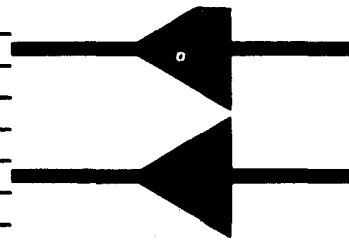


**Sixth Annual Applied Power  
Electronics Conference  
and Exposition**





**APEC '91**

**Sixth Annual  
Applied Power  
Electronics  
Conference and  
Exposition**



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**Conference  
Proceedings  
1991**

**March 10-15, 1991**

**Hyatt Regency  
Dallas, Texas**

**91CH2992-6**

## **1991 IEEE 6th Applied Power Electronics Conference**

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# FOREWORD

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Howdy y'all!

On behalf of the APEC '91 Conference Committee, I would like to welcome you to the Sixth Annual Applied Power Electronics Conference and Exposition. This year's APEC continues the tradition of being the premier conference for the practicing power electronics professional. In Texas we do things bigger and better and this year's conference is no exception.

This year an important new direction is taken. For the first time, the Power Sources Manufacturers Association joins the Power Electronics and Industry Applications Societies of the IEEE in sponsoring APEC. The continues are efforts begun last year with the addition of IAS as a sponsor to broaden the range of topics covered while maintaining our focus on the practicing power professional. As real world competition puts new demands on professionals to broaden their scope, we at APEC endeavor to match these demands with broader program coverage. This is shown this year with sessions on manufacturing technology and marketing acknowledging the interdependence of these functions with our engineering base.

The APEC Committee is proud of the conference program we bring you this year. Nearly 100 papers are scheduled for fifteen Technical Sessions and Bill Warwick, President of AT&T Microelectronics, will deliver a keynote address focusing on competing in today's environment. Nine Professional Education Seminars offer current information on topics of interest to today's power professionals. The Rap Sessions offer a chance to exchange experience and opinions on current issues in the power electronics industry.

The Exposition is bigger and better than ever, allowing more opportunities to visit with leading power electronic industry vendors. It will open Monday night with

a reception and Wednesday afternoon will be devoted to the vendors. In addition to the exhibits being open Wednesday afternoon, several Exhibitors will be offering seminars to update users on their latest products and the traditional Micromouse Contest will be held. Additionally, a tour of the AT&T Power Systems facility in nearby Mesquite will be offered. This facility is one of the largest in the world devoted exclusively to power electronic design and manufacture.

The old adage cautions against "all work and no play" and the social program is an integral part of the conference. You can't visit Texas and not have barbeque and we have arranged for the conference banquet to be held Wednesday night at the Circle R Ranch, a short bus ride from the hotel. There we will have a traditional Texas barbeque and listen to the music of a live country band. The conference siting in downtown Dallas offers numerous opportunities for unscheduled time. The West End, a renovated warehouse district with lots of shops and clubs and frequent outdoor entertainment is only a short walk from the hotel. The Dallas Arts District and numerous fine restaurants are only a short cab ride away.

The APEC Committee is all volunteers who work long and hard to bring you the best technical, educational and social program of any conference in power electronics. Your comments and suggestions are important to us. The feedback sheets are all read and tabulated and we strongly encourage you to fill them out for us. I would also ask that during the week, you seek out the committee members listed on the next page and let them know what you liked and what could be improved to better meet your needs. We'll do our best to incorporate your suggestions into next year's conference.

Welcome to APEC '91—better than ever.

Chuck Harm  
General Chair

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On behalf of the APEC Committee, I would like to thank the following individuals for contributing the time and effort that went into preparing the outstanding technical program of APEC '91.

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# APEC '92

## **Seventh Annual IEEE Applied Power Electronics Conference and Exposition Announcement and Call for Papers**

February 23-28, 1992

**The Westin Hotel, Boston Massachusetts**

The IEEE Power Electronics and Industry Applications Societies and the Power Sources Manufacturers Association are sponsoring the Seventh Annual Applied Power Electronics Conference and Exposition (APEC '92). APEC '92 will address the practical application of new components and circuits, design-oriented analysis techniques and current trends in the design and manufacture of power electronic products and systems.

*Papers and Seminars are Solicited in All Areas of Power Electronics Including:*

Off-line Power Supplies  
DC-DC Converters  
High Power Factor AC-DC Converters  
Uninterruptible Power Supplies  
High Frequency Techniques  
High Density Techniques and Packaging  
CAD/CAE Tools and Applications  
Simulation of Power Electronic Circuits  
Power Systems for Electronic Equipment

Modeling, Analysis and Control  
Measurement Techniques  
Novel Methods for Sensing and Control  
Motion Control and Servo Systems  
Electronically Controlled Motors  
DC-AC Inverters  
Integrated Circuits  
Smart Power Circuits

Manufacturing Processes  
High Voltage Integrated Circuits  
Discrete Semiconductors  
Design for Manufacturability  
Thermal Design  
Battery Applications  
EMI and EMC Issues and Considerations  
Regulatory Agency Issues

*Deadline for Receipt of Abstract and Digest is August 16, 1991.*

*Preparation of Abstracts and Digests:*

Prospective authors are asked to submit a 50 word Abstract and a three to five page Digest of their planned presentation. Both the Abstract and digest should be typed, double space on 8½" × 11" paper.

The heading of the Abstract must include:

Title of the presentation  
Author(s)  
Affiliation(s)  
Mailing address  
Daytime telephone number

The heading of the Digest should include the title only.

The Digest should clearly state:

- a) The purpose of the work;
- b) The methods used; and
- c) The specific results.

Inclusion of key figures, tables, and conclusions is encouraged.

Eight copies (originals are not required) of all material should be mailed to:

APEC '92  
655 15th Street N.W., Suite 300  
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Papers submitted for consideration will be subjected to a peer review process. The principal criterion in reviewing papers for acceptance will be the usefulness of the presentation to the practicing engineer.

Authors will be notified of acceptance, with instructions for publication by October 18, 1991.

Manuscripts are expected to be from 5 to 10 pages, including diagrams and figures, and are due in final form by December 6, 1991 for publication in the Conference Proceedings.

### *APEC '92 Exposition*

A comprehensive trade show consisting of exhibits on the latest advances in components, equipment and services will be featured during APEC '92. Exhibitors will include commercial firms and organizations involved in the manufacture, sale or distribution of components, equipment and professional or technical services.

*For more information: APEC '92*

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(202) 639-4990

# CONFERENCE SCHEDULE

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## **SUNDAY, March 10** **Professional Education Seminars**

---

- 1:30 p.m.-5:00 p.m.    **SEMINAR 1**    **Electric Power Factor Correction (Part 1)**  
Rudy Severns, Springtime Enterprises, Inc.
- SEMINAR 2:**    **Simulation of Power Electronics Circuits**  
Ned Mohan, University of Minnesota
- SEMINAR 3:**    **Power Supply Markets and Marketing**  
Mohan Mankikar, Micro-Tech Consultants
- 

## **MONDAY, March 11** **Professional Education Seminars & Plenary Session**

---

- 8:30 a.m.-12:00 p.m.    **SEMINAR 4:**    **Electronic Power Factor Correction (Part 2)**  
Rudy Severns, Springtime Enterprises, Inc.
- SEMINAR 5**    **Switched Reluctance Motor Drives**  
R. Krishnan, Virginia Polytechnic Institute and State University
- SEMINAR 6:**    **Quality Requirements for the 90's**  
James Parker, Xerox Corporation
- 1:30 p.m.-5:00 p.m.    **SESSION 1:**    **Plenary Session**
- 5:30 p.m.-8:00p.m.    **EXHIBITORS RECEPTION**
- 

## **TUESDAY, March 12** **Technical Sessions**

---

- 8:30 a.m.-12:00 p.m.    **SESSION 2:**    **Resonant Techniques**
- SESSION 3:**    **Sine-Wave Output Conversion**
- SESSION 4:**    **Quality Manufacturing**
- 2:00 p.m.-5:30 p.m.    **SESSION 5:**    **High-Frequency Converters and Applications**
- SESSION 6:**    **Brushless Drives & Motion Control**
- SESSION 7:**    **Power Sources Marketing**
- 6:00 p.m.-7:30 p.m.    **RAP SESSIONS**



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**WEDNESDAY, March 13**  
**Technical Sessions & Exhibitor Seminars**

---

- 8:30 a.m.-12:00 p.m.   **SESSION 8A:**   **Control Techniques**  
                                 **SESSION 8B:**   **Simulation Tools**  
                                 **SESSION 9A:**   **Induction and Synchronous Motor Drives**  
                                 **SESSION 9B:**   **Three-Phase Line Harmonic Control Design**  
                                 **SESSION 10A:**   **Test and Measurement Methods**  
                                 **SESSION 10B:**   **Magnetic Amplifiers**
- 1:30 p.m.-5:30 p.m.   **EXHIBITOR SEMINARS**
- 2:00 p.m.   **MICROMOUSE CONTEST**
- 6:30 p.m.-10:30 p.m.   **RECEPTION AND BANQUET**
- 

**THURSDAY, March 14**  
**Technical Sessions**

---

- 8:30 a.m.-12:00 p.m.   **SESSION 11:**   **Single-Phase Power Factor Correction**  
                                 **SESSION 12:**   **Circuit Modeling & Analysis**
- 2:00 p.m.-5:30 p.m.   **SESSION 13:**   **UPS & Battery Systems**  
                                 **SESSION 14A:**   **Power Semiconductors & Packaging**  
                                 **SESSION 14B:**   **Magnetic Components**  
                                 **SESSION 15:**   **Converter Analysis**
- 

**FRIDAY, March 15**  
**Professional Education Seminars**

---

- 8:30 a.m.-12:00 p.m.   **SEMINAR 7:**   **EMI Control and Filter Design**  
   Mark J. Nave, Sverdrup Technologies, Inc.
- SEMINAR 8:**   **Pulse-Width-Modulation Techniques: Theory Application**  
   P. Enjeti and M. Ehsani, Texas A&M University
- SEMINAR 9:**   **Product Safety Compliance—An Introduction**  
   Arthur E. Michael, Product Safety International

# TABLE OF CONTENTS

## SESSION 1: Plenary Session

Monday, March 11  
Reunion FH  
1:30 p.m.-5:00 p.m.

- |     |  |    |
|-----|--|----|
| 1.1 | <b>A Novel Zero Voltage Switching PWM DC/DC Converter for Medium Power Applications</b><br>L. Salazar and P. Ziogas, <i>Concordia University, Montreal, Quebec, Canada</i>                 | 3  |
| 1.2 | <b>Characteristics Of Load Resonant Converters Operated In A High Power Factor Mode</b><br>M. Schutten, R. Steigerwald, and M.H. Kheraluwala, <i>GE Corporate R&amp;D, Schenectady, NY</i> | 5  |
| 1.3 | <b>Modelling For Power Electronic Circuits And Systems</b><br>G. Franz, <i>GE Astro Space, Princeton, NJ (invited)</i>   | 17 |
| 1.4 | <b>The World Market</b><br>D. Field, <i>Coutant-Lambda, Ilfracombe, North Devon, UK (invited)</i>  | 19 |
| 1.5 | <b>Smartpower In Motion Control: How Semiconductors Are Reshaping The Marketplace</b><br>L. Rinehart, <i>IXYS Corporation, San Jose, CA (invited)</i>                                      | 22 |
| 1.6 | <b>Applying Power Electronics To Residential HVAC—The Issues</b><br>L. Sulfstede, <i>Trane Company, Tyler, TX (invited)</i>  | 27 |

## SESSION 2: Resonant Techniques

Tuesday, March 12  
Reunion F  
8:30 a.m.-12:00 p.m.

- |     |   |    |
|-----|---|----|
| 2.1 | <b>Experimental Study of the LLC-Type Series Resonant Converter</b><br>R. Liu, C. Lee, and A. Upadhyay, <i>University of Illinois at Chicago, Chicago, IL</i>   | 31 |
| 2.2 | <b>Conception And Design Of A Parallel Resonant Converter For Induction Heating</b><br>E. Dede, J. Jordan, J. Gonzalez, J. Linares, V. Esteve, and E. Maset, <i>G.H. Industrial S.A., Valencia, Spain</i> | 38 |
| 2.3 | <b>Design And Analysis Of the Ward Converter For Capacitor Charging Applications</b><br>J. Schatz and R. Nelms, <i>Auburn University, Auburn, AL</i>  | 45 |
| 2.4 | <b>Constant Frequency PWM Capacitor Voltage Clamped Series Resonant Power Supply</b><br>J. Vieira and I. Barbi, <i>Universidade Federal de Santa Catarina, Florianopolis, Brazil</i>                      | 52 |
| 2.5 | <b>150 W Resonant Converter With T-Type Tank Circuit</b><br>M. Shioya, H. Takano, Y. Shiozawa and M. Hanawaka, <i>Yokogawa Electric Corporation, Tokyo, Japan</i>   | 58 |

- |     |   |    |
|-----|---|----|
| 2.6 | <b>Effects of Resistances and Leakage Inductances on Cross Regulation in SRC</b><br>J. Agrawal and C. Lee, <i>University of Illinois, Chicago, IL</i> | 65 |
|-----|---|----|

- |     |   |    |
|-----|---|----|
| 2.7 | <b>High Frequency High Power DC-DC Full Bridge Converter With Zero-Current Zero-Voltage Commutation</b><br>E. Morad, P. Ziogas and G. Joos, <i>Concordia University, Montreal, Quebec, Canada</i> | 71 |
|-----|---|----|

## SESSION 3: Sine-Wave Output Conversion

Tuesday, March 12  
Cascade B  
8:30 a.m.-12:00 p.m.

- |     |  |     |
|-----|--|-----|
| 3.1 | <b>Inverter Topologies And Control Techniques For Sinusoidal Output Power Supplies</b><br>D. Divan, <i>University of Wisconsin, Madison, WI (invited)</i>  | 81  |
| 3.2 | <b>Economic Single Phase To Three Phase Converter Topologies For Fixed Frequency Output</b><br>P. Enjeti, R. Jakkli, and A. Rahman, <i>Texas A&amp;M University, College Station, TX</i>                                   | 88  |
| 3.3 | <b>A Novel Single To Three Phase Converter</b><br>J. Nesbitt, C. Chen, D. Divan, and D. Novotny, <i>University of Wisconsin, Madison, WI</i>   | 95  |
| 3.4 | <b>Advanced Random Pulse Width Modulation Technique For Voltage-Controlled Inverter Drive Systems</b><br>S. Legowski, <i>University of Wyoming, Laramie, WY</i><br>A. Trzynadlowski, <i>University of Nevada, Reno, NV</i> | 100 |
| 3.5 | <b>Control of Three Phase Power Supplies for Ultra Low THD</b><br>R. De Doncker and J. Lyons, <i>GE Corporate R&amp;D, Schenectady, NY</i>   | 107 |
| 3.6 | <b>Simplified Harmonic Neutralization Techniques For High Power Inverters</b><br>E. Stacey, <i>Westinghouse Science &amp; Technology Center, Pittsburgh, PA</i>  | 109 |

## SESSION 4: Quality Manufacturing

Tuesday, March 12  
Cascade A  
8:30 a.m.-12:00 p.m.

- |     |   |     |
|-----|---|-----|
| 4.1 | <b>Japanese Electronics Manufacturing: An Overview</b><br>A. Kamp, <i>Zytec Corporation, Redwood Fall, MN</i> | 113 |
| 4.2 | <b>Just In Time (JIT)—A Customer Perception</b><br>B. McKnight, <i>Abbott Labs, Irving, TX</i>                | 115 |
| 4.3 | <b>ESD Damage: What It Is and What We Can Do About It</b><br>W. Cowan, <i>Hewlett Packard, Palo Alto, CA</i>  | 117 |

4.4	<b>Quality and Reliability: A Customer's Perspective</b> L. Bennet, T. Dodenhoeft, <i>Storage Technology Corp., Louisville, CO</i>	120	6.3	<b>Using A Boundary Layer Technique To Reduce Chatter in Sliding Mode Controllers</b> J. Hung and R. Nelms, <i>Auburn University, Auburn, AL</i>	195
4.5	<b>Quality Data Collection: Don't Waste Your Time</b> F. Westerfield, <i>NCR Corporation, Lake Mary, FL</i>	123	6.4	<b>Four Quadrant Sensorless Brushless ECM Drive</b> R. Becerra, <i>GE-Motors, Fort Wayne, IN</i> ; T. Jahns, <i>GE Corporate R&amp;D, Schenectady, NY</i> ; M. Ehsani, <i>Texas A&amp;M University, College Station, TX</i>	202
4.6	<b>Test Equipment—A Call for Standardization</b> R. Cox, <i>Autotest, San Antonio, TX</i>	125	6.5	<b>Permanent Magnet Motor Speed Control Loop Autotuning</b> F. Gagneux, D. Jouve, and J. Rognon, <i>ENSIEG, St. Martin d'Heres, France</i>	210

## SESSION 5: High-Frequency Converters and Applications

Tuesday, March 12  
Reunion F  
2:00 p.m.-5:30 p.m.

5.1	<b>Integrated-Magnetic Pre-Converter Networks for Switchmode Power Converter Circuits</b> G. Bloom, <i>e// BLOOM Associates, Inc., San Rafael, CA</i> ; D. Mitchell, <i>Rockwell International—Collins Defense Communications, Cedar Rapids, IA</i>	133
5.2	<b>A Half-Bridge Zero-Voltage Switching Pulse-Width Modulated DC-To-DC Converter</b> I. Barbi, <i>Universidade Federal de Santa Catarina, Florianopolis, Brazil</i> ; H. Hey, <i>Universidade Federal de Uberlandia, Uberlandia, Brazil</i>	140
5.3	<b>An Efficient Full Bridge PWM DC-DC Converter Topology Using Lossless Snubber And Simple Active Energy Recovery Network</b> V. Agelidis, P. Ziogas, and G. Joos, <i>Concordia University, Montreal, Quebec, Canada</i>	146
5.4	<b>High-Voltage, High-Power, ZVS, Full-Bridge PWM Converter Employing An Active Snubber</b> J. Sabate, V. Vlatkovic, R. Ridley, and F. Lee, <i>Virginia Polytechnic Inst. &amp; S.U., Blacksburg, VA</i>	158
5.5	<b>Low-Profile 60-W Power Pack for Telecommunications Systems</b> N. Murakami, J. Asoh, <i>NTT Applied Electronics Laboratories</i> , and S. Ishizuka, <i>NTT Network Systems Development Center, Tokyo, Japan</i>	164
5.6	<b>Hybrid High Speed Voltage Regulator with Reduction of Miller Effect</b> E. Perusse, <i>Hughes Aircraft Company, Fullerton, CA</i>	171
5.7	<b>High Voltage DC Shifted RF Switch-Mode Power Supply System—Design For Gas Lasers Excitation</b> S. Sbenaty and C. Ventrice, <i>Tennessee Technological University, Cookeville, TN</i>	173

## SESSION 6: Brushless Drives & Motion Control

Tuesday, March 12  
Cascade B  
2:00 p.m.-5:30 p.m.

6.1	<b>Commutation Of SR Motors</b> R. Becerra, <i>GE Motors, Fort Wayne, IN</i> ; M. Ehsani, <i>Texas A&amp;M University, College Station, TX</i> ; T. Miller, <i>University of Glasgow, Glasgow, Scotland</i>	181
6.2	<b>Sliding Mode Control of the Energy Recovery Chopper in a C-Dump Switched Reluctance Motor Drive</b> S. Bolognani, E. Ognibeni, and M. Zigliotto, <i>University of Padova, Padova, Italy</i>	188

6.6	<b>A New Direct Digital PWM Technique For Microprocessor-Based PWM Inverters</b> S. Kwon, I. Choy and K. Kim, <i>Korea Institute of Science and Technology, Seoul, Korea</i>	219
-----	---	-----

## SESSION 7: Power Sources Marketing

Tuesday, March 12  
Cascade A  
2:00 p.m.-5:30 p.m.

7.1	<b>The Military Market</b> D. Fuller, <i>OECO, Milwaukee, OR</i>	223
7.2	<b>The Market for Distributed Power Systems</b> C. Heath, <i>Venture Development Corp., Natick, MA</i>	225
7.3	<b>The Battery Market</b> S. Deshpande, <i>GNB Ind. Battery Co., Lombard, IL</i>	230
7.4	<b>Advertising and Promotion Made Easy</b> M. Neavill, <i>AT&amp;T Microelectronics, Berkeley Heights, NJ</i>	237
7.5	<b>Productivity Tools for Marketing and Sales</b> J. Steel, <i>Zytec Corporation, Eden Prairie, MN</i>	239

## SESSION 8A: Control Techniques

Wednesday, March 13  
Reunion F  
8:30 a.m.-10:30 a.m.

8A.1	<b>Improved Transient Performance of a 3-Phase Controlled Rectifier Using Predictive Control</b> E. Nowicki, S. Dewan and A. Sedra, <i>University of Toronto, Toronto, Canada</i>	247
8A.2	<b>Real-Time Median Filtering With A Fast Hardware Sorter</b> S. Leeb, A. Ortiz and J. Kirtley, <i>Massachusetts Institute of Technology, Cambridge, MA</i>	254
8A.3	<b>Optimum Digital Controller of PWM Converter Systems</b> L. Malesani, C. Offelli, M. Pardi, L. Rossetto, and P. Tenti, <i>University of Padova, Padova, Italy</i>	261
8A.4	<b>Phase-Shifted PWM Control—A New Integrated Controller Eases the Design of Efficient High-Frequency Bridge Power Switching</b> R. Mammano and J. Putsch, <i>Unitrode IC Corporation, Santa Ana, CA</i>	263

## SESSION 8B: Simulation Tools

Wednesday, March 13  
Reunion F  
10:30 a.m.-12:00 p.m.

- |      |   |     |
|------|---|-----|
| 8B.1 | <b>Interactive Analysis and Design Program For Phase-Controlled Rectifiers</b>  | 271 |
|      | A. Kelley, J. Nance, and M. Moore, <i>North Carolina State University, Raleigh, NC</i>                                |     |
| 8B.2 | <b>A Multi-Simulator Environment for Power Supply Simulation</b>  | 278 |
|      | R. Michelet, <i>Valid Logic Systems, San Jose, CA</i>   |     |
| 8B.3 | <b>Modeling Losses And Stresses Of High Frequency Power Converters Using Saber</b>                                    | 285 |
|      | R. Farrington, M. Jovanovic, and F. Lee, <i>Virginia Polytechnic Institute &amp; State University, Blacksburg, VA</i> |     |

## SESSION 9A: Induction and Synchronous Motor Drives

Wednesday, March 13  
Cascade B  
8:30 a.m.-10:30 a.m.

- |      |   |     |
|------|---|-----|
| 9A.1 | <b>Inverter Motor With Sinusoidal Starting Currents</b>   | 295 |
|      | G. Mohlenkamp, <i>Ruhr-Universitat Bochum, Bochum, Germany</i>  |     |
| 9A.2 | <b>A Flux Observer For Induction Machines Based On A Time-Variant Discrete Model</b>  | 302 |
|      | C. Bottura, <i>Universidade Estadual de Campinas, Campinas, Brazil</i> , J. Silvino and P. Resende, <i>Universidade Federal de Minas Gerais, Belo Horizonte, Brazil</i> |     |
| 9A.3 | <b>Analysis of a Load Commutated CSI-Fed Induction Motor Drive</b>  | 309 |
|      | J. Song, T. Yoon, K.H. Kim, K.B. Kim, and M.J. Youn, <i>KIST, Seoul, Korea</i> ; M. Youn, <i>KAIST, Seoul, Korea</i>  |     |

## SESSION 10A: Test and Measurement Methods

Wednesday, March 13  
Reunion H  
8:30 a.m.-10:00 a.m.

- |       |   |     |
|-------|---|-----|
| 10A.1 | <b>An Automated Reverse-Bias Second-Breakdown Transistor Tester</b>   | 339 |
|       | D. Berning, <i>National Institute of Standards &amp; Technology, Gaithersburg, MD</i>   |     |
| 10A.2 | <b>Substrate and Metallization Selection for High Power Hybrid Circuits Based on Thermal Resistance and Temperature Cycling Reliability</b> | 347 |
|       | K. Dalal, <i>Brush Wellman, Inc., Cleveland, OH</i>   |     |
| 10A.3 | <b>Magnetic Current Sensors For Space Station Freedom</b>   | 355 |
|       | C. Sullender, <i>Rockwell International Corporation, Rocketdyne Div., Canoga Park, CA</i>   |     |

## SESSION 10B: Magnetic Amplifiers

Wednesday, March 13  
Reunion H  
10:00 a.m.-12:00 p.m.

- |       |   |     |
|-------|---|-----|
| 10B.1 | <b>Megamp Design with Ferrite Core Saturable Reactors</b>   | 359 |
|       | C. Jamerson and M. Barker, <i>NCR Power Systems, Lake Mary, FL</i>  |     |
| 10B.2 | <b>Stabilizing Megamp Control Loop By Using An Inner-Loop Compensation</b>  | 365 |
|       | D. Chen, <i>VPI &amp; SU, Blacksburg, VA</i> ; C. Jamerson, <i>NCR Power Systems, Lake Mary, FL</i> , C. Yang and Y. Wu, <i>Taiwan University, Taipei, Taiwan</i> |     |
| 10B.3 | <b>Evaluation and Selection of Forward Rectifiers for Mag Amp Secondary Post Regulators</b>   | 373 |
|       | S. Cash, <i>University of Iowa, Iowa City, IA</i>   |     |
| 10B.4 | <b>Megamp Post Regulators for Symmetrical Topologies with Emphasis on Half-Bridge Configuration</b>   | 380 |
|       | C. Jamerson, <i>NCR Power Systems, Lake Mary, FL</i> , D. Chen, <i>VPI &amp; SU, Blacksburg, VA</i>   |     |

## SESSION 11: Single-Phase Power Factor Correction

Thursday, March 14  
Reunion F  
8:30 a.m.-12:00 p.m.

- |      |  |     |
|------|--|-----|
| 11.1 | <b>Near-Unity-Power-Factor Single-Phase AC-To-DC Converter Using A Phase-Controlled Rectifier</b>                | 387 |
|      | A. Kelley, M. Hallouda, M. Moore, and J. Nance, <i>North Carolina State University, Raleigh, NC</i>              |     |
| 11.2 | <b>Electronic Fluorescent Ballast Using A Power Factor Correction Technique For Loads Greater Than 300 Watts</b> | 393 |
|      | J. Spangler, B. Hussain and A. Behera, <i>Illinois Institute of Technology, Chicago, IL</i>                      |     |
| 11.3 | <b>AC To DC Power Conversion With Unity Power Factor and Sinusoidal Input Current</b>                            | 400 |
|      | G. Rim and R. Krishnan, <i>VPI &amp; SU, Blacksburg, VA</i>  |     |
| 11.4 | <b>A Power Factor Enhancement Circuit</b>  | 407 |
|      | M. Elmore, W. Peterson, and S. Sherwood, <i>GE Aircraft Control Systems Dept., Binghamton, NY</i>                |     |

## SESSION 9B: Three-Phase Line Harmonic Control

Wednesday, March 13  
Cascade B  
10:30 a.m.-12:00 p.m.

- |      |   |     |
|------|---|-----|
| 9B.1 | <b>A Passive Input Current Waveshaping Method for Three-Phase Diode Rectifiers</b>  | 319 |
|      | A. Prasad, <i>MPF Technologies, Inc., Dorval, Quebec, Canada</i> , P. Ziogas, <i>Concordia University, Montreal, Quebec, Canada</i> , S. Manias, <i>National Technical University of Athens, Athens, Greece</i> |     |
| 9B.2 | <b>Input Current Harmonic Reduction in High Power AC/DC Rectifiers</b>  | 331 |
|      | A. Maswood, G. Joos, P. Ziogas, and J. Lindsay, <i>Concordia University, Montreal, Quebec, Canada</i>   |     |
| 9B.3 | <b>Unbalance Supply And Its Effect On Rectifier Input Filter kVA Ratings</b>  | 333 |
|      | A. Maswood and M. Rashid, <i>Concordia University, Montreal, Quebec, Canada</i>   |     |



- 11.5 **Switch-Mode Power Supply Power Factor Improvement Via Harmonic Elimination Methods** 415  
J. Lai, D. Hurst, and T. Key, *Power Electronics Applications Center, Knoxville, TN*
- 11.6 **Modeling And Simulation Of A Digitally Controlled Active Rectifier For Power Conditioning** 423  
R. Hudson, S. Hong and R. Hoft, *University of Missouri-Columbia, Columbia, MO*
- 11.7 **A Unity Power Factor Multiple Isolated Output Switching Mode Power Supply Using A Single Switch** 430  
I. Barbi, *Universidade Federal de Sta. Catarina, Florianopolis, Brazil*; and C. Canesin, *Universidade Estadual Paulista, Soiteira, Brazil*

## SESSION 12: Circuit Modeling & Analysis

Thursday, March 14  
Reunion H  
8:30 a.m.-12:00 p.m.

- 12.1 **Physical Origins Of Input Filter Oscillations In Current-Programmed Converters** 439  
Y. Jang and R. Erickson, *University of Colorado, Boulder, CO*
- 12.2 **Modelling And Analysis Of Zero Voltage Switching Converters** 441  
W. Moussa, *IBM Corporation, Endicott, NY, J. Morris, SUNY-Binghamton, Binghamton, NY*
- 12.3 **Computer-Aided Small-Signal Modeling of Switching Power Converters** 443  
P. Maranesi and G. Naummi, *Politecnico di Milan, Milan, Italy*
- 12.4 **Generalized In-Place Circuit Averaging** 445  
J. Noworolski and S. Sanders, *University of California, Berkeley, CA*
- 12.5 **Improvement of Stability In Current-Programmed SEPIC DC/DC Converters** 452  
M. Johnson, *IBM Corporation, Lexington, KY*
- 12.6 **Current-Mode Control: A Unified Model for Open-Loop Instability** 459  
A. Kislovski, *Ascom Energy Systems, Berne, Switzerland*
- 12.7 **High-Frequency Extension Of The Small-Signal Model Of The Constant-Frequency Current-Mode Controlled Converter** 466  
R. Redl, *ELFI S.A., Onnens, Switzerland*

## SESSION 13: UPS & Battery Systems

Thursday, March 14  
Cascade B  
2:00 p.m.-5:30 p.m.

- 13.1 **A Microcomputer-Based UPS Battery Management System** 475  
Z. Noworolski, J. Noworolski and C.A. Bennett, *Polytronics Engineering, Ltd., Mississauga, Ontario, Canada*
- 13.2 **Comparing Battery Backup Units** 480  
R.A. Priegnitz, *Sola Electric, Elk Grove Village, IL*

- 13.3 **Stand Alone Transformerless Sinusoidal Power Inverter for PV Systems** 484  
R. Fiorello, *Powercube Corporation, Billerica, MA*, Z. Salameh, *University of Lowell, Lowell, MA*
- 13.4 **Selecting Batteries For Uninterruptible Power Supply Systems** 491  
B. Essig and G. Braun, *Gates Energy Products, Inc., Gainesville, FL*
- 13.5 **The Use Of Equalizing Converters For Serial Charging Of Long Battery Strings** 493  
D. Hopkins, C. Mosling, and S. Hung, *Auburn University, Auburn, AL (invited)*
- 13.6 **Microcontroller Based Arbitrary Waveform Inverter** 499  
B. Leibovich, U. Hardon, and S. Ben-Yaakov, *Ben-Gurion University of the Negev, Beer Sheva, Israel*
- 13.7 **Improved GTR's Quasi-Resonant DC Link Inverter** 506  
W. Feng, *Hangzhou Institute of Commerce, Hangzhou, People's Republic of China*

## SESSION 14A: Power Semiconductors & Packaging

Thursday, March 14  
Reunion F  
2:00 p.m.-3:30 p.m.

- 14A.1 **2.5 Million Cell/Inch<sup>2</sup> Low-Voltage DMOS FET Technology** 513  
H. Yilmaz, I. Hsieh, M. Chang, and J. Van Der Linde, *Siliconix, Inc., Santa Clara, CA*
- 14A.2 **Electrical and Thermal Performance Of A Hybrid High-Power Density Inverter Phase Switch** 519  
T. Latos and T. Sutrina, *Sundstrand Corporation, Rockford, IL*
- 14A.3 **Autonomous Control Technique For High-Performance Switches** 524  
P. Krein, *University of Illinois, Urbana, IL*, R. Bass, *Georgia Institute of Technology, Atlanta, GA*

## SESSION 14B: Magnetic Components

Thursday, March 14  
Reunion F  
3:30 p.m.-5:30 p.m.

- 14B.1 **Electrical and Thermal Performance of PWB Transformers** 533  
M. Sayani, G. Skutt, and P. Venkatraman, *Digital Equipment Corporation, Maynard, MA*
- 14B.2 **Fabrication Method for a Winding Assembly With A Large Number of Planar Layers** 543  
K. Ngo, *University of Florida, Gainesville, FL*, R. Alley and A. Yerman, *General Electric Company, Schenectady, NY*
- 14B.3 **High Frequency Planar Power Transformers For Resonant Converters** 550  
M. Morrill, V. Caliskan, and C. Lee, *University of Illinois, Chicago, IL*
- 14B.4 **Controlled Transformer** 556  
M. Knights and K.L. Erickson, *Zytec Corporation, Eden Prairie, MN*

## SESSION 15: Converter Analysis

Thursday, March 14

Reunion H

2:00 p.m.-5:30 p.m.

- |      |  |     |      |   |     |
|------|--|-----|------|---|-----|
| 15.1 | <b>Coupled Inductor Boost Converter with Input and Output Ripple Cancellation</b><br>R. Martinelli, <i>Analytic Artistry, Torrance, CA, C.</i><br>Ashley, <i>Hughes Aircraft Company, El Segundo, CA</i>                                 | 567 | 15.4 | <b>Constant Frequency Controlled Full-Bridge LCC-Type Parallel Resonant Converter</b><br>C. Lee, S. Sooksatra, and R. Liu, <i>University of Illinois at Chicago, Chicago, IL</i>  | 587 |
| 15.2 | <b>A Lossless Commutation Pulse-Width-Modulated Converter By Using A Resonant Disconnecting Circuit</b><br>L. Freitas, E. Coelho, H. Hey, V. Farias and J. Viera, Jr., <i>Universidade Federal de Uberlandia, Uberlandia, MG, Brazil</i> | 573 | 15.5 | <b>Analysis And Design Of A Modified Series Resonant Converter</b><br>A. Bhat, <i>University of Victoria, Victoria, B.C., Canada</i>  | 594 |
| 15.3 | <b>Steady State Analysis of DC To DC Resonant Converter</b><br>O. Mandhana and R. Hoft, <i>University of Missouri, Columbia, MO</i>  | 580 | 15.6 | <b>High-Voltage Light-Weight DC/DC Converter</b><br>G. Karady and M. Muralidhar, <i>Arizona State University, Tempe, AZ</i>   | 601 |
|      |  |     | 15.7 | <b>Steady-State Analysis Of Dual Converters With Circulating Current Used In Four-Quadrant DC Magnet Power Supplies</b><br>S. Dewan, <i>University of Toronto, Toronto, Ontario, Canada</i> ; J. Kim, <i>University of Victoria, Victoria, B.C., Canada</i> | 608 |

# **SESSION 1**

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## **PLENARY SESSION**

**Monday, March 11, 1991**

**Reunion FH**

**1:30 p.m.-5:00 p.m.**

**Chairman:**  
**T. M. Jahns**  
**GE Corporate R&D**





## **1.1 A Novel Zero Voltage Switching PWM DC/DC Converter for Medium Power Applications**

**L. Salazar and P. Ziogas  
Concordia University  
Montreal, Quebec, Canada**

**Paper Not Available at Time of Printing**