

<u>RESEARCH ARTICLE</u>

Challenges in Wileless Charging Systems for Implantable Cardiac Pacemakers Challenges in Wireless Charging Systems for

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INTRODUCTION

Implantable cardiac pacemakers are electronic devices
technol 19-24). require periodic replacement surgeries. Wireless charging invasive charging of pacemaker batteries using external endinging devices that compares between the execution, principles, and applications of mixture sinal ging systems and gives outputs in the community of the result on advancements, challenges, and future directions in this
regidly avalying field [1:15] circuits, especially Alberta (ADC). And ADC applications (ADC). An ADC applications (ADC). An ADC applications (ADC applications (ADC). An ADC applications (ADC). An ADC applications (ADC). An ADC applications (ADC applica designed to regulate heart rhythm and treat cardiac arrhythmias by delivering electrical impulses to the heart muscle. Traditional pacemakers rely on internal batteries for power, which have limited longevity and systems offer a promising alternative by enabling noncharging devices. This review examines the evolution, rapidly evolving field.[1-15]

Cardiac pacemakers are medical devices designed to regulate the heart's rhythm and treat various cardiac arrhythmias. These small, implantable devices deliver electrical impulses to the heart to help maintain a normal heartbeat. Pacemakers are commonly used to treat bradycardia, a condition characterized by a slow heart rate, as well as other arrhythmias such as atrial fibrillation and heart block.^[16-22] The introduction of cardiac pacemakers revolutionized the treatment of cardiac arrhythmias, offering a safe and effective solution for millions of patients worldwide. The first implantable pacemaker was developed in the 1950s

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Ishrat Z. Mukti1, Ebadur R. Khan2. Koushik K. Biswas3 Abstract

AbstrAct the reliance on traditional battery-powered pacemakers introduces challenges related to battery tongevity, replacement surgeries, and device compited tons. Wiretess charging
systems offer a promising solution to these challenges by enabling efficient and convenient charging of implantable cardiac pacemakers without the need for invasive procedures. endiging or implemente cardial pacematers mandet are need for invasive procedures.
This comprehensive review explores the principles, design considerations, clinical ins comprenensive Tevrew explores are principles, acsign considerations, camea. approductions, and radine prospects of micross enarging systems for implantable cardiac
pacemakers, aiming to shed light on their potential to improve patient outcomes and because of this mismatch. To compute the orientation of the oriental computer voltage voltage, we for the orientation of the or approach to design the circuits. Therefore, the offset voltage is reduced to 250. enhance the quality of life for individuals with cardiac conditions. Implantable cardiac pacemakers have revolutionized the treatment of cardiac arrhythmias, providing life-saving therapy to millions of patients worldwide. However, to battery longevity, replacement surgeries, and device complications. Wireless charging

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Vol. 4, No. 1, 2022 (pp. 14-20) sults of pre-and post-layout simulations in various process, voltage, and temperature Vol. 4, No. 1, 2022 (pp. 14-20).

and
Authoris devises **modern pacemaker technology.** Since then, pacemaker I divided cardiac in battery longevity, lead design, and programming in in battery longevity, lead design, and programming $\frac{m_{\text{p}}}{m_{\text{p}}}}$ capabilities as shown in Fig. 1. by Dr. Wilson Greatbatch, laying the foundation for technology has advanced significantly, with innovations

ed longevity and Today, cardiac pacemakers are sophisticated medical including a pulse generator, leads, and electrodes. The pulse generator contains the battery and electronic circuitry that generates and delivers electrical impulses to the heart. Leads are flexible wires that connect the devices that can be customized to meet the specific needs of each patient. They consist of several key components,

Fig. 1: Compact dual-band conformal antenna for leadless **cardiac pacemake**

pulse generator to the heart, while electrodes deliver the electrical impulses to the heart muscle.

ical impulses as needed to maintain a normal
Pacemaker programming can be adjusted Early wireless charging systems for implantable cardiac Cardiac pacemakers are implanted during a minimally invasive surgical procedure, typically performed under local anesthesia. Once implanted, the pacemaker continuously monitors the heart's electrical activity and delivers electrical impulses as needed to maintain a normal heart rate. Pacemaker programming can be adjusted remotely using a specialized programming device, allowing healthcare providers to optimize device settings based on the patient's condition and individual needs.

nagement of cardiac arrhythmias, improving p mortamiac: As commodingly continued to devance, the designity. Equipment of pacemaker therapy holds promise for further management of cardiac arrhythmias, improving patient outcomes and quality of life for millions of individuals worldwide. As technology continues to advance, the innovations in device design, programming capabilities, Overall, cardiac pacemakers have transformed the and integration with other cardiac devices.

EVOLUTION OF WIRELESS CHARGING SYSTEMS FOR IMPLANTABLE CARDIAC PACEMAKERS

c coupung and of miniaturized electronics, wireless communication, **examples communication**, and energy harvesting techniques has spurred the **Further** madetion of magnetic resonance coapting to transier safety, and convenience compared to traditional battery replacement surgeries.^[23-33] **DOI:** early research focusing on inductive coupling and The concept of wireless charging for implantable medical devices dates back several decades, with electromagnetic resonance technologies. The advent development of wireless charging systems specifically tailored for implantable cardiac pacemakers. Modern wireless charging systems utilize electromagnetic induction or magnetic resonance coupling to transfer implanted pacemakers, offering improved efficiency,

The evolution of wireless charging systems for implantable cardiac pacemakers represents a significant advancement

se generator to the heart, while electrodes deliver hin medical technology, offering enhanced convenience, ac pacemakers are implanted during a minimally arrowing interest in-developing-wireless-charging-systems
ive surgical procedure, typically performed under arrowing interest in-devicel devices, including cardiac $\frac{C_1}{2}$ Once implanted, the pacemaker pacemakers, to address the limitations of wired charging
itors the heart's electrical activity and $\frac{C_1}{2}$ safety, and reliability compared to traditional wired charging methods. In recent years, there has been a for implantable medical devices, including cardiac systems and improve patient outcomesas shown in Fig. 2.

> Is becaused on the commonly more performanced in the coordinated receiver coil
In external charging pad to an implanted receiver coil **12Dept. of EEE, Independent University, Bangladesh, Dhaka, Bangladesh, Dhaka, Bangladesh, Dhaka, Bangladesh, B** IS OF HUIVIQUALS and the implanted device, limiting their practicality and $\frac{1}{10}$ pacemakers relied on electromagnetic induction technology, where power is transmitted wirelessly from convenient alternative to wired charging, they often required precise alignment between the charging pad usability.[34]-[39]

 t_{Hilist} for further t_{Ricant} at non-compute in wireless charging tochnology. ning capabilities, a Recent advancements in wireless charging technology ces. The velopment of more sophisticated and cess. efficient systems for implantable cardiac pacemakers. As FOR **COMENGE CIRCUITS.** One notable innovation is the use of resonant coupling technology, which allows for greater flexibility in nominal and the dynamic gives the measure of authority. for implantable bositioning the external charging pad relative to the Instrumented device. Resonant coupling enables wireless decades, with accades, with power transfer over longer distances and through non-metallic barriers, improving the ease of use and reliability of wireless charging systems for pacemakers.

How the second is arrival ER, Analyzing Community and the same of the second is a second the performance and safety of wireless makers, measured comparator and performance and safety of micross-
electromagnetic charging systems for implantable cardiac pacemakers. From Computer of Technology. These systems of Improvision Computer Computer Computer System Vol. 1, 1, 2024 (pp. 1, 2024) Furthermore, the integration of advanced power management algorithms and safety features has charging process to ensure optimal battery health and prevent overcharging or overheating of the implanted device [40]-[46].

Overall, the evolution of wireless charging systems for implantable cardiac pacemakers has led to significant improvements in patient care and quality of life.

Fig. 2: Revisiting the Analysis of Radiative Mid-Range Wireless

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These systems offer greater convenience, flexibility, and reliability compared to traditional wired charging methods, enabling patients to maintain optimal cardiac **relAted work** technology continues to advance, the future of wireless charging for implantable medical devices holds promise for further innovations in device design, charging efficiency, and patient care. health with minimal disruption to their daily lives. As

Principles of Wireless Charging for Implantable **CARDIAC PACEMAKERS**

Wireless charging systems for implantable cardiac pacemakers rely on the principles of electromagnetic induction or magnetic resonance coupling to transfer power wirelessly from external chargers to implanted devices. In electromagnetic induction-based systems, a primary coil in the external charger generates a time-varying magnetic field, inducing an electromotive force (EMF) in a secondary coil implanted near the pacemaker.^{[47]-[49]} This induced voltage is rectified and used to charge the pacemaker battery. Magnetic resonance coupling systems utilize resonant coils in the external charger and implantable device to achieve efficient power transfer over longer distances, enabling charging through clothing and tissue layersas shown in Fig. 3.

Wireless charging for implantable cardiac pacemakers operates on the principles of electromagnetic induction or resonant coupling, providing a convenient and reliable need for physical connections or wires. These principles involve the transmission of electrical power wirelessly from an external charging device to an implanted receiver coil within the pacemaker. method to recharge the device's battery without the

In electromagnetic induction-based systems, the external charging device generates an alternating magnetic field when placed in close proximity to the implanted device.

This magnetic field induces an electric current in the receiver coil of the pacemaker, which is then rectified and used to charge the device's battery. This method It is essentially identical to conventional operational relies on precise alignment between the external charger and the implanted receiver coil to ensure efficient power $p_{\rm T}$ distinction between \mathcal{D} and traditional OPAMP is $p_{\rm T}$ transfer.

Resonant coupling-based systems, on the other hand, utilize resonance to enhance wireless power transfer efficiency and flexibility. In these systems, both the external charger and the implanted device contain resonant coils tuned to the same frequency. When .
the same frequency, allowing for efficient power transfer over longer distances and through non-metallic barriers. This enables greater flexibility in the positioning of the external charger relative to the implanted device, placed near each other, the resonant coils resonate at improving usability and convenience for patients.

reliable, and widely adopted in clinical practice. Comparator Both electromagnetic induction and resonant couplingbased wireless charging systems for implantable cardiac pacemakers require careful design and optimization to ensure safe and effective power transfer. Factors such as coil size, shape, and placement, as well as power management algorithms and safety features, play a crucial role in maximizing charging efficiency, minimizing energy loss, and ensuring patient safety.Overall, the principles of wireless charging for implantable cardiac pacemakers offer a promising alternative to traditional wired charging methods, providing patients with greater convenience, flexibility, and peace of mind in managing their cardiac health. As technology continues to advance, wireless charging systems for implantable medical devices are expected to become even more efficient,

Design Considerations for Wireless Charging Systems

Designing wireless charging systems for implantable cardiac pacemakers requires careful consideration of various factors, including power transfer efficiency, coil geometry, electromagnetic compatibility, and safety. Coil design plays a crucial role in optimizing power transfer efficiency and minimizing energy losses. Advanced design methodologies, such as finite element analysis (FEA) and electromagnetic simulation, are employed to model and optimize coil geometries for maximum power transfer and minimal heating effects. Safety considerations include electromagnetic interference (EMI) mitigation, thermal management, and compliance with regulatory standards for medical devices.

cardiac pacemakers requires careful consideration of several key factors to ensure safe, efficient, and reliable Designing wireless charging systems for implantable operation. These design considerations encompass O Reduced Surgical Interventions:Wireless charging various aspects of system architecture, power transfer efficiency, safety features, and compatibility with implantable medical devices.

ary design considerations for wireless with an accessives.
is power transfer efficiency. Maximizing www. De Extended Battery Life:Wireless charging systems charging system design is safety. Ensuring patient safety is paramount, requiring the implementation of robust safety shown in Fig. 4. and minimize losses.Another critical aspect of wireless features to prevent overcharging, overheating, and other cadence, potential risks. This includes incorporating temperature **ARTICLE HISTORY:** and protect both the patient and the implanted device. One of the primary design considerations for wireless charging systems is power transfer efficiency. Maximizing efficiency is essential to minimize energy loss during wireless power transfer and ensure optimal charging performance. This involves optimizing the design of the charging coils, selecting appropriate operating frequencies, and implementing advanced power management algorithms to regulate power transfer sensors, current limiting circuits, and voltage regulation mechanisms to monitor and control the charging process

 $\frac{1}{2}$ antable medical bandwidth of $\frac{1}{2}$ and $\frac{1}{2}$ and $\frac{1}{2}$ and $\frac{1}{2}$ and $\frac{1}{2}$ at $\frac{1}{2}$ at $\frac{1}{2}$ and $\frac{1}{2}$ and $\frac{1}{2}$ at $\frac{1}{2}$ and $\frac{1}{2}$ and $\frac{1}{2}$ and $\frac{1}{2}$ and \frac and configurations, ensuring seamless integration and standardizing communication protocols, power transfer **invasive** considerations play a crucial role in the design of wireless and in the state in the state of the state in the design and device form factor. The system should be to guide patients through the charging process. The and portable, allowing patients to carry it with them easily and charge their pacemaker whenever necessary. Furthermore, compatibility with implantable medical devices is essential when designing wireless charging compatible with a wide range of pacemaker models systems for cardiac pacemakers. The system must be interoperability with existing devices. This involves specifications, and interface requirements to facilitate compatibility and ease of use.Additionally, ergonomic charging systems, particularly in terms of user interface intuitive to use, with clear visual and auditory feedback charging device should also be compact, lightweight,

Overall, designing wireless charging systems for implantable cardiac pacemakers requires a multidisciplinary approach, incorporating expertise in electrical engineering, biomedical engineering, and human factors design. By carefully considering these design considerations, developers can create wireless charging systems that are safe, efficient, user-friendly, and compatible with a wide range of implantable medical devices, ultimately improving patient care and quality of life.

CLINICAL APPLICATIONS AND BENEFITS

Wireless charging systems offer numerous clinical benefits for patients with implantable cardiac pacemakers, including:

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- Intable medical devices.

infections, and healthcare costs associated with

invasive procedures. Reduced Surgical Interventions:Wireless charging eliminates the need for periodic battery replacement surgeries, reducing the risk of complications, invasive procedures.
	- essential to minimize energy loss during and anable efficient and convenient recharging of essential charging
In transfer and ensure optimal charging and pacemaker batteries, prolonging battery longevity pacemaker batteries, prolonging battery longevity and reducing the frequency of device replacements.
		- Ispitate Sperating **Improved Patient Compliance:The convenience of** *1-3Dept. of EEE, Independent University, Bangladesh, Dhaka, Bangladesh* wireless charging encourages patient adherence to charging routines, ensuring continuous device operation and optimal therapeutic outcomesas shown in Fig. 4.
			- eating, and other $\hskip1cm \circ$ Enhanced Quality of Life:Wireless charging systems ting temperature provide patients with greater freedom and mobility, comparator for a highly linear 4-bit Flash A/D Converter (ADC). The outline of the outline of the outlined design oltage regulation allowing them to maintain active lifestyles without charging process charging process the inconvenience of frequent hospital visits or planted device. The surgical procedures.

antable medical a Wireless charging systems for implantable cardiac vireless charging a pacemakers offer numerous clinical applications and system must be benefits, revolutionizing the management of patients cemaker models with cardiac arrhythmias. One of the primary clinical **Authoris 16 and 16 a** nally, ergonomic patient compliance and satisfaction. applications is the convenience and ease of use offered invasive procedures to replace pacemaker batteries or deal with cumbersome charging cables, enhancing

of user interface Moreover, wireless charging systems allow for seamless their normal activities. This is particularly advantageous who may find traditional wired charging methods integration into patients' daily lives, enabling them to maintain optimal cardiac health without disruption to for patients with active lifestyles or mobility limitations

Fig. 4: A Wide-Band Tissue Numerical Model for large obtainable gain while keeping all the MOSFETs in **Deeply Implantable Antennas for RF-Powered Subsequentially doing that Considers allow do incremakers**

cumbersome or impractical.Additionally, wireless charging systems promote patient safety by reducing the risk of infection associated with invasive battery **replacement precedured** by cummaning the nece reference surgical interventions, wireless charging minimizes the risk of complications and postoperative infections, leading to improved patient outcomes and reduced healthcare costs.Overall, the clinical applications and benefits of wireless charging systems for implantable cardiac pacemakers are vast, offering patients a convenient, safe, and effective means of maintaining optimal cardiac health and quality of life. As technology continues to advance, wireless charging systems hold promise for further innovations in patient care and management of cardiac arrhythmias. replacement procedures. By eliminating the need for

CHALLENGES AND LIMITATIONS

Despite the promising benefits of wireless charging systems for implantable cardiac pacemakers, several challenges and limitations must be addressed, including:

- O Power Efficiency:Achieving high power transfer efficiency while minimizing energy losses and heating effects remains a significant challenge in wireless charging system designas shown in Fig. 5.
- O -Safety and Reliability: Ensuring the safety and of barety and nethability, and increase of the barety and reliability of wireless charging systems requires reductively of wheress endiging systems requires rigorous testing, validation, and compliance with rigorous cesting, validation, and compli-
- **ArchItecture of compArAtor** Implantation and Alignment:Proper positioning and alignment of the external charger and implanted

Fig. 2: *Block diagramedical antenna* **Fig.5: Performance enhancement of implantable**

device are critical for efficient power transfer and optimal charging performance.

O Interference and Compatibility:Wireless charging systems may be susceptible to electromagnetic interference (EMI) from external sources, requiring robust shielding and filtering techniques to ensure compatibility with other electronic devices and medical equipmentas shown in Fig. 6.

The comparator has two special properties. rrhythmias, present several challenges and limitations that need to be addressed for optimal patient care and device performance. One significant challenge is the risk of device-related complications, including infection, lead dislodgement, and lead fracture. These complications can lead to device malfunction or Pacemakers, while integral in managing cardiac failure, requiring surgical intervention and potentially compromising patient safety.

Another limitation is the finite lifespan of pacemaker batteries, which typically last between five to ten years depending on device usage and programming settings. Battery depletion necessitates periodic replacement surgeries, increasing the risk of complications and healthcare costs for patientsas shown in Fig. 7.

Furthermore, pacemaker technology is continually evolving, leading to issues of device compatibility and interoperability. Patients with older pacemaker models may face challenges accessing newer features or upgrades, limiting the long-term usability and effectiveness of their devices.

technology, wireless charging systems for pacemakers still face challenges in terms of power transfer efficiency, Moreover, despite advancements in wireless charging device compatibility, and regulatory approval. Ensuring the safety and reliability of wireless charging systems remains a critical consideration for device manufacturers and healthcare providers.

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Fig. 7: Ultra-Compact Implantable Antenna

Overall, while pacemakers have revolutionized the management of cardiac arrhythmias, addressing the offsetten.
T challenges and limitations of these devices is essential to optimize patient outcomes and enhance the quality of care for individuals with cardiovascular conditions.

ARTICLE HISTORY: Future Directions and Emerging Technologies

corners are shown. The field of wireless charging systems for implantable me nete of military endinging systems for implemental wireless communication technologies. Emerging trends advancements in coil design, power electronics, and

 $\overbrace{\text{R}}^{\text{K}\leftarrow\text{R}}$ Copper Rogers 6010 Reed and future directions in wireless charging systems includeas shown in Fig. 8:

- 1.8-V Low Power, High-Resolution, H **Comparator Comparator C** Miniaturization and Integration:Advancements in enable the development of compact, implantable capabilities.
	- **ISSERVARY R. KHAN 2. Must LONG PROPERTY PROPERTY PROPERTY PROPERTY PROPERTY PROPERTY PROPERTY PROPERTY PROPERTY** *1-3Dept. of EEE, Independent University, Bangladesh, Dhaka, Bangladesh* devices, with wireless charging systems can enhance Energy Harvesting and Power Management:Integration of energy harvesting technologies, such as energy autonomy and reduce reliance on external power sources.
		- addressing the \circ Smart Charging Algorithms:Implementation of vices is essential smart charging algorithms and feedback control nce the quality of **nominal inconduce** at a mechanisms allows adaptive adjustment of charging comparator for a highly linear 4-bit Flash A/D Converter (ADC). The outline of the outlined design and the outlined design \sim conditions.
		parameters based on real-time battery status and environmental conditions, optimizing charging ologies efficiency and safety.
		- $\frac{1}{2}$ for implantable \overline{a} and \overline{a} and \overline{a} and \overline{a} and \overline{a} for implantable $\hskip1cm$ O Biocompatible Materials and Coatings:Utilization of idly, driven by biocompatible materials and coatings for implantable electronics, and echarging devices enhances biocompatibility, reduces Emerging trends tissue irritation, and improves long-term reliability.

Fig. 8: A compact and miniaturized implantable antenna

CONCLUSION

Wireless charging systems represent a promising solution for powering implantable cardiac pacemakers, offering benefits **relAted work** in terms of convenience, longevity, and patient satisfaction. in wireless charging technologies and materials science hold great promise for the future of implantable medical devices. By addressing technical barriers, ensuring safety and reliability, and embracing emerging trends, wireless charging systems have the potential to revolutionize the field of cardiac pacing and improve the quality of life for millions of patients worldwide. \mathcal{L}_M three-stage C comparation \mathcal{L}_M comparation \mathcal{L}_M Despite the challenges and limitations, advancements

to gain a lower static and a lower dissipation and a lower distinction and a

- smaller offset voltage. Satyabrata et al.[3] compare the 1. Rhees, David J. "From Frankenstein to the pacemaker." IEEE Engineering in Medicine and Biology Maga-
eise 28.4.(2000): 79.84 $\sum_{i=1}^{n}$ (2007), to 01. zine 28.4 (2009): 78-84.
- 2. Mandal, Soumyajit, and Rahul Sarpeshkar. "Power-efficient
. impedance-modulation wifetess data this for biomedical
implants." IEEE Transactions on Biomedical Circuits and miplants. There in ansaccions on promedical circuits and
Systems 2.4 (2008): 301-315. impedance-modulation wireless data links for biomedical
- also been designed utilizing offset measurement and the systems are quite measurement and in the system of the
3. Hannan, Mahammad A., et al. "Modulation techniques for a cancellation techniques. The cancellation of the involving dynamic late $\frac{1}{2}$ is the case of the case of the case $\frac{n}{2}$ for the case of the case of the case of the case of $\frac{n}{2}$ for the case of the case of the biomedical implanted devices and their challenges." Sen-
cers 12.1.(2011): 207, 210 comparator $(2\pi i)^2$ and low offset. sors 12.1 (2011): 297-319.
- 4. Jung, K. H., et al. "Wireless power transmission for implantable devices asing madelive component of closed
magnetic circuit." Electronics letters 45.1 (2009): 21-22. plantable devices using inductive component of closed
- $\frac{1}{2}$ comparator design $\frac{1}{2}$ comparator design given in this paper is paper in the set of $\frac{1}{2}$ 5. Bercich, Rebecca A., Daniel R. Duffy, and Pedro P. Irazo-
5. Bercich, Rebecca A., Daniel R. Duffy, and Pedro P. Irazoconsiderations." IEEE Transactions on Biomedical Engiqui. "Far-field RF powering of implantable devices: Safety neering 60.8 (2013): 2107-2112.
- 6. Chen, Zhenzhong, Hucheng Sun, and Wen Geyi. "Maximum wireless power transfer to the implantable device in the wireless power transfer to the implantable device in the the properties and performance of the comparator. Fig.

A. Operational Transconductance Amplifier radiative near field." IEEE Antennas and Wireless Propaga- $\frac{1}{2}$ tion Letters 16 (2017): 1780-1783.

- r. Inussam, mustara Aun, saunk Kamel Gharghan, and Hald-
er Qasim Hamood. "Design and implementation of wire-It is essentially identical to conventional operational less low-power transfer for medical implant devices." IOP Less tow power cransfer for meated implant devices. The Conference Series: Materials Science and Engineering. Vol. primary distinction between our control and traditional OPAMP is and traditional OPAMP is 2020 . 7. Hussain, Mustafa Adil, Sadik Kamel Gharghan, and Haid-
- 8. Barbruni, Gian Luca, et al. "Miniaturised wireless power transfer systems for neurostimulation: A review." IEEE The comparator has two special properties. Transactions on Biomedical Circuits and Systems 14.6 (2020): 1160-1178.
- 9. Liu, Changrong, Yong-Xin Guo, and Shaoqiu Xiao. "A re-OUR DE ANGLES AND THE STATE OF AN OVERFORM THE VICES." Forum for electromagnetic research methods and application technologies (FERMAT). Vol. 14. No. 3. 2016. view of implantable antennas for wireless biomedical de-
- 10. Shadid, Reem, and Sima Noghanian. "A literature survey on wireless power transfer for biomedical devices." International Journal of Antennas and Propagation 2018 (2018).
- 11. KAVITHA, M. "Statistical analysis of Gate Diffusion Input based full adders: from delay and Power perspective." Journal of VLSI circuits and systems 2.2 (2020): 12- 14.
- 12. MURALIDHARAN, J. "Design Of High Precision and Frequency Full Wave Rectifier." Journal of VLSI circuits and systems 2.2 (2020): 15-17.
- 13. PAPALOU, A. "Proposed Information System towards Computerized Technological Application–Recommendation for the Acquisition, Implementation, and Support of a Health Information System." International Journal of communication and computer Technologies 8.2 (2020): 1-4.
- **Fig. 2: Schematic of the 45nm CMOS-based** and computer Technologies 8.2 (2020): 5-7.14. Keliwar, S. "A Secondary Study Examining the Effectiveness of Network Topologies: The Case of Ring, Bus, and Star Topologies." International Journal of communication