An evaluation of step-up DC-DC power condition ICs for energy harvesting applications

Ali Mohammed Abdal-Kadhim*, Kok Swee Leong, Chow Khoon Keat

Fakulti Kejuruteraan Elektonik dan Kejuruteraan Komputer, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

*Corresponding e-mail: ali.challenger89@yahoo.com

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ABSTRACT – This paper evaluates and compare the functionality of two DC-DC step-up power condition circuits based on the popular MAX757 and TPS61040 integrated circuits ICs. These two circuits are potential to be used as a power condition circuit of a wireless sensor node powered by energy harvester. The evaluation will discuss the circuit design, circuit complexity, starting voltage, power, and charging time of a supercapacitor. The findings reveal that the conditioning circuit that based on TPS61040 required a slightly higher starting voltage compares to MAX757. That makes TPS based circuit achieved higher output power and hence shorter charging time. Moreover, TPS circuit produced low ripple noise due to the high switching frequency comparing to the MAX circuit.

1. INTRODUCTION

Wireless Sensor Networks WSNs play a major role in the field of multi-hop wireless networks applications, ranging from structural and human health monitoring, to border security and environmental control[1]. A typical WSN node consists of four main units: microcontroller; sensor; wireless; and power. Amongst other units, power unit is the most critical unit whereby, it's responsible for delivering the electrical power to the rest of the nodes' units.

In light of this, many of the researchers have used different types of power conditioning circuits as illustrated in Table 1.

Table 1 power condition circuit examples

Year	Power source	Power condition ICs	Refs.
2017	Thermal energy harvesting	MAX757	[2]
2017	Vibration energy harvesting	LTC1540 and LT1761	[3]
2017	Vibration energy harvesting	LTC3588-1	[4]
2017	triboelectric nanogenerator and solar panel	LTC3588-1	[5]

It is clear from the Table 1 that most of the studies are presenting the usability of using the DC-DC condition circuit. These circuits were used to manage the power flow to a wireless sensor node based on different energy harvesting approaches. Since there are plenty of these kind of circuits, a direct comparison to determine the most suitable circuit is crucial.

Therefore, this research will focus on experimentally evaluate two popular circuits based on MAX757[6] from Maxim Integrated and TPS61040[7] from Texas Instruments. These ICs were chosen based on their availability, low cost, and small form factor.

2. EXPERIMENT SET-UP

For the evaluation experiment, the complete circuits for both ICs are designed and constructed as shown in Figure 1.

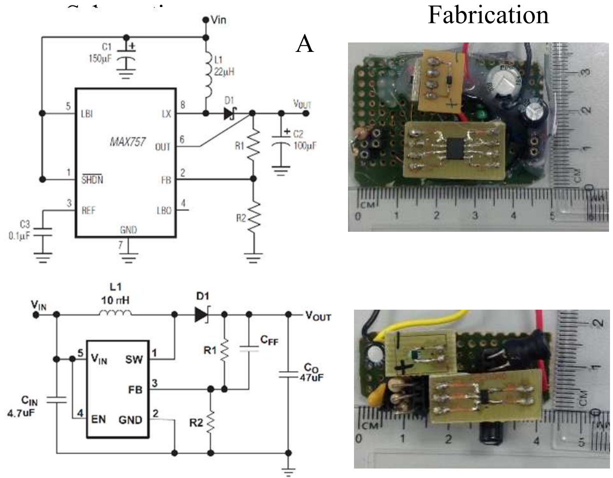

Figure 1: The schematics and the fabricated circuits for A-MAX757, B-TPS61040.

The design and the components of the circuits shown in Figure 1 were set to maximize the output power, reduce the starting voltage, and lower the noise. The output of the circuits was set to 3.3v by using the voltage divider (R1, R2). A variable DC power supply connected to the input of the circuit to examine the minimum start up voltages. A variable resistor decade connected to the circuits' output as a resistive load. The voltage drop and the current drawn by the load is measured and recorded by a voltmeter and ammeter, as shown in Figure 2.

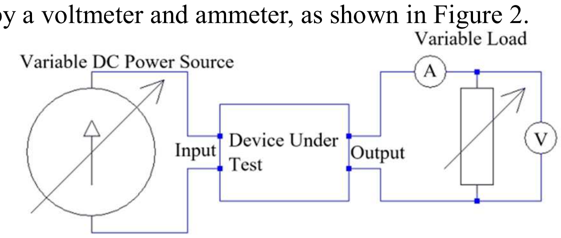

Figure 2: Evaluation experiment set-up.

3. RESULTS AND DISCUSSION

The circuits fabrication was handmade and in lab soldering. However, it's been tried to make it as small and compact as possible. From Figure 1, can notice that the MAX package is physically bigger than TPS, add-on the pins count higher also. Therefore, the condition circuit based on MAX is larger than the condition circuit that based on TPS, That makes TPS the first choice if the application required small size IC. Even though both of the ICs sharing the same boosting technology, adjustable output, and designed for low power application, TPS has lower quiescent current of 28µA and shutdown current of 1 µA, whereas MAX required 60 µA and 20 µA for quiescent and shutdown current respectively. The first phase of the evaluation is to investigate the minimum starting voltage of both ICs. When the supplied voltage was increased from 0v until 1.2v, MAX started to function after about 50ms and delivered a stable 3.3v at its output. Whereas, the TPS requires 1.5v of the supplied voltage with about 200ms of delay to function and deliver a stable of 3.3v at its output, as shown in Figure 3.

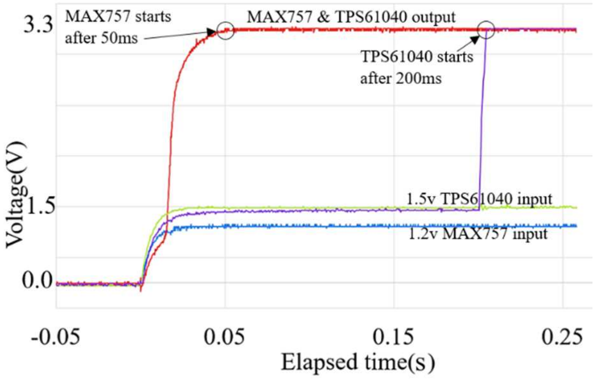

Figure 3: The starting points of both MAX and TPS.

From Figure 3, MAX is showing good results since it is able to function at lower voltage and shorter time compared to TPS. However, MAX low switching frequency is about 0.5MHz, resulting a higher noise and ripple at the output voltage about (800-900)mv Pk-Pk, comparing to TPS which is about (400-500)mv Pk-Pk with switching frequency at about 1MHz. Means that MAX is not a good choice for application that is sensitive to the output power noise.

Next phase is to examine the maximum power that can be delivered by the conditioning circuits at the minimum input. The circuit with TPS delivered about 240mW which it's the highest power comparing to the MAX circuit which it delivered about 200mW only. The 40mW different is due to the fact that TPS starts to function at minimum of 1.5v which is higher than the MAX, and that's proves why TPS has a slightly higher power than MAX. Figure 4 illustrates the power of the two circuits along with the measured voltages.

The final phase of this evaluation is to replace the resistive load with a capacitive load of 1.5F supercapacitor and measure the charging time from 0v up to 3.3v. The amount of the delivered power is reflected on the charging time of the supercapacitor. Since the TPS circuit has the highest power delivery, it was able to charge the supercapacitor within 1 minute only compare to 2 minutes required in case of MAX circuit. That gives another point to TPS for the fast charging time.

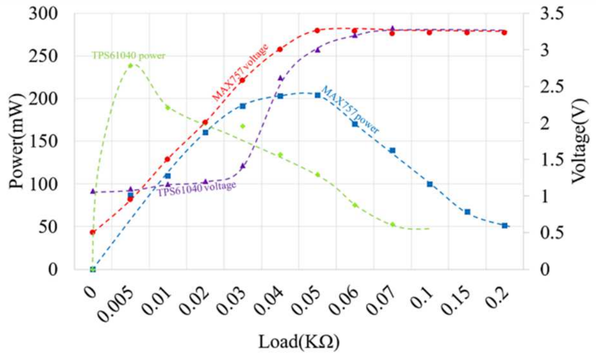

Figure 4: Power and voltage of both MAX and TPS.

4. CONCLUSION

Two power conditioning circuits based on the popular DC-DC boost converter ICs MAX757 and TPS61040 have been designed, fabricated, and evaluated. The outcomes concluded that the TPS61040 is a very good choice in case of small size, low ripple on the output, and low quiescent current applications. However, it required higher startup voltage compare to the MAX757. That gives the MAX757 the priority in the energy harvesting application.

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