A New Interface Technique for Vibration-based Energy Harvesting using Synchronous Switch and Intermediate Capacitor

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This paper proposed a new interface technique called SSIC(Synchronized Switch and Intermediate Capacitor), which includes two synchronous switches and double intermediate capacitors for vibration-based energy harvesting using piezoelectric elements. The theoretical calculation of the harvested power obtained by using such a technique is implemented and compared with the so-called Standard, SECE (Synchronous Electric Charge Extraction), Series-SSHI (Series Synchronized Switch Harvesting on Inductor) and Parallel-SSHI (Parallel Synchronized Switch Harvesting on Inductor) techniques usually used in piezoelectric vibration-powered generator considering constant displacement amplitude and force amplitude respectively. In terms of harvested power being independent of load, both SSIC and SECE are the better ones, but the further experimental results show that the harvested power increases dramatically by 2 times with the proposed SSIC technique compared with the SECE under the same amplitude of displacement excitation.

Energy harvesting experiment was setup in this paper. One end of the cantilever is fixed to the electromagnetic vibrator, and the other end free, the free end installed a small mass. There are four PZT sheets by $30\times30\times0.5mm^3$ bonded on the cantilever surface. Signal generator output a 59Hz sinusoidal AC signal, amplified by the power amplifier and then driving the electromagnetic vibrator to make the beam free-end to vibrate. The cantilever vibration displacement signal transform into the voltage signal by a laser displacement sensor, the voltage signal is input to the microcontroller A/D converter port, and then generates control signals required for a variety of interface technology through the microcontroller internal operations and processing.

It can be seen from the experimental results that the harvested power of SECE and SSIC technologies decrease when the load is very large or small, which is due to the load resistance is small. The filter capacitor terminal voltage is small, the energy loss of the buck-boost charge current is large, so that the harvested power became decrease; when the load resistance is large. Since the impedance of the measuring device is not large enough, then the equivalent load equivalent RL parallel with the impendance of the measuring device. This makes the equivalent impendance smaller. The smaller equivalent impendance results to a smaller voltage, and the energy loss of the freewheeling diode D3 became increase, so that ultimately the harvested power is smaller than the actual. In fact the standard, parallel-SSHI and series-SSHI interfaces also exists this phenomenon, but these three interface circuits themselves have harvested power decline.

When the piezoelectric generator is driven with constant displacement amplitude, the harvested power of standard, S-SSHI, P-SSHI interface circuits are influenced by the load resistance value, SECE and SSIC interface circuits' harvested power are not influenced by the load resistance, furthermore, the SSIC interface circuit increases the harvested power dramatically by almost up to 200% compared with the SECE method under the same vibration condition, SSIC interface circuit's harvested power only less than the maximum power of P-SSHI interface circuit using the optimum load.

When the piezoelectric generator is driven with constant force amplitude, at the electromechanical coupling coefficient smaller, SSIC circuit's harvested power is larger than other interface circuits. When the system has a large electromechanical coupling coefficient, the harvested power of SSIC interface circuit is only smaller than the standard interface circuit. When the electromechanical coupling coefficient greater than the critical value, the harvested power of SECE began to decline. The standard interface, S-SSHI, P-SSHI and SSIC circuits' harvested power become saturated with the electromechanical coupling coefficient gradually. Thus, SSIC interface circuit has a good performance in the case of constant force amplitude.