Design Group

D17-017

使用綠能獵能器之能源自主無線收發機

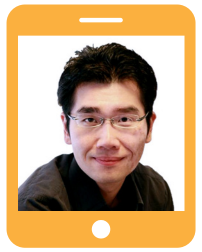
An Autonomous Wireless Transceiver with Green Energy Harvesters

隊伍名稱　綠射鴨店
Green Shot Duck Shop

隊　　長　張勝凱 / 成功大學電腦與通信工程研究所

隊　　員　陳冠維 / 成功大學電機工程研究所
陳仕恩 / 成功大學電腦與通信工程研究所
余道承 / 成功大學電機工程研究所

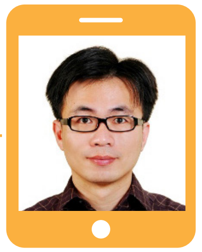
指導教授
鄭光偉
成功大學電機工程學系



研究領域

超低功率射頻積體電路、類比與混合信號積體電路與系統、無線供電與獵能技術。

美國華盛頓大學電機工程博士，現為成功大學電機工程學系助理教授。曾任聯發科技資深工程師、美國國家半導體電路設計工程師、新加坡科技研究局微電子研究院計畫主持人。



指導教授
楊慶隆
成功大學電機工程學系

研究領域

整合微波前端電路，無線生醫應用、生醫檢測儀器，微波感測器，無線傳輸電力，植入式天線，RFIC、無線感測網路（WSN）、分集化設計，獵能技術（Energy Harvesting）及轉換電路、軟性電子。

美國普度大學電機工程博士，現為成功大學電機工程學系教授。曾任工業技術研究院副工程師、USA Delphi Electronics & Safety 副研究工程師、美國佛羅里達州大學電機系訪問教授。

作品摘要

本作品實現了一個使用綠能獵能器之能源自主無線收發機，因應物聯網概念的快速發展，無線感測節點必須具備低功耗、高效率、小體積之特性，透過自行開發之一顆獵能晶片、一顆發射機晶片與一顆接收機晶片為核心，得以實現此一整合目標。壓電獵能發射器（EH-TX）為從壓電片汲取能量使用，供給低功耗發射機晶片進行無線訊號傳輸；光獵能接收器（EH-RX）則是接收資料後控制家電用品開關。

獵能系統之壓電獵能器晶片採用新型瞬時突發式獵能技術，有別於傳統連續式獵能之方式，利用按壓遙控器之外力即產生自我供電的能量，在極短時間內有效獵取原按扣之瞬時能量供應後級低功耗發射機。不僅提升整體效率並同時縮減壓電片面積，避免廢棄電池造成的環境污染問題，符合綠色能源之永續發展目標。

壓電獵能後藉由線性穩壓器產生穩定直流輸出供給發射端電源。無線發射機晶片在架構上，透過注入鎖定與邊緣組合功率放大器實現倍頻功能，使得本地震盪源得以操作在低頻有效大幅降低功耗，也因而大幅減少所需之壓電陶瓷片面積，有效降低整體發射端體積，以符合整體產品微型化之需求。透過單次按壓遙控器按鈕，即可供電給發射機及微控制器，發射出射頻訊號。

無線接收機晶片透過注入鎖定包絡直接偵測技術簡化系統架構，並可解調 OOK/FSK/PSK 三種數位訊號，應用範圍相當廣泛。射頻前端電路整合 PCB 天線設計，實現高品質之線圈電感有效降低前端電路功耗，同時提出高靈敏度、大動態範圍之差動式自偏壓開源級包絡檢測器，實現高靈敏度與超低功耗的目標。因接收機功耗遠低於光能獵能器之平均獵取能源，即使接收機保持持續開啟以減少系統通訊延遲，仍可儲存大部分能源供應負載使用，一旦接收機收到通訊需求，便會驅動微控制器執行命令。

本團隊自行設計的晶片組採用TSMC 0.18 µm CMOS製程，開發出高效率獵能器與超低功耗收發機，同時兼顧傳輸性能。以三個晶片整合成一具綠能獵能器之無線傳訊系統，經單次按壓後即可控制完成傳輸，實測距離可達為 8 公尺以上。遙控發射端整合之體積僅 8.5×3.5×2.5 cm³，產品體積小便於操作與攜帶，既便利又環保。接收端在不造成電源負擔下不間斷偵測，也能保持高效率操作。本作品突破現今技術之功耗瓶頸，完成高效率獵能器及低功耗收發機之整合，達成綠能智慧居家之應用目標，且成本低廉，產品化可行性高，未來在市場中將具備競爭力，極具前瞻與價值。

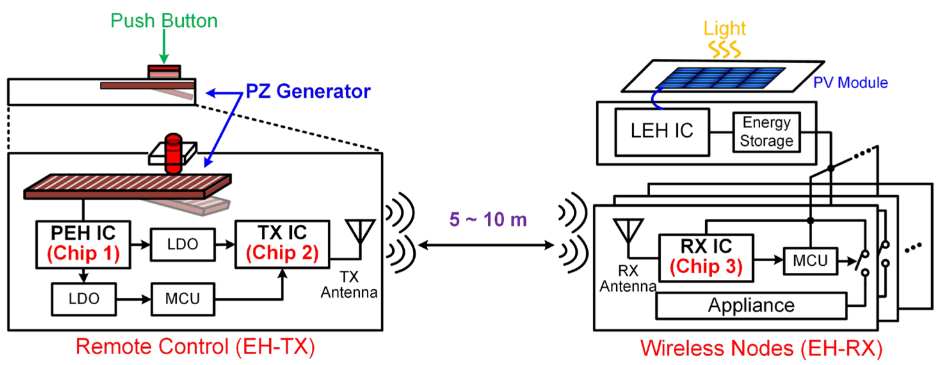


圖 1. 系統架構圖

Abstract

Due to the rapid development of the internet of things (IoT), wireless sensor nodes must have the characteristics of low power consumption, high efficiency, and small volume. This work realizes an autonomous wireless transceiver with three self-developed chips, including a harvester, a transmitter (TX), and a receiver (RX) to achieve the goals. The energy-harvesting transmitter (EH-TX) scavenges the energy from the piezoelectric film to supply the TX for wireless signal transmission, and the energy-harvesting receiver (EH-RX) powered by the light harvester receives the data to control the appliances.

The proposed piezoelectric harvester operates in a burst mode, instead of the traditionally continuous conduction mode. It not only enhances the overall efficiency, but also reduces the piezoelectric film area. When the remote control is triggered, the TX can be effectively self-powered in a short period for transmission purpose. Therefore, this approach can achieve a great reduction of battery usage, leading to less environmental effect and sustainable development of green energy.

The piezoelectric harvester produces a stable DC output through the linear regulator, providing energy to the TX. The wireless TX chip adopts injection locking techniques and an edge-combined power amplifier in place of the phase-locked loop to implement frequency multiplication. As a result, the local oscillator can operate at low frequency, which significantly reduces the power consumption, and thus decreases the required area of piezoelectric film to meet the needs of miniaturization. Through a single trigger of the remote control, the transmitter and the microcontroller are powered on to emit the radio frequency signal.

By means of the injection lock and envelope direct detection technology, the wireless RX system architecture can be simplified, and demodulate OOK / FSK / PSK three types of digital modulation signals for a wide range of applications. The RF front-end circuit integrates a PCB antenna to achieve high-quality factor coil inductance, which effectively reduces the power consumption of RF front-end circuits. Moreover, large dynamic range of the envelope detector can achieve high sensitivity and ultra-low power. Since the receiver power consumption is much lower than the average light-harvesting energy, the receiver can be permanently turned on to reduce the system communication latency, saving most of the energy for supplying the load. Once the RX receives the communication request, the microcontroller will execute the command.

The proposed three chips are fabricated in TSMC 0.18 µm CMOS process, developing highly efficient energy harvester and ultra-low power transceiver. The wireless transmission distance is measured up to 8 meters. The remote control is integrated into a volume of only 8.5 × 3.5 × 2.5 cm³, which is portable and eco-friendly. Thanks to the low power and high-efficiency operation, the RX does not add extra burdens to the light-harvesting supply under the continuous detection. This project breaks the bottleneck of power consumption and completes the integration of highly efficient energy harvester and low power transceiver. This work satisfies the demanding specifications for smart home applications and has the greatest potential for commercial products.