Using the HT77XX Step-up DC/DC Converter

D/N: HA0109E

Introduction

The HT77XX is a variable frequency voltage-mode step-up DC-DC converter for portable device such as PDAs and DSCs. The HT77XX combines a PFM step-up switching regulator, an N-channel power MOSFET, a bandgap reference generator, and a voltage detector in a single monolithic device. It offers extreme low quiescient current, high efficiency, and very low start-up and minimum hold-on voltages to ensure start-up even with a low battery voltage and is designed to maximise battery life in portable products.

The basic operation of the PFM, pulse frequency modulator, voltage converter is as follows: the output voltage is fed back by resistor divider and compared with a reference voltage by an output voltage control comparator. When the output voltage becomes smaller than the set voltage, the comparator will switch to send an oscillation start signal to an oscillator circuit. Then, the oscillator circuit outputs a switching pulse, so that the internal Mosfet is turned ON for a period of constant on-time decided by the oscillator. Otherwise, the Mosfet is turned OFF for a period of variable off-time which varies with load. Therefore in this way the circuit can control the output voltage. The complete operation can be understood by referring to the circuits in Figure 1.

When the PFM circuit operates with light loads, by referring to Figure 2, and before the output voltage initially rises from zero to the internal reference voltage, the error comparator enables the 115kHz oscillator to turn on the Mosfet with about 6.5μs on-time and 2.2μs off-time. Because the transition point occurs at the point where the voltage at the positive terminal of comparator is lower than the resistor on the negative terminal, the magnitude of the output ripple voltage will have strong influence on the PFM oscillator. A large load will provide a large ripple voltage, so the oscillator will be activated and will produce one high level pulse to drive the Mosfet until the positive terminal voltage of the comparator is higher than the reference voltage. During the time when the internal Mosfet switch is turned on, the external inductor current ramps up and stores energy in a magnetic field. When the Mosfet is turned off, the voltage across the inductor reverses and forces the current through the diode to the output filter capacitor and load. Therefore the energy in the inductor is transferred to output capacitor and load. The output capacitor stores the charge while the inductor current is higher than the output current. At preliminary off-time, an instant period oscillation due to the resonant effect of inductor, line stray capacitance and output capacitor occurs. Then, the stored energy in the inductor is consumed and the output capacitor carries on the task of the predecessor to supply the energy to the load and stabilise the output voltage. As the energy stored in the off-time is depleted, the current ramps down until the diode turns off and the next switching cycle occurs.

As the load increases, the output voltage initially decreases to become lower than the reference voltage during the period as shown in Figure 3. The oscillator is activated and generates a high level state with a constant on-time, resulting in the linear increase of the inductor current to storing energy in the inductor. Because of the heavy load, the output voltage exhibits a large degree of decrease during the on-time. Then, the output voltage increases slightly at the off-time. So, the oscillator continuously activates until the output voltage is higher than the reference voltage. If the load greatly increases, the whole circuit enters the continuous mode, which means the inductor current does not ramp to zero during each cycle as shown in Figure 3.

External Component Selection

Inductor

Selecting the proper inductor value is a trade-off between physical size and power conversion requirements. The HT77XX is designed to work well with a 47μH inductor for most application. 47μH is a sufficiently low value to allow the use of a small surface mount coil. Lower value inductors cost less, supply higher output current, but result in higher core losses, ripple current and voltage and reduce efficiency. Higher inductor values reduce ripple and improve efficiency, but also limit output current. The inductor should have a small DC resistance, usually less than 1Ω to minimize loss. It is necessary to choose an inductor with saturation current larger than the peak current that the inductor will encounter in the application. Always try to use the low EMI closed type inductors with a ferrite core. For highest efficiency, use an inductor with a series resistance less than 20mΩ.

Input Bypass Capacitor

Using an input capacitor can reduce peak current transients drawn from the input power supply, minimize the peak current ripple from the input source and improve the regulator switching EMI effect. When using the capacitor, it should be located as close to the Lx pin of the HT77XX as possible. Small ESR Tantalum or ceramic capacitors with a value of 22μF to 47μF are suitable components.

Output Diode

For best performance, using a Schottky diode can improve efficiency due to its low forward voltage drop and the reverse recovery time. The following characteristics are recommended for the best choose of diode.

- Low forward voltage, Vf is less than 0.3V
- Small reverse leakage current
- High switching speed
- Rated current larger than the peak inductor current.

Output Filter Capacitor

The ESR of the output capacitor directly affects the amplitude of the output voltage ripple because it is determined by the product of the peak inductor current and the ESR. Therefore, a capacitor with the lowest possible ESR should be selected or connect two or more capacitor in parallel. For HT77XX circuit applications, two parallel 22μF low profile SMD ceramic capacitors can be used. For the following equation, to reduce the ripple voltage, it is important that the output capacitor should have a large capacity and a small ESR.

$$V_{P-P} = \frac{(I_{PK} - I_{OUT})^2}{2I_{PK}} \times \frac{t_{OFF}}{C_L} + (\frac{I_{PK} + I_{OUT}}{2}) \times R_{ESR}$$

I_{PK} is the peak inductor current

Component Power Dissipation

Inductor loss includes the losses which dissipate in the dc resistance caused by the current flowing through and in the inductor's core due to the flux swing caused by the voltage across it. The loss in the inductor is given by:

$$P_{Inductor} = (\frac{I_o}{1-D})^2 \times \mathrm{R}_{esr} + P_{core}$$

Power switch loss is given by:

$$P_{sw} = \frac{2}{3}(\frac{t_{ON}}{L}) \times R_{DS(ON)} \times (\frac{V_{OUT} + V_D - V_{IN}}{V_{OUT}}) \times P_{OUT}$$

Output diode loss is given by:

$$P_{Diode} = V_D \times I_o$$

Where R_{esr} is the inductor equivalent series resistance; P_{core} is inductor core loss

V_D is the diode forward voltage drop; $P_{OUT} = V_{OUT} \times I_o$

Board Layout Guidelines

For grounding, a single point grounding method should be used for the input current return ground, the output current return ground, and the HT77XX pin ground to reduce random noise. The input and output ground traces should be thick and short enough for current flow to reduce grounding bounce. The guidelines listed bellow are used in the evaluation board.

- Thick and short traces:
  Vin to L, L to anode of D1, L to Lx pin of the HT77XX, cathode of D1 to Vo
- Use polygon planes as much as possible for GND
- Cin and Cout should be close to the L and GND pin of the HT77XX
- The Lx trace should not be below the bottom of the HT77XX

Power Measurement

Accurate measurement is useful for analysing circuits and immediately improving the product's performance. Improper measurement often results in error messages for users, such as efficiencies which are larger than 100% especially for low power applications. Figure 7 is the power measurement for the HT77XX circuit. The guidelines listed below are for user reference.

- General instruments such as power supplies, electronic loads have limitations in areas such as instrument bandwidth and cannot distinguish from the voltage and current value whether it is truly RMS or not from the digital panel of instruments.
- Use the true RMS multimeter or other accurate instruments to measure the current and voltage.
- For input power terminal, connect one true RMS multimeters in series with the positive terminal of Cin and the instrument of power supply to measure the input current; the other one in parallel with the positive terminal of Cin and the instrument of power

supply to measure the input voltage. For output power terminal, connect one true RMS multimeters in series with the positive terminal of Cout and the instrument of electronic load to measure the output current; the other one in parallel with the positive terminal of Cout and the instrument of the electronic load to measure the input voltage.

CE Pin Note

For the SOT-25 packages, when CE is pulled low, the internal blocks of the device, such as the reference bandgap, gain block, and all feedback and control circuitry will be switched off. The boost converter's output, VOUT, will be at a value one Schottky diode voltage drop below the input voltage while the LX pin remains in a high impedance condition. The output capacitor and load at VOUT determine the rate at which VOUT decays.

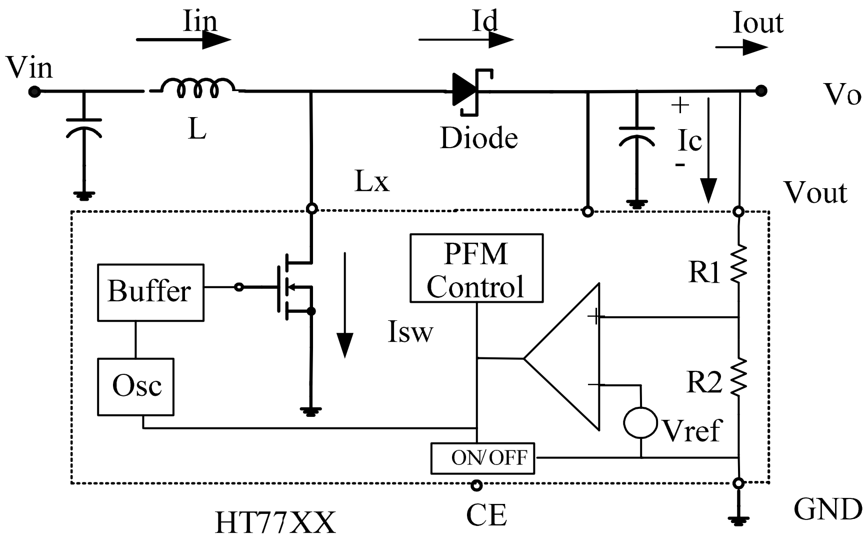

Figure 1. Step-Up Switching Regulator Circuit

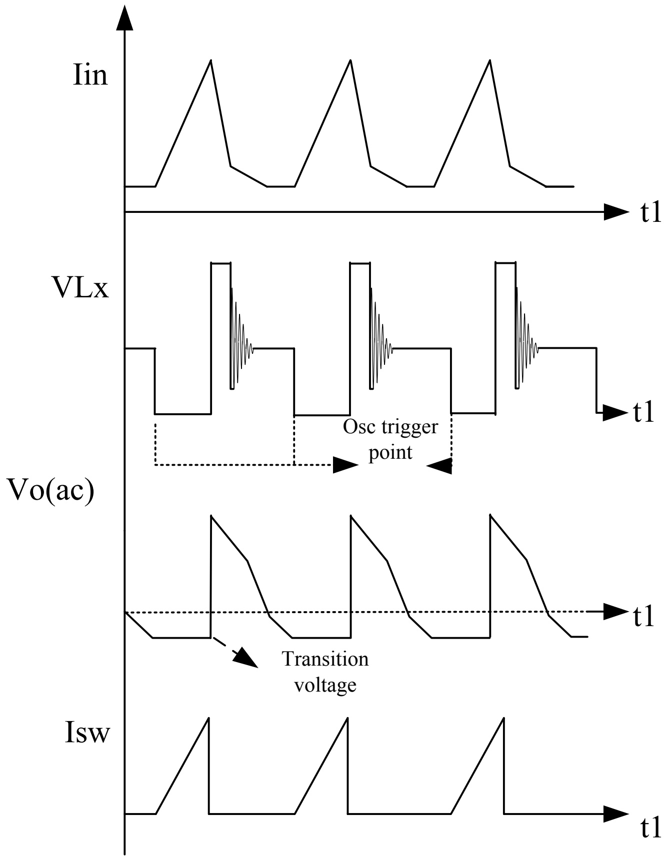

Figure 2. Discontinuous Conduction Mode for Light Loads

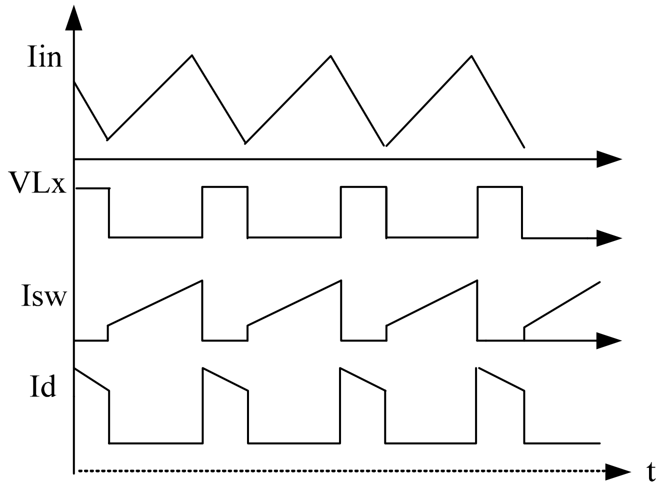

Figure 3. Continuous Conduction Mode

Type	Inductors	Capacitors	Diodes
Surface Mount	Sumida: CD54 Series CDR125 Series Murata: LQN6C Series Gangsong: GS54 Series	Nichicon: F91 Series Kemet: T491 Series	Nihon: EC10 Series Matsushita: MA735 Series ON SEM: 1N5817 1N5819
Component value in HT77XX circuit	100μH (SMD Type)	COUT: 100μF (Tantalum)	1N5817 (SMD Type)

Table 1. Suggested Components and suppliers

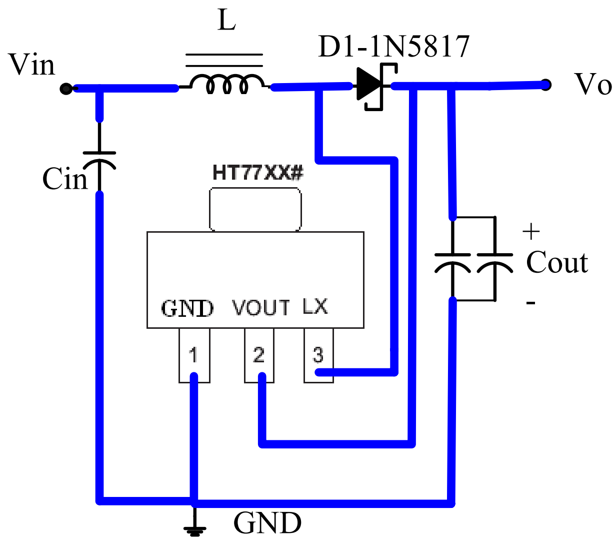

Figure 4. HT77XX Evaluation Board Schematic Circuit

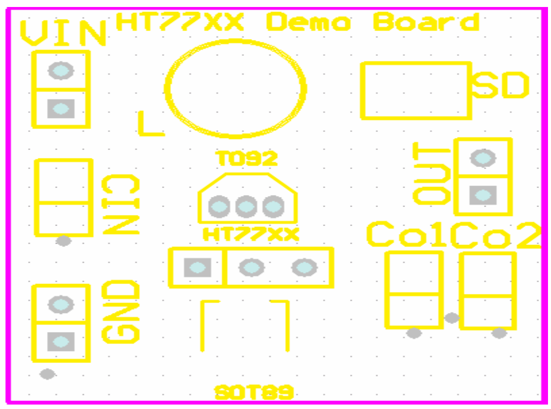

Figure 5. HT77XX PFM DC-DC Converter Evaluation Board Silkscreen

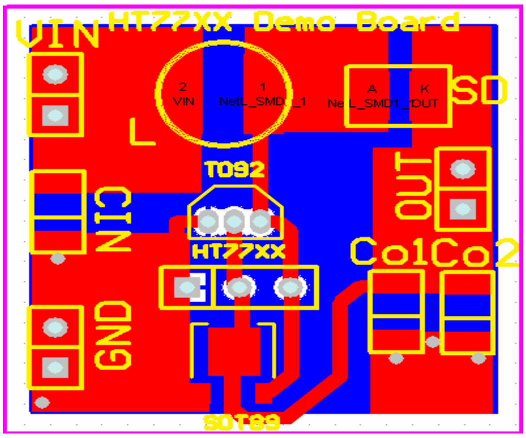

Figure 6. HT77XX PFM DC-DC Converter Evaluation Board Layout

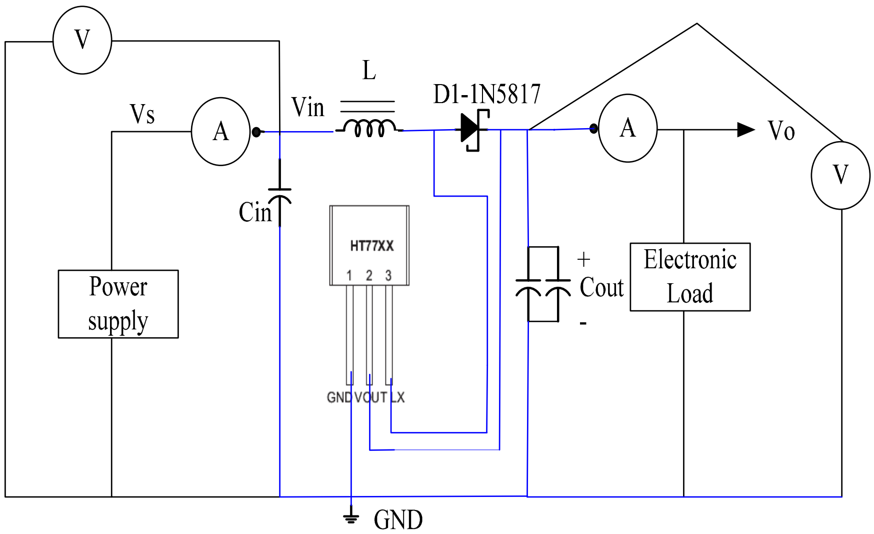

Figure 7. The Complete Power Measurement for the HT77XX