# ELECTROSPARK

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## DEPARTMENT OF ELECTRONICS & COMMUNICATION ENGINEERING

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## INSTITUTE'S VISION

To emerge as a centre of excellence in technical education, offering best of the teaching and learning by creating ambience for advanced level of education and research to serve the society.

## DEPARTMENT'S VISION

To aspire to become a department which can provide value-based quality education, foster research and innovation and to groom the students to be globally competent.

## INSTITUTE'S MISSION

**IM-1:** To create an ambience for advanced level of teaching and learning process.

**IM-2:** To generate new ideas by engaging in cutting-edge research and technology.

**IM-3:** To initiate collaborative projects which offer opportunities for long term interaction with industry and academia.

**IM-4:** To develop intellectual human potential for serving the society according to the regional, national and global needs.

## DEPARTMENT'S MISSION

**DM-1:** To Create an outcome-based teaching learning process to increase the creativity and innovativeness of the students and to face the challenging world.

**DM-2:** To motivate students and promote research and development culture among students, so that they can choose it as an optional career.

**DM-3:** To provide ethical and value-based education by promoting activities addressing the societal needs Editorial board.

# MESSAGE FROM HOD, ECE


## Dr. Chittajit Sarkar

**HEAD OF DEPARTMENT**
**ELECTRONICS & COMMUNICATION ENGINEERING**


Welcome to the department of Electronics and Communication Engineering, Asansol Engineering College. Our institution boasts a robust undergraduate program in Electronics & Communication Engineering, granting B. Tech degrees. Additionally, we provide opportunities for postgraduate studies through our M. Tech program. Each year, we admit 120 students into our B. Tech program and 13 students into the M. Tech program.

Every child possesses innate genius, and if a child isn't grasping knowledge through conventional teaching methods, perhaps it's time we adapt our approach to match their unique learning style. With this principle in mind, we've developed our teaching methodology. Our objective is to offer an outstanding platform for aspiring hardware and software engineers, equipping them to meet the ever-evolving demands of the modern industry. Our department takes pride in its commitment to academic excellence, innovation, and fostering a dynamic learning environment. As the Head of the Department, I am honored to lead a community of dedicated faculty and enthusiastic students who share a passion for knowledge and growth. Here at Electronics and Communication Engineering, we strive to provide a comprehensive educational experience that combines rigorous academic programs with practical applications. Our faculty members are not only experts in their respective fields but also mentors who are deeply invested in students' success. They are committed to nurturing students' intellectual curiosity and helping them to achieve academic and career goals.

Undergraduate students are actively encouraged to engage in a wide range of research initiatives through the Students Innovation Centre (SIC). The creation of an IEEE student chapter focused on Microwave Theory and Technology – Society further promotes and supports students in their pursuits within this field.

# EDITORS' MESSAGE

It gives us immense pleasure to present to you the latest edition of our Electronics and Communication Engineering Department magazine, ELECTROSPARK. This magazine is a humble attempt to showcase the vibrant spirit, creativity, and technical brilliance of our students and faculty.

In an era where technology is evolving at an unprecedented pace, the field of Electronics and Communication remains at the heart of innovation. From the advancement of communication systems to the development of embedded technologies, our department continues to make remarkable strides in both academics and research.

This edition features a blend of technical articles and creative expressions. Each contribution reflects the passion, dedication, and intellectual curiosity of our community.

We extend our heartfelt thanks to all the students, faculty members, and contributors who have made this magazine possible. Special appreciation goes to the editorial team for their unwavering commitment and teamwork. We hope you find this edition informative, inspiring, and reflective of the dynamic world of ECE.

Warm Regards,
*Somnil Neogi, Kaustav Biswas, Subhankar Roy, Nilanjan Dutta, Ananya Ghosh, Arijit Roy, Srijan Sinha, Shreya Ghosh*
Editors, ELECTROSPARK
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# NANOROBOTS: A REVOLUTIONARY PARADIGM IN NANOTECH AND ITS APPLICATION

DR. SANDIP HALDAR, DR. RANJITA SINGH, KUMARI NIBEDITA

## ABSTRACT

Nanobots has become evident as a recalibrating force in various aspects, offering unrivalled and reasonable opportunities for miniaturization, enhanced sensing, actuation abilities and innovative material properties. These tiny agents of nanotechnology, promise groundbreaking applications across multiple domains. In medicine, they offer precise drug delivery, targeted therapies, and real-time diagnostics by navigating through the body's intricate pathways. Environmental remediation benefits from their ability to efficiently remove pollutants at the molecular level, ensuring cleaner water sources and sustainable solutions. In manufacturing and materials science, nanobots enable precise fabrication of nanostructures, advancing electronics, photonics, and energy storage technologies. They also hold potential in revolutionizing computing, sensing, and data storage, paving the way for ultra-compact, high-performance devices. However, ethical and safety considerations accompany their development, necessitating responsible innovation. Despite challenges, the integration of nanobots into practical applications promises to address pressing societal needs while unlocking new frontiers of exploration and discovery, heralding a transformative era in nanotechnology.

This article gives view of the integration of nanotechnology with robotics, focusing recent advancements, structure and mechanism, challenges, applications, conclusion and future directions.

## INTRODUCTION

Nanobots are significantly advancing in the field of nanotechnology. Growing rapidly nanotech, given machines wings at a microscopic level. A nano scale is the 1 lakh division of a human hair or simply billionth part of 1m.

1m = 10^9nm or 1 nm= 10^-9m. Nanotechnology is the term for the methodologies and techniques used in all these particles at nanoscales.

In 1959 American thersitical physicist, Rechard Feyemen, gave a speech on " There's a plenty of Room at the Bottom" in which he mentioned the concept of machines could be miniaturized and masses of information could be encoded in tiny structures. Although, a Nobel laureate his thought was ignored for couple of decades.

They indeed gave us a better way to interact, Communicate and control the work & function in an atomic level, with, ions and molecules can manipulate with the smallest building block of life.

Being a multidisciplinary subject, it deals with branches of technology, engineering, biology and chemistry. NBs are called nanobots often are made with materials like steel, aluminum, Cast iron, hard plastic. Uses of various organic and inorganic elements are involved. More widely carbon nanotubes and graphene are in use. For actuation, they are feuded with coding, different programs and software commands that make it operable. They run with battery or electricity. They are also given commands to auto work and replicate themselves according to the environment. Such as RICE UNIVERSITY made a molecular car whose wheels made by buckminsterfullerene UNIVERSITY OF MINES generated an atomic engine that is fitted in electromagnetic cone and vibrated using laser to produce heat energy. Zurich technical researchers developed elastic nano swimmers, can move in biological fluids and controlled by magnetic forces. More like Cambridge university developed Actuating Nano Transducers (ANTs)operated via light. Nanorockets, microsponges etc. are few examples of innovation for nanobots.

***Design and mechanism***: The structure of NBs is designed on nano scales. They are designed in the micro bacterial model mainly used component is Carbon due to its inert properties, tensility, strength and thermal conductivity.

They are composed using machinery parts as gear, motor, bearing balls, are made using Hydrogen, sulfur, oxygen, nitrogen or silicon. Their substructure also includes the power supply, sensors, nanochips.

NBs are made of various types of designs like Scaffolds, biohybrids, helical, etc.

Its actuation is controlled by different ways -external fields, magnetic fields, ultrasonic, optical, changing fuel compositions concentration and gradients.

Also, there are light driven nanobots like photocars. They use motive forces by exchange of angular momentum bet. NBs & photons cause the actuation is the bots.

In Fabrication, there's the methods of fabrication involving lithography, imaging, electrochemical deposition, physical vapour deposition, rolled up technique, LBL assembly and biohybrid method. Standard techniques of fabrication are implied with more biocompatibility & biodegradability.

## APPLICATIONS

Inspired by Rechard Feyman thoughts. K.Eric Drexler, wrote a book Engines of creation . In which he told about molecular genetical programmed device heat can go into bodies, can treat targets tissue or cells. There are various applications of nanobots mentioned below.

### IN MEDICAL SCIENCE

In the field of biology and medicines, it has contributed immensely. These small actuator and sensors bots are proved to be great use for delivering drugs directly to the affected cells in the patient's body. The NBs are injected in our body through blood and treat the affected cells only. They made surgeries at nano level possible. Diseases like cancer, diabetes, are now curable.

Nanorobots designed (and inspired) by harnessing properties of biological materials (peptides, DNAs), their designs and functionalities. These are inspired not only by nature but machines too. Nanorobots could propose solutions at most of the nanomedicine problems.

### ENVIRONMENTAL CLEANINGS

It also proved to be Cleaning agent for the environment. Are able to interact with the air molecules and water molecules, and clean them, eliminating the pollutants and foreign particles. They are also capable of measuring the Concentration of pollutant molecules. Use of nanorobots for environmental remediation also seems to imply a direct exposure to organisms in the environment in that sense being similar to pesticides applied to agricultural land. The probability of nanorobot exposure to relevant organisms might thus be high for these two promising applications.

### SPACE EXPLORATION

They in this field beneficial in order to make the solar sail light weight, that help to propel the space craft.

Space robotics covers all types of robotics for the exploration of a planet surface as well as robotics used in orbit around the bodies and the sensors needed by the platform for navigation or control. Orbital robots can be envisaged for repairing satellites, assembling large space telescopes, capturing and returning asteroids, or deploying assets for scientific investigations, etc. Planetary robots play a key role in the surveying, observation, extraction, close examination of extra-terrestrial surface, constructing infrastructures on a planetary surface for subsequent human arrival, or mining planetary resources, etc.

### IN INDUSTRIES

Using nanorobots, manufacturers could improve the efficiency and quality of manufacturing processes. Nanorobots could perform tasks with a level of precision and accuracy that's difficult to achieve with traditional manufacturing methods. Thus, it can improve the quality of product and it's consistency by minimizing the waste production and labour efficiency.

## CONCLUSION

Few Predictions has been made by some of the scientists,

"Nanobots will also be able to read human brain" - Deblina Sarkar.

"They are believed to be able to connect the internet to the Brain by 2030" - Ray Kurzweil

Using nano sensors in attacking weapons (like gun) to avail info of the surroundings and conveying radio signals, will make aware and help to take preventive step before the opp. Attacker. This may be proved to hold good in defense field.

Nanobots have a Promising future direction ahead. Previously, was only an idea in brain and today it is an enhancing and growing innovation field which has made many impossible tasks easier. With the development in section of health, environment, Data storage and energy conservation and sustainability. Interactions of NBs with individual cells and simultaneous screening of vast populations of cells can be studied. Undoubtedly, the field of next wireless nanorobotics integrating remote control, reactions networks, programmable responses, and biomedical tools have bright prospects.

# AN OVERVIEW OF AC/DC POWER SUPPLIES

SUBHANKAR ROY, ROUNAK KAYAL
3rd YEAR, ECE

AC/DC power supplies are used in several electronic devices, encompassing computers, smartphones, radios, and TVs. AC/DC power supplies come in many dimensions and configurations, tailored to suit the specific requirements of the device they are supplying power to.

## AC/DC POWER SUPPLY

The power supply is an electronic device's beating lifeblood. This article defines and describes the fundamental operation of AC/DC power supplies.

A device that transforms alternating current (AC) to direct current (DC) is known as an AC/DC power supply. In a residence or office, AC is typically supplied by an electrical outlet, whereas DC is utilized by the majority of electronic devices.

A variety of electronic devices, including televisions, cellphones (i.e., wall adapters), and computers, utilize AC/DC power supplies. Additionally, they have numerous industrial applications.

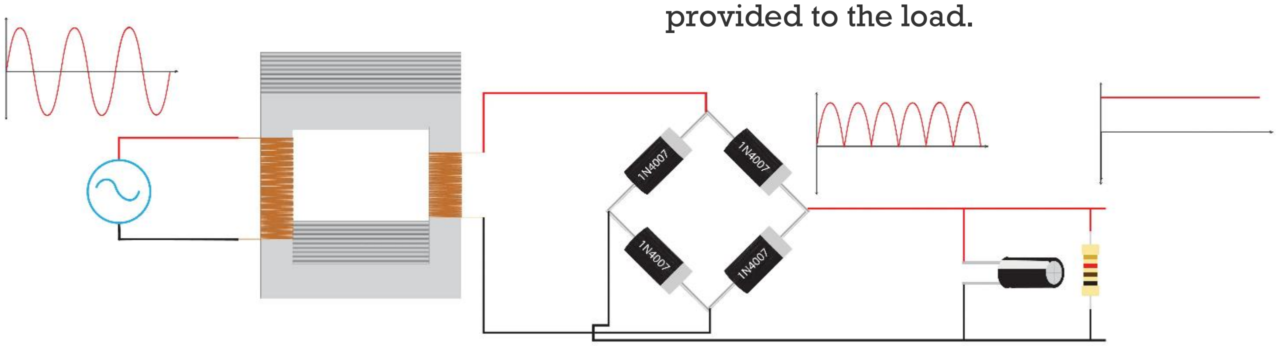
Most electronic systems and devices today require a constant DC voltage (e.g., 3.3 VDC, 5 VDC, 12 VDC). AC voltage, which varies from country to country between 100–120 VAC or 200–240 VAC, forms the fundamental basis of mains electricity. The input AC mains are transformed by an AC/DC power supply into the required DC voltage on the output side.

Hence, the fundamental function of an AC/DC power supply (often referred to as an AC/DC converter) is to transform the elevated, and to a certain extent perilous, AC voltage into the diminished and secure DC voltage required by the device.

## OPERATION OF AN AC/DC POWER SUPPLY

The many AC/DC power supplies possess distinct characteristics and modes of operation. However, we may attribute the overall working principle to the block design depicted in Figure.

In order to achieve a stable DC supply, the procedure of rectification alone is insufficient. The prominent spikes in the DC curve require smoothing. This is achieved by the utilization of the output capacitor in the power supply. The capacitor exhibits rapid energy storage and subsequently releases it between two peaks. This procedure fills the droplets to a specific quantity and refines the curve. The outcome is a consistent direct current (DC) voltage on the output in Figure which is provided to the load.




Upon examining the AC diagram depicted in Figure 1 (located in the top left corner), a sine wave is observed. This indicates that the alternating current voltage undergoes a continual reversal of its polarity. The standard frequency values are often 50 or 60 Hz, which vary depending on the country.

The initial stage involves the conversion of the high alternating current (AC) voltage into a reduced AC voltage through the use of a transformer. The transformer guarantees galvanic isolation and enhances safety by segregating the primary circuit, which operates at a greater voltage, from the secondary circuit, which operates at a lower voltage.

Since the majority of devices necessitate a direct current (DC) voltage on the input side, the alternating current (AC) voltage must be converted to DC in the subsequent stage. The outcome of this procedure is illustrated in the DC diagram depicted in Figure 1 (located at the top center). Following the rectification operation, we observe a positive polarity. This is achieved by the use of a bridge rectifier, which consists of four identical diodes.

## TYPES AND APPLICATIONS OF POWER SUPPLIES

A linear power supply is a type of power supply that delivers one or more stable and consistent output DC voltages, regardless of variations in the input voltage or the load. Based on the same idea depicted in Figure, a linear power supply is comprised of a transformer, a rectifier, a filter, and a regulator. The transformer decreases the magnitude of the power grid voltage, the rectifier converts the alternating current (AC) voltage into a direct current (DC) voltage, the filter stores energy to ensure a steady output voltage from the rectifier, and the regulator stabilizes and controls the output voltage. Such power source is commonly employed in laboratory apparatus, medical instruments, and audio systems.

A switched-mode power supply (SMPS) is a type of power supply that uses a switching regulator to convert electrical power efficiently. A power transistor, which alternates between the on and off states, enables the storage and subsequent release of energy to the load. This is commonly achieved by utilizing an inductor as an energy-storage component. Unlike linear power supplies, Switched Mode Power Supplies (SMPSes) rapidly deliver power to the load. A pulse-width modulation (PWM) signal is utilized to activate the transistor. The frequency and duty cycle of the PWM signal alter the magnitude of the output voltage. This power supply variant is extensively utilized in consumer electronics, appliances, and industrial machinery.

# ZENER DIODE SIMULATION

ARIJIT KONAR, PRITTHISHA GHOSAL

2nd YEAR, ECE

Zener Diode - This device resembles a compact cylinder, much like the conventional diode, with two terminals at the ends that can be wired or soldered to an electronic circuit. It is a polarized component having a positive anode and a negative cathode.

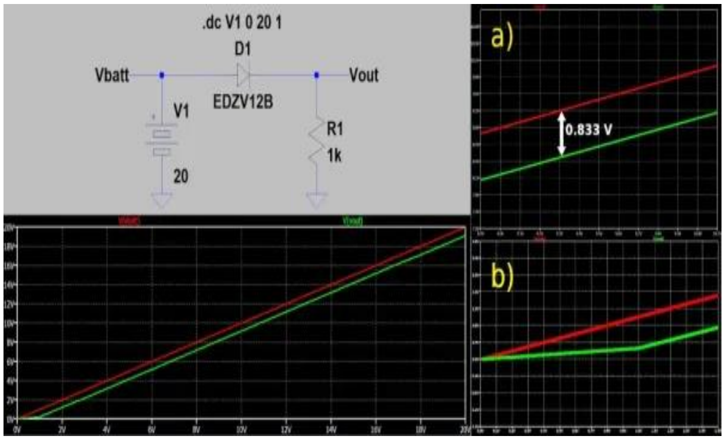
The device's body has a band printed right next to the cathode, or negative terminal. It goes without saying that the Zener must differ from the typical diode in the schematics. Its symbol is quite similar to the traditional diode's, with the difference that two tiny lines have been added to differentiate them. LTspice is the most commonly used electronic simulation software. With improvements and models to make the simulation of analog circuits easier, it combines a high-performance SPICE simulation tool with a schematic capture tool and a waveform viewer.

## THE ZENER DIODE

If directly polarized, as with a normal diode, the Zener diode leads. It also leads if reverse-polarized, unlike a conventional diode, but only if a specific voltage threshold (Vz) is exceeded. In electronic circuits, the Zener diode is inversely polarized to exploit this conduction characteristic beyond a certain voltage level Vz. Due to the Zener's ability to conduct only above a specific voltage value, Vz, it can be employed in all situations where a specific function needs to be carried out. Let's get a basic understanding of how the Zener diode operations are performed.

In Figure, we can see a simple electrical scheme in which the semiconductor (EDZV12B at 12 V) is directly polarized. The simulation of the DC type between 0 V and 20 V shows the output voltage on the resistance R1 dependent on the battery voltage. The main graph and Graph A confirm a constant voltage difference between the cathode and the anode of approximately 0.833 V (junction voltage). This constant voltage difference begins when the voltage on the anode is greater than 0.8 V (Graph B).

The simulation of the DC type between 0 V and 20 V shows the output voltage on the resistance R1 dependent on the battery voltage. In this mode, of course, a normal diode does not conduct current. But with a Zener, if the reverse voltage exceeds a certain threshold (for our diode, it is 12 V), it starts conducting. For example, if the battery voltage is 18 V, on the resistance we will find the voltage of 6 V (18–12).




## ZENER DIODE AS REGULATORS

The previous experience has made us understand that if a Zener diode inversely polarized goes to conduction, there is a fixed voltage, Vz, on it. For example, if there is always a voltage of 12 V on a 12-V Zener, regardless of the supply voltage, then the Zener can be used as a voltage stabilizer. This is one of the major uses of the Zener diode, as a stabilizer at a fixed value, a voltage useful for having a fixed reference voltage and for supplying fixed-voltage circuits.

Zener diodes are components that stabilize voltage optimally. Unfortunately, they cannot deliver high currents, but they are very useful for providing a precise voltage reference for subsequent power stages. All electronics are regulated by precise mathematical formulas. The calculation of the conditions of the Zener diodes also follows this rule.

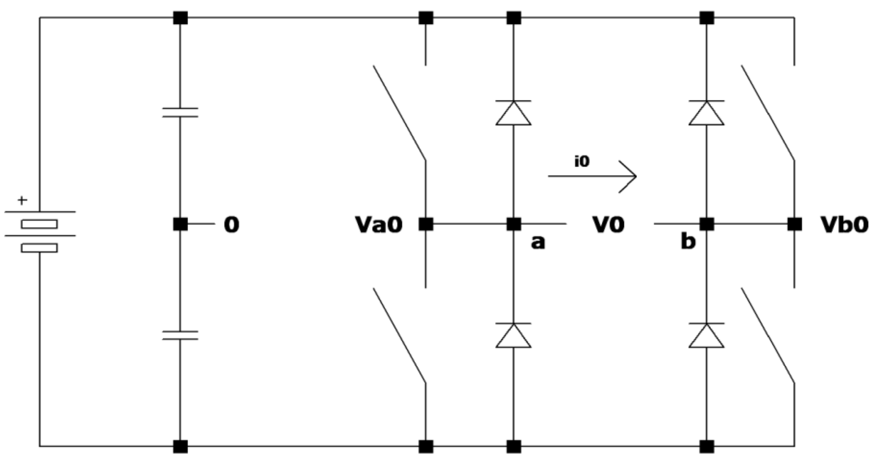
# SINGLE PHASE FULL-BRIDGE INVERTER

ANKAN MAJI, ABHIJIT MONDAL
1st YEAR, ECE

Single-phase full-bridge inverter, an electronic apparatus employed for the conversion of direct current (DC) into alternating current (AC). This conversion is accomplished by utilizing a diode bridge circuit, which enables higher efficiency compared to alternative inverter designs. Single-phase inverters are simpler than three-phase inverters. Single-phase bridge inverters are generally dependable and economical for transforming solar energy into useful electrical power. Given the escalating need for environmentally friendly energy sources, it is anticipated that their popularity would persistently rise in the next few years.

## Principle of Operation

As previously stated, single-phase full-bridge inverters are utilized to convert direct current into alternating current. The circuit utilizes electrical switches that function in pairs. During one half-wave, only S1 and S2 are closed, while during the other half-wave, S3 and S4 are closed. The inverter produces an oscillating voltage with a frequency that can vary, depending on the frequency of the waveforms used to operate the devices. Figure 1 depicts the overall operational schematic of this inverter. Practically, the electronic switches in part "a" of the circuit are operated in a complementary manner to the electronic switches in part "b". The switches in this scenario are considered to be optimal devices. Both signals are modulated using reference voltages that are identical in magnitude but opposite in direction. Usually, the identical electrical carrier is employed for both driving signals.




The single-phase full-bridge voltage generator inverter consists of four chopper circuits. In it are four transistors, or MOSFETs, (Q1, Q2, Q3 and Q4). They can be driven individually and independently, so the final operation is different depending on the sequencing and how the electronic switches are turned on and off. This device is also called an "H-bridge" because of the peculiar graphic shape that its electronic components form. The end result is the combination of two single-phase, two-level inverters using the same supply voltage. We will examine, below, the different activation sequences:

- if switching elements Q1 and Q2 are both closed, the load (present between nodes "a" and "b") is subjected to a voltage equal to Vs, and precisely at node "a" there is a voltage value of about Vs and at node "b" there is a voltage value of about GND
- if switching elements Q3 and Q4 are both closed, the load (present between nodes "a" and "b") is subjected to a voltage equal to Vs, but this time reversed in polarity, and precisely at node "a" there is a voltage value of about GND while at node "b" there is a voltage value of about Vs.

The current flowing through the load is not ideal but it is influenced by the resistive values of the electronic switches, which, as we know, are not real either. On the contrary, the current, passing through two transistors connected in sequence has to cross, for all intents and purposes, two resistive lines with a very low but still significant value.

# AN OVERVIEW OF SEMICONDUCTORS

SRIJAN SINHA, KOYENA CHAKRABORTY
2nd YEAR, ECE

Semiconductors are crucial in building a future marked by environmental sustainability and more automation in the constantly changing field of technological innovation. In light of the pressing need to decrease carbon footprints and improve efficiency, semiconductors are becoming essential components for the advancement of environmentally friendly and highly automated technology. This article examines the potential of these powerful materials to transform businesses, creating a new era where environmental awareness effortlessly intersects with advanced automation.

Regarding electrical conductivity, solids can be roughly categorized into three groups:

- **Insulators:** Insulators are substances that possess poor electrical conductivity, making them suitable for creating a barrier between two surfaces where the passage of electric current is undesirable. Some examples of these materials are plastics, paper, and quartz, which is composed of silicon dioxide (SiO2).
- **Metals:** metals are substances that possess the ability to easily transmit electricity, making them suitable for the purpose of transferring electrical current and establishing connections between two conducting materials. Some examples of these materials are copper and aluminum.
- **Semiconductors:** semiconductors possess the distinctive characteristic of being able to transition from a non-conductive state to a conductive one when subjected to an external influence, such as the application of voltage. When discussing semiconductors used in electronics, we typically refer to those that have a well-defined and repetitive crystal orientation, meaning the atomic orientation is organized in a specific manner. They may comprise of individual components, such as silicon (Si), or compound materials comprising many distinct elements, such as silicon carbide (SiC) and gallium nitride (GaN).

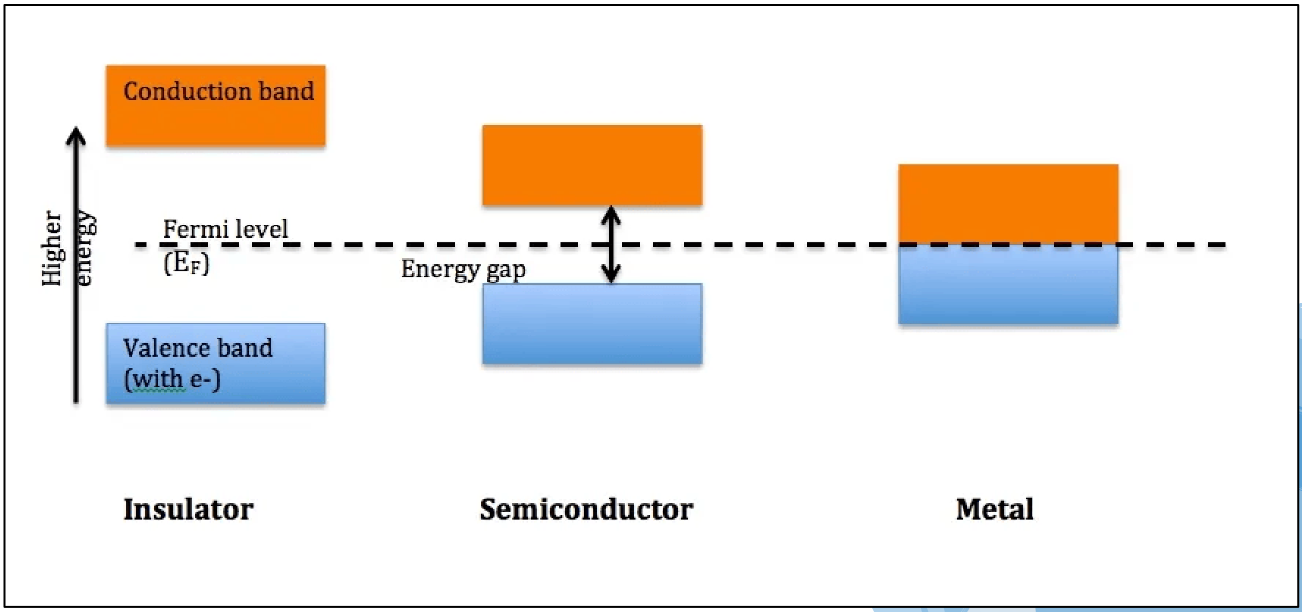


Figure shows a visual depiction of these three categories. This illustrates the energy bands present in the substance. The valence band corresponds to the outermost shell of the atomic structure and contains the electrons that are readily available for bonding. The conduction band corresponds to unoccupied electron states with the lowest possible energy. The conduction of electric current in a semiconductor occurs by stimulating the movement of electrons from the valence band to the conduction band, which is separated by an energy gap.

In a metal, this gap is non-existent due to overlaps of these bands, and hence, they have high electrical conductivity. In an insulator, this gap is large (e.g., ~10 eV in SiO2, where eV is the amount of work done on an electron to make it go through a 1-V potential difference). In a semiconductor, the energy gap is typically in the 1-eV (Si) to 3-eV range (SiC and GaN). This gap makes it suitable for use in an application in which an externally applied voltage (typically a few volts) can change the behavior from insulating type to conducting type. The Fermi level EF in Figure is a measure of the energy of the least tightly held electron in a solid. In an intrinsic semiconductor, it would typically lie between the valence and conduction band.

## Different types of semiconductors and their uses:

The vast majority of all semiconductors used in electronics applications are based on silicon. Decades of technology development on this material have resulted in astounding levels of progress in the devices that are built from this, largely following Moore's Law of a doubling in device density every two years. Some of its unique advantages include:

- The ability to easily dope its crystalline structure with atoms that can move the EF level up or down. In silicon, this can typically be done through ion implantation of ions like P, As (donors to create n-type Si) to B (to create p-type Si). In an n-type Si, the excess of electrons occupies vacant sites and so conduct electrons toward a positive voltage. In a p-type Si, electrons are pulled away from valence sites, creating a positive charge called a hole, which effectively flows in a direction opposite to an electron.
- The ability to readily form a high-quality, insulating SiO2 oxide layer on its surface. This allows for control of the device state with high reliability in a device called a metal-oxide–semiconductor field-effect transistor (MOSFET). An applied positive voltage on the gate of the NMOS creates an electron channel under the oxide, effectively connecting the source and drain nodes.
- The ease of forming both n- and p-type devices, along with a high-quality gate oxide that basically prevents static current draw on the gate supply VG, led to the rapid advancement of complementary MOS or CMOS technology. The main advantage of CMOS is that because the PMOS and NMOS are in series on a basic logic gate, one of these devices is always off, therefore making static current draw ID on VDD very low. The NMOS and PMOS ID versus VG curves indicate the turn-on voltage VT, at which the voltage applied on the gate turns on the channel between the source and drain.
- Silicon is very cost-effective. Semiconductors are typically processed using flat, circular discs, which in turn are produced for a cylindrical boule that is sliced. High-quality, large-diameter (12-inch) silicon can be created at relatively low temperatures, making the starting wafer price typically a small fraction of the overall processed wafer cost.

# EV BATTERY SUSTAINABILITY USING CHIP-ON-CELL TECHNOLOGY

SUBHADEEP MAITY, NILANJAN DUTTA
3rd YEAR, ECE

The race to electrify our world, especially in the transportation industry, is currently in progress. With the rising number of electric vehicles (EVs) in circulation, a significant proportion of batteries will inevitably reach their end of life. It is our duty to guarantee that these batteries are not a threat to the environment and are instead properly managed through recovery, reuse, and recycling within a circular economy. The advancement of stationary energy storage systems relies on effective, reliable, and secure data handling. As the intricacy of these systems grows, they necessitate increasingly elaborate communication wiring to enhance battery performance and guarantee safety, resulting in possible sites of failure.

An electric vehicle (EV) battery exhibits more sustainability as its lifespan increases, enabling its cells to be repurposed for alternative EVs or diverse energy storage purposes. Alternatively, the battery can be recycled, with its constituent materials recovered and utilized in the production of new batteries.

Nevertheless, overseeing the well-being, efficiency, and security of these batteries presents an intricate dilemma. Conventional wired and wireless battery management systems (BMSes), while somewhat effective, have fundamental limitations. Dukosi's chip-on-cell technology is a revolutionary way for monitoring battery cells, effectively addressing these difficulties.

## Wired vs. wireless BMS

Traditional wired BMSes use an elaborate network of physical wiring that connects every individual cell in a battery pack to a central controller. The intricacy of the wiring increases proportionally with the number of cells in a battery pack. The inclusion of extra wiring not only results in added weight and possible areas of failure, but it also complicates the process of installing, maintaining, and diagnosing issues with the BMS. An intricately wired system can also limit the flexibility of battery pack designs, as fitting the necessary wiring may restrict the ways in which battery cells can be placed or stored. Furthermore, in the case of problems or failures, the troubleshooting process can be time-consuming and tedious, as each wire and connecting point must be inspected and checked.

Conversely, a wireless BMS provides a more efficient method by eliminating the requirement for physical connections. This streamlines battery pack designs and decreases the corresponding weight. Nevertheless, employing a wireless methodology is not devoid of its own array of difficulties. Signal interference can occur due to diverse external sources or even from different components within the same system, thus compromising the precision and dependability of data transmission. In addition, wireless systems are inherently vulnerable to cybersecurity risks, as unauthorized actors may try to intercept or manipulate the transmitted data. Additionally, it is crucial to guarantee the continuity and dependability of wireless communication, since any interruption in communication may result in inaccurate data or possibly hazardous operational circumstances for the battery pack. Essentially, although a wireless BMS mitigates certain limitations of a wired system, it presents a fresh set of challenges that must be meticulously addressed to guarantee secure and effective battery management.

Dukosi's chip-on-cell technique aims to address these restrictions by integrating a compact chip directly onto every battery cell. Dukosi was established in 2003 and has its main office in Edinburgh, United Kingdom. The company focuses on battery-monitoring technology with the aim of addressing the challenges that commonly affect battery-powered applications. The chip-on-cell technology utilizes a contactless communication system that relies on near-field communication (NFC) to monitor and record operational data and events of each individual cell in the battery. This data is then transmitted to the Dukosi system hub chip, which is integrated into the conventional BMS.

# DEVICE EFFICIENCY COMPARISONS IN POWER SUPPLY DESIGN

ANKIT MONDAL, TANMOY MAJI
1st YEAR, ECE

Within the scope of this article, multiple simulations of power circuits driving resistive loads using various devices are presented. The objective of this test is to identify the electronic switch that, given a constant load impedance and power supply voltage, achieves the highest level of efficiency.

## The evolution of switching devices across the years

Electronic switches have made significant advancements and gained more power over the course of their history. Their development is influenced by a variety of factors including:

- Resistance of the conduction channel
- Ever-lower costs
- Ever-higher switching speed
- Reduction of the occupied space and less overall dimensions
- Higher efficiency

These are extremely essential characteristics that enable applications that were inconceivable thirty years ago. Initially, the only true power converter was the bipolar transistor. It has problematic thermal drift, requires a high base current to conduct, and has very sluggish shutdown characteristics. MOSFETs gained popularity due to the fact that they are controlled by voltage and not current.

MOSFETs are unaffected by thermal drift and have reduced switching losses. Because of this, it was the most prevalent component in power converters. In the 1980s, IGBTs dominated. An IGBT is a hybrid component consisting of both bipolar transistors and MOSFETs. It possesses the conduction characteristics of a bipolar transistor but is controlled by voltage like a MOSFET.

## Efficiency

In the world of power electronics, efficiency is an easy term to conceptualize: 100% is a great value, 0% is bad. Efficient use of energy is a key factor in many applications. Efficiencies above 90% are considered good results, but modern devices allow even higher efficiencies. An efficient power supply obtains less energy waste in the form of heat, which reduces the average life of the electronic components. Efficiency has a great effect on the reliability and durability of the final equipment, as well as on energy consumption.

If efficiency is higher, power dissipation and thermal losses are lower. In very high-power converters, even a small percentage of efficiency improvement translates into enormous energy savings and, therefore, economic savings. Furthermore, the higher the efficiency, the lower the operating temperature of the passive and active components and the better the overall reliability of the system. Efficiency is calculated as the output power divided by the input power and is usually expressed as a percentage. The difference between input power and output power is the wasted and lost power in the power supply in the form of heat. The basic formula for calculating the efficiency of a circuit is:

$$Eff\,(\%) = \frac{P(out)}{P(\mathrm{in})} \cdot 100$$

The lower this resistance of the conduction channel of the device, the greater the efficiency of the circuit. In this way, the electronic component will dissipate less heat and will work better.

## Electronic components used

For our tests and simulations, we have chosen some very powerful and robust electronic components (see Figure), real workhorses used massively in power projects and which are still widely used today. The following list also describes the most important characteristics:

- Transistor BJT 2N3055: VCE: 100 V, IC: 7 A, P: 115 W, Tj: 200°C, beta: 70
- MOSFET Si IRF530: VDS: 100 V, Rds(on): 0.18 Ω, Id: 14 A, P: 75 W, Tj: 150°C
- IGBT IXYH82N120C3: VCE: 1200 V, VGE: 20 V, IC: 200 A, P: 1250 W, Tj: 175°C
- SiC MOSFET UF3SC065007K4S: VDS: 650 V, Rds(on): 0.009 Ω, VGS: 20 V, Id: 120 A, P: 789 W, Tj: 175°C

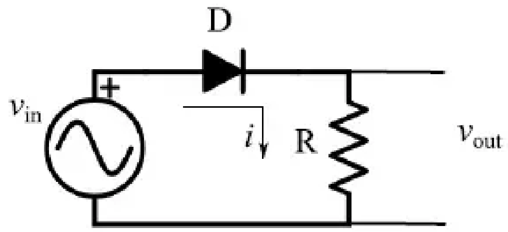

# ANALYSIS OF WBG-BASED HALF WAVE RECTIFIER

ANANYA GHOSH, DEEDHITI DEY
3rd YEAR, ECE

Within the scope of this power electronics tutorial, we will investigate the behavior of a silicon carbide (SiC) rectifier whose operating temperature is significantly greater than the temperature of the surrounding environment. When we conceive of a circuit, we can compare it to an electromechanical traction system that must function in a "hot environment."

## Simulation and analysis using Mathematica

A wide-bandgap (WBG) semiconductor diode is shown in Figure, denoted with the letter D. When we talk about the output voltage associated with a sinusoidal input, we are referring to temperatures that are significantly higher than 300 K, which is the standard ambient temperature. Moreover, we presume that the load resistance is already known.




The current 'i' flowing through the silicon carbide diode is given by the following expression:

$$i = i_0 \left( e^{\frac{v}{\eta V_T}} - 1 \right) \qquad (1)$$

Equation (1) has a number of different terms, all of which are easily recalled by us. The quantity v represents the voltage drop across the diode, whereas the term i0 represents the reverse saturation current, which is of the order of 1 μA. The parameter η is dimensionless, and we can approximate it to 1. An electric potential is denoted by the symbol $V_T$.
The following equation gives the expression of the electric potential $V_T$:

$$V_T = \frac{k_B T}{q} \qquad (2)$$

$$k_B = \text{Boltzmann constant} \longrightarrow k_B = 1.380 \times 10^{-23}\,\mathrm{J\,K^{-1}}$$

$$q = 1.602 \cdot 10^{-19}\,\mathrm{C} \quad \text{(absolute value of the charge of the electron)}$$

Based on the information provided in the equation (2), we can see that $V_T$ encompasses the behavior of the diode and, by extension, the rectifier when they get hot. In equation (1), Kirchhoff's second principle is utilized in order to ascertain the voltage that is present across the diode:

$$v = v_{in} - Ri \qquad (3)$$

Through the use of the necessary substitutions, we are able to get a sinusoidal input with frequency f, given by the following expression:

$$v_{out}(t) = Ri_0 x(t), \quad \text{where } x(t) = \frac{i(t)}{i_0} \text{ and} \qquad (4)$$

$$V_T \ln(x+1) + Ri_0 x = V_M \sin(2\pi f t)$$

At this point, the answer to the problem expressed by equation (4) in the high-temperature limit needs to be discovered using appropriate software like Mathematica.
Now, we'll look at the magnitude's circuit meaning:

$$V_T = \frac{k_B T}{q} \qquad (5)$$

Known as the voltage equivalent of the temperature. From equation (1), assuming η = 1, we see that:

$$(i(v) = 0 \Longleftrightarrow v = V_T) \Longrightarrow V_T \equiv V_\gamma \qquad (6)$$

where Vγ is the offset voltage of the diode.4 Therefore, we can state the following: The voltage equivalent of the temperature is the offset voltage.

It follows that bringing a diode to temperatures higher than 300 K (typical room temperature) is equivalent to increasing the offset voltage. More precisely, we obtain the plots shown in Figure 4, where we also see that, for the same v, the current decreases as T increases. This happens because, as the temperature increases, the differential resistance of the diode, which is approximately equal to the ratio between VT and the current i,4 increases. SiC semiconductors can get rid of heat better than silicon or germanium because they have a high thermal conductivity. This means that they don't need a heatsink. However, we will have to examine the effects of temperature on the working point in our next tutorial on power electronics.

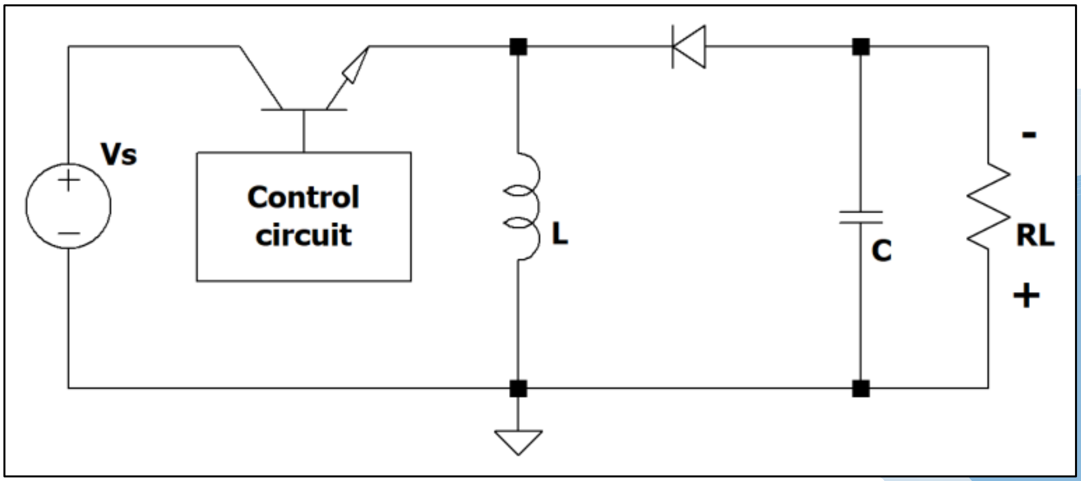
# BUCK – BOOST REGULATOR

ARIJIT ROY, SHREYA GHOSH
2nd YEAR, ECE

Buck and boost converters can operate in two distinct and autonomous setups. The first circuit aims to decrease the input voltage, whereas the second circuit aims to increase the voltage. This post will show how to merge the two circuits into a single one that is simpler and more convenient to handle. Combining the two layouts might create a unified solution that would reduce weight, save space, and save costs. Enhanced efficiency is an additional benefit.

## The buck-boost regulator

The circuit shown in Figure illustrates one of the most basic versions of the buck-boost voltage regulator. An electrical switch is connected in series with the line input to regulate the circuit. This could refer to any electrical power switch, such as a bipolar transistor, a power MOSFET, or similar controllable device capable of switching between ON and OFF states. The resistor RL in the schematic diagram symbolizes the load connected to the output, which may actually refer to any subsequent circuit that consumes current.



The unique characteristic of the buck-boost regulator is its ability to produce an output voltage that is either greater or lower than the input voltage. It functions in a non-linear regime. Put simply, the device takes in a DC voltage at the input and adjusts it up or down as required by the application at the output. The output voltage is negative relative to ground, which is an important factor to consider. In the circuit schematic, the load experiences a reverse potential difference compared to a typical converter.

This polarity must be taken into account when designing any application. Its circuit is similar to those of buck and boost converters, but the whole system is contained within a single circuit, with the addition of a control device. They are used in consumer electronics devices, self-regulating power supplies and power amplifiers. It is therefore possible to use both buck and boost functions in a single configuration, acting on the input pulses. Let us now examine, in broad terms, the operation of this type of converter.

The circuit, as we saw earlier in the circuit diagram, contains an electronic switching component (transistor, MOSFET or other. It can be switched on and off (at high speed) by means of a pulsating signal from an oscillator circuit. The circuit also contains an inductor, a diode and a capacitor as well as, of course, the load. The electronic switch, therefore, operates under two different conditions, in the ON state and in the OFF state. During the ON state, current flows through the transistor and also flows instantaneously through the inductor, as the diode is inversely polarised. The inductor limits this sudden current and stores a certain amount of current.

When the transistor switches to the OFF state, blocking the normal passage of input current, the inductor sends its current (stored in it) back to the diode and thus to the output of the circuit on the load. The current is also stored in the capacitor. During the next ON state, the cycle repeats, but this time without current in the inductor. It is the capacitor that supplies the stored energy to the output.

## Buck or Boost?

The behavior of the circuit is determined by the pulse width on the electronic switch and the ratio of the ON state to the OFF state. If the ON time of the transistor increases, the circuit starts to behave as a boost converter; vice versa, if the OFF time of the transistor exceeds the ON time, the circuit starts to behave as a buck converter.

The pulses on the electronic switch follow, therefore, the rules of PWM signals and can be modulated with any type of square oscillator, even with the use of microcontrollers. By appropriately adjusting the duty cycle of the PWM signal, therefore, the output voltage of the converter is decisively determined.

# REDUCING NOISE IN POWER SUPPLIES

DEBAYAN KARAR, AGNIVA CHATTERJEE
1st YEAR, ECE

Power supply noise is a common outcome that designers and everyone involved in electronics manufacture must expect and strategize to minimize. Here are some practical methods to accomplish noise reduction in power supplies.

## Applying a filter

An approach that offers various potential outcomes is to employ filtering techniques for the purpose of controlling power supply noise. Output capacitors can be utilized to mitigate noise by counteracting the output impedance of the power supply circuit. Nevertheless, capacitors possess equivalent series resistance (ESR) and equivalent series inductance (ESL). Choosing a component with a lower Equivalent Series Resistance (ESR) and Equivalent Series Inductance (ESL) will decrease the amount of noise.

It is important to note that a significant decrease in ESR (Equivalent Series Resistance), which might occur when replacing an electrolytic capacitor with a ceramic one, may lead to power supply instability. This is because the ESR plays a role in generating error signals related to feedback.

In contrast, ferrite beads are highly effective in attenuating high-frequency output noise when used for filtering purposes. They disperse high-frequency noise energy and accomplish this over a wide frequency spectrum. Nevertheless, the ferrite beads exhibit resistance within the intended frequency range, causing the dissipation of surplus noise as thermal energy.

Electromagnetic interference and radio-frequency interference filters can effectively assist in managing noise by preventing the entry of such electrical disturbances into a system, hence preserving its functionality. These filters additionally prevent your gadget from emitting electrical interference into power lines. The significance of the second component lies in the fact that government regulators establish specific limits on the amount of noise that a device can generate and transmit across alternating-current power lines. There are distinct differences in the limitations between North America and Europe.

Ferrite clamps, often known as clamp filters, are commonly used intervention methods, especially in items such as computers or office equipment. The filters consist of a cylindrical ferrite core that is enclosed within plastic and divided into two portions along its length. An inherent benefit of a clamp filter is its compatibility with pre-existing electronic equipment configurations, since it may be seamlessly integrated without the need for cable modification. Additionally, these filters provide protection for the gadget against static electricity.

## Define the device’s operating temperature

Extreme temperatures can impair the functionality of an electronic device and result in increased power supply interference. Nevertheless, via the integration of design considerations and customer education, corporate representatives can enhance the probability of users being satisfied with the product’s performance.

For instance, a power supply with ventilation can effectively regulate the system's temperature. However, it is not suitable for usage in dusty or rainy conditions. Furthermore, in the event of a potential hazard where the power supply may become excessively hot and present a danger of burns to the operator, designers must carefully evaluate the most efficient methods to maintain its coolness.

In contrast, low temperatures can amplify the voltage ripple generated, so introducing additional noise into the power supplies. Suboptimal temperature conditions can have an adverse impact on the power supply's ability to regulate its output. Electronic devices often exhibit superior performance at cold temperatures compared to hot temperatures. However, severe temperatures in either direction can have detrimental effects on the device's function.

Advising clients to avoid using the power supplies in extremely cold weather conditions, which might cause an increase in system noise, is a simple and effective method of minimizing potential issues. Furthermore, furnish a comprehensive specification sheet that individuals can readily consult during their ownership or use of the goods.

# TI DEVELOPS AWR2544 SINGLE-CHIP RADAR SENSOR FOR SATELLITE VEHICLE ARCHITECTURE

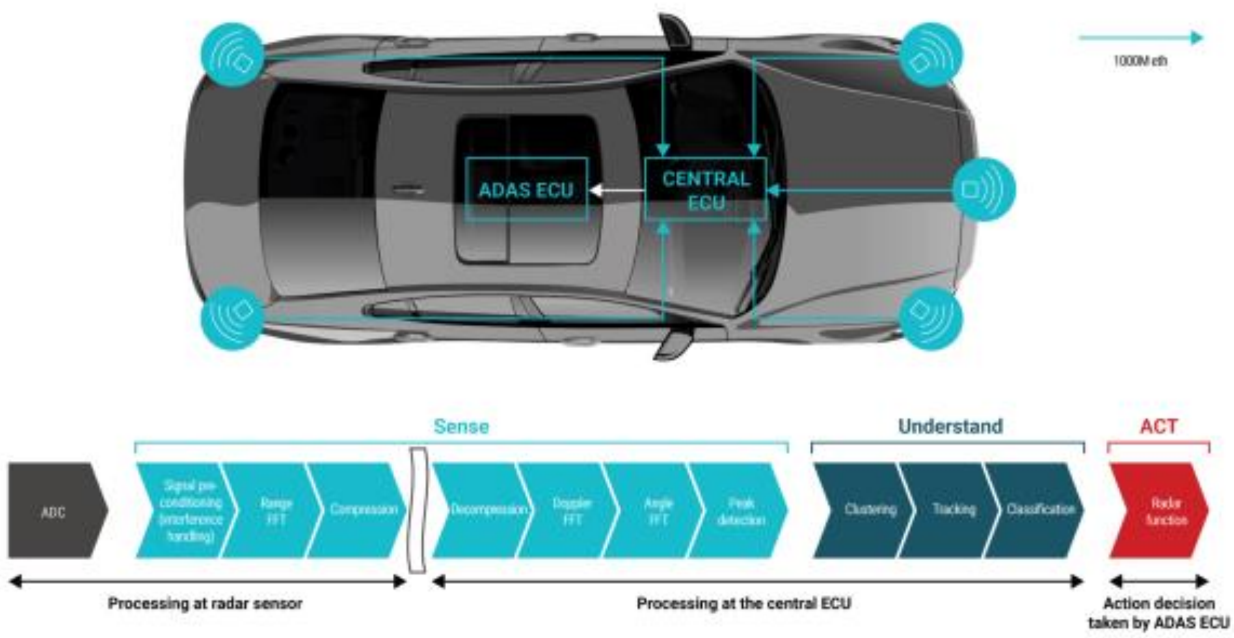
ANURAG BANERJEE, AMIT SEN
3rd YEAR, ECE

Autonomous vehicles rely on radar and LiDAR sensors, complemented by edge-based cameras to perceive their environment, make well-informed choices and navigate safely. These embedded devices are used for object detection and creating 3D maps of their surroundings, enabling precise positioning and image recognition. The introduction of Texas Instruments' (TI's) AWR2544 radar sensor marks a significant industry advancement, particularly for satellite vehicle architecture.

The traditional edge architecture used in advanced driver-assistance systems (ADAS) has sensors that share processed data through a controller area network or 100-Mb Ethernet interface to an ADAS electronic control unit (ECU) over a distributed system. Conversely, satellite architecture consolidates intelligence at the controller level, streamlining sensors to contain only essential hardware for basic operation, while processing is executed in the domain controller. This approach enhances system flexibility, scalability and performance.

Centralized processing of satellite architecture enables a sensor fusion algorithm similar to how the human brain makes decisions based on inputs from both eyes instead of each eye deciding independently. This architecture minimizes latency and accelerates decision-making by allowing the domain controller to process data without waiting for sensor-level processing. Moreover, integrating additional satellite sensors becomes more straightforward and economically feasible as the level of automation increases.

Furthermore, satellite architecture contributes to a lighter hardware system by eliminating redundant components like power supplies, housings and brackets, achieving up to 30% reduction in mass compared with a traditional ADAS. Additionally, satellite systems offer enhanced maintainability, as centralized software updates via over-the-air are efficient, and domain controller hardware can be upgraded over time.




TI unveiled the AWR2544 single-chip radar sensor at CES 2024, designed to extend vehicle sensing ranges beyond 200 meters, thereby improving the accuracy of ADAS in decision-making processes. The sensor is based on the Arm Cortex-R5F core, which is a mid-range CPU designed for deeply embedded, real-time systems, built on the Arm v7-R architecture. The Cortex-R5F core is equipped with advanced safety features like a flexible second core for redundancy, improved bus protection and an error-correction code, which makes it a compelling option for the development of safety-critical applications.

The secondary CPU core is utilized to switch system operation to a backup CPU in situations of a primary CPU failure, thus ensuring the reliability of the system. The core's instruction cache and data cache stores frequently accessed instructions and data from the main memory to facilitate critical decisions. For effective error handling, the R5F core leverages tightly coupled memory ports for reduced latency, providing fast access to local RAM, which is important for real-time system performance.

The AWR2544 radar sensor comes with multiple interface options that allow compatibility with a range of other devices. It is equipped with one SPI, two UARTs and an I2C interface for communication with external devices. The I2C enables interaction with devices like E2PROMs, additional sensors or microcontrollers using a simple two-wire interface. Meanwhile, the UARTs enable the sensor to connect with GPS modules, Bluetooth modules or other sensors operating on UART communication.

The sensor can be deployed in a variety of applications, with key use cases including lane-change assistance, blind-spot detection, automatic emergency braking (AEB), adaptive cruise control (ACC) and cross-traffic alerts. Specifically, AEB systems leverage radar sensors to detect potential collision threats and automatically initiate braking to prevent accidents. These systems involve radar detectors positioned at the front of the car that continuously emit high-frequency radar waves. Both AEB and ACC rely on the radar's ability to detect close-range objects to trigger emergency braking and continuous object monitoring while cruising.

## Advanced Radar Sensor Manufacturing

TI has manufactured the radar sensor with launch-on-package technology that reduces the need for an external antenna and thereby simplifies the design of wireless devices. This is achieved by integrating a specialized 3D antenna on the flip side of the circuit board, reducing the sensor size by up to 30%, according to the company.

Equipped with an integrated 77-GHz transceiver that comprises four transmitters and four receivers, the radar sensor delivers high resolution and accuracy essential for applications like collision avoidance, ACC, blind-spot detection and cross-traffic alerts. Its ability to perform reliably in adverse weather conditions like rain or fog highlights the importance of millimeter-wave in modern automotive radar technology.

"From more advanced driver-assistance systems to smarter electric-vehicle powertrain systems, TI is working alongside automakers to reimagine how reliable and intelligent technology can enable safer vehicles," said Fern Yoon, TI's director of automotive systems.

# A TUTORIAL ON UPS

SURANJAN SENGUPTA, DISHA GHOSH
2nd YEAR, ECE

The term "Uninterruptible Power Supply" (UPS) denotes the apparatus that is linked to the electrical power supply network and the protected devices in order to supply power to them during an outage or power failure. It is important to differentiate the UPS from other protective devices, including isolation transformers, voltage stabilizers, transient suppressors, and so forth.

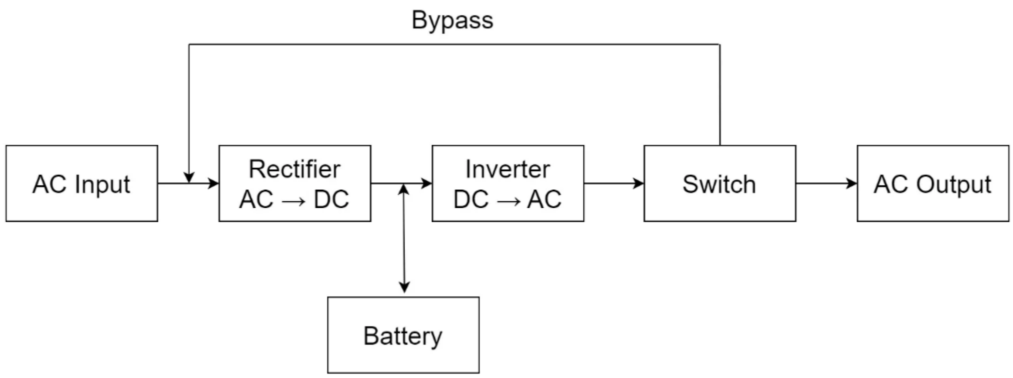
## STATIC UPS

A UPS generally corrects high and low-voltage events, such as spikes and sags. Therefore, to implement protection for your devices you need adequate protection that guarantees normal operational functioning even in the absence of electricity. By installing an adequate UPS, the devices are protected from the dangerous effects deriving from electrical disturbances. In the event of a prolonged power failure, the UPS provides power for a sufficient time to save data and orderly close application programs, thus canceling the effect of the interruption. Once this maintenance has been carried out, the device can be turned off as batteries have limited autonomy according to their specific electrical capacity. Typically, a UPS provides a backup electrical power supply for about 10 or 15 minutes, although with large capacity batteries longer autonomy times can be obtained.

Since UPSs provide only a limited amount of power during a prolonged power outage, users should take some precautions to prevent data loss before the UPS can no longer provide power to their devices. The most sophisticated UPS models have a communication port that allows logical connection with the equipment to be protected. Static UPSs use power electronics, instead of a motor generator, to provide electrical energy to the load. Nowadays most UPSs are of this type. The general structure of a UPS is depicted in Figure.

A widely used type of UPS is called “double conversion”, whose peculiarity lies in the fact that the input and output are never in direct contact, and this is because they carry out two conversions, from alternating current to direct current and vice versa. At the intermediate point, the batteries are inserted into the summing node that powers the inverter, i.e., the block that carries out the second conversion, in this way there is no switching, and no voltage variation can influence the output.

Sometimes, this type of UPS is equipped with a transformer that also performs an isolation function. With this type of operation, there is no latency time when the power supply passes between the mains and the battery. Another operating mode is defined as “offline”, in which the inverter is operated only when the mains voltage fails. The energy required to manage the system is, obviously, less than the previous one but, in this case, the change of the energy source requires a latency period of a few milliseconds during which the load is disconnected from all sources of energy.




## BENEFITS OF UPS

As previously stated, UPSs are apparatus designed to supply backup power in the event of a power failure or brownout. They are implemented to safeguard delicate electronic devices against potential harm resulting from power outages or voltage fluctuations. Under the influence of mains power, UPSs undergo a conversion process from AC to DC, whereby the converted DC is stored in a battery. The UPS converts DC to AC and then uses the energy contained in the battery to power connected devices in the event of a power outage. There is a wide range of sizes and electrical capacities available for UPSs. Sensitive electronic devices are safeguarded against mild to severe voltage fluctuations and sudden power disruptions through the utilization of UPSs. Additionally, they enable the continued operation of devices in the face of a power outage. This is particularly crucial for critical operations, including data storage systems, servers, and security systems.

With device protection, UPSs help reduce the cost of repairing electronic devices damaged by voltage fluctuations or power outages. Most of the devices that are equipped with UPS are likely personal computers. A power outage would cause your computer to shut down or crash, resulting in the loss or deletion of valuable work and data, causing unimaginable damage. An entire hard disk could be destroyed if a disturbance occurs while performing writing operations. For businesses, sensitive data and documents stored on the computer are often of much greater value than the hardware that contains them. Despite the high reliability achieved by today’s personal computers, they are vulnerable to fluctuations and drops in mains voltage. Even though today’s technologies have achieved notable results, there is still no disturbance-free electricity distribution line, and problems, even imperceptible ones, are almost commonplace.

# ADDING CAPACITORS IN PARALLEL ON BRIDGE RECTIFIER

PRIYA MONDAL, HRISHIKESH GHOSH
1st YEAR, ECE

This article will analyze the applications and operations of capacitors coupled in parallel with the four diodes of a bridge rectifier, commonly referred to as a Graetz bridge. Their responsibility lies in minimizing the interference resulting from diode activity, addressing electromagnetic interference that may jeopardize compliance with EMC rules, and enhancing the efficiency of the diode bridge while establishing a low-noise power supply.

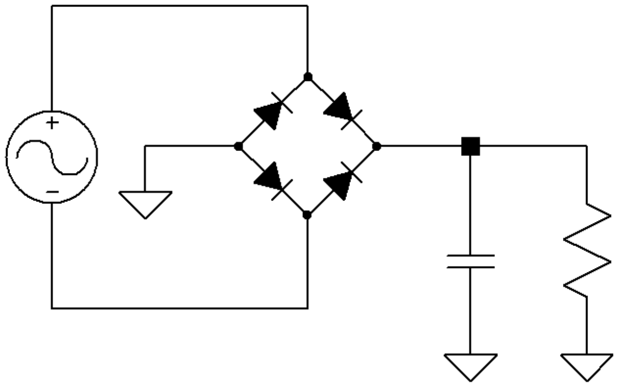
## How adding parallel capacitors to a bridge rectifier improves performance

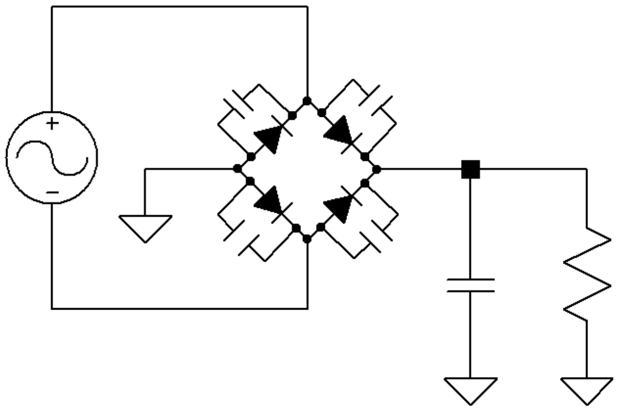
Typically, a power supply is comprised of a power transformer, which is then followed by a conventional bridge rectifier. The bridge rectifier is constructed using four diodes that are interconnected in a certain arrangement.

These components generate electrical interference which is significantly reduced by the incorporation of capacitors. The voltage transformer, being an imperfect component, possesses a leakage inductance and a parasitic capacitance. When the four diodes of a bridge rectifier are not conducting due to the presence of reverse current, the "non-ideal" components create a resonant circuit that oscillates at a high frequency. Put simply, when a diode transitions from conducting to reverse current, it briefly continues to conduct before abruptly ceasing to conduct in the reverse current state.

This phenomenon occurs rapidly, resulting in the resonance of the inductances and parasitic capacitances. The disruptions are contingent upon the velocity at which the junction halts the counter-current. The oscillation, together with its corresponding high-frequency signal, propagates throughout the entire circuit, resulting in numerous types of disturbances. The disruptions also have the ability to spread throughout the surroundings, as a result of their elevated frequencies.

An effective approach to alleviate this discomfort is to utilize capacitors that are connected in parallel with the diodes. They do not eliminate the oscillation, but they significantly diminish it. This procedure is unconventional, as traditional approaches rarely consider this alternative. Figure displays the old design at the top and the scheme incorporating capacitors in parallel with each diode at the bottom.





When converting alternating current to direct current using a bridge of four diodes, two diodes are conducting while the other two are blocking current flow at any given time. Non-linear signal fluctuations are inevitably produced during the shift from conducting to blocking diodes. Introducing a low-capacitance capacitor mitigates this signal defect and reduces the noise produced by the oscillation. The outcome is a significantly more purified and uninterrupted signal. The faulty signal arises from both the diodes and the inductive switching of the transformer. These capacitors serve the purpose of reducing the 50 Hz harmonics generated by the diodes, preventing them from reaching high frequency (HF) ranges, including the MHz range.

The inclusion of the capacitor introduces a slight temporal delay in the transmission. Typically, a capacitance of 10 nanofarads is sufficient, although capacitances in the range of a few hundred picofarads are also suitable. Diode behavior exhibits variation among manufacturers and among different lots. Therefore, an alternative approach is to define and test various diode models.

# ZOOMING IN ON CIRCUIT FAULTS WITH NEXT-GEN IMAGING

RACHNA TANTI, BAPI KUNDU
3rd YEAR, ECE

Electrical engineers have manually identified circuit faults using multimeter testing and visual inspections, spending countless hours measuring currents and inspecting for soldering defects. Next-generation imaging could expedite the finding of trace faults in electronic circuits, leading to more accurate fault detection and isolation. These assets are altering how labs view microelectronics, which are the lifeblood of the digital age.

## The Need for Advanced Fault Detection and Isolation

Critical infrastructure like telecoms and renewable energy runs on microelectronics like semiconductors and capacitors. Digital integrated circuits on printed circuit boards may have millions of connecting devices, making these some of the most intricate pieces of technology on the planet. Trace faults in electronic circuits are essential for rigorous inspection and quality control before heading to manufacturing and market. These are some other common defects that imaging could highlight:

- ✓ Soldering issues
- ✓ Broken pieces
- ✓ Interrupted circuit paths
- ✓ Bad etching
- ✓ Inadequate voltage management
- ✓ Contact faults
- ✓ Overcurrents
- ✓ Poor thermoregulation
- ✓ Incompatibility with other parts, like the power supply

One faulty PCB in a governmental security system could incite international conflict or shut down hospitals because data center hardware is short-circuited. Too many delicate and necessary operations rely upon these raw materials and healthy circuits in the modern era, rendering fault discovery and remediation some of the most important work of electronics and control engineers.

Imaging alleviates burdens while making operations more targeted and productive. The demands on microelectronics engineers are the highest they have ever been, and pressures will only amplify as analog items become more digitized. It bridges the best mentalities in model- and data-based fault diagnosis methods for more powerful operations.

## Optical Microscopy

This is one of the most well-known yet understated imaging methods, as microscopic technologies become more robust yearly. Optical microscopes are adept at detecting visible failures and degradation in circuits. Numerous customizations and sizing options are available depending on the suspected fault.

Labs may view board parts in sections in a non-destructive environment. It allows for simple contrasting at varying resolutions to comprehensively understand the circuit's health. Combine it with more strategies for effective issue identification, including but not limited to:

- Thermal laser simulation
- Photoemission electron microscopy
- Electroluminescence
- Transmission electron microscopy

## Deep Reactive-Ion Etching

Peeling away the layers of a PCB is sometimes necessary for uncovering a fault. This is reverse engineering at its most practical. Reactive ion etching with other techniques, like wet chemical etching or ion beam milling, can quickly locate performance anomalies.

Though this is not an imaging technique on its own, it is necessary for enhancing the quality and success of a reliable image. Reactive ion etching inputs charges into the circuit's traces at varying depths to see how far issues permeate.

## Scanning Acoustic Microscopy

PCBs comprise substrates and screens, and these thin laminates require as much examination as the integrated circuit's other components. SAM is an imaging method that could reveal if delamination has occurred based on sound waves bouncing off these delicate features. Sometimes, the positioning of acoustics processes a more crystallized picture than light in other forms of fault detection.

Frequency manipulation is critical for penetrating deep enough into the PCG's layers and honing on the specific features engineers may consider the problem sites. Are echoes reflecting off surfaces properly, or are the images revealing escaping signals? Though it may indicate a manufacturing error, it could also verify packaging oversights or aggressive assembly, causing punctures and fractures in the layers.

## Radiographic Testing

Many imaging methods examine external faults, so what reveals internal issues? Radiographic testing with X-rays or gamma rays is a potent resource for identifying misalignments, cracks, and soldering inefficiencies. It is a nondestructive method, allowing electronics engineers to inspect deep within assembled microelectronics, no matter how complex the structure. This saves time and labor from carefully separating components — potentially yielding more defects in the process.

Advanced radiography makes images appear faster and with greater clarity. Programs allow engineers to manipulate, zoom in, and inspect photos to improve decision-making for how and when to tackle the fault. Innovations like radiography demonstrate the potential of hands-off imaging to discover what careful hands would otherwise spend hours accomplishing.

## Hot Spot Analysis

Thermal imaging and hot spot analysis are ideal for pinpointing invisible defects related to heat dispersal and voltage. This is another noninvasive method, letting the imaging equipment identify temperature variances throughout the circuit. It keeps technicians safe from having to get close to partially active devices. It could prove a leak somewhere in the device or the power supply is releasing a current that is too intense for the board to handle.

Some methods of hot spot detection incorporate liquid crystal, while others employ laser beams. Ideally, the crystal will reveal light and dark spots throughout the board where heat pockets rest. Lasers will bounce through substrates, and the movement identifies where influxes of heat are. Ultrasonic waves are a modern alternative attempting to reduce the likelihood that the external technology will impact the board's functionality after identification.

## Scanning Electron Microscopy

SEM is another popular variant of microscopy that leverages electron beams and atomic interactivity to highlight defects. The topography of integrated circuits becomes immediately visible for a high-resolution, zoomed-in cross-section of each solder joint.

The method is highly versatile and compatible with other forms of fault detection, such as energy-dispersive X-ray spectroscopy. It helps engineers locate the elements of a PCB to verify they are in the right place and generate the correct responses to inputs. Additionally, SEM integrates with computer-aided design systems and conventional review methods, like device parameter testing, for a holistic fault evaluation experience in a single location.

## Finding All the Trace Faults in Electronic Circuits

Advanced imaging will be the core of next-generation fault detection in microelectronics. Fault detection and isolation used to be a demanding business, and it still is. However, electronics engineers will experience a new era of precision and action as imaging accelerates diagnostics. Trace faults in electronic circuits will be a concern forever, primarily as the tech becomes more intricate and diverse in application. Therefore, implementing new imaging techniques for quality control now is critical for industrial stability.