needed to cope with the situation. Unlike other companies that sought to make imitation products, Linear Technology manufactured products with enhanced performance for its customers, but such products

failed to win acclaim. This was because customers designed in less expensive devices, even though they may have been outdated. The prices of outdated devices had dropped to less than half their original levels. Meanwhile, Linear Technology's new devices featuring enhanced performance failed to arouse much interest in the consumer market.

Nevertheless, although offering neither the opportunity for overwhelming victory nor the risk of loss, the consumer market was characterized by big volumes and low profits. Linear Technology decided to defocus from this market. Needless to say, it was Swanson who made this decision.

Regarding the issue of how much focus Linear Technology should put on the consumer segment, Swanson did not agree with the policy of the president at that time, Dave Bell. This resulted in Dave Bell's resignation from the company.

Swanson's thinking was, "What does Linear Technology need to do to survive as a sound, healthy company?"

Although he pondered this question for a while, he finally concluded that the direct answer did not lie in focusing the company's efforts on consumer markets. If the company took this tack, human resources allocated to consumer products could be invested in fields where Linear Technology excelled. This would be the way to realize the survival of Linear Technology as a sound, healthy company.

During his tenure with National Semiconductor, Swanson oversaw three groups. Two of these were the Linear Group that was in charge of staple operational amplifiers such as the LM741 and the Advanced Linear Group that developed new products. When the time came, products developed by the Advanced Linear Group were transferred to the Standard Linear Group.

The third was the Consumer Group.

It was from this time that Swanson thought that the setting of products prices based on cost was a ridiculous strategy. Prices should be decided based on product value. If a product is good, there is no need to bow down to demands from customers to supply at a low price. It was for this very reason that Swanson formed a company that was

like an independent version of the Advanced Linear Group, capable of competing on a purely value basis.

Twice a year, managers from countries around the world gather for meetings at Linear Technology. This is known as the Area Sales Managers (ASM) meeting. Meetings are held over a period of one week, during which time each manager gives a two-hour presentation before an audience of approximately 100 on the current half-year performance and policies for the next six months. Speakers take the podium to give their presentations and the audience is seated at long desks set up in rows in front of the podium. There are more than 10 rows of long desks and more seating is provided on the three sides enclosing the arrangement of desks. Swanson's seat is always at the end of the seating enclosure to the speaker's right, along with CEO Lothar Maier, CTO Bob Dobkin and members of the Linear management team.

ASM meetings are held from Monday through Friday. Swanson makes a speech before the dinner on Thursday. As always, he has his notes for his speech in his hand.

"What do we need to do to realize corporate growth?" "It is wrong for us to wage price wars on markets where advances in technology have come to a halt?" "We need to tackle new fields where we can grow, not existing markets."

While agreeing that Swanson was absolutely right, the country managers listening to Swanson's speech were shaken by this decision. This was because they themselves would have to abandon a sales volume in excess of 300 million U.S. dollars and make up for it by other means.

However, Linear Technology's products feature a high degree of universal usability and can be used in various applications. Therefore, there was also no doubt that, if more companies became aware of and designed in Linear Technology's products, their customers would increase.

It was decided that, in industrial fields, as well as existing segments related to manufacturing and communications, new efforts would be

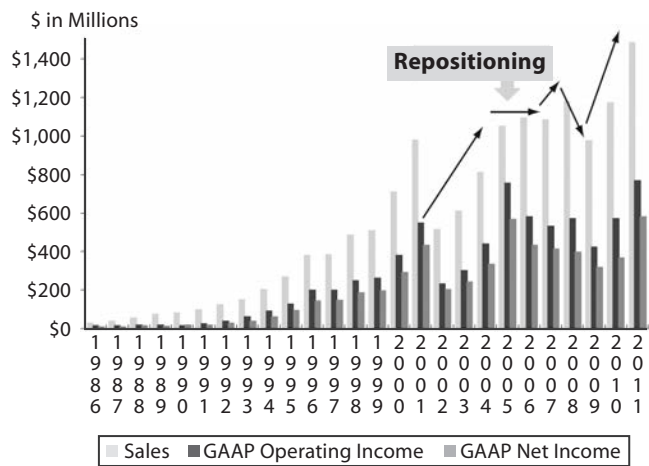
made to cultivate business in areas such as medical devices, sensors and networks, and a more positive approach would be made toward the automotive market.

However, even if the rudder was turned, it would be some time before the ship actually changed course.

Swanson himself said, “That was one of the most agonizing periods of the company’s entire 30-year history.”

Times of Slow Transition and Hard Struggles

As they were going through the process of organizational restructuring known as “repositioning,” there is no doubt that the continuous soaring growth that Linear Technology had enjoyed up to this point had declined (Figure 3.1).



3.1: Changes in Sales Volume and Profits After Linear Technology’s IPO

Figures on the vertical axis are in units of 1 million U.S. dollars. In 2004, the company implemented “repositioning,” a strategy to reduce the supply of products for consumer devices such as digital handheld devices, and increased the supply of products for automotive, industrial and other devices. Although this strategy resulted in a temporary reduction in operating profits, for example, the company recovered from this and recorded sales of \$1.48 billion for the year 2011 (from Linear Technology PR materials).

Although the company had enjoyed continuous growth in revenues with 512.3 million U.S. dollars in 2002, 606.6 million U.S. dollars in 2003, 807.3 million U.S. dollars in 2004 and 1.05 billion U.S. dollars in 2005, sales volumes continued to level out from 2006 into 2007, with 1.09 billion U.S. dollars in 2006 and 1.08 billion U.S. dollars in 2007.

Then, in 2008, just as the effects of repositioning were beginning to manifest themselves, the shock brought on by the collapse of Lehman Brothers struck. Sales volume for the first fiscal quarter of 2009 was 310.4 million U.S. dollars. This continued to fall to 249.2 million U.S. dollars and 200.9 million U.S. dollars in the next two quarters, respectively.

It was the Japanese and Korean markets that suffered the greatest impact of this repositioning to defocus from consumer product fields. Approximately 60% of Linear Technology's products previously sold in Japan were shipped to consumer markets.

At the time in question, only Japanese manufacturers were producing products that required high-performance power supply circuits such as laptop computers, mobile phones and mobile game devices. At the time, Linear Technology's products sold to manufacturers such as these with almost no effort on the part of Linear Technology itself. This was because features such as low power consumption and compactness were in demand. However, once such features reached a certain point, demands for discounts increased. This meant that Linear Technology was unable to do business in its own unique way. It was at this point that Swanson issued his declaration that the company was to distance itself from these markets.

For example, business opportunities that could be realized if the company was willing to lower its unit price by two more cents were abandoned at an early stage. The company no longer responded to insistent demands from consumer customers for discounts that come once every four quarters and stopped taking part in bidding. As this continued, needless to say, customers stopped approaching Linear Technology.

What was the company to do to cover decreasing sales volumes in consumer markets? It was, after all, a uniquely Japanese market that presented itself as a candidate—the automotive industry.

It was not as if the company had had no dealings in the past with automakers and their subsidiaries. Although tenuous, Linear Technology had built a solid relationship with such companies.

This goes back to the 1990s. Linear Technology, which had established a Japanese subsidiary in 1986, had been approaching Japanese automakers at that time. However, the response the company met from these manufacturers was: “Prepare yourselves for the worst and if things go wrong, pull out.”

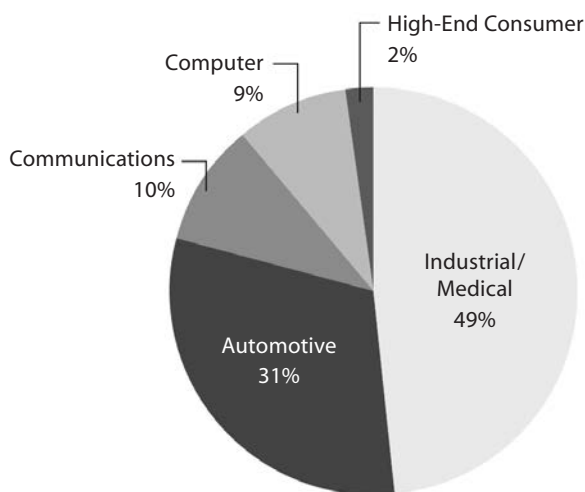
Manufacturers were in a position where they had no choice but to use Linear Technology’s products, as there were no other companies manufacturing such outstanding products. Major Japanese automakers of the time were, however, far more insular than they are nowadays and were very resistant to the idea of purchasing products from foreign manufacturers with whom they were not well acquainted. This was what was behind the warning to Linear Technology to prepare itself for the worst.

The staff member in charge at the time felt, “This was really frustrating. We wanted Japanese automakers to really get to know and understand Linear Technology.”

Although things got off to a slow start, Linear Technology gradually won the trust of these companies and this led to the establishment of a track record. This was due to the unwavering determination of Swanson, at the company’s headquarters in the United States, to gain a firm foothold in the automotive market, and even if the undertaking took time, allowances were made for slow, steady progress.

In addition to Linear Technology, other foreign semiconductor manufacturers were also making overtures to automakers in Japan. A special team was put together to make daily visits to automakers, but was met with harsh comments, and growing sales volume proved difficult.

Compared with Japanese manufacturers, developing business relationships with European automakers was relatively easy. As long as a component manufacturer satisfied official standards such as ISO, it would be considered as a candidate, regardless of its country of origin. On the other hand, Japanese companies tended to place the emphasis on independent rather than official standards and this presented unique difficulties. Although other foreign semiconductor manufacturers had withdrawn from the Japanese markets because of their dislike of this attitude, Linear Technology persisted stubbornly without giving up and succeeded in forging business relationships. This was to become a source of support for Linear Technology almost 15 years later (Figure 3.2).



3.2: Sales Volume by Product Segment in Japan

This figure shows a breakdown of the sales volume of Linear Technology's base in Japan (announced at the end of FY2011). Fields such as industrial instrumentation and medical devices occupy the top position with 49%, followed by the automotive segment with 31%. Shares of communications and computers are 10% and 9%, respectively. The share of products such as digital home appliances (digital consumers) has diminished to a mere 2%. Digital handheld devices previously accounted for more than 10% (from Linear Technology PR materials).

Sales Merits and Demerits

Although offering discounts would make it possible to realize a significant sales volume, discounts that would mean degrading product value are not permissible. As a result, customers are snatched up by other companies under the very eyes of the manufacturer.

This is certainly an unpleasant experience for the sales management. Sales staff who have confidence in their company's products have a strong sense of wanting customers to use their products.

Nevertheless, what Swanson says is final. The company must distance itself from customers in the field of consumer products where price competition is intense and concentrate on the automotive and other markets where there is a demand for quality products.

Continued perseverance paid off as, little by little, Linear Technology found itself able to do business the way it used to in the early days of its founding. "It has to be Linear Technology and no one else." "Their prices are high, but so is the quality of their products."

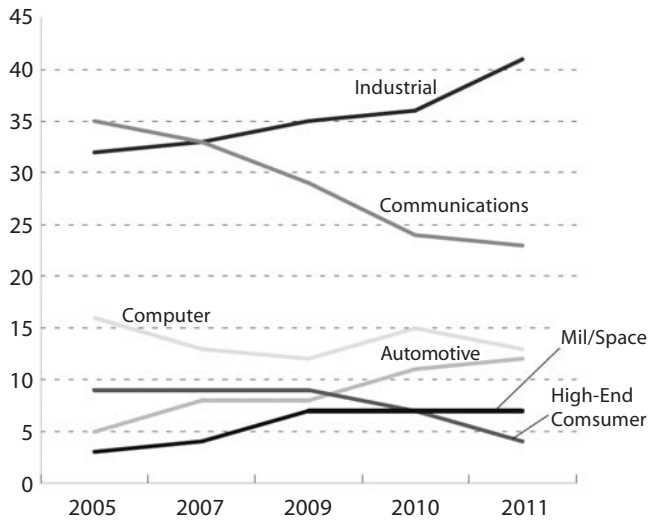
Comments like this bring joy to the company as it goes about its business of selling products. The feeling is different when one has to bow to demands for discounts when selling products.

Looking back, the Marketing Manager at the time reflected, "Sales personnel feel servile when they only sell products because they're cheap. Naturally, it is really challenging to get customers first to understand the value of our products and then to buy them, but when you succeed, it gives you a real feeling of accomplishment."

By the autumn of 2008, Linear Technology had more or less completed the shift to the industrial area, characterized by market fluctuations that are minor compared to those in the field of consumer products. Then came the Lehman Shock. The impact of this event on Linear Technology was slight compared to that suffered by other companies in the same industry, and the company pulled through without having to close plants or reduce its workforce. The result was that when the economy recovered, Linear Technology was able to restore its track record with greater speed than other companies.

Looking back, Lothar Maier, the CEO, reflected, “At a time when other companies were going into the red, we had operating profits higher than other companies even when they were doing well. Our sales volume has doubled over the last six quarters and recently we have been consistently achieving growth over and above first quarter forecasts.”

Let’s put that into concrete terms. The sales volume that hit the bottom in the third quarter of FY2009 recovered slightly to 208 million



3.3: Comparison of Applicable Market-Specific Distribution of Linear Technology’s Products

This figure illustrates annual changes in the applicable market-specific distribution of Linear Technology’s products. The horizontal axis shows the United States accounting year and the vertical axis, the structural ratio (%). Growth can be seen in the fields of industrial and automotive devices, while the communications device share is decreasing. Communications devices are divided between mobile phones (terminals) and network infrastructure devices for applications such as base stations. Although the share for mobile phones in 2005 was 11%, this drops to 1% in 2011. On the other hand, infrastructure devices achieved a 24% share in 2005, maintaining a 22% share in 2011. This shows that, while the share for components for mobile phones for consumers is decreasing, the share for base stations is being maintained. In addition, the share for high-end consumer devices is decreasing. This figure shows that Linear Technology is gradually reducing the number of products it manufactures for consumer devices (from Linear Technology PR materials).

U.S. dollars in the fourth quarter. Since then, generally, double-digit growth has continued in each quarter with figures of 14%, 9%, 21% and 18%, respectively.

Let's take a look at the shares. In FY2005, 28% of Linear Technology's sales volume was achieved in consumer markets. This figure, however, dropped to 9% in FY2010. Therefore, if we consider what is driving the company's growth, we will see that the industrial devices, automotive, military and aerospace segments account for 55% (Figure 3.3). This is followed by computing and communications infrastructure with 36%. If limited to the Japanese subsidiary, automotive accounted for 31% of Linear Technology's sales volume.

During Linear Technology's fiscal year ended June 2011, the company achieved record sales volume, profit per share and operating profit. A comparison of sales volume distribution reveals that industrial devices account for 41%, communications devices 23% and automotive 12%.

One Step Toward Defocusing from Consumer Markets

From this point, Linear Technology's policy was to reduce sales volumes in consumer product fields and to approach a level of zero. According to Swanson, "No matter how many innovative products we invest in consumer product fields, at the end of the day, customers opt to use cheap products that utilize outdated technologies. This is because existing products available at half the price are prioritized over new high-performance products."

Looking back, one can only say that this policy was right on the mark, but examination of other companies at the time reveals that a surprising number had chosen a path exactly opposite of that adopted by Linear Technology.

One reason for this was the advancing shift to digital technology. A second was the increase in the shift to consumer markets that presented the possibility of volume sales.

This is exemplified by Japanese home appliance manufacturers. As a result, in the last few years, such manufacturers have been strug-

gling with low profits. Companies such as Sony, Panasonic and Sharp, whose track records slumped due to the impact of the sudden drop in flat-panel television prices, are typical cases in point.

One point in the 2000s saw the rise of what might be called a “digital home appliance mania,” and new products such as televisions and DVD players were launched to promote global market strategies. Although favorable results were achieved for a while, in the long term, there was no shortage of companies that slumped into the red.

The reason the digital home appliance business is so tough is intense price competition. If we were to ask why price competition is so intense, the answer would lie in the large number of players in the arena. To put it another way, anyone can produce the products concerned. In contrast to this, only gurus can produce outstanding analog circuits.

Taking televisions as an example, all manufacturers use the same liquid crystal panels and the same digital LSIs that adjust picture quality, and tuner circuits can be acquired by anyone. Given this situation, the result is a price war where the issue becomes “how cheaply can products be manufactured?” With digitization comes the danger of falling into the “digitization trap,” a pitfall resulting from the dramatic reduction of differentiating elements.

In this type of market, victory or defeat is determined by cost competitiveness. Even more so than technological prowess, it is factors such as investment prowess and management decision-making speed that determine the outcome. The principle whereby companies with a slow investment decision process drop out of the running is readily understandable if one takes a look at the contrast between Korean and Japanese home appliance manufacturers nowadays.

Although this has already been said, Swanson of Linear Technology is not an expert in areas such as management or investment. He is an analog expert. This is why, from the start, he never competed in areas where he was at a disadvantage and avoided putting his all into consumer product fields, even though he was familiar with these fields to a certain degree.

Consumer markets are characterized by a short product cycle and this also serves to intensify demands for price reductions. It is not unusual for the price of final digital home appliance products to fall by half within the space of a single year. This makes it impossible for manufacturers supplying components to realize high profits.

Now that we have reached the 2010s, Japanese device manufacturers are keenly feeling the circumstances that Swanson so aptly foresaw when he founded Linear Technology 30 years ago.

This may be a postscript, but Swanson declared, "I don't know why everyone was so committed to digital technology alone." Certainly, the digital market growth rate was high, but that does not mean that everyone could succeed in such a market. The higher the number of players, the greater number of winners; but there will inevitably be a high number of losers, too. So, do you compete on this playing field in the first place? And, regardless of whether you do or don't, how do you achieve differentiation over others?

Companies without a well-defined policy on this point will soon find themselves losing their way and forfeiting their rung on the ladder, even in a market that is growing overall. Companies that entered the digital home appliance market with the attitude that "if others turn to the right, then we should also turn to the right" found themselves facing the expected outcome. It may be that Swanson knew this when he founded Linear Technology.

After coming this far, Japanese manufacturers are also finally beginning to advocate the strategies of withdrawing from consumer and digital home appliance markets, almost as if they were following Linear Technology's lead. Companies are beginning to adopt the policy of focusing their efforts in fields such as energy, the environment and medical devices in preference to digital home appliances. The enhancement of earning capacity by companies such as Hitachi and Mitsubishi Electric that have already reduced their commitment to consumer fields may also be behind the decision-making process of Japanese manufacturers who have begun moving away from digital home appliances.

In retrospect, Swanson's decision was the right one and this has enabled Linear Technology to grow in its own preferred way. "We cannot use the resources of our invaluable engineers in fields such as consumer products. This business does not suit us." If a manager who could bluntly make such a statement was at the top in the field of Japanese electrical manufacturers, we may not have witnessed the decline of the last 10 years.

Swanson's declaration that he would defocus from consumer product markets created shockwaves even within Linear Technology itself. However, seeing the company's current earnings capacity and profit margin, employees at Linear Technology have also come to realize that Swanson's decision at that time was right. "Everything that is happening is right." This idiomatic phrase truly applies to Linear Technology.

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Senior Engineers Bring About Innovation

It Takes 10 Years to Become a Full Fledged Engineer

In the early days, engineers at Linear Technology were, without exception, experienced analog IC designers from other companies. At the time the company was established, analog gurus including Bob Dobkin, Bob Widlar and George Erdi were on the staff and this, in turn, attracted engineers who wanted to work with these celebrities.

There is another reason why the company employed experienced engineers only: it takes a long time to become a full-fledged analog engineer.

It takes 10 years before a person can be a full-fledged analog engineer. The period of 10 years after graduation from university is akin to a period of training. Unless a company can invest in human resources training, it cannot hire new recruits. In addition, it is not just design skills that the engineer needs to acquire during the training period. Linear Technology requires more from its engineers than designing analog ICs. Engineers must also have knowledge of customers and must learn how to bring about innovation.

It is for this very reason that engineers who have developed over a long period of time are the true assets of Linear Technology. Swanson has said that it takes only a few engineers to design an analog IC, but without these few engineers, the company could not continue to operate.

Although Linear Technology is located in Silicon Valley, where changing jobs is an everyday occurrence, there have been very few instances of engineers resigning from the company. The number of engineers resigning over the past 30 years can nearly be counted on one hand. This is extremely unusual for a company in Silicon Valley. Why do these engineers choose to stay with Linear Technology? The first thing that comes to mind is salary, but it is not merely a matter of money.

Steve Pietkiewicz, Vice President and General Manager, Power Products, says that people stay with the company "because they enjoy working here. Engineers are not burdened with red tape. They don't have to put up with tiresome comments from their bosses. All they hear from their bosses are comments like, 'That's a good idea. Let's give it a try.' And they don't have to wait forever before they can try out new ideas."

For engineers who want to create new products one after another, this environment is like a dream. It is not enough that engineers at Linear Technology simply create products. No matter how much they may want to continue working at the company, they will fail to measure up to Swanson's ideals if all they do is simply create products. In addition to analog-related skills, engineers are expected to develop presentation and consultation skills.

Wednesday 3:00 and Friday Meetings

Wednesday afternoon every week is a special time for engineers because this is when they have an opportunity to make presentations before employees such as executives, including Swanson himself, design managers and test managers.

As long as they submit an application in advance, engineers can present proposals for new products from an outline set out on a single sheet that they hold in their hands and they must convince the executives that their idea is sound.

Engineers present an outline specification and describe the product they hope to produce, as well as the market demand for the product. The presentations go on to describe similar products manufactured by other companies and how the product proposed is superior to these others. The proposing engineer even touches on manufacturing processes. Before making their appearance at such a meeting, an engineer will think carefully about issues such as yield, packaging and the size of the final product.

Comments such as, "The product will sell if we peg the price around this level" will incur Swanson's wrath.

"Are you only capable of designing products that will sell only if they are cheaper than products of other companies?"

The audience listening to the proposal will make a decision on the spot as to whether the presenter's proposal is viable and calculate the cost of going ahead.

If it is decided that the product will reap sufficient profit, the green light is given for development.

"Engineers, too, are always thinking of profits. This is one aspect of Linear Technology that is decidedly different from other companies," says CEO Lothar Maier, who became involved with Linear Technology after working for Intel and Cypress Semiconductor.

Engineers working in Silicon Valley make these presentations under the very eyes of the executives, as do engineers across the globe using teleconference systems from their offices in places such as Boston, Vermont, North Carolina, New Hampshire, Phoenix, Dallas and Munich, Germany. While there are days when no proposals are put forward, there are days when more than 10 proposals are presented. Executives do their best to ensure that they have no other engagements on Wednesday afternoons.

New circuits given the go-ahead for development may reach the pre-commercialization stage in about two years. Meetings are held at this point, too. These meetings are always scheduled for Friday.

At these meetings, it is determined whether the decision taken two years earlier remains viable. Does the circuit that was valued at two dollars two years ago still have a two-dollar value?

"In most cases, the answer is 'Yes,' " says Swanson.

Once the decision to proceed with commercialization has been taken, sales strategies are shared with the team. How is the product different from other in-house products and products of other companies? The debate deepens to include discussion of what kind of customers the product will be suitable for and continues to cover whether the product in question has the potential to be the only solution. The price finalized at this stage is based, not on development and manufacturing costs, but on the intrinsic value of the product.

Expressions such as "average selling price" or "release product lot" come up often in these meetings, though engineers at other companies would not generally use them.

All Product Ideas Are Born on the Shop Floor

The engineer's job does not end with designing circuits and attending in-house meetings. Engineers also visit customers. During these visits, engineers listen to the customers' requirements and determine what kind of product the customer really needs.

A product the customer specifies may not necessarily be the ideal product for a particular application. It may be that other factors such as scalability and product lifetime will point to another product as most suitable. Customers focus on the overall product life cycle and costs. They are not so concerned with short-term cost increases.

It is safe to say that this situation is completely different from consumer markets from which Linear Technology decided to defocus at

an early stage. Life cycle costs are not a great concern in consumer markets where the matter is over once a sale has been made. Rather, low initial costs are prioritized over the consideration of how long a product will continue to operate stably. This is why Linear Technology's strengths cannot be applied in such markets.

The ability to make technical proposals that exceed customer expectations not only eliminates the possibility of becoming involved in price wars, but also enables acquisition of new ideas that will help determine what kind of products should be developed next.

"All our ideas for new products come from the customers and the shop floor."

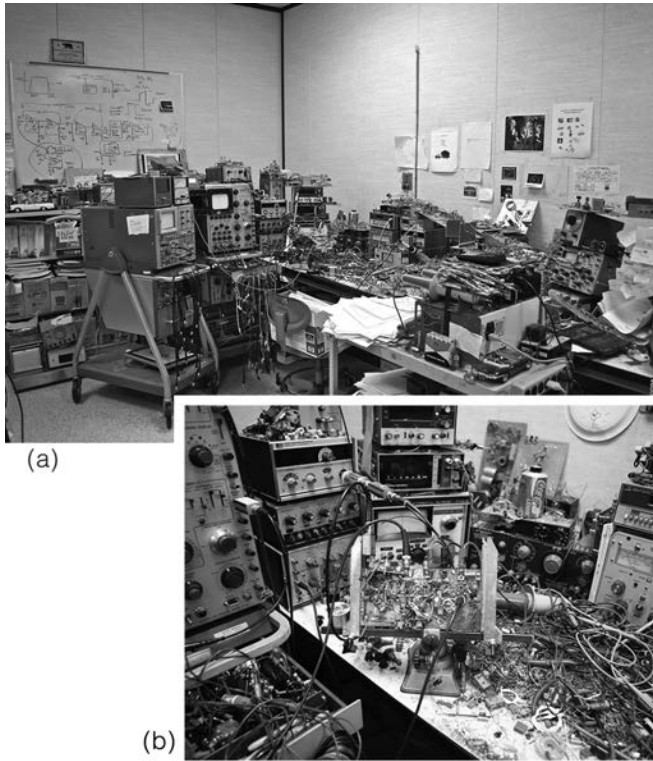
However, engineers do not engage in conversation with customers they visit on the same level as they would in discussions with other engineers from Linear Technology. Technical discussions with customers must be matched to the customers' level of understanding. There was one engineer who was particularly good at this. So says Jim Williams.

Jim Williams also moved to Linear Technology from National Semiconductor after working there for three years. From that time, he took the lead in circuit design, a position he held for 30 years.

Williams' desk was well-known at Linear Technology. His desk was stacked with boards and components he used to design circuits, and to say it was a jumble would be an understatement.

But, there was a reason for this.

One of the major tasks he was entrusted with was accepting telephone calls from customers or other engineers and providing on-the-spot responses. He had no time to hunt through lockers or drawers looking for the relevant circuits once he had taken a call. That's why he kept everything he needed on his desk, where he could quickly lay his hands on what he wanted. The side of his desk was covered with memos listing the telephone numbers of engineers he considered important, both in-house and outside the company.



4.1: A Pile of Circuit Boards Mounted with Analog ICs (b) Can Be Seen on Jim Williams' Desk (a).

The desk of analog guru, Jim Williams. All kinds of circuits were placed within easy reach in this cramped space.

Pietkiewicz, who had already built a career before he met Williams, learned a good way of writing data sheets. Data sheets provide a summary of product specifications for submission to customers. "The point is how to reduce the number of follow-up phone calls."

If the engineer produces a data sheet that the customer can easily understand, and that leaves no room for doubt, he will find that he won't need to handle subsequent telephone enquiries. This approach eliminates bother and is helpful both to the engineer and the customer. Williams also produced a book that could be called an analog circuit design textbook.

Williams' impressive communication skills have even been highly acclaimed by journalists completely unacquainted with analog circuits. It is difficult to explain what an analog circuit is to someone who knows nothing about the subject and even more difficult to give such a person an understanding of the nature and number of merits and demerits. This is because the more skilled the expert, the easier it is for them to lose sight of what the layman does and does not understand.

John Hamburger of Linear Technology recalls that a French reporter writing an article on the company's staff gave Williams' name as the employee that made the greatest impression on him. That was because Williams was the best at explaining things in a way that was easy to understand.

Needless to say, as an analog designer, Williams also had outstanding abilities on a par with the analog gurus. There is an episode that illustrates the truth of this. This episode, initiated by Bob Dobkin, took place when they were still working at National Semiconductor.

Bob Dobkin once tampered with his boss's electronic calculator. This calculator contained semiconductors manufactured by National Semiconductor. Bob Dobkin secretly mounted an analog circuit in the calculator to delay the operating frequency. His boss asked the semiconductor development team to repair the calculator's slow operation. With their prestige on the line, the team members began to examine the calculator, but they failed to spot the analog circuit. It took nine months before they finally sorted out the problem. It was episodes like this that set Dobkin on the throne as an analog guru.

His interest piqued, he decided on the wall clock in the room where designers met as his next target. Again, he mounted an analog circuit in the clock, this time in an attempt to slow the clock's operation. However, things did not go as well as they had in the case of the calculator. When he came to work the following morning, rather than operating slowly, the clock was fast. When he checked, he found that someone had tampered with the clock to make it run fast.

Once again, he made readjustments to slow the operation of the clock and this time, set up a hidden camera. But his adversary was clever. The following day, right in front of Dobkin's very eyes, the clock was running backward. When he examined the clock, a memo was affixed to it that read, "Don't try to catch me out with tricks like this!"

This tit-for-tat game with the wall clock went on for a month. Dobkin's adversary in this game was Williams.

Thirty years after following Dobkin to Linear Technology, Williams suffered a stroke on June 10, 2011, and passed away two days later at the age of 63.

Williams' death came as a great shock to Linear Technology and to all analog circuit designers.

Paul Rako, former analog editor of EDN magazine, said, "The death of Jim Williams represented a huge loss to the analog community."^{*} The funeral that took place on June 18 was also attended by many analog circuit designers from competitors such as Analog Devices and National Semiconductor.

Bob Pease was also among the mourners. Like Williams, he was also responsible at National Semiconductor for handling inquiries from both inside and outside the company. On his way back from the funeral, the car Bob Pease was driving swerved off the road and ran into a big tree. It was reported that he died instantly at age 70.

"They have been taken from us," was one comment made on the passing of these two legendary analog designers, one after the other.

Ability and Passion, the Criteria for Hiring Engineers

Linear Technology, a company that in its early days hired only experienced engineers, now also hires new graduates.

The company hires mainly from the top institutions such as Stanford, MIT (Massachusetts Institute of Technology), University of California, Berkeley, Virginia Tech and Georgia Institute of Technol-

^{*} Source: www.edn.com/article/518569-Analog_engineering_legend_Bob_Pease_remembered.php

ogy. Every year, one or two graduates from each institution join the company as new recruits after undergoing a period of internship. These top students subsequently undergo a process of training lasting almost 10 years.

According to Pietkiewicz, in addition to excellence in the field of analog technology, the criteria for selection includes whether candidates have the desire or passion for creating new products. The focus in hiring personnel is not only on whether applicants have outstanding technical skills, but also on their humanity.

Pietkiewicz himself joined the analog IC company PMI as a new graduate and subsequently transferred to Analog Devices. He then went on to Linear Technology. Pietkiewicz states that, "I believe that I was forced to resign from Analog Devices." When the company's research institute in San Jose in Silicon Valley was merged with the facility on the East Coast, he was left with no choice but to resign if he wished to stay on the West Coast. That was when he interviewed with Linear Technology.

Pietkiewicz recalls that, during the interview, Swanson asked him, "Do you want to succeed? Do you want to be rich?" He went on to say, "If you want to work for the best company in the world, join us right now!"

Pietkiewicz was overwhelmed by Swanson's confidence and intensity. Swanson pressed on doggedly, "I've heard that you are a talented analog IC designer. Let's be successful together!"

At the time, Pietkiewicz also had an offer from PMI, the company where he used to work, but he chose to go with Linear Technology—24 years have passed since then.

The other day, when he happened to meet the person who had dismissed him from PMI, he politely expressed his gratitude by saying, "Thank you so much!"

The “Home of Analog Gurus” Lives On

Although Linear Technology has design centers at 13 locations across the globe, the biggest of these is in Silicon Valley, where the company’s head office is located. The large nameplate that reads, “Linear Technology – Home of the Gurus” is positioned in plain view near the road (Figure 4.2).



4.2: Nameplate Inscribed with the Legend “Home of The Gurus”

The nameplate of the IC Design Center at the head office in Silicon Valley clearly visible from the road bears the legend “Home of The Gurus.”

Photograph: Koichiro Hayashi

Although Dobkin is the sole survivor of all the gurus on the scene at the time company was established, young designers are proud to work in the same company with him.

Upon entering the building, you will see rows of framed magazine covers on display that tell of Linear Technology’s past (Figure 1.4). Spaces where engineers work are divided by partitions. This is where personnel work on designs using PCs.

Apart from this is a room where actual circuit samples combining components such as transistors, diodes and resistors are produced and evaluated. This room is almost like a small factory or workplace added on to a home garage. During busy periods, some of the engi-

neers also eat here. When they are not so busy, they can enjoy their meals in the spacious cafeteria. You will always find someone in the checkerboard-tiled cafeteria.

Although the executives each have their own private offices, they are not as spacious as one may imagine. Swanson's office, too, is surprisingly small. His current office is located near the bathrooms.

Swanson will celebrate his seventy-third birthday this year. It is perhaps natural, then, that he thinks about the future of Linear Technology. There is no doubt that Linear Technology has made steady advances over the past 30 years. Will the company be able to retain its strengths in the future after its charismatic co-founder and the last analog guru retire? Swanson and his team are confident that the smooth transition to CEO Lothar Maier's leadership will ensure the continuity of Linear's strategy.

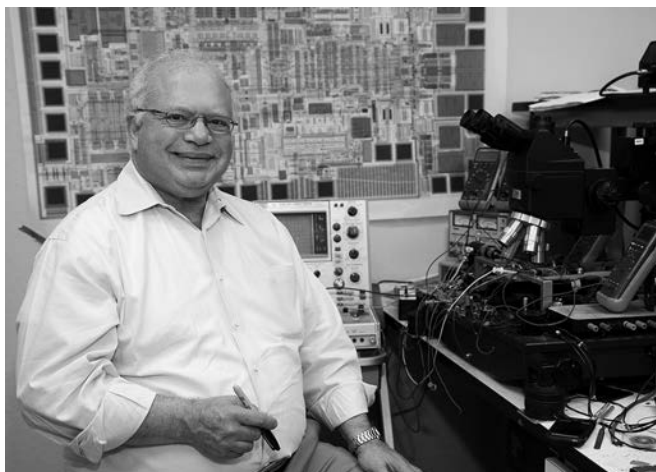
Continuing to meet challenges in growth markets, avoiding areas of cost competition, valuing people—as long as the company can sustain its culture by these principles, it will surely not be shaken from its present position. This sentiment was echoed by many members of the staff interviewed during this project.

Here is something that Swanson often says to the young employees who support Linear Technology: "You can do better."

Message from Bob Dobkin to Young Engineers: "Ardent Desire Is the Mother of Invention"

Although he is the CTO, Bob Dobkin doesn't put on airs or graces. He always enjoys speaking with young engineers. If he has an idea, he will pass it on in a carefree manner, and he is pleased to give advice to young engineers. This message is from Bob Dobkin, a man who, while displaying great affection and respect for senior engineers, is also devoted to mentoring young engineers (Figure 4.3).

People are the resources of Linear Technology. People cannot be exchanged or replaced. It is no exaggeration to say that it is this very idea of valuing people that forms the culture of Linear Technology.



4.3: Bob Dobkin, CTO and Analog Guru

We are called “gurus.” That means we are masters or teachers. There is a spirit at Linear Technology that embodies respect for these long-serving senior engineers. This thinking may be typical of the world of analog.

I often say things like the following to young engineers.

The most important thing you need to design or create new circuits and products is “an ardent desire.” You mustn’t feel satisfied just because you’ve resolved one problem. You have to build up ever-better resolutions until you achieve the best solution, and this leads to invention.

But, you have to watch young engineers. When a young engineer thinks “this is satisfactory,” in most cases, it is not. It takes time and experience to “do something satisfactorily without the need of repetition.” You need to know what has been done in the past. Materials such as books and other literature are good tools for learning.

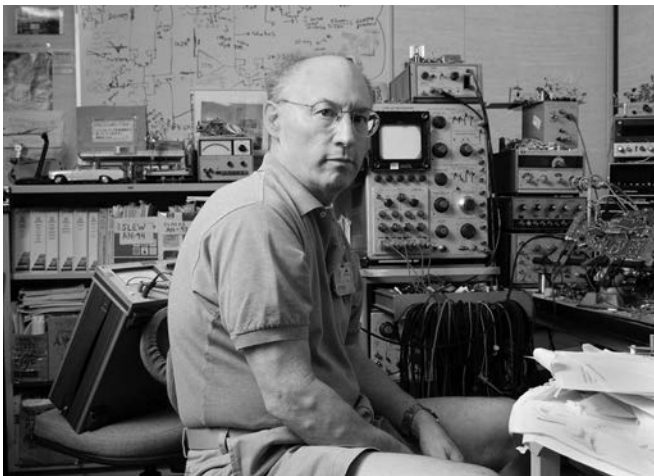
IC design is an art. To me, it’s like drawing a picture on a silicon chip. But you need a scientific approach. As long as you have this approach, you can create ICs that function as intended. In electronic engineering, the scientific approach leads to good answers, very much as it does in fields such as physics and chemistry.

The Words of Jim Williams

Jim Williams was one of the gurus who supported Linear Technology (Figure 4.4). He often spoke at all kinds of venues about the importance of test boards. To evaluate the characteristics of new products such as semiconductor components, a test board mounted with the semiconductor product to be evaluated is shipped along with the various parts for testing with its connectors installed. The following are actual comments made by Jim during a talk he gave at Design Conference '99 Japan, a lecture conference for circuit designers held in Yokohama on May 19 to 20, 1999. The event featured a gathering of superstars from the world of analog technology, such as Barry Gilbert from Analog Devices.

Jim Williams' Comments:

Let me say something about university education. The problem is that testing at universities is carried out mainly on computers. Surely, this is one of the reasons that is causing young engineers to distance themselves from the use of test boards (breadboards). While there is no doubt that simulation software offers a wealth of



4.4: Jim Williams, Legendary Analog Guru

functions not previously available and has become a powerful design tool, we must not forget verification using breadboards. The breadboard is undoubtedly still an important tool for those wishing to become veteran analog engineers.

I would like to see more focus put on testing using breadboards at universities, but I also realize that universities are restricted by circumstances. You need all kinds of components and oscilloscopes for testing using a breadboard. You also have to set up a test lab. Seen from the standpoint of expenses, it's natural that simulations have become the main approach in university education. All you need for that are a computer and a keyboard. What do you do to provide education that will give students the skills they need within a limited time frame? Do you make a half-hearted attempt to teach using both breadboards and simulations or do you focus completely on one or the other? No doubt, the inevitable answer from universities would be to focus solely on the option that costs less.

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Die Bank System That Has Attracted Attention Around the World

The Third Strength of Linear Technology

The reason Linear Technology continues to attract such intense attention from major companies around the world is not limited to its high profits and low job turnover rate. Production processes, such as the company's unique inventory management system, are worthy of special note. Why has Linear Technology introduced procedures such as a system for the storage of inventory for surprisingly long periods of time compared to other companies around the world? A closer scrutiny of this issue reveals that elements such as the company's strengths and corporate policies are more three-dimensional in nature.

In this chapter, we will be focusing on Linear Technology's semiconductor product inventory management system and taking a look at the company's thinking regarding manufacturing and future market strategies.

Waiting List of People Wishing to View the Company's Inventory Management System

"We are inundated with requests to view our company's manufacturing division's inventory management system, especially from Japanese companies," says Yasushi Mochizuki, Representative Director of Linear Technology K.K.

In today's global semiconductor industry, Linear Technology is attracting intense attention for its inventory management system. This unique system introduced by Linear Technology is highly acclaimed for its immunity to events such as unexpected disasters and market fluctuations, as well as its ability to ensure stable supply of products to customers.

The unique inventory management system employed by Linear Technology is referred to as a "die bank." This system ensures a constant inventory of chips (die) in wafer form for four to six months that have completed the semiconductor manufacturing process.

Normally, front-end processing (wafer processing) of analog semiconductors on the production line is a lengthy process that may take as long as 12 to 14 weeks in the case of high-performance analog ICs. In addition to this, since back-end processing (package assembly / test process) takes an average of four weeks, a period of 16 to 18 weeks is required to produce the finished product.

This means that, for example, in the event of a semiconductor fabrication plant halt due to a major disaster such as an earthquake or tsunami, producing finished products presents difficulties even if production is initiated at an alternative plant.

Maintaining a Four to Six Month Inventory

To address this problem, Linear Technology's die bank maintains a four to six month inventory of semiconductor wafers that have completed front-end processing in the plants.

This system ensures availability of die (semiconductor chips) that have completed front-end processing, which can then be completed as

finished products in a consistent average of four weeks by undergoing package assembly and test processing.

The die bank is a system that was initially introduced to allow for products with short delivery deadlines and to ensure stable operation of the semiconductor fabrication line. However, it also functions as a buffer for product shipments in the event that the semiconductor fabrication line suffers some kind of damage. For the last few years, development of systems to enable uninterrupted shipment of materials and components even if manufacturing industries are struck by disasters have been promoted under the catch-phrase BCP (Business Continuity Plan). This has brought about a renewed focus on the die bank system.

Semiconductor manufacturers other than Linear Technology, such as Maxim Integrated Products and Texas Instruments, have already adopted mechanisms similar to the die bank. In addition, some semiconductor manufacturers handling logic LSI are also exploring the possibility of introducing similar mechanisms.

However, one unique feature of Linear Technology's die bank is that it maintains a four- to six-month inventory at its plants: a considerable volume equivalent to three to four times that of other companies. This is why Linear Technology has won acclaim as being better prepared than other companies for emergency situations such as disasters.

The reason Linear Technology is able to maintain inventory for longer periods than other semiconductor manufacturers is that many of its analog semiconductors are manufactured for industrial systems with a long product life, or for onboard devices, resulting in a low risk of obsolete inventory.

The long-term maintenance of inventory of semiconductors for short-life products such as smartphones, televisions or digital home appliances is extremely risky and this is why other semiconductor manufacturers are unable to adopt the approach of maintaining inventory for such extended periods.

Undaunted Even by the Floods in Thailand

When the Chao Phraya River overflowed its banks causing massive flooding in Thailand in the summer of 2011 (the “Thailand floods”) resulting in damage to the plants of many Japanese semiconductor manufacturers producing automotive analog ICs, Linear Technology found itself inundated with orders for alternative products. According to Mr. Mochizuki of Linear Technology, at the time “our company’s short delivery of an average of four weeks won us high acclaim from customers.”

Although normally it is easy to think of maintaining inventory as “a bad idea,” in the case of analog ICs, the process of final testing after package assembly is costly. This means that, in terms of risk mitigation, the merits of keeping chips on wafers in storage are considerable. In fact, the maintenance of inventory in the die bank presents no management risk to Linear Technology.

A look at the company’s financial results for FY2011 reveals that the value of die bank inventory was a mere 45 million U.S. dollars against sales volume of 1.48 billion U.S. dollars. Moreover, since the majority of analog ICs the company handles are intended for industrial products, instrumentation or medical devices with a long product life of 10 or more years, there is little risk of inventory being left unsold on the shelf.

Additionally, the company has front-end and back-end processing manufacturing plants at more than two locations, resulting in a structure that enables another plant to take over production if one of the plants is rendered inoperable due to an event such as a disaster. Moreover, die banks themselves are set up at three locations worldwide, mitigating the risks posed by disasters. In this way, Linear Technology takes every precaution to focus its efforts to assure continuity of its semiconductor production business.

Practices such as these are integrated into Linear Technology’s high added-value analog IC-specialized business strategies and, undoubtedly, cannot be easily imitated by other companies. It is because Lin-

ear Technology designs and develops products that never lose their competitiveness that the company is able to adopt this approach of maintaining inventory over prolonged periods of time.

Japanese manufacturers that have experienced the successive calamities of the Great East Japan Earthquake and Thailand floods are beginning to follow the example set by Linear Technology. There are many aspects of this bold inventory management technique that could benefit not only the semiconductor industry, but also manufacturers in other segments of industry.

Aiming to Manufacture the Best Products in the World

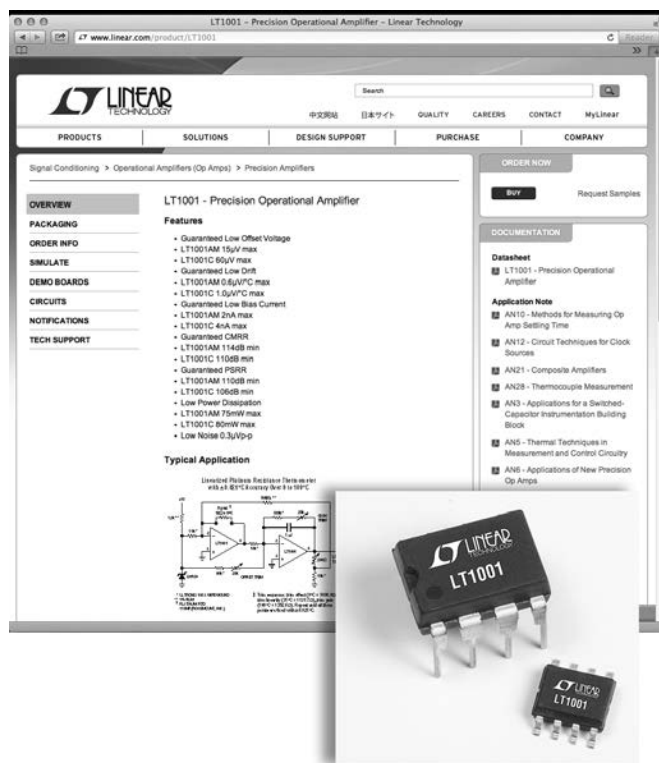
Since its founding in 1981, Linear Technology has advocated “the best production in the world.” To this end, it has undertaken improvements in its manufacturing equipment. This was because, at the time, manufacturing divisions of Japanese manufacturers were acclaimed for their extremely high quality. As a result, Linear Technology is highly focused on producing unique general-purpose products via self-sufficient production and solid business continuity planning.

One point on which the company is especially particular is its policy that states, “As long as we have even one customer, we will never discontinue production.”

Although to date, the company has launched sales of over ten thousand types of semiconductor products, only a very few have been dropped from production. The company’s policy states that it will not discontinue production unless it finds itself in a situation where “it has no customers” or where “it can no longer acquire the necessary materials or components for production.” This is why the LT1001, launched when the company first began operations, still appears in product catalogs 30 years later and is selling to this day, available for purchase from the company’s website (Figure 5.1).

Regarding its policy of non-discontinuation of production, the founder, Swanson, says, “This policy shows how customer-oriented we are.” In other words, this policy was proposed by Swan-

son himself and is an “ironclad rule” that could be considered the company’s credo.



5.1: The LT1001, Launched Nearly 30 Years Ago, Is Still Selling Today

Linear Technology’s policy of not discontinuing production of products unless exceptional circumstances arise is set out on the company’s website. There are only two exceptional circumstances that may result in the discontinuation of production: (1) products that have not sold at all for many years, and (2) unavailability of rare materials necessary for production. For example, the LT1001 series, the first product the company sold after it was established, is still available. (From Linear Technology’s website)

Reason for Focus on Long-Term Stable Supply

Why is Swanson so focused on not discontinuing production? This has a lot to do with the fact that he originally worked in manufacturing.

Up to the time he launched Linear Technology, Swanson had been working in the analog semiconductor division at National Semiconductor, and says that it was there that he developed a strong sense of the importance of the manufacturing division. The thinking behind this is that, when dealing with customers, the ability of the manufacturing division to achieve a stable product supply is extremely important as a product added value.

Compared to similar products manufactured by other companies, Linear Technology's semiconductor products are generally considered to be expensive. This is based on the thinking that customers buy Linear Technology's products in spite of their high prices because, as a Linear Technology employee stated, "calculation of long-term costs have shown that using our company's products leads to reduced costs for the customer in the long run." This can be called the core product policy that pervades the entire company.

When considering total costs, the ability to continually provide the customer with a stable supply of products is absolutely essential. In appealing to customers, it is extremely important "to look at the long-term costs, not the short-term costs," the existence of a long-term support, and a structure that ensures stable supply even if the company's facilities are struck by a disaster.

Backbone Supporting Infrastructure Companies

One further reason in the background that explains the emphasis Linear Technology places on its business continuity planning is that its customers include public infrastructure companies.

The company's customers include a great many companies involved in public infrastructure such as railway systems, ports, large-

scale factories, electric power systems and communication base stations. Among the devices used in infrastructure such as these are many systems used over long periods of 10 years or more.

Linear Technology supplies components for such systems. The discontinuation of manufacturing of semiconductor products for systems in long-term use after five or six years would create problems. For example, even if a single company is the sole customer, in many cases, the infrastructure devices owned by that company provide support for society. In this respect, the characteristics of a company such as Linear Technology differ significantly to those of companies that engage in the semiconductor business for digital home appliances, where short life cycles are the norm.

Requirements imposed on components used in infrastructure devices such as product durability and the ability to operate in wide temperature ranges (characteristics that indicate whether a device will operate normally even in extreme-temperature environments) are stricter than those applied to components used in devices with short life cycles. It is by producing products that will stand up to these stringent criteria that Linear Technology attempts to achieve differentiation over other companies.

The First Company Acquired in 30 Years

Linear Technology had, in the past, modeled and refined its production management techniques based on Japanese manufacturers. Now, however, the situation has been reversed, with Japanese manufacturers attempting to learn from the initiatives implemented by Linear Technology.

Another area in which Linear Technology can serve as a model is its intense focus on the industrial market.

As mentioned earlier, Linear Technology is significantly curtailing its expansion in consumer product markets and plans to achieve more or less zero involvement in these markets a few years down the line. Meanwhile, the company is pursuing a policy of reinforc-

ing, to a greater extent than ever before, expansion of products for industrial applications that support the manufacturing industry infrastructure. Behind these initiatives lies the fact that Linear Technology's business style is extremely well matched to factors such as customer needs and product reliability requirements in industrial fields. Among other things, this is exemplified by the company's introduction of the die bank based on the premise of development of ICs with long life cycles.

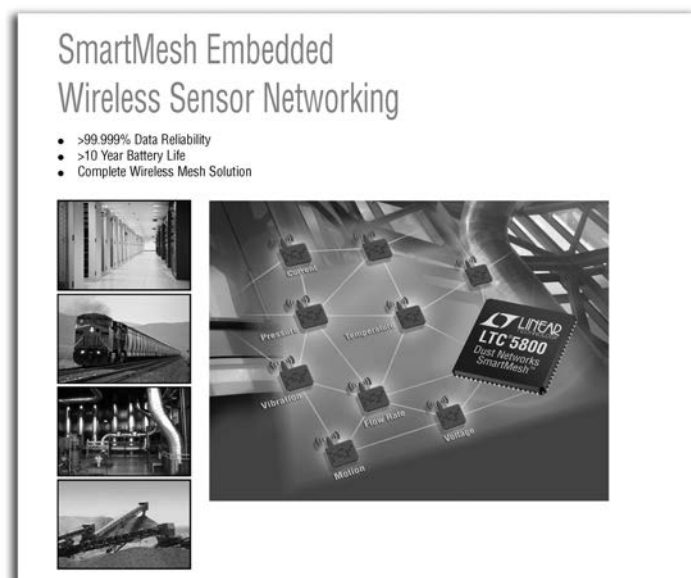
An event that endorsed this direction the company is taking occurred in December 2011. In the 30th year since its inauguration, Linear Technology made its first corporate acquisition. Linear Technology, which had not made a single acquisition in the 30 years up to this point, finally broke this taboo in an event that attracted significant worldwide attention.

The target for acquisition was Dust Networks, Inc., a company that handles wireless sensor network technology for industrial devices.

Dust Networks, Inc. delivers embedded software and hardware technology required for wireless sensor networks that monitor manufacturing equipment in factories and improve safety in work environments (Figure 5.2). In particular, the company excels in technology for "mesh networks," with multiple sensor nodes connected in a network formation that autonomously determine paths and implement information exchanges. Among other achievements, Dust Networks has also won global acclaim for its early launch of products based on WirelessHART, a standard communication protocol that has attracted attention in the field of industrial devices. The company's solutions are already in use by major industrial automation device manufacturers.

Expansion of Scope to Include M2M

In acquiring Dust Networks, it was the aim of Linear Technology to make advances into fields such as industrial devices and industrial automation to a greater extent than ever before. It seems fair to say



5.2: Dust Networks Product Selector Card on the Linear Website

The first company to be acquired by Linear Technology in the 30 years since its founding. The company acquired, Dust Networks, Inc., excels in wireless sensor network technology.

that by breaking its 30-year long silence and acquiring a company engaged in wireless sensor networks for industrial fields, Linear Technology was boldly indicating its future direction of downplaying its digital home appliance-oriented business.

Reflecting on the acquisition of Dust Networks, Lothar Maier, CEO of Linear Technology said, “We hadn’t acquired a single company in 30 long years. However, our acquisition of Dust Networks at the end of 2011 was based on the thinking that this was a company that would really complement our technology. Dust Networks is focused on wireless technology for industrial fields and this meshes with our fields of focus. In addition, we are also committed to energy harvesting, a method of extracting energy from diverse natural phenomena, and the low power consumption wireless technologies produced by Dust Networks are essential to this undertaking. If we use this company’s technologies, we will be able to construct

a sensor network that combines energy harvesting and wireless technology.

“For example, it is well known that San Francisco is a crowded city where it is difficult to find a parking space. So, how would it be if a sensor network was embedded in parking spaces on roads in that area? This would make possible wireless acquisition of information on which parking spaces are vacant. Transmission of this information to smartphones would give users free access to such data and enable them to direct their cars to suitable parking spaces. Likewise, in the field of industrial devices, sensor networks could be laid in all kinds of places such as railways or factories. This is what we call the M2M, or Machine to Machine, market. It is because it has been forecast that this market will grow in the future that we broke our 30-year taboo and acquired Dust Networks. Of course, we handle wireless components for mobile phone network base stations, for example, and we have solid fundamental technology in such fields. However, there will be demands for next-generation wireless technologies such as mesh networks in the future, and we felt that Dust Networks was necessary to us as a complement to our efforts in this direction.” (Figure 5.2)

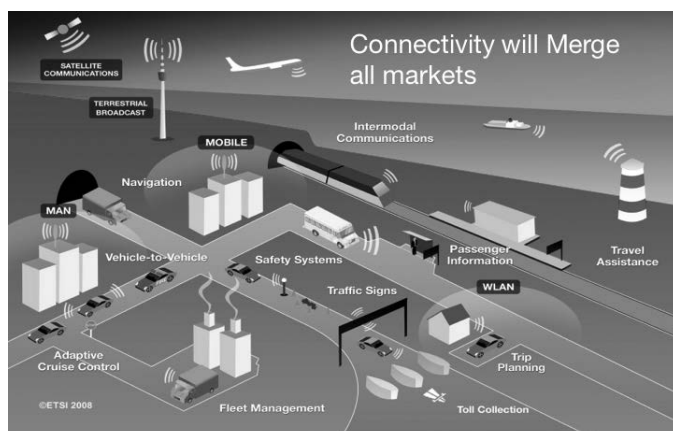
At the present time, many entities such as semiconductor manufacturers and communication-related companies see promise in sensor networks and M2M markets, and are putting out feelers to test the waters. For example, Qualcomm Incorporated, a major producer of microprocessors for devices such as smartphones, is developing components such as compact wireless communication modules for M2M and is making resolute moves toward applications in medical and other fields. Likewise, Linear Technology also anticipates the future growth of the M2M market, but rather than consumer product fields, its approach is geared toward industrial fields. This will evolve because, of all the many M2M-related companies, Linear Technology allied itself with Dust Networks.

Linear Technology supports both the infrastructure industry and industrial devices. Out of the drama of the acquisition of Dust

Networks, we can fleetingly glimpse one side of Swanson and the other members of the management team, who are unwavering in their firm belief that it is in these fields especially that their company will shine brilliantly.

Next Areas of Focus: Automobile and Communication Infrastructure

In addition to factory automation (FA) devices and industrial infrastructure markets where the application of sensor networks is anticipated, Linear Technology is also taking more proactive initiatives in other markets. The company is particularly focused on the automotive, communications infrastructure and medical device markets.



Source: Frost & Sullivan

5.3: Conception of the Communications Field of the Future

An image of future segments of communications where Linear Technology's products will be applied. This illustration shows that communication functions will become essential in infrastructure, industrial and other applications of the future. In particular, wireless networks including mobile phone networks, wireless LAN (WLAN) and Metropolitan Area Networks (MAN) will become responsible for automobile traffic safety and navigation as well as onboard communications in railway cars and service management. It is Linear Technology's policy to supply components for wireless network/infrastructure devices and sensor devices depicted in this image of the future. (From Linear Technology PR materials, Frost & Sullivan)

Compared to consumer markets, steady growth is anticipated in all these markets.

Linear Technology's sales volume for FY2011 (July 2010 to June 2011) of 1.48 billion U.S. dollars represented an increase of approximately 26% over the previous fiscal year, while operating profits showed a 47% increase at 767 million U.S. dollars, both figures representing an all time record for the company. Significant capital investments by customers in the fields of industry and instrumentation, where the highest percentages were recorded, were the main driving force behind these favorable business results. The future outlook in these fields is for solid growth and, according to Lothar Maier, Linear Technology's CEO, "Significant growth is expected in the fields of on-board devices and communications." (Figure 5.3)

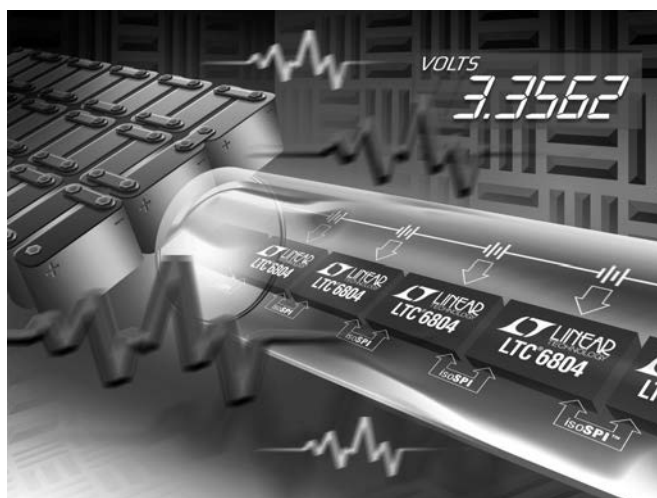
The share of Linear Technology's sales volume occupied by components for automotive devices was 12% in FY2011, which rose to 16% during the first quarter of FY2012 (July to September 2011). The growth rate of this field exceeds the growth rate of Linear Technology's overall sales volume. Regarding the on-board device business over the coming two or three years, Lothar Maier declared that "it is not hard to imagine that this rate of growth will top 20%."

Anticipation of Battery Monitoring IC Market Growth

In addition to the increasing electronics in automobiles for enhancing automotive safety and comfort, in the field of on-board devices, Linear Technology is focused on battery monitoring ICs for electrically powered automobiles including hybrid vehicles (HV), plug-in hybrid electric vehicles (PHEV) and electric vehicles (EV) (Figure 5.4). The company's battery monitoring ICs are used in the electrically powered vehicles of a number of automakers, and preparations are underway for the introduction of even more advanced battery monitoring ICs.

Automobiles such as hybrid and plug-in hybrid vehicles use high-capacity rechargeable lithium-ion batteries. The use of batteries

to drive the vehicle enables reductions in gasoline consumption. To achieve this, multiple cells, the smallest rechargeable lithium ion battery units, need to be connected in series. Depending on the type of hybrid vehicle, up to several hundred of these battery cells may be connected in series for use.



5.4: Battery Monitoring IC

Battery monitoring ICs used in electrically powered automobiles such as hybrid vehicles (HV), plug-in hybrid electric vehicles (PHEV) and electric vehicles (EV) are used in the electrically powered automobiles of multiple automakers. These ICs monitor the charge and discharge status to avoid safety hazards and improve battery efficiency. This market is expected to grow in the future.

When charging or recharging these battery cells, failure to properly adjust the voltage of these multiple cells can lead to a dangerous situation. Overcharging of only certain battery cells, resulting in excessively high voltage or, conversely, excessively low voltage, can lead to over- or under-charging, presenting possible safety risks after a number of repeated charge/discharge cycles. Also, proper monitoring of battery stacks can improve battery efficiency and can extend battery life.

To prevent this from occurring, the charge and discharge status of battery cells needs to be monitored by analog ICs called battery monitoring ICs. The greater the number of battery cells, the greater the number of ICs used. In addition, since automobiles such as plug-in hybrid electric vehicles or electric vehicles use more battery cells than hybrid vehicles, they are mounted with more ICs.

Targeting the Electric Powered Vehicle Market

If cars such as hybrid vehicles and electric vehicles become mainstream in automotive markets, this will create the possibility of a major growth market for battery monitoring ICs.

Linear Technology is also focusing efforts into the development of new products and has announced plans to launch sales within 2012 of a third-generation battery monitoring IC that not only features enhanced accuracy of battery-cell voltage detection, but also a higher conversion rate for improved accuracy and efficiency.

Automobiles such as plug-in hybrid electric vehicles and electric vehicles require more battery cells than hybrid vehicles. Because battery cells are still expensive, increasing the number of such cells entails a significant increase in cost. Use of this third-generation product will make it possible to minimize increases in the number of battery cells mounted. This is because enhanced detection accuracy will enable expansion of the range of usage of each battery cell.

The battery-cell monitoring IC is but one example. Taking advantage of the advent of the era of electrically powered vehicles, Linear Technology intends to supply automakers and automotive electronics manufacturers all kinds of analog semiconductor products for use in automobiles, including hybrid and electric vehicles.

Bright Outlook for Analog ICs

One more area where Linear Technology is intensifying its efforts is the market for semiconductor products for use in the field of communications.

Advances in the global expansion of communications infrastructure have spurred expectations for further growth of this market in the future. To meet the needs generated by rapid increases in communications traffic brought on by the spread of devices such as smartphones and tablet terminals and the growing number of Internet-connected devices, it is expected that efforts by telecommunications carriers worldwide to build out the communications infrastructure will pick up pace. This is why the outlook is bright for analog IC products developed by Linear Technology for communications infrastructure.

Up to this point, Linear Technology has demonstrated its prowess in devices such as high-frequency components and analog semiconductors used in mobile-phone network base stations. Now, we are witnessing an ongoing transition between generations in the world of communications. The 4G mobile communications (e.g., LTE: Long Term Evolution) services capable of even faster data communication are in the process of taking over from third-generation communications to become the mainstream. Transition of service generations such as this will lead to large-scale capital investment by telecommunications carriers and renewal of facilities such as communications devices at base stations. It is market fluctuations such as this that spur Linear Technology's prospects in the field of communications.

Power Supply ICs for Environmental Power Generation

In addition, there is one more field in which Linear Technology has recently been focusing its efforts and this is energy harvesting. Known by the term "environmental power generation," this technology is a means of extracting electric power using diverse phenomena occurring in the natural world. For example, minute amounts of electric power are created using energy generated by phenomena such as dif-

ferences in temperature, pressure fluctuations or sunlight, and this is used to drive devices such as sensors.

To realize energy harvesting, not only electric generating elements, but also electric power supply circuits are essential to make the fine adjustments necessary to ensure that the minute amounts of power so painstakingly obtained can be used. Linear Technology has strengths in this area. As an example, even a small amount of electric potential of approximately 0.03V acquired by electronic generating elements can be efficiently boosted to a voltage value capable of being used in other circuits using Linear Technology's step-up energy harvesting IC. Because of the extremely high efficiency of Linear Technology products such as this, the company anticipates that its power supply ICs will be used more and more as the energy harvesting market grows.

For example, in the fields of industrial, instrumentation and medical devices that accounted for 44% of the company's sales volume in FY2011, it is forecast that, in addition to products for existing devices, business for products for energy harvesting will expand. Although not yet generating major sales volume, it is expected that, with the spread of sensor networks, the market for ICs for energy-harvesting devices capable, for example, of boosting minute amounts of voltage or communicating using small amounts of electric power, will soon expand dramatically.

Applying Strengths in Other Fields

As the above illustrates, with strengths such as its unique die bank inventory management system, Linear Technology has won over major customers by providing infrastructure support. Now, it is attempting to extend its leadership to other fields while maintaining its strengths.

This direction encompasses a wide range of fields including industrial automation such as factory automation, automotive, communication infrastructure and medical devices. In all these fields, Linear Technology is aiming to expand its sales channels armed with the

characteristic strengths it has developed to date, such as its die bank system and non-discontinuation of products. Linear Technology is confident in its future because it is a company that knows its own strengths. This is reinforced by other analog companies following Linear Technology's direction, as it focuses on fields with great market potential.

Interview with CEO Lothar Maier About the Company's Future, Vision, Products and Employees

As CEO, what is your vision regarding the company's future?

About the Business—Market and Product

The last decade has been a period of extreme economic and market turbulence, with world economies transitioning through several prosperity-recession cycles. But one constant has remained: the need for technology and innovation. Our customers continue to be more demanding, requesting new innovative products, increased differentiation, shorter lead-times and ever better quality. This environment presents many future market opportunities for a company such as Linear Technology, which has the ability to determine how and where to invest our engineering, sales and manufacturing skills, allowing us to navigate around the crowded consumer electronics markets. As markets and customers evolve, Linear has shown that it is skilled at staying ahead of these changes.

Several years ago it became clear that developing products for the consumer marketplace was not going to meet the company's business goals, so the company's product focus was redirected away from consumer, placing more emphasis on the industrial and automotive markets. This redirection was done with the belief that these markets would need more analog innovation, would grow and would value new products, meeting the company's business goals.



5.5: Lothar Maier, Chief Executive Officer

Looking back, that is exactly what happened. In 2005, 37% of the company's sales came from the industrial and automotive markets. In fiscal year 2012, that had increased to 57%, with Linear's sales growth in each of these markets growing substantially faster than the overall analog market. Looking ahead, this type of redirection will continue into the future. Product development and market acceptance of analog products can take 2 to 4 years, so products presently in development will be part of this future redirection. The industrial and automotive markets will continue to grow, since both of these markets are going through strong innovation cycles. This is conspicuous in the automotive market, where vehicle manufacturers are demanding better fuel efficiency, improved safety, greater comfort features and a growing offering of hybrid and electric vehicles.

The same is true in the industrial market, but less conspicuous, since there are thousands of medium to small industrial customers, but the need for innovation in the industrial market is ubiqui-

tous. Looking further into the future, we will reap the benefits of our recent acquisition of Dust Networks. Just as the digital revolution increased analog market growth, the disruptive impact of a connected world will also benefit the analog market. The “Internet of Things” is an emerging market for devices that manage machine-to-machine (M2M) communications. Forecasters are predicting that this could be a several hundred billion dollar/year market by 2020, with nearly 10 connected devices for every person on the globe. This new market will clearly require wireless products such as Dust Networks wireless sensor network products, as well as an increasing array of standard analog products, since these connected machines will sense, measure and monitor—something that analog does best.

About the Management Team

The semiconductor market, which includes analog, is a complex market. In this market there are frequent product transitions and upgrades, with new markets developing and other markets fading. In the semiconductor market, technology, innovation, creativity and risk-taking all play a role, adding to the complexity. So having a talented and experienced management team to keep pace in this dynamic business environment is essential if a company is going to be successful.

The Linear management team is made up of experienced industry veterans with tenures that range from 10 years to over 30 years working at Linear. This long tenure avoids the obvious costs of turnover, but more importantly, with product development and market acceptance cycles stretching into many years, having a consistent management team is even more important. A management team that knows the market, understands long-term value creation and has the technical expertise to manage in a highly technical, fast-changing marketplace. The success of a management team depends on having a clear company strategy, consistently executed. Linear’s strategy has always been to bring compelling analog products to market which are valued by our customers. Linear’s consistent,

outstanding financial performance, decade after decade, is the result of having the same strategy for over 30 years, deployed by an experienced management team. The compensation structure of the management team is designed to incentivize performance via variable compensation, with company performance the largest component of compensation. This further aligns the management around a common strategy for success.

Since Linear has employees in nearly every country in the world, with large design and manufacturing facilities far removed from the headquarters, it is vital to have a common strategy. The company strategy deployed by management has three important elements: consistency, coherence and alignment. In our diverse global organization it is important that direction and decision-making are done in a consistent manner. It is essential that the many decisions made every day throughout the organization are consistent with our strategy and that there is a common alignment, avoiding the inefficiencies of overlap and redundancy.

About Human Resource (Hiring and Training)

When we hire individuals at Linear, they tend to stay their entire career. One of the largest turnover categories that we track is retirement. With very low turnover, this gives us the opportunity to only hire the best, which we call “A” candidates. In the very competitive analog space, one would normally think that only hiring “A” candidates would be very difficult. But since Linear only designs original, innovative and creative new products, this exclusive product focus is widely recognized in the analog engineering community. This is what attracts many of the best and most talented engineers to Linear, since they all want to do original engineering work—not replication or improvement of some existing product.

But these experienced engineers are a finite resource, and to support our engineering growth requirements, Linear also has an internship program aligned with several universities that have strong analog programs. Students will work for Linear as interns once or

twice during their college careers, and if successful will be offered a job to work at Linear, which is when the real training begins. Once hired by Linear, these new interns will then work closely with some of the industry's leading analog engineers and gain further skills, which after 5 or 10 years will give them the expertise to design or even select and design their own new products. This approach assures that some of today's interns will become the analog gurus of tomorrow.

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Linear Technology's Next Target: Environmental Power Generation

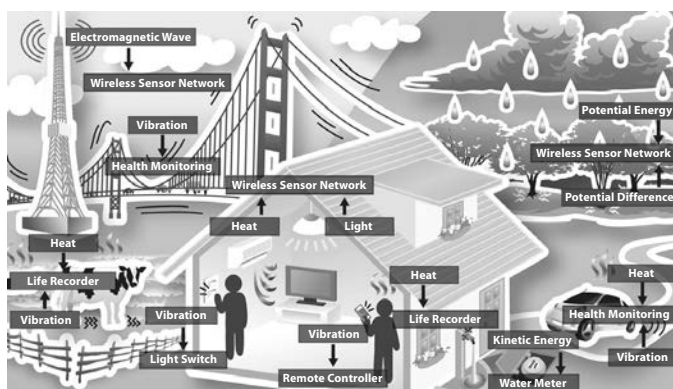
Harvesting Small Amounts of Energy in Our Immediate Environment

For the past few years, Linear Technology has been proactively engaged in activities such as the development of technologies and markets for the field of Energy Harvesting.

Energy harvesting is a technology that collects and uses small amounts of energy present in our immediate environment from sources such as vibration, light, heat and electromagnetic waves. This concept, which makes effective use of extremely small amounts of energy usually discarded has become a major focus of attention. "The size of the energy harvesting-related device market in 2010 was 605 million U.S. dollars and this will expand to 4.4 billion dollars by 2020" (IDTechEx Ltd., U.K.). "The market size, which was 79.5 million U.S. dollars in 2009, is growing at a rate of 73.6% and will reach 1.254 billion dollars in 2014" (Innovative Research and Products, Inc., the United States). Energy harvesting, also known as environmental power generation, offers the benefits of generating power in all kinds of places. However, the amount of electric power acquired is extremely small.

In the majority of cases, a single power-generating device is capable of generating power only on the order of microwatts. Mounted in a smartphone, such a device would be “incapable of generating sufficient power to eliminate the need for recharging.”

The reason for high expectations for market growth despite the fact that energy harvesting technology is capable of generating only minuscule amounts of power, lies in its high degree of convenience. The main advantage of energy harvesting is that devices into which this mechanism is deployed will no longer require troublesome and expensive procedures such as the replacement or wiring of primary batteries or related maintenance. In a sense, this technology will enable the realization of “no power” as opposed to “low power.”



6.1: Utilize Energy Anywhere

Energy harvesting is technology that enables harvesting of small amounts of unused energy which can be effectively utilized. Energy sources include vibration, light, heat and electromagnetic waves.

Source: Reiko Kusumotoi

Because control signals are exchanged wirelessly, new wiring for switches will be unnecessary. In institutions such as museums where the layout of exhibits is frequently rearranged, laying wire for power cables, for example, has always been a major burden. This is a situation where the advantages of wiring-free energy harvesting can really prove their worth.

Changes in Peripheral Components

The typical structural elements of an energy-harvesting system are as follows.

- (1) First, an energy source is located and power generated,
- (2) The harvested power is converted by a power supply circuit and stored in a device such as a capacitor or rechargeable battery,
- (3) The accumulated power is used to activate devices such as microcontrollers or sensors, and
- (4) Information acquired by sensors is transmitted to external devices by wireless signal transceiving.

The price of a single unit that incorporates functions 1-4 is said to be about 12 U.S. dollars if 50,000 units are purchased.

The concept of energy harvesting has existed for some time now and has a long history of research. The reason that the introduction of this concept has recently expanded dramatically lies in advances made in peripheral components using power-generating devices. These components correspond to the functions described in steps 2-4 above. Accordingly, the range of devices to which energy harvesting can be applied has also increased.

Advances in peripheral components is the result of major reductions in the power consumption of devices such as power supply circuits, making efficient use of generated power, wireless ICs used for signal transceiving, microcontrollers and sensors. Until now, the power so carefully harvested by power-generating devices has been entirely consumed by such peripheral components as these, leaving no power for use by the desired functions. The availability of ICs with circuits featuring high efficiency and low power consumption finally heralds the beginning of the stage where energy harvesting can be put into practice.

Interview with Robert Swanson on His Expectations for Environmental Power Generation

Linear Technology's power supply ICs are playing an important role in the development of energy-harvesting markets. Let's now look into the reasons for the company's focus on the field of environmental power generation outlined by Swanson, the founder, in an interview we conducted with him. It seems that Linear Technology, a company in the process of defocusing from consumer product markets, considers energy harvesting a key technology and market in the process of developing for the industrial devices market.

Could you provide background on the efforts you are investing in the field of energy harvesting?

Since our founding, we have always tackled the challenges of new fields. Energy harvesting is one of the fields in which we have recently become involved. Looking back over the last 10 years, some of the fields in which we have developed our analog technology include the Internet, PoE (Power over Ethernet), 3G, navigation, electric vehicles (EV), digital power supplies and compact power modules. Now, the next field we are tackling is energy harvesting.

At the present time, the energy harvesting market has hardly gotten off the ground. We hope that by using analog technology to achieve breakthroughs in the field of energy harvesting, we will be able to create new markets. The process of energy harvesting comprises a flow of acquiring power from sources such as temperature differentials, sunlight, humidity and electromagnetic waves, and using that power to operate microcontrollers and transmit data wirelessly. Although this process flow requires analog circuits, this has not yet been fully explored. Analog circuits represent the missing link in the construction of an optimum system.

Voltage conversion circuits are a good case in point. Voltage acquired from power generation using temperature differentials, for example, is miniscule; no more than 10mV to 20mV. Because operating a microcontroller and transmitting data wirelessly using such

small voltages presents challenges, voltage needs to be increased using a step-up circuit. Although devices such as microcontrollers that can be driven by an extremely small supply current are commercially available, voltage needs to be increased to actually operate these devices. In addition, the voltage conversion circuit must be highly efficient. This is because the amount of power generated is small. This is where advanced analog technology is required.

We have developed a DC/DC converter IC for applications for generating power from temperature differentials. The small voltage of 20mV acquired from power-generating elements can be stepped up with high efficiency to as much as 2.5V or 3V. In addition, we now have a lineup of four or five products for energy harvesting including this same IC for power-generating applications using voltage elements.

Recently, we are hearing a great deal about the subject of energy harvesting. I believe that there are very high expectations for related markets.

We took part in a trade show in Germany in the autumn of 2010 and I walked around many of the booths there. Wherever I went, everyone was talking with great excitement about energy harvesting. It is impossible to deny that the future potential of energy harvesting is great. The important thing is, when will this develop into a major business?

I predict that the energy harvesting market three years down the line will be worth several million U.S. dollars and that this will grow to several tens of millions of U.S. dollars in five years. I think, though, that it's unlikely that the market will exceed 100 million U.S. dollars within the next five years. Nevertheless, the potential for applications is expanding endlessly. This is why we are extremely interested in energy harvesting and are forging ahead to establish a position as a company capable of solving these challenges with analog circuits, representing the missing link.

Because energy harvesting is a business of the future, no doubt there will be many cases of customers concerned about what kind of applications this technology will be capable of handling. To address

this, we are in the process of compiling documentation to resolve such concerns.

I think we can say that we are now at the beginning of the stage where many device designers are making preparations to acquire the capability of using energy harvesting.

Does Linear Technology need to collaborate with other companies in its development of analog circuits for energy harvesting?

To create and expand the energy harvesting business, collaboration with other companies is essential. By joining hands with other companies and sharing areas in which we can each manifest our strengths, we will be able to deliver solutions that are easy to use.

EnOcean GmbH in Germany is one of the leading companies in the field of energy harvesting. We worked in collaboration with this company to develop a product that realizes optimum linked operation with a circuit they developed. This is the DC/DC converter IC I mentioned before that generates power from temperature differentials.

At the request of EnOcean GmbH, we incorporated a function into the LTC3109 IC that is capable of tracking even when the potential difference polarity fluctuates. The LTC3108, the previous generation product, does not incorporate this function. This achievement was made possible because we collaborated with an advanced company in the field of energy harvesting.

We are also working together with a company that handles microcontrollers. This company is working on the development of a microcontroller for energy harvesting, specifically remote sensing, that features extremely low power consumption. We are thinking along the lines of integrating analog ICs in devices such as this microcontroller.

Do you need to collaborate with device manufacturers?

Of course we do. It's interesting to be able to make exciting discoveries by becoming involved with people considering the use of energy harvesting.

We have several thousand analog products that we have introduced to countless hundreds and thousands of engineers around the world who have evaluated these products. It is this feedback from engineers that allows us to pinpoint future applications. Once we have identified these applications, we make modifications to realize a finished product that is easy to use for the projected application.

No doubt, we can expect that the same will be possible with analog products for energy harvesting. I have every confidence that many engineers have practical ideas for product improvements.

For example, the possibility of using energy harvesting is also being explored in the aviation industry. The idea being explored involves installing hundreds of sensors in aircraft for applications such as the monitoring of metal fatigue, and transmitting signals when hazards are detected. Methods like this never crossed my mind when we first started looking at energy harvesting, and I have no doubt that many more such ideas will emerge in the future.

