

News bits

Three earn certification

Three individuals have joined the ranks of certified ESD Control Engineers. Fred Tenzer, Desco; Shigeru Ohki, Texas Instruments Japan, Ltd.; and Terttu Peltoniemi, Nokia Networks, passed their October certification exams and completed the other requirements to achieve professional certification. Seven other individuals also passed the certification exam in October, but still need to complete their other requirements.

Threshold appointments

The ESDA has appointed two persons to oversee the preparation of *Threshold* during 2002. Leo G. Henry, Ion Systems, has been reappointed as *Threshold* chair. Mike Chaine, Micron Technology, Inc., will be the new BOD sponsor. Mike Brandt, Marketing Resources, Ltd., continues as editor.

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New corporate sponsor program provides significant savings

Although professional organizations such as the ESD Association are founded on individual participation and membership, the activities and influence of such organizations go well beyond the individual members themselves. For example, an individual attending an ESDA sponsored tutorial program not only increases personal knowledge and skills, that knowledge and skill also reverts to the individual's company as improved job performance, production efficiency, higher product quality, and perhaps even enhanced profitability. Similarly, these companies support the activities of the Association in a variety of ways, for example, by permitting their employees to become actively involved in activities such as standards development. Thus, the benefits of professional associations accrue not only to the individual members, but also to their companies.



Kay Adams

One of the challenges for many professional membership organizations is how to effectively allow for increased company participation and recognize their support yet still retain the essential individual nature and structure of the organization. Many organizations have turned to some type of corporate sponsorship program to accomplish these goals.

In introducing a new corporate sponsor program, the ESD Association aims to provide opportunities that benefit the companies, the individual ESDA members,

and the Association itself. The new ESD Association corporate sponsorship program is differentiated from many other sponsorship programs in that it returns significant value to its corporate sponsors in exchange for the company's support.

Increased participation, reduced costs

"The corporate sponsorship program recognizes the support of our various companies, as well as providing them with a means of increased participation at reduced costs," explains, Kay Adams, chair of the

Association's Member Services committee that developed the program in conjunction with other Association business units. "It is designed for OEMs and contract manufacturers as well as suppliers of ESD products and services who have an ongoing interest in the benefits technology, standards, services, and education that the Association has to offer."

Customized packages

In actuality, the corporate sponsorship program is two separate packages customized specifically for OEMs and contract manufacturers and for suppliers of static control products and services. The program provides a number of services and benefits such as multiple individual memberships in the ESD Association at a total cost that is substantially less than if the individual components were purchased

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Members Only
section

www.esda.org

From the Threshold chair

ESDA continues its work with Asociación ESD de Mexico.

Thursday October 11th, 2001 was a very good day. It was a day when ESDA liaison activities operated at level worth reporting.



Leo G. Henry

I was in Guadalajara, Mexico, facing for the first time, a group (about 20 or more) of Mexican ESD engineers and technicians and I had not even practiced how to say "Electrostatic Discharge" in Spanish. But there I was, appearing before members of the Asociación ESD de Mexico, which has just been officially recognized as a local chapter by ESDA.

As a board member, I was representing the ESDA. Roger Smith, chapter liaison to the ESDA, had arranged with local chap-

ters chair Kay Adams to have someone visit Mexico to present the benefits of affiliating with the ESDA

A formal introduction by Roger was followed by the inaugural presentation (in Spanish) by chapter president, Victor Hugo Sanchez. He outlined the strategies for the Mexican ESD chapter. I was totally lost until Roger did a great job translating

After some discussion it was my turn. My presentation, *The ESDA-The Key to a Bright Future*, lasted one hour instead of the 15-30 minutes originally planned. The members' undivided attention was a welcome surprise. Maybe it was my rambling Antigua (antique to Ed Weggeland) accent. In any case, the chapter members indicated both during and after the presentation that they were quite happy with the information. A hard copy of the presentation was provided to the chapter.

My presentation started with the history and overview of the Association. I

bet that there are a few of you who did not know

1. That the first EOS/ESD Symposium was sponsored by the IIT Research Institute (IITRI) in 1979 in Denver, Colorado
2. That the ESDA first became a cosponsor of the EOS/ESD Symposium that was held in 1984 and became sole sponsor in 1990
3. That the first ESDA Advisory Committee was convened and a constitution was produced in 1981
4. That the ESDA was officially incorporated in 1982 in New York
5. That the ESDA started with 15 members, and now has more 2200 members in 43 countries.

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Threshold

THRESHOLD™ is published six times a year for members of the ESD Association, a not-for-profit corporation. It strives for the advancement of theory and practice of electrical overstress avoidance and of allied arts and sciences and the maintenance of a high professional standing among its members and others.

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Association news

ESDA plans ESD design seminar March 26-27

Scheduled for March 26-27, 2002, the ESD Association's first ESD Design Seminar is rapidly taking shape. Developed by the Association's Council on Education (ACE), the two-day technical seminar for on-chip ESD protection designers will be held in the Santa Clara, California area. Announcement of the exact venue will be made as soon as details are finalized.

Developed specifically to meet the needs of persons responsible for ESD protection in circuit design, the seminar is part of the Association's effort to expand technical education beyond the annual EOS/ESD Symposium.

The seminar program will include in-depth technical education in a number of specific areas including the following:

ESD in the Industrial Semiconductor IC Context: What is ESD? Why is it

important? What methods are used to control it?

ESD Models and ESD Testing: Description of the three models and model issues from the designer point of view.

ESD Device Operation: Fundamentals of MOS device operation, the role of the PMOS, BiCMOS and the similarity of the techniques for CMOS, Bipolar devices, DENMOS and DMOS devices and protection techniques.

ESD Circuit Operation: Operation of, and issues with, nMOS circuits including implementation, simulation and experimental results.

Technology Impact on ESD Design Choices: Review of ESD protection design options as a function of technology and process fluctuations.

Special Circuit Requirements and Their Impact on ESD: Mixed voltage pro-

tection, RF and analog protection, BiCMOS and high voltage protection.

CDM ESD Protection: Concerns and considerations; fast enough diodes, transistors and SCRs; the on-chip CDM event.

Design Examples and Case Studies: Layout methods, ESD rules, case studies of protection design problems, class exercises.

Instructors for the seminar are Koen G. Verhaege, Sarnoff Europe; Charvaka Duvvury, Texas Instruments; and James W. Miller, Motorola.

Detailed information on the seminar will be distributed shortly and will also appear on the ESDA web site, www.esda.org. For more information on the ESD Design Seminar contact ESDA headquarters.

Calendar of events

January 2002

ESD Northwest Membership Meeting: January 9, 2002, www.esdnw.org

Midwest ESD Chapter Meeting: January 9, 2002, Zap Zar Panel, Bimbo's Restaurant, Palatine, IL, www.midwestesd.org

Silicon Valley EOS/ESD Society Membership Meeting: January 15, 2002, Ramada Inn, Sunnyvale, CA, www.esdsiva.org

Texas Chapter Membership Meeting: January 28, 2001, Sematech, Austin, TX, www.centxesdassoc.homestead.com

February 2002

ESDA Standards and Committee Meetings: February 1-5, 2002, Omni Charlotte Hotel, Charlotte, NC, www.esda.org

Midwest ESD Chapter Meeting: February 13, 2002, High Voltage and ESD, Al Cash, Northrop Grumman, Bimbo's Restaurant, Palatine, IL, www.midwestesd.org

Silicon Valley EOS/ESD Society Membership Meeting: February 19, 2002, Ramada Inn, Sunnyvale, CA, www.esdsiva.org

March 2002

Midwest ESD Chapter Meeting: March 13, 2002, Personnel Grounding—Back to the Future, Joe Jesse, Key Industries, Bimbo's Restaurant, Palatine, IL, www.midwestesd.org

Texas Chapter Membership Meeting: March 18, 2002, Sematech, Austin, TX, www.centxesdassoc.homestead.com

Silicon Valley EOS/ESD Society Membership Meeting: March 19, 2002, Ramada Inn, Sunnyvale, CA, www.esdsiva.org

ESD Design Seminar, March 26-27, Santa Clara, CA (Tentative), www.esda.org

April 2002

Midwest ESD Chapter Meeting: April 10, 2002, ESD-Safe Plastics and Ploymers, Peter Ristikangas, Premix Thermoplastics, Bimbo's Restaurant, Palatine, IL, www.midwestesd.org

October 2002 Symposium: Connect in Charlotte



Charlotte, North Carolina

Editors Note: This article and the accompanying photographs were provided by the Charlotte Convention and Visitors Bureau.

There's a certain energy about Charlotte, North Carolina – call it magnetism – that will draw you to this year's EOS/ESD Symposium. In Charlotte, you can count on a great atmosphere to conduct business, as well as plenty of world-class attractions to spark the varied interests of your attendees. Make plans to connect with colleagues October 6-10 in a city where power and excitement come together!

The center of the action

The EOS/ESD Symposium will be held at the state-of-the-art Charlotte Convention Center, located in the heart of Center City and within walking distance from more than 3,400 hotel rooms, 100 restaurants and a host of great attractions. You'll be pleased to discover an attractive city with clean, safe, tree-lined streets, and courteous, customer-focused service personnel – ready to welcome you with "Southern hospitality."

Arts, culture and attractions

The Southern culture of Charlotte represents a colorful spectrum – from the sophisticated fine artwork of the Mint Museum on Randolph Road, and its sister venue, the Mint Museum of Craft + Design in Center City – to the engine-racing thunder of Winston Cup cars that draw more than 200,000 fans to Lowe's Motor Speedway for races each spring and fall.

History buffs will appreciate the Charlotte Museum of History, Afro-American Cultural Center, and the Levine Museum of the New South. The Levine Museum has recently re-opened following an \$8 million expansion, and now offers the region's most comprehensive history of the South since the Civil War. The interactive displays tell the story of those individuals who played a part in shaping the Charlotte region's diverse history – from cotton fields to skyscrapers.

A short drive from Charlotte, visitors can step back in time to the Revolutionary War and visit historic Brattonsville and the James K. Polk Memorial.

Galleries at the Tryon Center for Visual Art and various private galleries in the North Davidson area (NoDa) offer interesting and eclectic displays of varied media. Regional, national and international musicians and performers take the stage at the Queen City's theater showplace, the North Carolina Blumenthal Performing Arts Center.

Discovery Place science museum in Center City is always a favorite stop, whether to explore a tropical rainforest or aquarium or to travel to brave new world via 3-D films at the OMNIMAX Theater and Planetarium. Fall is an excel-

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The Mint Museum

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Connect in Charlotte

lent time to explore the Historic Latta Plantation and adjacent Carolina Raptor Center, the Charlotte Nature Museum, and Reed Gold Mine.

Don't miss a trip on the refurbished Charlotte Trolley and a visit to the Trolley Barn Museum off South Boulevard. By this fall, you'll be able to ride the trolley from South End shops and restaurants, through Center City to the North End arts and cultural district.

Charlotte is one of the hottest cities in the United States for sports. The city is proud of its NFL Carolina Panthers, NBA Charlotte Hornets, and WNBA Charlotte Sting, as well as Charlotte Checkers minor league hockey, Charlotte Knights AAA baseball, and a scorecard of amateur sports tournaments, excellent golf courses and recreational venues for just about every interest.

The racing empire of Lowe's Motor Speedway offers high-speed excitement – and the exclusive year-round Over the Wall tour takes you behind the scenes of one of the Carolina's most successful industries. Another attraction, Dale Earnhardt, Inc., takes race fans to the heart of the Earnhardt racing empire, with a tour of the racing organization and the legacy of the man who made #3 famous.

No trip to Charlotte would be complete without a shopping excursion. Uptown, the Overstreet Mall offers more than 40 shops connected by pedestrian walkways to many hotels and facilities. Concord Mills, near Charlotte in Concord, offers the area's newest "shoppertainment" experience, combining themed shopping areas and entertainment under one roof. Phillips Place, near SouthPark Mall, brings major-market upscale shopping boutiques and restaurants to Charlotte shoppers.



Lowe's Motor Speedway

Dining

Charlotte sets an inviting table, ready to tantalize and delight every taste. Whether you prefer your food ready to go, or presented elegantly with china and crystal, Charlotte's culinary experts are known for creations to stimulate the senses and satisfy the palate.

You can count on dramatic presentation and interesting flavor combinations, as well as just good down-home cooking – all served with a generous helping of Southern flair.

You'll want to visit popular Center City restaurants including Mimosa Grill (Southern), Bijoux (French), Bistro 100 (American/French), LaVecchia's Seafood Grille, Latorre's (Latin/American), Palomino (Mediterranean Bistro), Monticello (Continental/American), and The Capital Grille (Steak).

Extend your visit

Combine your trip to Charlotte with visits to North Carolina wineries, the famous Biltmore Estate, or the pristine beaches of the Atlantic Ocean. Charlotte is just a few hours away from the mountains and the beaches, as well as the famous golf courses of Pinehurst, two outstanding zoos, and the country's largest furniture shopping center. Fall is a great time to explore North Carolina, and getting to these destinations is easy via excellent interstate highways.

For more information on planning your journey to the EOS/ESD Symposium in Charlotte (and beyond), visit the Charlotte Convention and Visitors Bureau website, www.visitcharlotte.org or call the Visitor Information Line at 800-231-4636. Once you're here, pick up maps, brochures, and lots of friendly advice at INFO! Charlotte, at 330 S. Tryon Street.

2002 challenges and the board's response

Your newly elected officers and Board of Directors (BoD) are being challenged by shifts in economic conditions, the tragedy that occurred during Symposium week, and the demands of industry for greater support.



Steve Halperin

The Association's charter is to serve industry in the field of electrostatics through education and by providing a forum for technology dissemination. This commitment continues regardless of world or economic conditions. Your BoD meets these challenges through extensive financial and activity planning, heated debate, and ongoing communication throughout the year. As conditions change, so do we. This is the job you elected us to do, and with your support it is the job we will do.

Meeting member needs

Our future is based on how well our business units (Symposium, Standards and Certification, and Education) meet the needs of industry members as markets and technology change. Over the years, we have created standards and delivered information and education that has had significant impact on the evolution of technology, product design and test, manufacturing process control, and material development in virtually every segment of the electronics industry. Our impact spans the world and affects government and military agencies, standards bodies, academia, as well as virtually every major corporation. In fact, we have created our own standard of performance and growth, our own *monster* so to speak,

which demands ever-increasing technical information, expansion of educational programs, and ongoing standards development.

How do we meet industry and membership demands in the face of economic turndown, yet continue our growth and impact as a responsible organization? We work smart, capitalizing on our existing resources, and providing services that meet our membership's immediate needs. This year, you will see us focus on ANSI/ESD S20.20 facility certification, regional education development activities, and new support programs for our industry's corporations. All of these innovations utilize resources that we presently have at our disposal.

S20.20 emphasis

Our Standards business unit is investigating ways to provide professional support programs for those who: (1) implement and manage S20.20 programs; (2) serve as S20.20 advisors or consultants to industry; and, (3) provide S20.20 educational services. Our current thinking is to develop the first segment of this potential program for those service organizations that advise facilities desiring S20.20 certification.

Regional education programs

Our Association Council on Education (ACE) is planning new regional education programs for delivery to members who are unable to travel to the Symposium, increasing the flow of advanced technology to industry and our membership. One example of this new effort is the ESD Design Seminar scheduled for March 26-27, 2002. This two-day on-chip ESD protection technical seminar is designed to support industry's device engineers and their needs. See page 3 for more information on this seminar.

Corporate sponsorship program

The Association's new Corporate Sponsorship Program is complete. Developed by our Member Services Committee in conjunction with other business units, the program is designed for electronic industry manufacturers and suppliers that have an ongoing interest in the benefits of electrostatic technology, standards, services and education. It provides a standards site license, employee Association memberships, and additional services and educational opportunities never before available to our corporate supporters. This program is offered in recognition of years of support, and as a means of reducing corporate costs of education, technical information gathering, Symposium participation, and implementation of electrostatic standards. See page 1 for more details.

Pointing to success

Your Board of Directors and business unit managers are creating these new programs and services in a fiscally responsible manner. Our goal is to increase delivery of services throughout the year, in addition to Symposium week, while enhancing the organization's growth and financial stability. In doing so, we will make 2002 successful and will overcome the challenges placed before us. While we have the resources and the desire, the secret to our success will be delivering these benefits to our members, and our membership participating in them. After all, if you do not support and participate, we all fail. We are counting on you this year, just as you are counting on us.

As we roll out these and other new programs, you will find detailed information in the pages of Threshold or on the ESDA web site, www.esda.org. You can direct comments and suggestions to the Board of Directors and business unit managers through Association headquarters.

Association news

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Corporate sponsor program

separately. For example, the OEM/contract manufacturer package includes a standards site license while the supplier package includes advertising and promotion components. The specific provisions of each package are available from Association headquarters, an overview of each is provided below.

OEM/CM package

The program for OEMs and contract manufacturers includes multiple individual memberships, a standards site license, a paper S20.20 review of the company's ESD control program, admissions to the Symposium and tutorials, and Symposium proceedings. The annual fee for the user program is \$8,000, a savings of approximately 45% if the services and benefits were purchased separately.

Supplier package

The program for suppliers of ESD control products includes multiple individual memberships, an annual standards subscription, a single Symposium booth, a web site buyers guide listing, institutional listings in *Threshold*, attendance at ESDA-sponsored educational programs, and other benefits. The annual fee for the vendor program is \$4,000, a savings of approximately 27% if the services and benefits were purchased separately.

First quarter special

Companies who choose to participate in the corporate sponsorship program will receive special pricing (\$7,500 for the OEMs and contract manufacturers package and \$3,500 for the suppliers package) and a 10% discount on all ESDA products and services if the package is purchased and paid for in full before March 31, 2002.

"Our goals in introducing this new program are to strengthen the organization, deliver expanded services to industry, recognize the support of the many companies over the years, and provide a means

for expanded participation of these companies at a cost savings," says Steve Halperin, Association president. "Kay and her member services committee have provided us with a good foundation upon which we can build for the future."

For additional information on the new corporate sponsor program, contact ESD Association headquarters.

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From the Threshold chair

All this was shared with Asociación ESD de Mexico.

After spending some time discussing the purpose, the membership benefits, and future concepts, the presentation ended with how to partner with a local chapter. Additional ideas included developing a list of voluntary speakers to give 30-40 minute presentations at membership meetings, featuring a local chapter in Threshold, and sending a representative to an Association meeting series.

I was at Mexitronica for three days, visiting the booth that was provided to the Asociación for free. The traffic was reasonable for first timers as over 45 names were actually collected from those people who visited the booth.

Overall, the Guadalajara visit was good and the officers of de Asociación de Mexico appeared to be quite enthusiastic over this new beginning. Of course, I was actually attending Mexitronica to represent my company at the ION Systems booth. Who says that a person cannot serve two masters simultaneously?

My thanks to Kay and Roger for their planning and their overall support, and good luck to the Asociación ESD de Mexico. I am sure that they will get our total support.

Until next time,
Be happy!

Leo G

On the local scene

Local chapter forms in Mexico

The definition of "local" chapter has taken on a somewhat broader meaning as the newly formed Asociación ESD de Mexico, A.C. has received recognition by the ESDA as a local ESD chapter.

With activities and membership concentrated in the Guadalajara, Mexico area, the fledgling chapter held its kick-off meeting in October 2000 with its first official meeting the following month. For 2002, the chapter is planning bi-monthly meetings, normally on the first Thursday of the month.

Numbering 31 paid members, the chapter has ambitious plans for 2002-2003 that include an ESD basics tutorial, an ESD standards training series, a standards library, networking, and an educational program to help members prepare for professional certification.

During the recent Mexitronica show in Guadalajara October 10-12, the chapter promoted the chapter and its activities in a booth that was provided by the show sponsor, ROC Exhibitions. Nearly 50 persons visited the booth to find out more about the chapter.

The officers and board for the chapter are Victor Sanchez, Consultant, president; Matias Aliseda, 3M, vice president; Roberto Martinez, IBM, secretary; Jose Miguel Fuentes, Estatec, treasurer; Roger Smith, Bennett & Bennett, USA liaison; Delia Esquivel, Sierra International, member at large; Luis Villegas, ESD International member at large; Antonio Navarro, IBM, honorary president.

The chapter's constitution and by-laws have been completed and approved. In December, the chapter was recognized by the ESD Association as an affiliated local chapter.

For more information on the first non-US local chapter, visit the chapter's web site at www.geocities.com/esdmex/principal.html or contact Roger Smith, Guadalajara, Jal. Mexico; phone: 011-52-333-630-2604, Fax: 011-52-333-615-8520, cell phone: 011-52-333-156-5946; Email: rsmith@megared.net.mx

Radio frequency technology and the ESD challenge

by **Steven H. Voldman**
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Introduction

Radio frequency (RF) applications are beginning to open a new era in global communication.

At the 2001 EOS/ESD Symposium, the first RF ESD session helped bring this new world into focus. In his paper "The Future of RF Technology for Established Wireless Markets and



Emerging Wireless Applications," D. R. Pehlke of Ericsson, Inc. presented some startling facts.

For instance, the number of cellular subscribers worldwide has doubled an average of every 19 months since 1992 for a total of 707 million subscribers. The growth is not isolated to a single part of the world; it is in the U.S., China, Europe, 168 countries in all. Whether you are in New York City, Hong Kong, Singapore, or Tel Aviv, cellular phones are everywhere. With our first session on RF technology at the EOS/ESD Symposium, we have begun to learn and share our knowledge of how to provide ESD protection to RF technology.

New technologies

What are the technologies utilized in this new era? They are going to range from RF CMOS, silicon germanium, silicon germanium carbon, gallium arsenide, and gallium nitride, to indium phosphide. They include new materials of binary compounds, ternary alloys, and the mixing and matching of different elements—arsenics, zinc, indium, carbon—a pot-pourri of the Periodic Table—to push the

performance or reliability of devices will play a role in the RF revolution.

While ESD protection is a fact of life to our semiconductor device brethren, little ESD thought has been given to RF. Why? One reason is that the technologies were not mainstream and not built in volume. Second, there was no pressure from customers to achieve better results—one of a kind applications and zero competition. One quick gaze in a shop in the electronic stores in Hong Kong and it is easy to see the level of competition is strong.

Pushing the ultimate limitations of the bipolar transistor and achieving ESD protection simultaneously are not clear achievable goals without tradeoffs or future novelty. ESD protection of RF products is increasingly important as application frequencies move into the 1 to 50 GHz regime. Below 1 GHz, the ability to simultaneously achieve excellent ESD protection and performance objectives was possible in most CMOS, BiCMOS, and SOI applications. But as semiconductor applications extend beyond 1 to 100 GHz, providing ESD protection and satisfying performance goals will increase in difficulty.

Today, SiGe technology produces heterojunction bipolar transistors that show significant increases in unity current gain cutoff frequency (f_T) in every technology generation. The speed of the transistors has been improving with each successive generation. Tak Ning, keynote speaker at the 2001 Symposium presented data for the latest IBM 200 GHz SiGe HBT device. As the power supply voltage decreases, low breakdown voltage devices can exist. The lower breakdown voltage allows for faster transistors. A fundamental relationship, known as the Johnson Limit, exists between the frequency response of the transistor and maximum power applied across the transistor element. The Johnson Limit in its power for-

mulation is given as

$$(P_m X_c)^{1/2} f_T = E_m v_s / 2\pi$$

where P_m is the maximum power, X_c is the reactance $X_c = 1/2 P f_T C_{bc}$, f_T is the unity current gain cutoff frequency, E_m is the maximum electric field and v_s is the electron saturation velocity. In this form, it states that there is an inverse relationship between the maximum power and frequency response. This can also be expressed in terms of maximum voltage, V_m

$$V_m f_T = E_m v_s / 2\pi$$

The formulation states that the product of the maximum velocity an electron can traverse a medium and the maximum electric field across that region is a constant. It also states that there is an inverse relationship between the transistor speed and the allowed breakdown voltage (Figure 1).

Based on the Johnson Limit condition, as BiCMOS SiGe technologies scale to provide a higher f_T , the BV_{CEO} of the tran-

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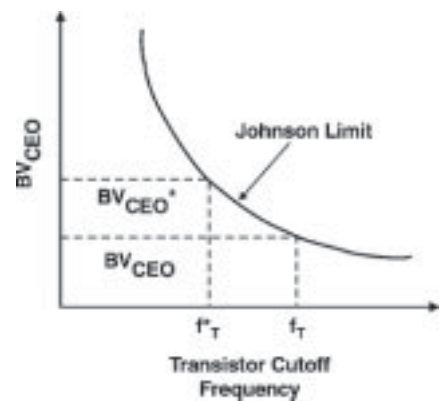


Figure 1. Johnson Limit relationship of BV_{CEO} vs f_T relationship

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RF technology

sistor decreases. Hence from the Johnson Limit,

$$V^* m f^* T = V_m f_T = \frac{E_m v_s}{2\pi}$$

where $V_m f_T$ is associated with a first generation transistor and $V^* m f^* T$ is associated with a second generation transistor. The ratio of breakdown voltages can be determined as

$$\frac{V^* m}{V_m} = \frac{f_T}{f^* T}$$

Using this Johnson relationship, one can anticipate the speed of the technology as the breakdown voltages are decreased with power supply voltages.

Other implications

What other implications result as bipolar transistors are scaled? The Johnson Limit establishes a specific maximum f_T value for a given technology. As the SiGe HBT is scaled to achieve the higher f_T and f_{MAX} values, this establishes an RF ESD scaling condition for utilization of these high f_T devices. From the ratio of the power-to-failure condition (Wunsch-Bell development) and the maximum power vs f_T relationship, a dimensionless group can be established explaining the relationship between thermal conduction, thermal capacity, failure temperature, pulse width, saturation velocity, maximum electric field condition and the unity current gain cutoff frequency. A dimensionless group Vo may be defined as

$$Vo = \frac{\text{Powerto failure}_-}{\text{JohnsonLimitMaximumPower}_-} = \frac{Pf(\tau)}{P_m}$$

In this dimensionless group, different physical models such as the Wunsch-Bell model and the Johnson Limit maximum power expression can be applied. In the

thermal diffusion time regime, we can express a dimensionless group Vo as

$$Vo = \frac{Pf}{P_m} = \frac{A \sqrt{\frac{\pi K C_p \rho (T - T_0)}{\tau}}}{\left(\frac{E_m^2 v_s^2}{(2\pi)^2} \right) X_c f_T^2}$$

What does the dimensionless group signify? It is a physical competition of the ability of a material to store and diffuse heat, the ability to transport electrons, and the electric field that can be placed across the medium. As the frequency of the SiGe HBT increases, the maximum power decreases. As the device dimensions are scaled to achieve these objectives, the power-to-failure will decrease unless doping and material changes are addressed. To produce future high f_T devices, dimensional scaling, doping concentration, and material changes will be needed. This will entail optimization of the base doping concentration, Ge concentration, and possibly the introduction of carbon.

What about ESD?

What ESD elements can protect these transistors? Circuits, ESD devices and ESD power clamps can be constructed from these transistors. With transistors whose f_T exceed 100 GHz, the ability to provide ESD power clamps are important for RF products because RF applications and BiCMOS chips can be small chips (e.g. low chip capacitance) and there is also the need to scale the size of ESD structure to reduce loading effects at the pin. Hence, using RF diode-based solutions, the current must flow through the chip power grid back to the ground plane. As a result, low impedance ESD power grids with low and/or scalable trigger solutions are needed for RF semiconductor chips. To provide an

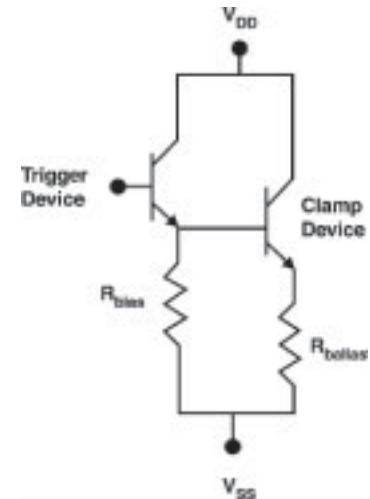


Figure 2. SiGe HBT ESD Power Clamp.

ESD solution that naturally scales with the BiCMOS technology and utilizes the limitation of bipolar transistors, ESD power clamps were designed which takes advantage of the Johnson Limit. Hence from the Johnson Limit equation,

$$V^* m f^* T = V_m f_T = \frac{E_m v_s}{2\pi}$$

where $V_m f_T$ is associated with a first transistor and $V^* m f^* T$ is associated with a second transistor.

Using this relationship, an ESD power clamp can be synthesized in which a trigger device with the lowest breakdown voltage can be created by using the highest f_T transistor and a clamp device with the highest breakdown voltage will have the lowest f_T . Figure 2 shows an example of a Darlington configured bipolar power clamp. For this configuration to be suitable as an ESD power clamp, we can take advantage of the inverse relationship between the BV_{CEO} and the f_T of the device. For a power clamp, the clamp device must have a high BV_{CEO} in order to address the functional potential between the V_{CC} power supply and ground potential. This

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On Paschen's Law and insulators

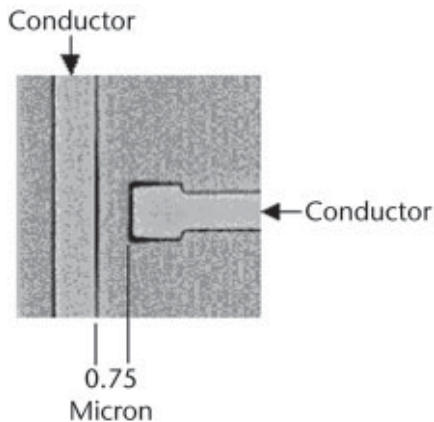
To the editor:

I read with great interest (as I always do) the article by Dr. Niels Jonassen, "Insulators and Paschen's Law", that appeared in the September/October issue of *Threshold*.

The article noted that the atmospheric pressure and the distance between the electrodes determined the breakdown field strength between parallel metal electrodes. The curve presented indicated a minimum breakdown voltage of around 300 volts occurring at 5-6 micron gap spacing.

In the real world we are often not dealing with parallel electrodes. Conductors come in a variety of shapes and configurations, many having sharp edges or corners that affect the magnitude of the local electric field. Do the predictions of Paschen need to be modified for these conditions?

Right now the semiconductor industry is particularly concerned about ESD damage on photomasks. Basically a photomask consists of numerous isolated chrome conductors deposited on top of a quartz substrate. Under some conditions, electric fields can induce voltage differentials on adjacent photomask conductors large enough to exceed the breakdown field strength and cause ESD. Eventually, the result is a defective photomask and product loss.



The typical geometry looks like the figure below. The gap width and width of the feature are currently around 0.75 microns, and will tend to shrink as the semiconductor industry follows its technology roadmap. Methods are being considered to measure the voltages at which the breakdown occurs.

In advance of those measurements, would Dr. Jonassen care to comment on what the theory might predict for the breakdown voltage for the photomask geometry?

Arnie Steinman
Chief Technology Officer
ION Systems

Mr. Static replies:

When I wrote the piece "Insulators and Paschen's Law?" (*Threshold*, Sep/Oct 01) the primary purpose was to warn people of using conductor-related terms in connection with insulators where often they do not apply, like estimating discharge risks from surface potentials. But after having written the piece I couldn't help starting a more general paper on breakdown phenomena, especially from and between conductors and with special attention to non-parallel electrodes.

This paper, however, is much too long for *Threshold*. Although it appears to be possible to predict breakdown field strengths and breakdown voltages for, at least spherical electrodes, to rather small dimensions, there's no evidence that the predictions hold true all the way down to the dimensions that Arnie Steinman is looking for.

So we don't know if there is a Paschen-law for mm-electrodes. But I don't see why it shouldn't be possible to find out. But a poor old pensioner cannot do it. At least not alone.

Niels Jonassen
Mr. Static

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RF technology

power clamp requires an f_T above the ESD pulse frequency to discharge the current effectively. For the trigger device, a low breakdown voltage device is needed in order to initiate base current into the clamp device at an early enough voltage.

For Si or SiGe transistors, the $BV_{CEO} \cdot f_T$ product is approximately 200 GHz-Volt. Hence for a 47 GHz trigger transistor, the BV_{CEO} will be approximately 4 Volts. From the TLP measurement, the 4 V trigger condition is observable for this SiGe HBT power clamp. (Figure 3)

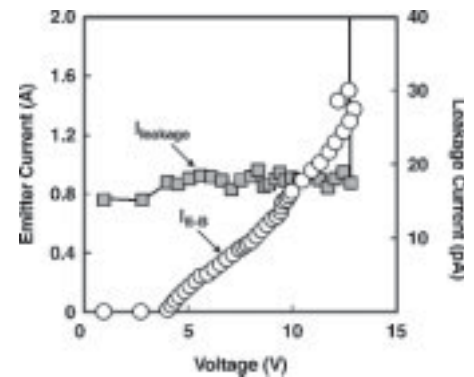


Figure 3. TLP I-V and leakage measurement of a SiGe HBT Darlington ESD Power Clamp.

In conclusion, there is a lot of ESD work ahead of us as we enter the RF era in this millennium! The fun is just beginning!

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