Abstract

This thesis focuses on vibration-based energy harvesting as a sustainable alternative to fossil-fuel-dependent energy systems. Among various vibration energy harvesting technologies—piezoelectric, triboelectric, electromagnetic, and electrostatic; among them, triboelectric energy harvesters (TEHs) and piezoelectric energy harvesters (PEHs) are emphasized due to their low cost, lightweight structure, high power density, and efficient energy conversion. The research addresses existing challenges in device design, fabrication, power management circuits (PMCs), and practical implementation of self-powered systems.

The work begins with the theoretical design and modelling of a triboelectric energy harvester for a self-powered smart mask. Different material combinations, structural designs, and operating modes are analyzed to generate an electric field strong enough to deactivate or electrocute incoming viruses. The feasibility of harvesting energy from human physiological activities is also investigated.

Next, several two-layered TEHs are fabricated using different triboelectric materials and tested using custom-built speaker-based and vibration-shaker experimental setups. Their performance is validated through simulation and experimentation. A Low-Drop Diode Equivalent (LDDE) power management circuit is integrated to efficiently rectify and store harvested energy in a capacitor, which successfully drives a low-powered light sensor in a self-propelled configuration.

To further improve energy extraction, a novel Multiple Working Region Semiconductor Switch-based Charge Pump (MWRSSCP) circuit is proposed. Unlike a conventional full-bridge rectifier, it operates effectively with the low current levels produced by TEHs and achieves higher energy transfer through multi-line current propagation. The circuit is theoretically analyzed, simulated, and experimentally validated.

For piezoelectric harvesting, a modified Parallel Synchronous Switch Harvesting on Inductor (PSSHI) circuit is developed to reduce switching delay and improve the inversion factor, resulting in a 41.3% increase in average harvested power. When combined with an analog Maximum Power Point Tracking (MPPT) circuit, the harvested power improves by 2.19 times compared to the conventional full-bridge rectifier.

Finally, the TEH- and PEH-based systems are demonstrated in self-powered sensing applications using low-power sensors such as the MAX44009 light sensor, ADXL335 accelerometer, and LM35 temperature sensor. A hybrid energy harvester combining TEH and PEH technologies is also implemented and outcomes are observed. The developed low-cost self-powered systems show strong potential for applications in healthcare, wearable electronics, structural health monitoring, and wireless sensor networks, contributing to a sustainable energy future.