# *Electronics Devices Worldwide Pvt. Ltd*

31, Mistry Industrial Estate, Cross Road A, MIDC, Andheri(East), Mumbai – 400093, Maharashtra. Email :corporate@edmail.in, bkpaul65@gmail.com,arunp26@iitbombay.org, **ccpl202122@gmail.com** , Mobile: 98336853327

Electronics Devices Worldwide Pvt Ltd is a leading packaging, welding and induction heating machinery solutions provider. We have innovation at the core of our operations and remain dedicated to indigenousness. Operational for more than five decades, we have delivered reliable industrial solutions to businesses worldwide. Industrial environments require innovation to meet the changing industry demands, and we are here to help with that.

The Electronics Devices brand is an amalgamation of three sub-brands under its name. Here's an overview:

- Sigma CapSeal (packaging machinery)
- Sigma Weld (welding inverters)
- Sigma Therm (induction heating)

***Our origins***

We began our operations in 1974 at a 200 sq. ft. facility. However, our commitment to innovation helped us expand our footprints rapidly. We launched a di-electric preheater as our first product, which also got exported to businesses in foreign countries. Today, we have a presence in industrial environments across the APAC, the Americas, and Europe.

- Export to 80+ countries
- 45+ years of experience
- 30,000 customers
- 1st ever machine built in 1974 still in working condition in our customer's factory

**Industrial manufacturing solutions**

Electronics Devices brings together industry veterans from various backgrounds. Our professionals deliver cutting-edge and cost-effective solutions that help businesses meet their goals. Our machines are built to last and offer the best uptime to help you finish your production requirements without any hassles. The support team ensures there are no hiccups with the regular operations of our machinery.

**Team**

Our ability to Making Things Happen for our customers starts with our strong team of 220+ experienced & capable Engineers. We come from a diverse set of experiences and backgrounds that range from Research, Machine Tool, Power Electronics, Pharma & FMCG professionals.

**Research and development**

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Our commitment to research and development helps us create equipment that lasts for years. Our machinery has robust designs that can withstand rigorous industrial environments. With stringent production and performance testing, you can expect the best solutions from us.

**Customization**

We understand that each business is unique and has varied production requirements. Our organization does not follow a one-size-fits-all approach. We offer tailored solutions to meet your business needs no matter how complex they are.

**Industries covered**

We offer various manual, semi-automatic, and automatic machines for different business needs. Here are the industries we cover.

- Dairy
- FMCG
- Food and beverage
- Dairy
- Healthcare
- Personal care
- Confectionery
- Specialty chemicals
- Construction
- Chemicals
- Automobiles
- Pharmaceuticals

**Brief history of the company** : The company Electronics Devices has started on 26th December in 1974 as a partnership company and subsequently in the year 2011 company's name has been changed to Electronics Devices Worldwide Pvt. Ltd. and also transformed from partnership to private ltd co by two technologists named Mr. R. B. Singh, alumni of BHU and Mr. S. V. Chinoy who is alumni of BITS – Pilani and our R&D unit has started in the year 2002. We are brand leader in Induction Cap Sealing and Induction Heating Machines, Die Electric Pre Heaters and Welding Inverters for SMAW, MIG, TIG and SAW applications, Welding SPM, Data Monitoring System, Induction Heating Equipment etc. We are manufacturing world class global standard products and we have filed many patent of our innovation products.. A few of our indigenous items replaced imported items and saving forex and ultimately helping our country to attain self sufficient. Our products using by prestigious organisation like DRDO, ISRO, DAE , L&T, BHEL, BEL, BEML, PIDILITE, CAMLIN etc and almost all pharmaceutical companies

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globally . Our total turnover is approx. 60 Crores and more than 20% through export sales.

**Nature of business** : Manufacturing of all kinds of welding inverters, power sources and die electric pre-heater. Wide range of inductions cap sealing equipment, complete range of inductions heating equipment, special purpose machine for 1) induction heating application , 2) induction cap sealing application, 3) arc welding application and 4) closure automation ( wad inserting, cap folding and cap assembly etc.).

**Main objectives of the Company** : M/S. Electronics Devices Worldwide Private Limited (EDWPL) strongly believed in creating and manufacturing advanced power electronics products in India for global consumption. To fulfil such objectives, company established independent R&D decades back. Accordingly, the requisite infrastructure has been established.

Business sustainability along with ensuring definite growth is one major challenge each technology company has been facing Now. Operating features of an industry involved in the business line of manufacturing power and control electronics controllers to meet challenges dynamically in metal working industry. This segment of the industry is extremely dynamic, primarily, due to the following reasons:

(a) Meet the dynamics of each product globally
(b) Meet all the features being offered/available in the world market competitively; it could lead to the addition of more products, completely new design and or introduce new product lines
(c) To cater emerging application domains, particularly, because of emergence of new materials frequently
(d) Meet the challenges posed by continuous drift in technology
(e) Meet the challenges posed by input conditions, e.g., change in component engineering
(f) Be innovative, integrate features first time in the world

**Import substitution** : Yes, more than 50 Crores. More than 20% of our revenue come from export sales to EU countries and USA and almost others 80 countries. Since 1974 we are manufacturing various import substitute products like Die-Electric Pre Heater used to import from EU countries by Cokeware, Melamine Crockery, Rubber Moulding, Cookware Handle and all Sigma Cap Sealing and Sigma Welding machine. We have already sold Di-Electric Pre-Heater 1000 qty @ 3000 USD since 1974 and save forex almost 3 Mns USD. Sigma Cap Seal we have already sold almost 15000 qty @ 3000 USD since 1991 and save forex almost 45 Mns USD and also we have sold Sigma Welding

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machine 10000 qty @1000 USD since 2007 and save forex almost 10 Mns USD. Our main objective for setting up our manufacturing unit as IMPORT substitute company

Award :

1) Received National Technology Award 2023 from Technology Development Board, Govt. of India for our innovative patented product Sigma IP-65 , A Golden prize with 15 Lakhs cash prize too
2) Received National Achievers Recognition Award Forum Award 2023 from NAAID-new Delhi on May23
3) Received FIPSA award for our innovative product on June'23
4) Received award India 5000 best MSME award on 30th Nov 2021
5) Received award for Exploring innovation in plastic packaging & machinery 19th may 21
6) Received award National Awards for Excellence in Packaging on 24th Feb 21

## A brief of educational, career journey and achievement of Arun Kumar Paul

- **Engineering Graduation done from : REC, Jalpaiguri Govt. Engg. College, West Bengal**
- **M. Tech from IIT- Bombay**
- **Ex-Sr. Scientific officers at BARC, Robotics Division**
- **Sr. Member : IEEE**
- **Life member of** Indian Institute of Welding
- **Director – Technical and R&D since 2002 at Electronics Devices Worldwide Pvt Ltd**
- **Expert | Induction Sealing Solutions | Liner Assembly M/c| Vision Integrated Robotic Assembly Machines |. Vision Inspection | Cap Assembly Machines**
- **1. Induction Sealing Solutions**
  **2. Liner Inserting Machines**
  **3. Cap & Closure Assembly Machines**
  **4. Vision Inspection Systems**
  **5. Robotic Assembly Machines**

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**Details Curiculmn vitae of Arun Kumar Paul as under for your ready reference to justify eligibilty for candidature :**

CURRICULUM VITAE

1. Name of the nominee: Mr. Arun Kumar Paul
2. Educational Qualification: M. Tech (Control & Instrumentation)
3. IEEE Membership number: 91288793 (Grade: Senior Member)
4. Life Member: Indian Institute of Welding (No.: BAR/M/R-13111/L)
5. Date of Birth: July 26, 1961, Village: Sattore, Post office: Taltore, Dist.: West Burdwan, West Bengal
6. Professional Affiliation: Electronics Devices (World Wide) Private Limited
7. Business address: 22 Mistry Ind. Est., Cross Road A, MIDC, Andheri (E), Mumbai 400093, Maharastra.
8. Home address: 1602, Fiona, Hiranandani Estate, G. B. Road, Patlipada, Thane (W): 400607, Maharastra
9. Email: arunp26@iitbombay.org
10. Linkedin address: https://www.linkedin.com/in/arun-paul-430a0a196/
11. Phone numbers: (Office): 022-26870311, (Mob.): 09833685327
12. Education:

| Degree | University | Year | Branch/Stream | Percentage |
|---|---|---|---|---|
| B. E. (Elect.) | North Bengal University | 1984 | Electrical Engineering | 77%, Ranked 3rd in EE in the University. |
| M. Tech | IIT Bombay | 1992 | Control & Instrumentation | CPI = 8.17/10.0 |

13. Employment History

| Designation | Employer | Period | Job Responsibility |
|---|---|---|---|
| Technical Director | Electronics Devices World Wide Private Limited, Mumbai | 01-01-2002 to till date | 1. High freq. power electronics product design for all types of arc welding, induction heating applications and customization<br>2. Quality engineering and<br>3. Component engineering |
| Consultant in Power Electronics Product Design | Memco Ltd, Ansa Indl. Est, Block A, Saki Naka, Andheri, Mumbai. | 1-12-1999 to 31-12-2001 | Design of inverter-based arc welding power sources (≤600A) suitable for constant current (CC) process. I, as well, helped manufacturing the products. |
| | Target Marketing Ltd., Sanjay Bldg. C, Mittal Indl. Estate, Marol, Mumbai 59. | | Design of on-line uninterruptible power supplies (up to 35 kVA). I guided manufacturing team for producing these products as well. |

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| | | | |
|---|---|---|---|
| | General auto electric corp., Ansa Indl. Est, Block D, Saki Naka, Andheri, Mumbai. | | Design and technology transfer of full range of battery chargers for Indian Railways. Handled product approval from SAMEER and RDSO and trained their manufacturing team. |
| Head, Engineering | Symatic Engineering Pvt Ltd, Plot EL 147, EL 127/128/139, TTC Industrial Area, Mahape, Navi Mumbai – 400710. | 1-07-1996 to 31-11-1999 | Handling engineering design of:<br>Relay control panels, Power and machine control centers, PLC based engine control and generator protection panels and PLC based process controllers |
| Sr. Quality Engineering Manager | Ultra Tek Devices Pvt. Ltd., 72, SDF III, SEEPZ, MIDC, Andheri (E), Mumbai – 400093 | 1-08-1994 to 31-7-1996 | Failure analysis of mass produced SMPS, first pass yield analysis, reliability study, design verification, cost reduction, component engineering, etc. |
| Manager, Robotics | Electro-pneumatics Pvt Ltd, Cross Road A, MIDC, Andheri (E), Mumbai – 93 | 1-01-1994 to 31-07-1994 | Design of servo drives for six axis robot joints using PMDC motor and managing design team for robot control |

**14. Publications / Patents:**

**Patents Granted**:

Number of National/International patents granted: Three

1. Patent IN 415961 (2022). Title: Zero ventilated induction sealing device with improved spatial distribution of optimized power loss, 2022. (the product received The National Technology Award 2023).
   Inventor: Mr. A. K. Paul. It is fully commercialized.
2. Patent IN 425208 (2023). Title: Induction sealing head and a coil assembly thereof for energy efficient sealing of containers. It is fully commercialized.
   Inventor: Mr. A. K. Paul
   Co-inventor: Mr. S. B. Chinoy
3. Patent IN 406392 (2022). Title: Transformer with mixed-core configuration in induction heating system. It is commercialized in induction heating systems for pre and post heat treatment applications.
   Inventor: Mr. A. K. Paul.

**Patents Pending:**

1. Patent filed (Application number: 202121006308), Title: SOSMC based Multi-loop Parallelly Connected Power Converters for High Current Submerged Arc Welding Process.
   Inventor: Mr. A. K. Paul.
   Co-inventor: Mr. Mangesh Waman.
2. Patent filed (Application number: 202321044830), Title: Pulse-transformer for isolated gate driving of parallel connected SiC Mosfets in induction cap sealing applications.
   Inventor: Mr. A. K. Paul.

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**Publication Record:**

(i) Total number of papers published: 73;
(ii) Number of papers published in Journals/Transactions: 36.
(iii) Number of papers published in IEEE platforms: 42
(iv) Number of papers published in IEEE Transactions: 15 (all first author, at least)
(v) Total number of first author articles: 62
(vi) Number of single author publications: 44
(vii) Number of single authored journal articles: 27
(viii) Number of single author articles published in IEEE Transactions: 12

**List of Publications (Mostly linked to industrial product design for commercialization)**

- **Papers Published in Journals**

1. A. K. Paul, "Power electronics: Gateway to efficiency reserve," Invited article to be published in WIE Tantra of IEEE Bombay Section (Technical Magazine) in the subject category 'The role of Technology in Climate Mitigation', 2023.
2. A. K. Paul, "Application Prospects of Hybrid Magnetic Circuits in High Frequency Power Transformers," IEEE J Emerg. Selected Top. Ind. Electron., Early Access.
3. A. K. Paul, "Efficacy of STC in high frequency full-bridge DC–DC converter," *IEEE J. Emerg. Select. Top. Ind. Electron*, vol. 3, no. 4, pp. 1020-1027, Oct. 2022.
4. A. K. Paul, "Practical study of mixed-core high frequency power transformer," *MDPI Magnetism* 2022, 2, pp. 306-327.
5. A. K. Paul, "Emulating full-load testing of air-cooled nanocrystalline IHT at zero power," *IEEE J. Emerg. Select. Top. Ind. Electron*., vol. 3 (3), pp. 725-732, July 2022.
6. A. K. Paul, "Zero-ventilated self-cooled induction heating device: Topology and component engineering," *Journal of Power Electron. Devices and Components*, Open Access, vol. 3, pp. 1-10, 100013, Elsevier, 2022.
7. A. K. Paul, "Choice of control function in magnetically-coupled full bridge DC-DC power controller for arc welding: A practical approach," *Journal of Power Electronics Devices and Components*, Open Access, pp. 1-10, April 2022.
8. B. Sai Ram, A.K. Paul, S.V. Kulkarni, "Soft magnetic materials and their applications in transformers," *J Magn. Magn. Mater*., vol. 537, 168210, Elsivier, Nov. 2021.
9. A. K. Paul, "Structured Protection Measures for Better Use of Nanocrystalline Cores in Air-Cooled Medium-Frequency Transformer for Induction Heating," *IEEE Trans. Ind. Electron*., vol. 68, no. 5, pp. 3898-3905, May 2021.
10. A. K. Paul, "ZVZCS SRI guides optimal use of copper and core for air-cooled nanocrystalline transformer for induction heating," *IEEE Trans. Ind. Appln*., 56(2), pp. 970-978, Mar/Apr 2020.
11. A. K. Paul, "Input power factor improvement using sensorless single-stage axial field PMDC motor controller for arc welding process", J Inst. of Engg., Series B, 2020.
12. A. K. Paul, "Sensorless robust speed controller design of pancake axial field PMDC motor," *IEEE Trans. Ind. Appln.*, vol. 56, no. 6, 2019.
13. A. K. Paul and M. Waman, "Efficient SMAW arc controller for wide range applications and also for emerging economies," Vol 52 (4), pp. 73-80, Indian Welding Journal, 2019.
14. A. K. Paul, "Robust PMDC motor control for accurate wire feeding in GMAW using back emf," *IEEE Trans. Ind. Electron.*, vol. 67, no. 1, pp. 413-420, 2020.

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15. A. K. Paul, "Arc controllers for TIG welding applications: A review", *Indian Welding Journal*, vol. 52, no. 2, pp. 56-64, 2019.
16. A. K. Paul and B. Bandyopadhyay, "Multi-functional arc welding controller using SOSMC technique," *IEEE Trans. Cont. Syst. Technol.*, vol. 27(5), pp. 2245-2253, 2019.
17. A. K. Paul, "Active-controlled passive distribution of power offers efficient heat-treating solution for quality arc welding joints of steel pipes," *IEEE Trans. Ind. Appln*., vol. 55, no. 5, pp. 4958-4966, Sep./Oct, 2018.
18. A. K. Paul, N. Chinoy, B. Das and S. Bhosle, "Air-cooled induction heating solution for heat treatment of P91 grade steel in welding applications", *Indian Welding Journal*, vol. 51, no. 3, pp. 81-88, 2018.
19. A. K. Paul, "Robust features of SOSMC guides in quality characterization of tank circuit in air-cooled induction cap sealing," *IEEE Trans. Ind. Appln*., vol. 54, no. 1, pp. 755-763, Jan./Feb. 2018.
20. A. K. Paul, "Robust control by SOSM facilitates optimizing under actuated induction cap sealing process," *IEEE Trans. Ind. Electron*., vol. 64 (6), pp. 4511-4519, Jun. 2017.
21. A. K. Paul and S. Chinoy, "Air cooled induction heater for efficient sealing of containers using wide range foils," *IEEE Trans. Ind. Appln*., vol. 52, no. 2, pp. 3398-3407, Jul./Aug. 2016.
22. A. K. Paul, "Robust product design using SOSM for control of shielded metal arc welding (SMAW) process," *IEEE Trans. Ind. Electron.*, 63(6), pp. 3717-3724, 2016.
23. A. K. Paul, "Capability, flexibility and legacy of PI hinder market penetration prospect of SOSM for control of GMAW process", *IEEE Trans. Ind. Appln*., vol. 52, no. 1, pp. 384-394, Jan/Feb. 2016.
24. M. K. Bera, B. Bandyopadhyay and A. K. Paul, "Variable gain super-twisting control of GMAW process for pipeline welding," *ASME J. Dyn. Syst., Meas. Control*, vol. 137, July, 2015.
25. M. K. Bera, B. Bandyopadhyay and A. K. Paul, "Output-feedback control of arc length for manual gas metal arc welding with higher order sliding modes", *Int. J. of Modelling, Identification and Control*, vol. 21, no. 4, pp. 418-428, 2014.
26. A. K. Paul, "Experimental design approach to explore suitability of PI and SMC concepts for power electronic product development", *Int. J. of Power Electronics*, vol. 6, no. 1, 2014, pp. 42 – 65.
27. A. K. Paul, "Practical inputs to maturity model of sliding mode control concepts in power electronics domain", *Int. J. of Power Electron.*, vol. 5, no. 2, 2013, 145-164.
28. A. K. Paul, "SiC Mosfets and Schottky power diodes help optimize the design of multi-functional arc welding equipment in popular power range", *Int. J. of Power Electron.*, vol. 4, no. 4, 2012, pp. 360-377.
29. A. K. Paul, "Practical insight on scope of sliding mode control in arc welding process", *Int. J. of Power Electron.*, vol. 4, no. 5, 2011, pp. 409-432.
30. A. K. Paul, "Experimental exploration of functional integrity, functional reliability and reliability of modern power electronics equipments", *Int. J. of Power Electron.*, vol. 3, no. 4, 2011, pp. 378 - 398.
31. A. K. Paul, "Qualitative study of status of indigenous arc welding equipments in India", *Indian Welding Journal*, vol. 44, no. 3, 2011, pp. 58 – 66.
32. A. K. Paul, "Practical Reliability, availability and acceptability of modern arc welding equipment", *Indian Welding Journal*, vol. 44, no. 1, 2011, pp. 19 – 29.
33. A. K. Paul, "Search for establishing nationally integrated optimum arc welding process", *Indian Welding Journal*, vol. 43, no. 4, 2010, pp. 22 – 33.
34. A. K. Paul, "Rooting for environment friendly arc welding process in India", *Indian Welding Journal*, vol. 43, no. 2, 2010, pp. 14 – 24.
35. A. K. Paul, "Energy efficiency prospects of power electronics: Example: Welding Inverter", *Indian Welding Journal*, vol. 42, no. 2, 2009, pp. 24 – 36.

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36. A. K. Paul and N. Chinoy, "Solving critical issues at low current in TIG welding by controlling levels of saturation at the input of the inverter", *Indian Welding Journal*, vol. 41, no. 1, 2008, pp. 27 – 33.
37. A. K. Paul, J. K. Mishra and M. G. Radke, "Reduced order sliding mode control for pneumatic actuator", *IEEE Trans. Cont Syst. Technol.*, 1994, vol. 2, no. 3, pp. 271–276.

**Book Chapter**

38. A, K, Paul, M. K. Bera, M. Waman and B. Bandyopadhyay, "Industry grade robust arc controller for constant voltage arc welding processes", vol. 218, pp. 393-417, 2021, Book Chapter, Springer Nature.
Book Title: "Emerging Trends in Sliding Mode Control: Theory and Application (ETSMC16)" edited by Axaykumar Mehta and Bijnan Bandyopadhyay

**Papers in Conferences**

39. S. Ghosh, A. K. Singh, A. K. Paul and S. N. Singh, "Disturbance observer-based sliding mode control of PV-battery assisted EV charging station," *Conf. Proc IEEE UPCON-2021*, Dehradun, India, 2021.
40. A. K. Paul, "Paradigm Shift on Choice of Flux Integrators in High Frequency Power Transformers," 2021 IEEE 4th International Conference on Computing, Power and Communication Technologies (GUCON), Kuala Lumpur, Malaysia, 2021, pp. 1-7.
41. A. K. Paul, "An Approach to Event Triggered SOSM Controller Design in GMAW," in *Conf. Proc. IEEE UPCON*, Prayagraj, India, pp. 1-6, Nov. 2020.
42. A. K. Paul, "Core material for design of air-cooled transformer operating near saturation in induction heating", *Conf. Prof. PCIM Europe 2020*, Nuremberg, pp. 1819-1826.
43. A. K. Paul and N. Chinoy, "High frequency TIG welding and its applications", 5th International Congress IC 2020, International Institute of Welding, Feb. 6-8, 2020, Mumbai, pp. 1-6.
44. A. K. Paul, N. Chinoy, S. Bhosale and B. Das, "Product customization in induction heating: Pre and post weld heat treatment applications", 5th International Congress IC 2020, International Institute of Welding, Feb. 6-8, 2020, Mumbai, pp. 1-6.
45. A. K. Paul, "PI and SOSM controller design for speed control of PMDC motor using back EMF", *in Conf. Proc. IEEE PEDES 2018*, IIT Madras, India, pp 1-6.
46. A. K. Paul, "Current density characterization of litz wires used in induction heating coils: A practical approach", in *IEEE PEDES 2018*, IIT Madras, pp 1-6.
47. A. K. Paul, "Simple means of resolving issues of AC-TIG welding equipment," in *IEEE Conf Proc. PEDES, Trivandrum, India*, pp. 1-6, Dec. 2016.
48. A. K. Paul, "Decoding the impact of robustness measures of SOSM control in SMAW process," in *Conf. Proc. IEEE PEDES*, 2016, pp. 1-6.
49. A. K. Paul, M. K. Bera and B. Bandyopadhyay, "Practical SOSM controller design for short-circuit mode of transfer in GMAW using two sliding surfaces", in *IFAC-PapersOnLine*, 49(1), pp.724-729, 2016.
50. A. K. Paul, "Practical study of inclusiveness properties of PI and SMC ideas for control of GMAW", in *Conf. IEEE PEDES*, Mumbai, 2014.
51. A. K. Paul and S. B. Chinoy, "Pareto optimal solution of constrained open loop under-actuated process in induction cap sealing", in *Proc. IEEE PEDES*, 2014, IIT, Mumbai.
52. A. K. Paul, "Practical realization of scalar optimization function of shielded metal arc welding process", in *IFAC Conf. ACODS*, 2014, pp. 684 – 691.
53. A.K. Paul, "Sliding surface in 1-sliding boosts multi-objective optimization program of shielded metal arc welding process," in *2013 International Conference on Advanced Electronic Systems (ICAES)*, Pilani, India, pp. 39-44,, 2013, IEEE.

54. M. K. Bera, B. Bandyopadhyay and A. K. Paul, 2013, "Robust nonlinear control of GMAW systems - a higher order sliding mode approach", in *Conf. Proc. IEEE ICIT, 2013*, pp. 175-180.
55. M. K. Bera, P. L. Priya, B. Bandyopadhyay and A. K. Paul, "Discrete-time sliding mode control of GMAW systems using infrequent output measurements", *Conf. Proc. IEEE ECC, 2013*, pp. 3736-3741.
56. M. K. Bera, B. Bandyopadhyay and A. K. Paul, "Integral sliding mode control for GMAW systems," in *IFAC Proceedings Volumes*, 46(32), 337-342, 2013.
57. S. Das, B. Bandyopadhyay, A. K. Paul and P. Trivedi, "Position control of pneumatic actuator using sliding mode control in conjunction with Robust Exact Differentiator", *IEEE Conf. Proc. CARE*, 2013,.
58. A. K. Paul, "Study of input translation in sliding mode structure switching for high frequency full bridge inverter", *Conf. IEEE PEDES*, Mumbai, pp. 1-6, 2012.
59. S. Das, B. Bandyopadhyay, A. K. Paul and A. Chalanga, "Position control of pneumatic actuator using multi-rate output feedback sliding mode control", in *7th Intl. IEEE Conf. on Electrical and Computer Engg.*, pp. 920-924, 2012.
60. A. K. Paul, "Complete characterization of arc welding equipment for performance, efficiency, acceptability and reliability and diversity reduction", *IIW Doc. XII-2027*-11, 2011, pp. 1- 11.
61. A. K. Paul, "Comparative study of functional integrity of major topologies in induction heating", in *Conf. Proc. IEEE PEDES*, N. Delhi, 2010, pp. 1- 6.
62. A. K. Paul, "Power electronics help reduce the diversity of arc welding process for optimal performance", in *Conf. Proc. IEEE PEDES*, N. Delhi, 2010, pp. 1- 6.
63. A. K. Paul, S. Singh and S. Chinoy, "Quality engineering aspects of series resonant induction heating power supply with wide coil range", in *Conf. Proc. PCIM Europe*, Nurnberg, pp. 173-178, 2008.
64. A. K. Paul, "Origin shift in worst case parameterization for industrial power electronics equipments" in *IEEE Conf. Proc. IECON*, 2007, Taiwan.
65. A. K. Paul, "Optimizing the transition process from sparking for non-contact TIG welding inverters", in *Conf. Proc. IEEE ICIT*, 2006, pp. 1413-1418.
66. A. K. Paul, "Enhancing operating range of discrete trench field stop IGBTs for welding applications", in *Proc. PCIM Europe 2005*, Nurnberg, pp. 262 – 270.
67. A. K. Paul, N. Chinoy, and S. Singh, "Making evolving design to perfection of high frequency inverter for induction heating applications: Design of experiment approach", in *IEEE Conf. Proc. PESC 2004*, vol. 4, pp. 2632-2638, 2004.
68. A. K. Paul, J. K. Mishra and M. G. Radke, "Sliding mode control of pneumatic actuator for robotic application", in *Conf. Proc. IROS 1993*, Yokohama, vol. 2, pp. 1268–1275.
69. A. K. Paul and M. G. Radke, "Sliding mode control of low moment of inertia actuator with power constraints", in *Conf. Proc. ISIR*, Bangalore, pp. 695–706, 1993.
70. A. K. Paul, J. K. Mishra and M. G. Radke, "Pulse width modulated control of linear pneumatic actuator", in *Conf. Proc. ISIR 1993*, Bangalore, pp. 714–724.
71. A. K. Paul, B. Bandyopadhyay and M. C. Srisailam, "A smooth variable structure position control of PCB DC motor," in *Conf. Proc. SICICI IEEE*, Singapore, vol. 1, pp. 1192-1197, Feb. 1992.
72. B. Bandyopadhyay, A. K. Paul, and M. C. Srisailam, "A smooth variable structure position control of DC motor," in *Proc. IEEE TENCON, 1991*. vol. 1, pp. 33-37.
73. A. K. Paul, M. G. Radke and M. S. Ramakumar, "Development of brushless DC motor for robotics applications", in *Natl. Robotics Symp*. (ROSYMP 90), 1990.
74. G. V. D. Arunkumar, A. K. Paul, M. G. Radke and M. S. Ramakumar, "Control and data acquisition of remote ultrasonic probe manipulator through PC interface", *Natl. Robotics Symp*. (ROSYMP 90), 1990.


**15. Achievements:**

# *Electronics Devices Worldwide Pvt. Ltd*

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(List at least any three most significant contributions of your professional work):

In last 22 years of my research at M/s. Electronics Devices Worldwide Pvt. Ltd. I have successfully completed the full-range (50-3000A) of arc welding controllers to cater almost 100% applications of arc welding. The energy-efficient controllers are suitable for constant voltage, constant current, AC/DC and pulsing applications. I have also developed wide range of induction heating controller for wide range applications ranging from 1 kHz till 300 kHz, both using either series resonant or parallel resonant principles. We are one of the major players in induction cap sealing business. Just to remain contemporary in product design, I keep trying publishing articles in platforms where review system educates the researchers. A few contributions are listed below:

a) **Zero-Ventilated 1.5 kW, 50 kHz Induction Sealing System, Winner of The National Technology Award 2023:** Due to its non-contact mode of power transfer to a metallic part, the induction heating principle is favourably used in the packaging industry for sealing of wide range plastic and glass containers. In cap sealing, the power transferred to thin aluminium foil is used to create a bond between the foil and the lip of the bottle. The process ambiance for sealing bottles containing different types of products could be different. Dust prone environment prevailing for sealing coffee, nutraceuticals, several pharma products, etc. recommends the use of an air-tight enclosure. Likewise, to avoid water particles entering the enclosure during its frequent cleaning of exterior surfaces, packaging solutions for the dairy industry need water-tight enclosure. The process ambiance and nature of products are such that those power controllers would increasingly be housed in IP 65 enclosures. The air movement inside i.e., the free convection is restricted. To make the controller inherently self-cooled, the product design ensures the internal convection effective by creating requisite buoyant force through proper choice of power converter topology where the component engineering plays vital role. The product has been patented and part of the design methodology is published at Elsevier Journal. It is under commercial production for domestic and global consumption. It has won this year's the prestigious The National Technology Awards 2023. It carries a citation and Rs. 15 Lac prize money.

[1] A. K. Paul, "Zero ventilated induction sealing device with improved spatial distribution of optimized power loss", Indian Patent 415961, 2022. (it received The National Technology Award 2023).
[2] A. K. Paul, "Zero-ventilated self-cooled induction heating device: Topology and component engineering," *J Power Electronics Devices and Components*, vol. 3, pp. 1-10, 100013, Elsevier, 2022.

b) **Air-Cooled Induction Sealing System for Wide Range Containers:** Induction cap sealing is a complex under-actuated process. Through non-uniform spatial distribution of power over fine annular ring on thin foil, the induction sealing controller not only ensures tamper proof sealing of container lip but also removes wax from the top surface of foil. It could be termed as under-actuated process. The indirectly controlled sealing process does not have any feedback to execute any corrective measures on sealing quality. Traditionally, the sealing operation is dominantly performed by induction heating effect and wax removal is by thermal conduction of the transferred heat throughout the surface. Due to inferior heat conduction features of extremely thin AL foil, the sealing quality degrades if large diameter foil is used. Therefore, modern cap sealing process needs to be dominantly controlled (both sealing and wax removal) by induction heating by using multiple heat sources over the foil surface to reduce the role of thermal conduction. In our internationally well-received product, the controlled multi-zone heating is effectively implemented through patented multi-segmented coil design. The multi-segmented coil is fed by a single series resonant inverter.

[1] A. K. Paul and S. Chinoy, "Air-Cooled Induction Heater for Efficient Sealing of Containers Using Wide Range Foils," in IEEE Transactions on Industry Applications, vol. 52, no. 4, pp. 3398-3407, July-Aug. 2016, doi: 10.1109/TIA.2016.2535112.
[2] A. K. Paul, "Robust Control by SOSM Facilitates Optimizing Under Actuated Induction Cap Sealing Process," in IEEE Transactions on Industrial Electronics, vol. 64, no. 6, pp. 4511-4519, June 2017, doi: 10.1109/TIE.2017.2652377.
[3] A. K. Paul and S. Chinoy, "Induction sealing head and a coil assembly thereof for energy efficient sealing of containers" Indian Patent 425208, 2023.

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c) **Pre and Post Weld Heat Treatment of Welding Pipes and Other Structures:** Using high energy density welding arc, the joining process makes pipe joints involving melting of base metal. It should be free from residual thermal stress and the prospect of hydrogen cracking should not exist. Both are achieved by employing proper heat treatment procedures, the physical, metallurgical, and mechanical properties of steel structures are regained for their long endurance under extreme operating conditions of pressure and temperature, particularly, in power industries. The joints need to undergo pre- and post-weld heat treatment. Induction heating principle is an environment friendly efficient approach and is now being used for heat treatment of pipes, tubes, pressure vessels, etc., often made up of a special material such as P91 Grade steel, etc. As the popularity of the heat treatment process is on the rise, it is important to look into the energy efficiency and power delivery aspects of the system. We have designed induction heating systems capable of delivering 100 kW power using air-cooled litz-wire based coil developed by us. Our product could as well be configured to feed multiple coils to increase the energy efficiency through superior energy distribution over the welding surface. Part of the work is published in IEEE.

[1] A. K. Paul, "Active-Controlled Passive Distribution of Power Offers Efficient Heat Treating Solution for Quality Arc Welding Joints of Steel Pipes," in IEEE Transactions on Industry Applications, vol. 54, no. 5, pp. 4958-4966, Sept.-Oct. 2018, doi: 10.1109/TIA.2018.2834311.

d) **Energy-Efficient High-Power (≤3000A) Controller Design for Multi-Purpose Welding Applications:** In industry, a single high-current-high-power controller is employed to cater several welding applications such as submerged arc welding, hard-facing, welding overlay, etc. These applications need continuous rated power source capable of delivering large current. The multi-input controller needs to meet the complex dynamic load because the load characteristics of each welding method and its power demand are different. The prospect of such equipment operating under light-load conditions is also high. It is particularly difficult to develop such power source delivering large current to arc load when the turns-ratio of transformer for nonlinear arc-load is sub-optimal. Procurement of high-current-high-power transformer could be another issue. Large power loss in power components makes the thermal design complex. To address those problems, this product uses parallel-connected power converters where hybrid IGBT (Si+SiC) modules are used at inverter and Schottky power diodes at the secondary rectifier. Together they reduce the power loss and distribute the power loss over larger component base so that more surface area is available to remove the heat loss by convective and radiative transfer. For light load conditions, lesser number of converter modules are enabled. Secondly, the distribution of heat loss would be shared optimally if the current sharing among the parallel-connected converters is equal. The current sharing approach should be compatible to the process behaviour. This product is commercially success till 2000A. The 3000A rated power converter is under extensive engineering evaluation at L & T, Hazira.

e) **Design, thermal characterization, and full-load testing at zero load power for high-frequency air-cooled nanocrystalline transformer**: High-power high-frequency air-cooled induction heating transformer (IHT), mostly used as current multiplier and isolation purposes, are custom designed. For their reliable performance and long life, the thermal evaluation at rated load is necessary. Creating an equivalent load as a test facility for reliability testing of IHT is difficult. Characteristics of such loads drastically change after Curie temperature and prolonged heating could increase the nearby ambient temperature and, more importantly, the traditional heat run test wastes energy. Whenever the coil is energized, windings of IHT draw respective rated current; even at no-load condition, the copper loss is at rated value. While both windings drawing rated current at a desired frequency, using the concept of localized eddy current loss as well as excess eddy current loss, we devised a novel method to inject requisite core loss to the magnetic circuit to emulate the characteristics of full-load condition but the power drawn from the transformer would be zero. The approach was validated where a 200-W resonant inverter was used to inject power loss equivalent to full-load condition of 30-kW IHT to emulate the heat run test. The concept is published in IEEE journal.

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An air cooled IHT often work at different frequency, decided by the frequency characteristics of an application. Apart from minimizing the power loss in core and copper, the design of its thermal circuit is complex. There exist multiple loss centres with different heat removal features. The power loss is concentrated around a small core volume and the rest of the core is available for convection and radiation. To cater superior heat removal features, we use mixed core configuration. Around the loss centre the core loss density of the core segment is chosen smaller, and/or its thermal conductivity is superior. In IHTs, the toroidal core using nanocrystalline cores of lower ribbon thickness are preferred in the inner cores. It helped optimize the performance of IHT over a certain range of frequency, the cost of the transformer is also reduced.


[1] A. K. Paul, "Application Prospects of Hybrid Magnetic Circuits in High Frequency Power Transformers," in IEEE Journal of Emerging and Selected Topics in Industrial Electronics.

[2] A. K. Paul, "Transformer with mixed-core configuration in induction heating system", Indian Patent, IN 406392, 2022.

[3] A. K. Paul, "Practical study of mixed-core high frequency power transformer," *MDPI Magnetism* 2022, 2, pp. 306-327, https://doi.org/10.3390/magnetism2030022.

[4] A. K. Paul, "Emulating Full-Load Testing of Air-Cooled Nanocrystalline IHT at Zero Power," IEEE Journal of Emerging and Selected Topics in Industrial Electronics, vol. 3(3), pp. 725-732, July 2022.

[5] A. K. Paul, "ZVZCS SRI guides optimal use of copper and core for air-cooled nanocrystalline transformer for induction heating," *IEEE Trans. Ind. Appln*., 56(2), pp. 970-978, Mar/Apr 2020.

[6] A. K. Paul, "Structured Protection Measures for Better Use of Nanocrystalline Cores in Air-Cooled Medium-Frequency Transformer for Induction Heating," IEEE Trans. Ind. Electron., vol. 68(5), pp. 3898-3905, May 2021.


f) **World's First Commercial Product Based on Higher Order Sliding Mode Control**: Parametric variations, wide range disturbances, and nonlinearity in arc and melting rate of weld and base metal are inherently present in abundance in all types of arc-welding processes, shielded metal arc-welding (SMAW) process is no exception. For stability of non-linear dynamic arc, it needs a controller with robust response characteristics where, for decades, PI control using high frequency power controller could achieve the desired performance. Due to the availability issues of active and passive components in India at right price for high-frequency soft-switched controller for extremely wide range arc loads, we developed a power controller using high-gain second order sliding mode control. However, high-gain fractional order control function had certain teething issues when the control actuation was at primary of transformer. The nonlinearity in the magnetic circuit injected DC bias, the prospect of magnetic saturation is more. We resolved the problem by introducing an alternate practical control function. The new control function-based arc welding controller has been commercialized and is active in the market.


[1] A. K. Paul, "Robust Product Design Using SOSM for Control of Shielded Metal Arc-Welding (SMAW) Process," in IEEE Transactions on Industrial Electronics, vol. 63, no. 6, pp. 3717-3724, June 2016, doi: 10.1109/TIE.2016.2522945.

[2] A. K. Paul, "Efficacy of STC in High Frequency Full-Bridge DC–DC Converter," in IEEE Journal of Emerging and Selected Topics in Industrial Electronics, vol. 3, no. 4, pp. 1020-1027, Oct. 2022.


g) **Pulse-Transformer based Gate Drive Circut for SiC Mosfets for High Frequency Capless Induction Sealing Controller:** The quality inspection in high-speed automated induction cap sealing process is not only cumbersome, it is time consuming and not full-proof. Due to the presence of cap and a cardboard between foil and cap, installing a thermal vision system for quality inspection of sealed bottle is not accurate. To ensure quality inspection of each sealed container, we have recently developed a high-frequency single-switch compact power controller to be operated in on-off mode to transfer requisite energy to thin aluminium foil for capless induction sealing of glass/plastic containers. For near continuous-duty operation of the converter, due to the superior power loss and thermal characteristics, two SiC Mosfets connected in parallel are preferred. The design of gate drive circuit (GDC) for these devices is complicated. The desired gate voltage is not only highly asymmetrical, due to small gate threshold voltage, it is sensitive to ringing in gate signal; the range of negative bias is constrained. The duty-cycle of the high-frequency gate signal for the switch for induction heating load could be small. Unlike the optically isolated active counterpart, using a single polarity power supply, here an innovative and simple passive transformer driven GDC is used to feed

desired asymmetrical gate voltage to several SiC Mosfets in parallel. For the gate drive of parallelly connected SiC Mosfets of the converter, an application specific novel transformer-based GDC is designed for proper use of Kelvin source terminals. The design of application specific gate drive transformer is critical. ***The product is not yet commercialized, but ready for demonstration anytime without any notice.***


[1] A. K. Paul, "Pulse-transformer for isolated gate driving of parallel connected SiC Mosfets in induction cap sealing applications", Application number: 202321044830, Patent pending.


h) **Design of Wire Feeding Controller for Constant Voltage Arc Welding Processes:** In constant voltage multi-input arc welding processes (e.g., submerged arc welding, welding overlay, etc.) electrode feeding and movement of electrode tip are motorized. Both need accurate speed control. Due to high-temperature ambience and large distance between the controller and the welding head, ideally the motor control should be sensorless, it helps reduce interconnection wires. Motor control units should be simple, low cost, and capable of producing accurate speed. Due to their negligible electrical and mechanical time constant, the pancake-type permanent magnet DC motor is suitable for wire feeding, where, due to negligible time-constant of the armature circuit, deriving the speed signal by sensing of EMF for feedback is easy. Our motor controllers are based on Second Order Sliding Mode Control approach and speed signal is derived from the input voltage applied to the armature available inside the controller card.


[1] A. K. Paul, "Robust PMDC motor control for accurate wire feeding in GMAW using back emf," *IEEE TIE*, 2020.
[2] A. K. Paul, "Sensorless robust speed controller design of pancake axial field PMDC motor," *IEEE Trans. Ind. Appln.*, 2019.


i) **Position Control Algorithms for linear Pneumatic Actuator:** For the first time in the world, a new position control algorithm, based on sliding mode control, has been developed for a pneumatic cylinder. In the proposed pneumatic system, commercially available two-way on-off solenoid valves have been used. The inherent robustness property of the sliding mode controller makes it easier to select the switching gains of the controller. Moreover, approximate dynamic modeling of the system makes the controller simple. Since in sliding mode control, the states remain on the sliding surface, the motion of the piston is smooth. This suggests the potential of pneumatic cylinders as actuators for robot manipulators. The controller is hybrid in nature, consisting of an error amplifier, data conversion devices and an 8088 microprocessor along with various digital circuit accessories. Only one feedback device (potentiometer) is used. Velocity is calculated from the sampled position signals.


[1] A. K. Paul, J. E. Mishra and M. G. Radke, "Reduced order sliding mode control for pneumatic actuator," in IEEE Transactions on Control Systems Technology, vol. 2, no. 3, pp. 271-276, Sept. 1994, doi: 10.1109/87.317984.
[2] A. K. Paul, J. K. Mishra and M. G. Radke, "Sliding mode control of pneumatic actuator for robotic application," IEEE Conf. IROS-1993, Yokohama, Japan, 1993, pp. 1268-1275 vol.2, doi: 10.1109/IROS.1993.583747.
[3] A. K. Paul, J. K. Mishra and M. G. Radke, "Pulse width modulated control of linear pneumatic actuator", in *Conf. Proc. ISIR 1993*, Bangalore, pp. 714–724.


## 16. Honours, Awards & Recognitions:

### A) Honors:

i) Invited by Editor-in-Chief of IEEE IC BS inaugural Technical Magazine Tantra to submit an article on Role of Technology on Mitigating Climate Change
ii) Invited by Editor of MDPI Journal for a Invited paper for their special issue titled, 'Mathematical Modelling and Physical Applications of Magnetic Systems' for free.
iii) Invited by Editor of Elsevier Journal to publish in their Special Issue Titled 'Design, Optimization and Integration of Magnetics in High Frequency Power Converters'
iv) Elevated to Senior Member IEEE in 2018.
v) Guest of Honor for the annual event of IIT Jodhpur
vi) Sent a reference letter for promotion of associate professor of IIT to professor grade
vii) Sent a reference letter for a Scientific Officer 'H' of BARC for his elevation to SM IEEE Grade

viii) Biography listed in Marquis Who's Who in Science and Technology since 2014.

ix) Biography listed in Marquis Who's Who in the World since 2013.

x) Invited by the Chief Editor of Indian Welding Journal to submit an article (Qualitative study of status of indigenous arc welding equipment in India) for 50th anniversary special issue (2011) on status of indigenous arc welding equipment in India

xi) Drafted and presented a document for Annual Assembly (2011) of International Institute of Welding on inverter power source for control of arc welding process.; Doc. No: *IIW Doc. XII-2027*-11.

**B) Awards:**

i) Winner of the National Technology Awards 2023 from Department of Science and Technology, Govt. of India for design and commercialization of an innovative product titled, "Zero-ventilated Induction Cap Sealing Device with Improved Spatial Distribution of Optimized Power Loss".

ii) Winner of Foundation for Innovative Packaging and Sustainability Award 2023 for the product titled, "Sigma Neo 65 Packaging Machine".

iii) Winner of 2022 Make in India Category Award for the product 'Multi-loop Parallel-Connected 2000A Power Converter for Hard-Facing and Strip-Cladding Applications' from the bi-monthly welding magazine WeldFab Tech Time.

iv) Best Paper Award at IEEE UPCON 2021

v) The product "**Zero-ventilated induction sealer"**, won the **PACKMACHINE 2020, The National Award for Excellence** in packaging industry, instituted by Indian Institute of Packaging (IIP), GOI.

vi) The product "**Capless Induction Sealer"**, won **PACKMACHINE 2017, The National Award for Excellence** in packaging industry, instituted by Indian Institute of Packaging (IIP), Govt. of India.

vii) Received '**Innovation Award**' from M/S. Semikron Limited, India in 2017 in recognition to my contribution in designing innovative energy efficient products for arc welding and induction heating.

viii) Winner of **The Albert Nelson Marquis Lifetime Achievement Award** for 2017.

ix) Best paper presentation award in the field of **Sliding Mode Control** at International IFAC conference **ACODS 2016 in 2016** at Trichy, Tamilnadu.

x) The high-speed high-power product '**SIGMA JET Induction Cap Seal**', won the **PACKMACHINE 2015, The National Award for Excellence** in packaging industry, instituted by IIP, Govt. of India.

xi) The product "**Induction Cap Sealer Model: Sigma III Touch**", won the **PACKMACHINE 2012, The National Award for Excellence** in packaging industry, instituted by IIP, Govt. of India.

xii) Delivered Guest of Honor Lecture titled "The role of a technologist for business sustainability of small-scale core engineering sector" at the inauguration function of TechFest of Indian Institute of Technology Jodhpur on 23rd January 2020.

xiii) Session Chair IEEE IECON 2007, Taiwan, IEEE PEDES 2010, IEEE ICAES 2013.

**B) Recognition**

1. Our R & D lab is DSIR certified, recognized by Dept. of Science and Technology
2. Delivered IEEE technical talk on "Air-Cooled Nanocrystalline Transformer Design for Induction Heating Applications" on 25th July, 2020.

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3. Delivered several lectures to promote energy efficient inverter technology for arc welding in India.
4. Delivered several lectures to popularize energy efficient, process-efficient, welder-friendly and productive arc welding processes in India.
5. Published several articles in Indian Welding Journal to educate on impact of different technologies on different arc welding methods in India. The journal has more than 5000 circulations, all linked to welding.
6. Member of program committee IEEE VSS 2012
7. Co-guided M. Tech and PhD students of IIT Bombay, IIT Jodhpur and VJTI.
8. Delivered invited talk in 2016 on Practical Implementation Aspects of Higher Order Sliding Mode Control at National Institute of Technology, Trichy, India.
9. I am Reviewer of:

IEEE Transactions of Industrial Electronics
IEEE/ASME Transactions on Mechatronics
IEEE Transactions on Industrial Applications
IEEE Transactions on Magnetics
IEEE Transactions of Power Electronics
ISA Transactions
Journal of Process Control
International Journal of Automation and Computing
International Journal of Institute of Engineers, Series B
International Journal of Power Electronics
Reviewer of Indian Welding Journal
International Journal of Modeling, Identification and Control
Elsevier Journal: Sensors and Actuators: Part A
Top IEEE IAS, PES, IES Conferences, ECC, etc.

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DT. 23-10-2023